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Note from the Editor-in-Chief

Dear readers,

It is my great pleasure to present you with this year's first issue of **Tehnički Glasnik-Technical Journal**, number 1, year 12. Therefore, we have begun our 12th year of the regular publishing process, a year that should be recorded by a significant intake of quality papers from various parts of the world. Our online PST (Paper Submission Tool) system has been storing papers since the beginning of this year, even though not at the speed that would guarantee a sufficient number of positively reviewed quality papers needed for regular publication. Our persistence in maintaining quality, even if it means fewer papers per issue, has paid off: Tehnički Glasnik-Technical Journal was selected for the inclusion in the services provided by the company Clarivate Analytics. Since January 2017, our journal has been indexed and abstracted in the Emerging Sources Citation Index (ESCI) under the Web of Science Core Collection (WoS), with the entire 2016 included in the ESCI. For that reason, it is our obligation to continue maintaining quality and working on citations so that in 2019 we could obtain the journal's first impact factor (IF) for 2018 in Journal Citation Reports (JCR).

In order for the journal to be included in some other index databases (e.g. INSPEC, Scopus, Ei Compendex, etc.), much work needs to be done regarding the Editorial Board and the International Editorial Council, as well as the membership in CrossRef which enables the use of the DOI numbers and brings other benefits.

With great efforts of the authors, reviewers and the editorial team, we have managed to complete this year's first journal issue with ten selected papers. Following the reviewers' remarks, the authors edited the papers in the form in front of you.

In the end, as always, we welcome you, our dear readers, to use your input to contribute to our joint work and permanent endeavor to retain the quality of our joint journal.

Best regards,

Full. Prof. Milan Kljajin, Ph.D.
Editor-in-Chief
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Original scientific paper

THE INFLUENCE OF DRILL POINT GEOMETRY ON TOOL LIFE

Zlatko BOTAK, Katarina PISAČIĆ, Marko HORVAT, Damir MAĐERIĆ

Abstract: Drilling is a cutting process that uses a rotary cutting tool to cut a cylindrical hole in a solid material. During machining, drill bits are exposed to rapid wear at high temperature. Sometimes, due to an ecological need for dry technology without any lubricant, the use of drill bits with coatings is required, typically titanium nitride (TiN), titanium carbon nitride (TiCN) or titanium aluminium nitride (TiAlN). This paper presents research on drilling done to determine how drill point geometry affects the drill lifetime and finished surface quality. We compared the chip removal ability and surface quality of bored holes in Hardox 500 created with high-speed steel drill bits and drill bits manufactured from hard metals, with and without coatings, under constant processing parameters. A cost/efficiency comparison was also carried out with respect to drill bit fabrication, sharpening, and use. Based on the data obtained on the damage drill points, the most economical drill bit for processing holes was determined.

Keywords: drill bits; drill point geometry; drilling

1 INTRODUCTION

Drilling is a machining process used to create satisfactory surface quality cylindrical holes at low cost. A drill bit used to create a hole has a cylindrical shape with cutting edges that taper to a sharp drill point. The spindle of the drill press clamps to the shank of the drill bit via the chuck, allowing transfer of rotation and cutting force/pressure to the drill bit to create a hole via the drill point. During the drilling process, as the interconnections of material particles are destroyed during cutting, the drill bit is exposed to mechanical, thermal, and chemical influences, or wear.

The durability and lifetime of the drill bit depends on the drill bit material, the workpiece material, operating modes, and, most importantly, the cutting speed. Commonly, a lubricant is used during drilling to dissipate the heat generated during the cutting process.

Due to economic and ecological reasons, drilling is sometimes carried out without a lubricant. In this case, the drill bit used is coated with a layer resistant to wear and high temperatures. Low-cost coating materials include titanium nitride (TiN) and titanium aluminium nitride (TiAlN).

Initial research has focused on identifying the optimal cutting speed and feed for different materials to increase the lifetime of the drill bit tool, i.e. the time between two sharpenings.

In this study, the effects of drill bit coating and geometry of the drill point on the drill bit lifetime were examined. The chip removal ability and surface quality of holes bored into the material Hardox 500 from drilling with high-speed steel (HSS) and hard metal drill bits were compared. The drill bits were sharpened with different drill point geometries and had different coatings. BU7 (5%) was used as the lubricant.

2 LITERATURE REVIEW

In [1], the authors predicted the tool life for coated and uncoated twist drill bits. They conducted experiments to establish empirical drill-life cutting speed equations for three coatings. Drilling was performed as the cutting speed and feed rate were varied. The results revealed that none of the three coatings offered any statistically significant advantage over the others in terms of the drill life.

In [2], an experimental analysis compared the performances of coated and uncoated twist drill bits to determine the effects of various input machining parameters: cutting speed, feed rate, point angle, and drill diameter, on machine milling under dry conditions. Analysis of variance results confirmed the validity of the established mathematical models describing the effect of finish drilling processing parameters on chip load, torque, and machining time.

A comparison of the abilities of coated and uncoated carbide drill bits to drill a Ti workpiece was presented in [3]. Experimental results were discussed based on machine tool vibration, thrust force, torque, burr dimensions, and surface roughness.

In [4], tool wear, surface roughness, and power requirements were presented for drilling operation using coated and uncoated HSS tools. The authors compared the characteristics of HSS drill bits coated with TiN and TiAlN for machining under dry conditions.

In [5], the authors investigated the effects of drill point geometry and drilling technique by drilling a Ti alloy. They used uncoated carbide drills with different geometries, under various cutting speeds and drilling methods. The experimental results revealed that both drill geometry and drilling techniques affect tool wear and tool life performance when drilling titanium alloy.

In [6], the authors explored the influence of drill bit geometry on the lifetime of a tool. Several types of drill bits, with and without coatings, were used to drill holes in steel. Microscopy analysis was used to evaluate the damage to the cutting tool blade.

3 MATERIALS AND DRILL POINTS OF DRILL BITS

Hard metal mark P01 (ISO 4499), obtained by sintering, is commonly used to make the drill bits. It consists of metal carbides for carrier hardness, including tungsten carbide (WC), titanium carbide (TiC), tantalum carbide (TaC), and niobium carbide (NbC), with cobalt (Co), nickel (Ni), and/or molybdenum (Mo) as binders.

Metal carbides have a hardness of 1300 to 1800 HV; at 1,000 °C, these values are reduced by ~10%. At 700 °C, sintered hard metals with TiC are harder than HSS at room temperature [6]. They have a high melting point, abrasion and wear resistance, high modulus of elasticity, high temperature stability, resistance to temperature changes, corrosion resistance, and high thermal and electrical conductivity.

The particle size of WC, in particular, is one parameter that directly affects the main properties of hard metals: hardness and toughness. Composition (e.g. %Co), pressing forces, temperature, and sintering time also have some effect, but to a lesser degree.

The flute length of the drill bits, i.e. the length of the spiral groove cutting edges, and the overall tool length, depend on the standard to which they are made. In standard designs, the flute length of the drill is commonly $3 \cdot d$, $4 \cdot d$, $5 \cdot d$, $8 \cdot d$, or $12 \cdot d$, where d is the diameter of the drill bit. For specific designs, a common flute length is the drilling depth + 4 mm [6].

The working body of the twist drill has a conical working tip and two spiral grooves (flute) for pulling out scrapings and delivering cooling liquids/lubricants. The drill bit body is tapered from the tip/point to the shank in a ratio of 1:1,000 or 0.1 mm to each 100 mm of flute length (Fig. 1). This reduces the friction between the non-cutting part of the tool and the workpiece material and prevents the tool from becoming wedged in the material.

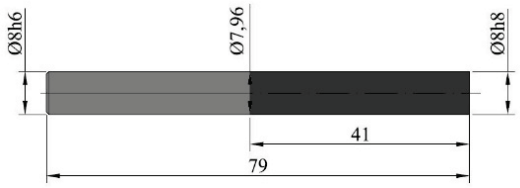

Figure 1 Removing the cone of the body

With regard to the cross-section of the drill bit at the drill point end, the web thickness of the drill bit increases toward the shank, as well as the chisel edge length, to increase tool strength. The shank, the solid cylindrical portion of the drill bit held by the chuck, is made according to DIN 6537 (tolerance h8) and DIN 6535 HA (tolerance h6). The shank length for an ∅8-mm diameter drill is 41 mm, the total length is 79 mm, and the maximum drilling depth is 36 mm [6].

In our study, the workpiece material for the drill bits was already ground to tolerance H6, so it was not necessary to process the shank. Only the cone (1:1,000) of the body was removed, which was 0.041 mm of the 41-mm length (Fig. 1). After grinding the cone of the drill bit body on a circular grinder, final grinding of the drill point was carried out with a computer numerical control tool grinder. Diamond cutters were used to construct the flutes and drill points.

The appropriate geometry of the cutting end of the drill bit depends on the workpiece material being processed. Thus, the drill points can take several different shapes, depending on the application. In our study, a standard-point drill bit, a split-point drill bit, a four-facet drill point, and a split point with a double margin were used.

The standard-point drill bit (Fig. 2) is mainly used in small-diameter drills for drilling soft steels, such as aluminium and its alloys, wood, and plastics. It is not resistant to wear.

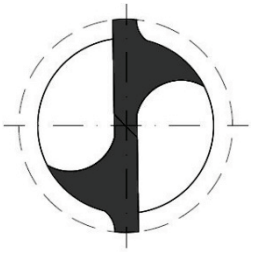

Figure 2 Standard-point drill bit

With a split-point drill bit (Fig. 3), metal is removed from the conventional drill point, and the web thickness at the chisel edge is reduced, such that less feed pressure is required for penetration into the material. The drill web has a small radius and is suitable for processing carbon steel, cast iron, and alloyed steels, up to 1,000 MPa.

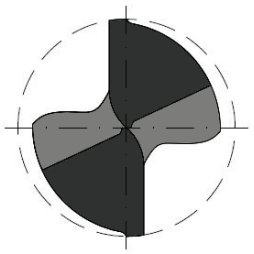

Figure 3 Split-point drill bit

A drill bit cone of 0.2/100 mm yields high-quality hole-processing. The cutting speed v_c is 60–100 m/min without cooling and 70–120 m/min with cooling, given a feed, f, of ~$0.025 \cdot d$ mm/rev. In fabricating the split-point drill bit, splitting and thinning of the drill point must be performed accurately with the grinding machine to ensure symmetry. A lack of symmetry in the length of the cutting lips leads to one cutting edge doing more work than the other; thus, without symmetry, the cutting forces would be unbalanced, the finished hole would not be round, and the tool wear would occur more rapidly.

Above 1,000 MPa, a four-facet drill bit (Fig. 4) is used to process stainless steel, cast iron, alloy steels, titanium alloys, and Ni alloys. The chisel edge comes with a self-centring point that eliminates the need for centre punching and pilot holes. The drill point of a four-facet drill bit

includes a separate cutting lip and secondary clearance facets. The primary facet angles depend on the processing material, while the secondary facet angles are commonly 20°.

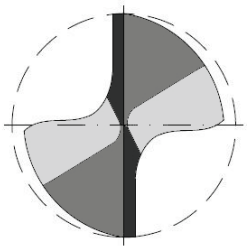

Figure 4 Four-facet drill point

The typical cutting speed with the four-facet drill ranges from 20–50 m/min without cooling and from 25–60 m/min with cooling, given a feed f of ~(0.0080–0.02)·d, mm/rev, depending on the strength of the material being processed.

A split point with double margin drill bit (Fig. 5) is used in the processing of carbon steel, grey cast iron, cast iron, and alloyed steels up to 1,000 MPa and higher, depending on the desired quality of the machined surface (flatness tolerance).

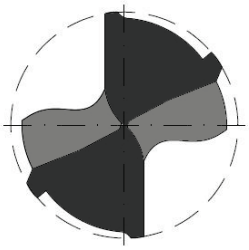

Figure 5 Split point with double margin

This drill bit is designed for drilling close-tolerance holes. Good conditions correspond to a machined surface quality of N8; very good conditions can be achieved at N7. It is manufactured with two margins, one at each end. The cutting speed is in the range of 60–100 m/min without cooling and 70–120 m/min with cooling, given a feed of 0.025·d, mm/rev.

4 EXPERIMENTAL RESULTS

In this study, two drill bits of HSS material with standard drill point geometry, and four drill bits manufactured from hard metal with three drill point geometries (split, four-facet, and double margin), were compared (Tab. 1).

The objective was to determine and compare the chip removal ability and surface quality of the bored holes created by the drilling bits when drilling holes in Hardox 500 material. Tab. 2 lists the mechanical properties of Hardox 500.

A cost/efficiency comparison for drill bit fabrication, sharpening, and use is also provided.

Table 1 Drill bits

Drill bit	Drill point geometry	Coating
1 (HSS)	Standard	-
2 (HSS 8% Co)	Standard	-
3	Split	-
4	Four-facet	TiN
5	Four-facet	TiAlN
6	With double margin	-

Table 2 Mechanical properties of Hardox 500 material

Properties	Value
Tensile strength (MPa)	1580
Yield strength (MPa)	1250
Elongation (%)	10
Density (g/cm3)	7850
Hardness (HB)	500

Drilling was performed on a classic milling machine at a speed of 355 rev/min. The cutting speed was 8.92 m/min for a drill bit diameter of 8 mm, and the point angle of the drill bits was 118°.

The costs of HSS drillings, fabrication time (metal + coating), and sharpening time are listed in Tab. 3.

Table 3 Price of drill bits

Drill bit	Price, €	Fabrication time, min	Sharpening time, min
1 (HSS)	1.1	-	1.85
2 (HSS 8% Co)	3.2	-	1.85
3	14.8	7.1	2.59
4	17.9	7.5	3.35
5	18.0	7.5	3.35
6	14.8	9.2	3.35

Each drill bit was used to drill holes in Hardox 500 (thickness: 25 mm), until the drill point became dull or the drill bit broke. The drilling results are shown in Fig. 6.

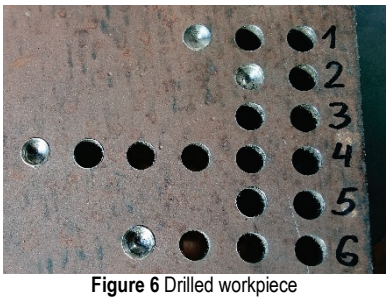

Figure 6 Drilled workpiece

Table 4 Cost per mm bore length

Drill bit	L, mm	Price, €	€/mm
1 (HSS)	51	1.5	0.029
2 (HSS 8% Co)	27	3.2	0.119
3	43	14.8	0.344
4	127	17.9	0.141
5	34	18.0	0.529
6	77	14.8	0.192

Finally, for each drill bit, the total drilling length and drilling cost per millimetre of drilled hole were calculated; the results are given in Tab. 4. We assumed that when making the tool, the price per hour was 50 €.

5 CONCLUSION

Due to the high yield strength of the workpiece material, the drilling was performed with cooling, including that done with the two coated drill bits. Because the coatings serve as an insulator and send the heat generated into the chips, the two drill bits with coatings would have an advantage over the others.

All of the drill bits had a point angle of 118 degrees, which is an acceptable angle for use in most materials, although it does not perform as well as the optimum angle for machining Hardox 500 material. It is known that harder workpiece materials require a larger point angle, and softer materials a sharper angle, to control wandering, chatter, hole shape and wear rate.

The chip removal process of all drill bits tested (1–6) was good, until the drill point became dull or the drill bit broke. In drill bit no.3 a fracture occurred and all the others experienced dulling of, or damage to, the cutting edge, after which the drill bit could no longer drill into the material.

Although it would be expected that drill bits of hard metal offer significantly improved durability, this was not the case in our test results. Under identical operating conditions, the drill bit with the TiN coating performed the best; the other drill bits fabricated from hard metal did not meet expectations.

Drill point geometry did not have a noticeable effect on the lifetime of the drill bit, although the surfaces of the bores drilled with the hard metal drill bits were of better quality. The results also revealed that the HSS drill bit with the standard drill bit geometry was the most cost-effective way to produce bores in the material; re-sharpening of the drill bits from hard metal was not profitable in this case.

It was assumed that re-sharpening was done correctly; this means that the point angle, lip relief angle and length of the cutting edges must be exactly as established and did not occur material structural modifications.

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Original scientific paper

MODELING AND OPTIMIZATION OF FACE MILLING PROCESS PARAMETERS FOR AISI 4140 STEEL

Gokhan BASAR, Hediye KIRLI AKIN, Funda KAHRAMAN, Yusuf FEDAI

Abstract: In this study, the effect of cutting parameters such as the depth of cut, feed rate, cutting speed and the number of inserts on surface roughness were investigated in the milling of the AISI 4140 steel. The optimal control factors for surface quality were detected by using the Taguchi technique. Experimental trials were designed according to the Taguchi L_{18} (2^1x3^3) orthogonal array. The statistical effects of control factors on surface roughness have been established by using the analysis of variance (ANOVA). Optimal cutting parameters were obtained by using the S/N ratio values. The ANOVA results showed that the effective factors were the number of inserts and the feed rate on surface roughness. However, the depth of cut and the cutting speed showed an insignificant effect. Additionally, the First-order and Second-order regression analysis were conducted to estimate the performance characteristics of the experiment. The acquired regression equation results matched with the surface roughness measurement results. The optimal performance characteristics were obtained as a 0.5 mm depth of cut, 0.08 mm/rev feed rate, 325 m/min cutting speed and 1 number of inserts by using the Taguchi method. Additionally, the confirmation test results indicated that the Taguchi method was very prosperous in the optimization of the machining parameters to obtain the minimum surface roughness in the milling of the AISI 4140 steel.

Keywords: AISI 4140 steel; milling; regression analysis; surface roughness; Taguchi method; variance analysis

1 INTRODUCTION

The metal cutting process is defined to remove the unwanted material from the metal parts by using a cutting tool. Materials were moved by a conventional chip forming process such as milling, drilling, boring, turning in the manufacturing industry [1, 2]. The milling process is one of the most significant metal removal processes in the traditional metal cutting operations.

The surface quality is a significant factor to appraise the productivity of both the mechanical parts and machined components. Hence, it is a very crucial measurement of the product quality. Surface quality is usually concerned with surface roughness. The surface roughness of the machine elements is understood to have a prominent influence on certain properties such as increasing the tribological properties of materials, wear resistance, fatigue strength, heat conduction, electrical conductivity, corrosion resistance and aesthetic appearance. However, it can also lead to increased production costs [3-5].

Nowadays, there have been numerous study advancements in the surface roughness modeling and the optimization of the performance of the manufacturing technologies. In order to produce a desired surface finish and to reach the greatest productivity of machining, cutting parameters should be chosen appropriately [6].

Regarding past research, surface roughness was examined in distinct research studies in which the experimental results, the mathematical models and statistical methods were assimilated. For instance, Filho et al. [7] studied the experimental numerical model of roughness in the finishing face milling of the AISI 4140 hardened steel. They applied the central composite design to optimize the cutting factors such as the cutting speed, feed and cutting depth in the end milling when machining the AISI 4140 steel with a CBN (cubic boron nitride) tool. The feed per tooth had a statistical prominent factor affecting the average surface roughness in the face milling. Ventura et al. [8] researched the machinability of the hardened AISI 4140 steel when turning with varied micro geometries. It is shown that the cutting edge micro geometry largely influences the feed and passive force components, whereas the cutting force, specific energy and cutting temperature are not strongly changed. Sales et al. [9] conducted the external vegetable oil-based minimum quantity cutting fluid in the milling of the AISI 4140 steel with a TiAlN coated cemented carbide insert. The minimum quantity fluid application supplied usually decreases the tool wear rate and as a result enhances tool life. Ozek et al. [10] used the Fuzzy logic to investigate the effect of the machining factors on the plasma arc machining process of the AISI 4140 steel. The fuzzy logic model was developed to predict the surface roughness. Results showed that the cutting speed had the statistical importance on the performance characteristic, whereas the plasma arc current had the least importance. Kıvak and Cetin [11] performed the Taguchi method and regression analysis to identify the machinability of the 15-5 PH Stainless steel with the PVD TiAlN-AlCrO and CVD TiCN-Al_2O_3-TiN-coated carbide-cutting-tool inserts. It was observed that feed rate was a maximum contribution to surface roughness, whereas the depth of cut was a maximum contribution to the cutting force. Sarıkaya et al. [12] researched the effects of machining factors such as the cutting speed, feed rate and the number of cutting inserts on surface roughness and tool life in the face milling process of the AISI D3 steel with carbide coated inserts by using the Taguchi design technique. The experimental results presented that the number of cutting inserts was the most significant parameter affecting surface roughness, while cutting speed was the most significant parameter affecting tool life. Motorcu et al. [13] machined the AISI 4140 steel with a tungsten carbide cutting tool on a lathe.

They investigated the effect of the depth of cut, the cutting speed and feed rate on the formation on surface roughness, the tool temperature and the tool-chip interface temperature by using the Taguchi method. Predictive models were developed to estimate the output performance characteristics by using the regression analysis. Ekici et al. [14] examined effects of wire speed, pulse on time and pulse off time on the material removal rate and surface roughness during the wire electrical discharge machining (WEDM) operation of the Al/B_4C/Gr reinforced hybrid material by using the Taguchi technique and Response Surface Methodology. It was eventually detected that the most important parameter for the material removal rate is the wire speed, while for surface roughness the most dominant parameter is pulse on time. Gupta et al. [15] studied the effects of machining parameters such as the cutting speed, feed rate and distinct cooling conditions on a cutting force and surface roughness in the turning of the AISI 4340 steel by using the uncoated carbide insert. The Taguchi technique and the utility concept were used for the determination of the optimal performance characteristics simultaneously. They found that the cooling condition has a dominant effect on the performance characteristics. Kıvak [16] researched the effects of machining parameters (cutting tools, cutting speed and feed rate) on surface roughness and flank wear by the aid of the Taguchi design technique in the dry milling of Hadfield steel. It was determined that in surface roughness, the most effective parameter is feed rate, while for flank wear, the cutting speed was the most powerful parameter. Ekici et al. [17] explored the influences of the cutting factors (wire tension, reinforcement percentage, wire speed, pulse-on time and pulse-off time) on the material removal rate and surface roughness in the WEDM process of the Al/B_4C composites produced via the hot pressing method by using the Taguchi method. The variance analysis results indicated that the dominant factor for the material removal rate is wire speed, while for surface roughness the most effective factor is pulse on time.

In this paper, the modeling and optimization of cutting parameters on surface roughness in the milling process of the AISI 4140 steel were researched by using the Taguchi technique and regression analysis. The furthest machining factors on surface roughness were conducted by using the analysis of the signal to noise (S/N) ratio and analysis of variance (ANOVA). The predictive equations were descended from the regression analysis to acquire the optimal surface roughness as a function of the milling parameters. Hence, the experimental and regression analysis results were compared with each other.

2 MATERIALS AND METHODS

The milling tests were conducted in dry cutting conditions by using a SPINNER MVC1000 model CNC milling machine equipped with a maximum spindle speed of 10000 rpm. The experimental set up is displayed in Fig. 1. The dimensions of the workpiece were 260 × 150 × 25 mm. Before the tests started, the steel bulks were ground to remove the reverse effects of any surface disturbance. The milling tests were carried out at two depths of cut (0.5 and 1mm), three feeds (0.08, 0.12 and 0.16 mm/rev), three cutting speeds (175, 250 and 325 m/min) and three numbers of cutting inserts (1, 2 and 3 piece). The milling process was applied by using a R 390-020B20-11M tool holder and a TiAlN+TiN, PVD-coated, R 390-11 T308M-PM 1030 solid carbide insert. In the milling tests, only one insert was used to minimize the effect of the tool tip run out on tool wear. The quality of a cutting surface is generally identified by the surface roughness and it is measured offline after the surface is cutting. After the milling tests, the average surface roughness (*Ra*) of workpieces was measured by the MITUTOYO SJ-400 transportable surface roughness tester. The cut off length and evaluation length were constant at 0.8 mm and 4 mm respectively. The measurement of surface roughness was carried out on a machined surface from three distinct points. The average value of the measurements was taken into evaluation to analyze the surface roughness attitude. Surface roughness measurements are illustrated in Fig. 2.

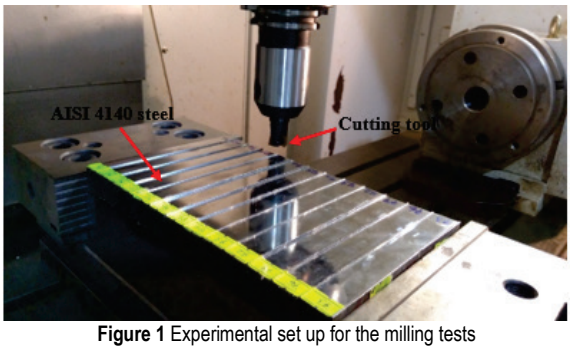

Figure 1 Experimental set up for the milling tests

Figure 2 Surface roughness of the measurement device

The depth of cut *ap* (mm), feed rate *f* (mm/rev), cutting speed *V* (m/min) and number of inserts *N* (pieces) were chosen as the control factors for surface roughness and their levels were detected as demonstrated in Tab. 1. The

Taguchi L_{18} mixed orthogonal design matrix was conducted for performing the experiments.

Table 1 Control factors and their levels

Parameters	Unit	Notation	Level of factors		
			1	2	3
Depth of cut	mm	*ap*	0.5	1	-
Feed rate	mm/rev	*f*	0.08	0.12	0.16
Cutting speed	m/min	*V*	175	250	325
Number of inserts	piece	*N*	1	2	3

3 ANALYSIS AND EVALUATION OF EXPERIMENTAL RESULTS

3.1 Taguchi Analysis

The Taguchi method is a strong design tool and it is extensively used in engineering problems. Furthermore, it considerably decreases the quantity of experiments using the orthogonal design matrix and reduces the influence of factors that cannot be controlled. Moreover, it ensures an easy, productive and systematical approach to indicating the optimal machining conditions for the manufacturing industry [18, 19]. The Taguchi technique uses a loss function to compute the deviation between the test values and the willed values. This loss function is also turned into a signal–noise (*S*/*N*) ratio [20].

Table 2 Experimental results and the S/N ratios for *Ra*

Trial run	*ap*	*f*	*V*	*N*	*Ra* (μm)	dB (*S*/*N*)
1	0.5	0.08	175	1	0.183	14.7510
2	0.5	0.08	250	2	0.230	12.7654
3	0.5	0.08	325	3	0.497	6.0729
4	0.5	0.12	175	1	0.220	13.1515
5	0.5	0.12	250	2	0.273	11.2767
6	0.5	0.12	325	3	0.730	2.7335
7	0.5	0.16	175	2	0.443	7.0719
8	0.5	0.16	250	3	1.100	-0.8279
9	0.5	0.16	325	1	0.140	17.0774
10	1.0	0.08	175	3	0.397	8.0242
11	1.0	0.08	250	1	0.213	13.4324
12	1.0	0.08	325	2	0.220	13.1515
13	1.0	0.12	175	2	0.367	8.7067
14	1.0	0.12	250	3	0.660	3.6091
15	1.0	0.12	325	1	0.143	16.8933
16	1.0	0.16	175	3	1.097	-0.8041
17	1.0	0.16	250	1	0.270	11.3727
18	1.0	0.16	325	2	0.633	3.9719

The smaller-is-better, the-nominal-best and the larger-is-better approaches are established considering the results of the *S*/*N* ratio. The objective of this research was to reduce the surface roughness. For this reason, the smaller-the-better quality characteristic was used as presented in the Eq. (1) and listed in Tab. 2. The average of the *S*/*N* ratio for each level of the machining parameters is calculated and given in Tab. 3. The graph of the mean of the *S*/*N* ratios versus the factor levels is shown in Fig. 3.

$$\frac{S}{N} = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right), \tag{1}$$

where y_i is the i^{th} measure of the actual test data in a run and n is the number of measurement in each experimental test [21].

Table 3 Results of the S/N ratios (dB) for *Ra*

Level	*ap*	*f*	*V*	*N*
1	**9.341***	**11.366***	8.484	**14.446***
2	8.706	9.395	8.605	9.491
3	-	6.310	**9.983***	3.135
Delta	0.635	5.056	1.500	11.312

*Optimal level

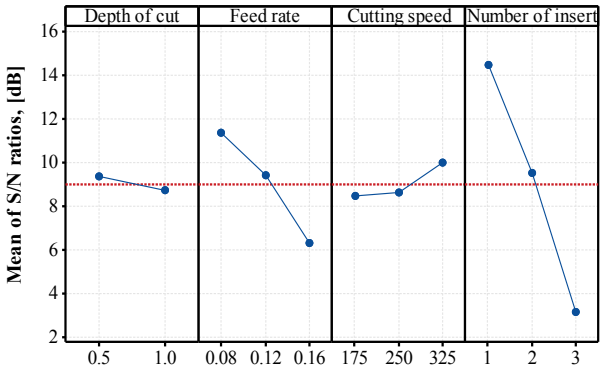

Figure 3 Mean S/N ratio graph for *Ra* (dB)

In this paper, ANOVA was employed to analyze the influence of the depth of cut, feed rate, cutting speed and number of inserts on surface roughness. The objective of ANOVA is to establish how the process parameteres affect the quality characteristics [22, 23]. This analysis was conducted for a confidence level of 95 %. The surface roughness is conducted to detect the utmost effect factor in the machining parameters by ANOVA. In the machining process, cutting parameters have an important effect in the experimental results. The ANOVA results for surface roughness are presented in Table 4. The number of inserts was determined as an important factor since its p value is less than 0.05.

Table 4 ANOVA results for *Ra*

Source	DF	Adj SS	Adj MS	F	P	% PC
ap	1	0.00188	0.001881	0.08	0.783	0.12
f	2	0.32588	0.162938	6.92	0.013	21.16
V	2	0.01481	0.007404	0.31	0.737	0.96
N	2	0.96237	0.481183	20.44	0.000	62.48
Error	10	0.23538	0.023538			15.28
Total	17	1.54031				100

R^2 = 84.72 %

As a result of the appraisal of surface roughness, the percentage contributions of process parameters for *ap*, *f*, *V* and *N* were defined as (0.12, 21.16, 0.96 and 62.48%), respectively, and the error was 15.28 %. Hence, it was discovered that the number of cutting inserts and the feed rate are more important than the cutting speed and the depth of cut concerning the surface roughness in milling the AISI 4140 steel.

The ANOVA analysis result declares that the number of inserts is the most important effect on surface roughness

with a percentage contribution of 62.48 %. Moreover, the feed rate had a considerable influence on surface roughness with a percentage contribution of 21.16 %. However, the depth of cut and the cutting speed proved to be an insignificant factor on surface roughness.

The result obviously indicates the influence of the number of inserts on surface roughness in milling the AISI 4140 steel whose vibration produced a sophisticated frequency between the cutting tool and the workpiece with the enhancement number of the cutting insert. The other variable that has an effect on *Ra* is the feed rate with 21.96 %. It is clear that increasing of the feed rate increases the chip volume removed per unit time [12, 24].

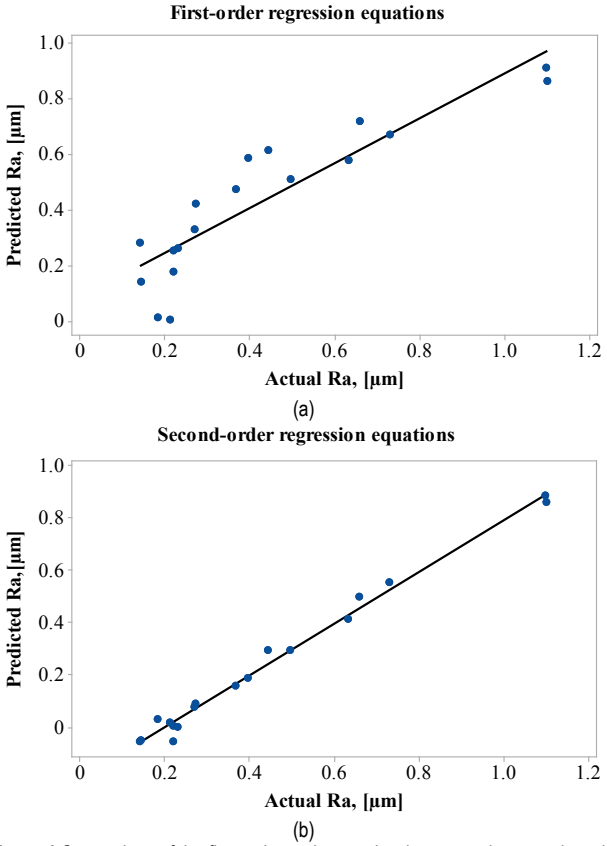

Figure 4 Comparison of the first-order and second-order regression equation with the experimental results for *Ra*

3.2 Regression Analysis

Regression analysis is performed for the modeling and analyzing of several variables, which have the relationship between a dependent variable and one or more independent variables [25]. In this paper, the dependent variable is surface roughness (*Ra*), while the independent variables are the depth of cut (*ap*), feed rate (*f*), cutting speed (*V*) and number of inserts (*N*). The experimental test results were utilized to obtain the mathematical models by using the first-order and second-order model. The predictive equations which were acquired by using the first-order and second-order regression model of surface roughness are given below.

First-order regression equation:

$$Ra = -0.539 + 0.041ap + 4.05f - 0.000382V + 0.2760N \qquad (2)$$
$$R^2 = 80.53$$

Second-order regression equation:

$$Ra = 1.665 + 0.100ap - 15.86f - 0.00231V - 0.725N + \\ +40f^2 + 0.000003V^2 + 0.1026N^2 + 2.22ap \cdot f - \\ -0.00054ap \cdot V - 0.066ap \cdot N + 0.00292f \cdot V + \qquad (3) \\ +4.094f \cdot N + 0.000583V \cdot N$$
$$R^2 = 98.95$$

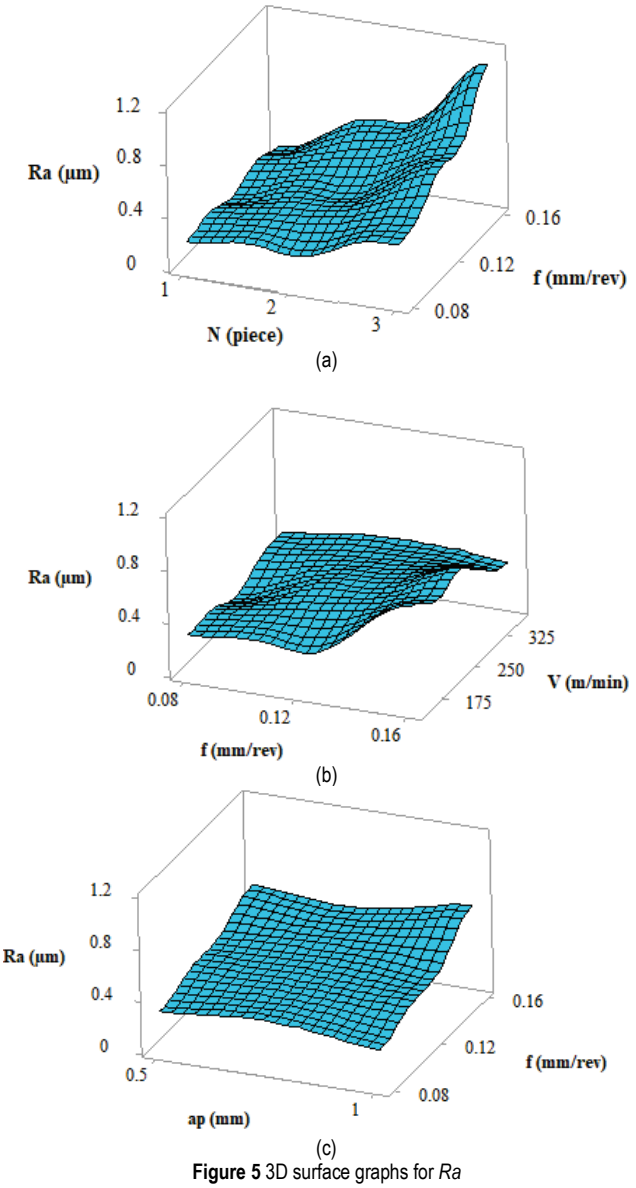

Figure 5 3D surface graphs for *Ra*

The comparison of the experimental results and the predicted values which were obtained by the first-order and second-order regression model are given in Fig. 4. The correlation coefficients (R^2) of the first-order and second-

order regression equations that advanced for the predictive surface roughness were computed as R^2 = 80.53% and R^2 = 98.95%, respectively.

Fig. 5 shows the 3D surface graphs, which provided a Minitab 17 software for surface roughness. The relationship between the feed rate (*f*) and number of inserts (*N*) is shown in Fig. 5(a), the relationship between the cutting speed (*V*) and feed rate (*f*) is shown in Fig. 5(b) and the relationship between the feed rate (*f*) and the depth of cut (*ap*) is shown in Fig. 5(c). It reveals that surface roughness decreases with a reduced feed rate and with a diminished number of inserts in Fig. 5(a). Hence, a minimum level of the feed rate and a minimum number of inserts is required for minimum surface roughness. It appears that surface roughness decreases with a slight change in the cutting speed (*V*) and with a diminished feed rate (*f*) in Fig. 5(b). It shows that surface roughness decreases with a minimized feed rate (*f*) and a slightly changed depth of cut (*ap*) in Fig. 5(c).

3.3 Confirmation Test

Before the optimum level of control factors is chosen, the last step of the Taguchi technique approach is to estimate and confirm the development of the control factors by using the optimum level of control factors.

Factors that will be utilized to achieve the optimal *Ra* value and their levels are detected as $ap_1f_1V_3N_1$ with the aid of Tab. 3 and Fig. 3. The minimum Ra and its *S*/*N* ratio that can be acquired considering these levels were computed by using the Eqs. (4) and (5). The Ra value and its *S*/*N* ratio were established as 0.125 μm and 18.0657 dB respectively.

$$\eta_G = \eta_m + \sum_{i=1}^{q} (\overline{\eta}_i - \eta_m) \tag{4}$$

$$Ra_{cal} = 10^{-\frac{\eta_G}{20}} \tag{5}$$

where η_G is the *S*/*N* ratio computed at the optimum levels (dB), η_m is the overall average of the *S*/*N* ratio, $\overline{\eta}_i$ is the average S/N ratio at the optimum level, and q is the count of the control factors that remarkably influence the performance characteristic. Then, Ra_{cal} is computed for the *Ra* value [26]. The confirmation test results were demonstrated by using the optimal control factors of surface roughness in Tab. 5.

Table 5 Confirmation test results for surface roughness

	Initial machining factor	Optimal machining factor	
		Prediction	Experimental
Level	$ap_2f_2V_2N_3$	$ap_1f_1V_3N_1$	$ap_1f_1V_3N_1$
Ra	0.660	0.125	0.137
S/*N* ratio (dB)	3.6091	18.0657	17.265
Improvement of the *S*/*N* ratio 13.656 dB			

A comparison of the experimental results and the predicted results obtained with the Taguchi method is shown. When the predicted value of *S*/*N* (18.0657 dB) was compared with the actual value of *S*/*N* (17.265 dB) in the optimum level of control factors, a relatively good agreement was found. The enhancement of the *S*/*N* ratio from the initial machining parameters to the optimum machining parameters is 13.656 dB. The confirmation test results noticed that the surface roughness decreased 4.81 times.

4 CONCLUSIONS

In this research, the effect of the feed rate, cutting speed, depth of cut and number of inserts on the surface roughness in the milling process of the AISI 4140 steel with TiAlN+TiN were analyzed. The PVD coated carbide insert was performed and researched by using the Taguchi design technique. The main results were as follows:

- To optimize surface roughness Taguchi's S/N value was employed. The effect of machining parameters on the performance characteristic was investigated by the analysis of variance. From signal to noise ratio analysis was employed. It was concluded that the optimum values for minimizing surface roughness were 0.5 mm for the depth of cut, 0.08 mm/rev for the feed rate. 325 m/min for the cutting speed and 1 for the number of inserts.
- The acquired results showed that the number of inserts was detected to be an effective factor among the controllable factors on surface roughness, followed by feed rate. However, the depth of cut and cutting speed proved to have an insignificant effect.
- The predictive models of surface roughness were also established by using the regression analysis.
- It was indicated that the experimental and regression analysis results could be effectively used for the estimation of surface roughness in the milling process of the AISI 4140 steel.
- The Taguchi design method was an effective method for the modeling and optimizing of surface roughness in the milling process.
- The development of surface roughness from the initial machining parameters to the optimal machining parameter is about 481%.
- In the manufacturing engineering applications, the Taguchi design technique and regression analysis were able to supply the minimum cost and time.

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INSTRUCTIONAL DESIGN IN GAME BASED LEARNING AND APPLICATIONS USED IN EDUCATIONAL SYSTEMS

Damir VUSIĆ, Andrija BERNIK, Robert GEČEK

Abstract: The paper examines literature on the subject of instructional design and game based learning with the aim of identifying its positive effects and impact on users. Special attention was given to learning, encouragement and development of skills acquired through the use of game based learning. Game based learning is considered to be a complex system that requires instructional support geared towards stimulating cognitive processes. Several empirical research papers which provide insight into this field of interest have been chosen. The second set of papers provides confirmation accompanied with an analysis of instructional support as a function of the learning support. Also included were recent works which indicated the need for further research and the heterogeneity of the existing research. Other works complemented the unit and are mutually interconnected by a methodological approach providing insight into the issues that should be investigated in the future.

Keywords: cognitive skills; game based learning; higher education; instructional support

1 INTRODUCTION

Game Based Learning (GBL) is a system which is being increasingly applied in the educational process, and which has been clearly evinced in a number of scientific papers that have been published over the last decade. In this context, the notion of game based learning has been approached via the cognitive and affective dimension of learning [15] where users can adopt such games for their own cognitive needs and interests and ensure the motivation for learning [11]. Game based learning allows the use of methods which are consistent with the modern theories on effective learning and encourage an active problem-oriented, experimentally-interactive and socially mediated access to educational processes in accordance with the current thinking [3, 4]. Hummel et al. [9] suggest that game based learning in institutions of higher education can be seen as a useful tool for developing, implementing, improving and facilitating the student's learning experience. Ucus [22] points out that game based learning can also be used as a tool for educating teachers. All et al. [1] cite recent research in which they clearly point out that there is currently a whole range of heterogeneous research which aims to demonstrate the effectiveness of learning systems that incorporate computer games. The validity and reliability of almost all proposed methods is questionable as such studies are neither sufficiently rigorous nor focused. The rapid development of the Internet and multimedia technology has led to the development of game based learning and has resulted in a significant financial incentive for the development and implementation of game based learning within schools and corporations. From the cognitive point of view on game based learning, it can be easily stated that such games include complex virtual spaces within which a respondent can be easily confused by the amount of information, design and other such elements of the game and, in this way, take a step away from the learning process [24].

This paper will provide an overview of important research regarding the instructional support and empirical evidence of the usefulness of game based learning within educational institutions. Instructional support includes a wide range of techniques and methods that target different cognitive aspects which will be discussed later in this paper. Mayer [13] divides computer game research into three categories: the first approach is based on the added value and explores how computer games promote learning and motivation, the second refers to the cognitive consequences in terms of what people learn from educational games, and the third relates to the comparison of the educational medium where it is examined whether learning with the help of an educational computer game is more effective than the traditional teaching material.

1.1 Game Based Learning (GBL)

GBL is a term that can refer to any educational environment which is based on educational elements and content and involves a computer or online game [18]. Prensky [18] states that integration leads to an innovative teaching model which positively affects the comprehension of an educational technology framework. In an ideal educational computer game, the student would learn through simply playing a game within a virtual simulation which involves the interplay of roles and platforms [3]. Ariffin [2] notes that it is important to understand the users of such systems, i.e. the respondents, because the learning performance through computer games is affected by elements such as culture, primary language, ethnicity and an intrinsic motivation to learn new concepts and skills. Ucus [22] links to the idea in his research that proposed the introduction of game based learning at all educational levels, starting at primary school, where it is necessary to educate the teachers as well so that they can understand the pedagogical possibilities of this approach and technology.

Many researchers have defined or classified computer game characteristics [7, 11, 18]. This work will be limited to a few related characteristics, of which the first is interaction [18, 21], specific and exactly defined set of rules and conditions [7], clear objectives conditioned by a creative and cognitive challenge [11] and the feedback derived from monitoring progress through the game by the acquisition of points or changes in the system [18]. The goal of game based learning is not to entertain the respondent, which is merely its added value, but to create a high quality environment for the development of strategic problem solving, communication and other such skills. Through an educational computer game, the user can be focused on two key elements: improving knowledge through goals or improving gaming skills through collecting points. Various research has shown that there is a correlation between the level of intrinsic motivation and educational points where intrinsic motivation refers to the internal desire to learn or solve a problem without requiring entertainment or challenge.

2 THEORETICAL FRAMEWORK

Playing computer games is more and more associated with learning and there have been several models developed to identify the effects of education while playing computer games. The authors [7] made a distinction between the learning outcomes based on skills (both technical and motor skills), cognitive outcomes (declared, procedural and strategic knowledge) and affective outcomes (beliefs and attitudes). This final outcome is related to the potential of games that can change a respondent's emotions with the aim of supporting the study. The research of a group of authors [24] proposed a model that contained four learning outcomes based on computer games and cognitive learning outcomes. These have been divided into knowledge, cognitive skills, motor skills, affective learning outcomes and communicational learning outcomes.

From a cognitive perspective, instructional support can be implemented in order to remove the existing limit in human cognitive architecture [12, 17, 16]. All et al. [1] also concluded that a teacher, administrator or responsible person who assists respondents when they are using game based learning should be entirely removed from the system. These functions should only remain as part of the procedural assistance, if required.

Two structures are crucially important in terms of information processing. The first of these is working memory, which has a limited capacity to process information and is often inappropriate for the study of complex, multi-modal and dynamic information.

The second is long-term memory, which theoretically has unlimited capacity. Regarding the cognitive architecture, these theories highlight several important cognitive processes involved in learning. Mayer's cognitive theory of multimedia learning states there are three types of cognitive processing: selection of relevant information with respect to the relevant materials, organizing new information in coherent structures and integration of a structure into existing knowledge [12]. Organization and integration of knowledge are very closely related, which is why cognitive perception in the form of instructional assistance is suggested, as it can be included in the process of learning as follows: the selection of relevant information from teaching materials and active organization of information that is integrated into the existing knowledge in long-term memory [14].

3 RESEARCH METHODS AND IMPLEMENTATION

3.1 Research 1

Researchers (Wouters and van Oostendorp) used the Google Scholar Search Engine for their 2012 survey which included the searched terms 'game based learning', 'serious games', 'educational games', 'simulation games', 'virtual environments', and 'muve' (Multi-user virtual environments). As it was necessary to narrow down the received outcomes, the search terms were amended by 'learning', 'instruction' and 'training'. They also studied works and many references that relate to game based learning [10, 15, 19, 21, 25]. The resulting works dated from 1990 to 2012. The selection of works was made according to the definition of game based learning that was stated earlier by authors in their work. Furthermore, only the works that included research related to the instructional design and clearly defined tests and research samples were taken into account. Of the 197 relevant papers, only 29 meeting the research criteria were included. The research related only to the cognitive domain of learning and these results are listed below. Wouters's [24] classification of cognitive domains shows a visible division between knowledge and cognitive skills. Knowledge refers to a learned trait that is expressed in verbal (i.e. in a written form) or non-verbal (i.e. images) forms. Cognitive skills relate to complex cognitive processes, such as the analysis during problem-solving, where a student applies factual knowledge and rules in the hope of resolving (a new) situation. The situation built during playing the game is the third type of cognitive learning because it can be based on intuitive learning. Instructional support, as mentioned previously, has many divisions which have been respectively listed with regards to cognitive activities.

Regarding the specific instructions that are difficult to classify, authors have decided to categorize them as 'Unknown' (Tab. 1).

Tab. 1 and Tab. 2 have been adopted from the original work of [25] and are listed in this section. For easier understanding, instructional support is also grouped into 10 categories which often occur in game based learning. The categories are classified as follows (Tab. 2): Reflection, Modelling, Advice, Collaboration, Control, Narrative Elements, Feedback and others.

Table 1 Types of instructional design and their classification in the cognitive process (based on [25])

Type of Support	Description	Cognitive Process
Advice	Systematically created proposals and suggestions	Selection
Adaptation	Adaptation of a game to the respondent	Selection
Assignment	Encouraging research of variables	Organization/Integration
Background Information	Domain information upon request	Unknown
Signalling	Signal for directing the respondent's attention	Selection
Collaboration (Cooperation)	Discussion directed to the explanation of implicit knowledge	Organization/Integration
Selection	Control over irrelevant elements of the learning activity	Unknown
Contextualisation	Presenting learning in a meaningful context	Organization/Integration
Elaboration	Additional task directed to cognitive activities	Organization/Integration
Feedback	Information on the veracity of the answers	Selection
Announcement	Announcing future events	Selection
Interactivity	The game responds to the actions of the respondent	Organization/Integration
'Just In Time' Options	Options appearing at the point when problems are being solved	Selection
Modality	Using audio channels for limitations	Selection
Modelling	Descriptions of how a problem has been solved	Selection
Narration	A story which can help organize teaching/educational materials	Organization/Integration
Pedagogical Agent	An agent which assists the respondent through the game using instructions	Unknown
Personalisation	Adjusting the context with personal interests	Unknown
Prior Research	Obtaining information of a certain domain in advance	Selection
Process/Objectives	The respondent has specific objective which is to obtain a specific ability	Selection
Reflection	Encouragement to start reflecting on the answers and on how to explain them	Organization/Integration
Surprise Elements	Unexpected events that trigger an update of mental models	Organization/Integration
Variability	Showing problems in different forms	Organization/Integration
Similar Examples	Showing how a problem can be solved	Selection

Table 2 Descriptions of Instructional Support Groups and how they are Associated with the Types of Instructional Support (based on [25])

Instructional Support Group	Specific Type of Instructional Support
1. **Reflection** Students are encouraged to think about their answers	Reflection, simple explanation, elaboration and task assignment
2. **Modelling** An explanation or indication of how to solve a given problem. An explanation can be given by a respondent or an expert in the form of words, pictures or animations	Different types of approaches to the solution, modelling and solved examples
3. **Advice** The system generates information to support and continue the student's learning (e.g. focusing attention)	All types of advice, either contextual or adaptive or no advice at all
4. **Collaboration** Working in discussion groups focused on the explanation of implicit knowledge	Respondents play in pairs, groups or participate in group discussion
5. **Interactivity** The student makes decisions in the game in order to solve problems or a specific task	Interactivity, student's control and decision on the playing elements
6. **Narrative Elements/Storytelling** Storytelling to create a cognitive framework	Fantasy, rich storytelling, hints and sudden events
7. **Modality** Textual information is displayed aurally	Modality
8. **Feedback** Information is displayed regardless of the accuracy of the action or answer and may (need not) be corrective or explainable	Feedback and guidance
9. **Personalisation** Ideas, characters, themes and messages are displayed in a way that specifically suits the respondent's interests	Personalisation, personalised messages
10. **Other** Group of instructional support that is difficult to categorise because of the small number of comparisons	Focusing on objectives, background information, selection and adaptability

3.2 Research 2

The main problem in the design and development of an effective educational computer game is the clear vision of the desired learning result and how to establish an optimum relationship between the desired game properties and desired learning goals [6]. When designing the game and its elements, it is necessary to know in advance which skills and knowledge are targeted.

Games, animations and simulations are interactive and support and contribute to more efficient learning in various ways [23]. For efficient learning it is suggested to use game based learning which offers students active and problem-oriented learning, where their own knowledge can be applied to information and real life examples. Also encouraged is the work on practical examples, where a different, critical analysis of the presented data and facts is possibly accompanied by the communication with active users, group or system.

That is why researchers [4] conducted a study in which they wanted to find empirical evidence that shows a positive impact of computer games on the learning outcome. Considering that the subject of research was computer games (Game Based Learning), term 'Game' was a frequently used word by all researchers within the field. The initial query: ('computer games' OR 'video games' OR

'serious games' OR 'simulation games' OR 'games-based learning' OR MMOG OR MMORPG OR MUD OR 'online games') of the listed researchers was amended by the learning outcome: AND (evaluation OR impacts OR outcomes OR effects OR learning OR education OR skills OR behavior OR attitude OR engagement OR motivation OR affect).

Scientific and professional works found as a result of this search were filtered according to four criteria: included abstract, included empirical evidence relating to computer games, timeframe from 2004 to 2009 and sample aged above 14, and 129 works relevant for the subject of research were filtered. These works were categorized according to the following domains: Digital - Non-digital Games, Primary Purpose of the Game, Game Genre and Game Platform. Categorization was also conducted according to the outcomes of learning: Behavioral Impact and Learning Outcomes, Intention and General or Specific Impact. This last categorization was based on methods: Design and research, Sample Selection, Sample Details, Group Comparison, Data Collection, Results and Conclusion. In total, 121 or 84% research studies were quantitative while only 8 or 6% included quantitative data, 43 (36%) were survey based, 12 (10%) resulted from random check questions and only one study applied the correlation approach. The eight works that included quantitative and methodological results used protocol and perspective analyses. Table 3 has been adopted from Research 2.

In comparing the genres of games, all eligible works show that simulations are by far the most popular games (43), followed by action games (14), puzzle/mystery/riddle games (11), role-playing games (8), strategic games (6) and adventure games (5). 22 studies researched the impact of general games and 4 focused on online games.

Table 3 Primary Game Purpose Based on All Works (Works with a Higher Quantitative Contribution) (based on [4])

Research Design	Purpose of the Game			Total
	Fun	Education	Serious Game	
Qualitative Research	1 (0)	4 (2)	3 (3)	8 (5)
Correlation Research	0 (0)	1 (0)	0 (0)	1 (0)
Quasi-experimental Research	32 (16)	28 (14)	5 (4)	65 (34)
Random Research	4 (4)	6 (4)	2 (1)	12 (9)
Survey	31 (16)	10 (6)	2 (0)	43 (22)
Total	**68 (36)**	**49 (26)**	**12 (8)**	**129 (70)**

The table also shows that 80% of all games included in the scientific research included simulation games or puzzle/ mystery/ riddle games.

As for the platforms used to play the games, the most popular platform is a PC (73), followed by video consoles (28) and online games (19). Three research studies focused on mobile games and one on a game played in the virtual world. Fun games were distributed evenly across the PC (24) and video consoles (26) and 13 were online. The majority of the games intended for game based learning was designed for a PC (38) and 6 are online. 11 of 12 serious games are available on a PC platform and one game was non-digital.

The main objective of this research was to develop a classification of learning outcomes and impacts of game based learning on motivation and learning. Outcomes received most frequently were affection and motivation (33), followed by the acquisition of knowledge/comprehension of content (32), perception and cognitive skills (20), behavioural changes (13), psychological outcomes (11) and social skills outcomes (11). The method which was most frequently used was the quasi-experiment, followed by surveys, quantitative methods and randomized questionnaires. Most common outcomes of game based learning included the acquisition of knowledge and content comprehension (26), followed by perception and cognitive skills (7). Quite contrary, in fun games, the focus was on the affective and motivational outcomes (26) and several studies showed perception and the cognitive learning outcome (13), and the psychological outcome. As for the serious games, outcomes were divided and there was not a single research that would include the perceptive, cognitive and psychological results of learning.

Simulations and mysteries/riddles are the most widely spread games in game based learning, but other types of games and their contribution to the educational system should also be studied in terms of tasks and activities found in other games. O'Brien [5] has provided an analysis of games that might contribute to the above statement. O'Brien divides games according to the genre into: linear, competitive, strategic, role-plays, with each category being specific and requiring sophisticated actions throughout the game.

Many authors analyzed computer games from a negative point of view, but it has been shown that there is a large number of positive experiences and that game based learning can be used for educational purposes. The stated research has been focused particularly on the positive impact developed through a computer game. It measured what impact fun games, game based learning and serious games have on the respondent and how they could support the learning and development of skills.

The researches [4] discovered many works (7392) that show a high interest for digital games, fun games, game based learning and serious games. A large part of works only assumed how games might affect learning, what the theoretical and design approach to them should be like but, since they did not include the empirical evidence for the application and impacts on the learning outcome, they were not included and considered in detail. 129 works presented empirical evidence of the impact on and outcomes of learning resulting from game based learning. The stated works also pointed to the lacking empirical research. 70 works provided high-quality evidence, although certain elements which were discovered varied from other studies.

A multi-component analysis developed by the authors stated in this research studies the main purpose of the games, their genre, discipline and educational and

behavioural outcomes of learning and provides a framework to organize and understand the games and their contribution considering the comparison of different variables. Empirical evidence has been identified for all educational and behavioural outcomes of learning, including those for the acquisition of knowledge, perceptive and cognitive, behavioural, affective, motivational, psychological and social. The most frequent learning outcome commonly studied through game based learning was the acquisition of knowledge and content comprehension. Affective and motivational outcomes were studied through fun games.

4 LEARNING OUTCOMES AND AN ANALYSIS OF INSTRUCTIONAL SUPPORT

An analysis of learning outcomes showed that there was a significant improvement in knowledge, skills and gaming performance. Comparisons made using the Holm-Bonferroni method showed that the instructional support effect is greater on the respondent performance compared to the performances and knowledge. Additionally, the effect of instructional support is greater for knowledge than the playing performance. In short, the respondent benefits from the instructional support for each learning outcome, but the effects are much greater on skills and knowledge.

An analysis conducted in accordance with the first classification shows that the instructional support for selection and organization/integration improved the learning outcome. In relation to this, the effect is significantly higher in selection in comparison with organization/integration. The results of the second classification analysis show that the instructional support improves learning in all cases. Other classifications did not prove to be statistically significant. Comparisons made using the Holm-Bonferroni method showed that modality improves learning in relation to collaboration, advice, control, other, reflection, narration, modelling and feedback. Similar to these aforementioned items, personalization raises learning outcomes in relation to collaboration and advice. Other comparisons showed no other significant differences. These authors concluded that instructional support facilitates learning in the selection of important information and improves learning more than the instructional support focused on the organization/integration of new information. Modelling, modality, personalization and feedback are shown to be particularly effective techniques.

In this study, game based learning is deemed to be a complex educational environment. From a cognitive learning perspective, this statement implies that, without instructional support, a respondent could end up using his/her cognitive capacity on non-effective activities (focusing on irrelevant information), which is detrimental to the activities that contribute to learning (reflection). The weighted average effect of quantity may be classified as medial and therefore confirms that the use of instructional support in educational games can improve learning.
These results are consistent with other studies of instructional support in complex educational environments. In compliance with the multimedia and educational environment, the research also confirms that a well-designed instructional support enhances learning as it helps the respondent to place an emphasis on the effective use of the cognitive capacity [14, 16, 24].

Instructional support which helps a respondent to select / choose important information is much more effective than other forms of instructional support that stimulates the organization and integration of new information. This also occurs in the analyses of different types of instructional support such as special modelling (showing information which is important for problem solving and how such information can be used for problem solving), modality (using audio channels for textual descriptions to limit visual search) and feedback (information about whether and why the answer is correct). These techniques are effective in aiding the selection of relevant information. Implementation of such instructional support that encourages respondents to actively participate in the organization and integration of knowledge is very difficult to be carried through. The only exception to this is reflection, which asks respondents to explicitly consider why they took such an action or gave a specific answer. Instructional support that does not use explicit stimulation for organizing and integrating information, such as narration and collaboration is less effective.

In game genres such as adventure games or role-playing games (RPGs), narration plays an important role and can serve as a cognitive framework that gives meaning to the situation and the story [18], but such an element does not increase learning efficiency and can actually create a situation in which a respondent gets distracted from educational materials. Furthermore, the implementation of collaboration does not improve the educational process, although it was intended to serve as a stimulus for students to express their knowledge [20]. Collaboration shows positive results when it is set as a task to respondents requiring from them to enter into discussions with peers or their partners within a group.

All et al. [1] state there is no specific instruction system to effectively implement game based learning. They suggest consultations with experts from relevant fields who have theoretical knowledge and experience of conducting experiments. Several researchers state that without instructional support within an educational computer game, a student is more likely to learn how to play such a game (improve his/her playing performance) than acquire specific knowledge or develop a specific skill [10]. Sitzmann [19] compared the effect of simulation games considering knowledge outcomes (declarative) and skill outcomes (procedural) and found no significant differences. Other authors [25] agreed with this statement but, if educational games are accompanied with instructional support, the results change and the learning outcomes of developed skills were better than of acquiring knowledge, considering that the development of skills is cognitively more demanding than acquiring knowledge. All et al. [1] concluded that research in clearly noticeable laboratory

conditions should be reduced because their impact on intrinsic motivation is not insignificant. They can be used in certain forms of research but jeopardize the objectivity of the experiment itself. Control groups should receive additional motivation material which would harmonize different groups.

5 CONCLUSION AND FUTURE WORK

Game based learning is considered a complex educational environment. From the cognitive point of view on learning, this statement implies that without instructional support, the respondent may use his/her cognitive capacity for non-efficient activities (focusing on irrelevant information), which is detrimental to the activities contributing to learning (reflection). Wouters and van Oostendorp [25] confirmed that the use of instructional support in game based learning can improve learning. For more efficient learning, game based learning with educational games is suggested, where student can benefit from active and problem-oriented learning allowing them to apply their own knowledge to the information and examples from the real world.

Hamari et al. [8] state that the challenge has to be especially analysed during the game and additional instruction design stages. The challenge should be adjusted and should at the same time follow the level of skills and knowledge of the respondent. Also studied was how increased challenges of the computer game increase excitement of the respondents.

The authors suggest, through the empirical evidence of impact and learning outcomes based on game based learning, that a more rigorous quantitative study should be conducted of affective and motivational learning outcomes. The approach that game based learning encourages educational activity in various domains, especially in health care, business and social environments, was accepted. The respondents like the idea of learning through playing, it boosts their motivation and the approach should be studied in more detail. Evidence showing that games contribute to a more efficient learning is not strong enough. Boyle et al. [4] published an amendment to an earlier research which stated that in the last 5 years, the number of works that study the relating area has almost quintupled. From 2009 to 2014, 129 works were discovered that met the criteria of a scientific work. In 2015, the number of works that met the study criteria was 512, which leads to a conclusion that the topic is of a very high importance. Another fact that demonstrates the relevant nature of the statement is that Boyle's et al. research was partially financed by the European Union Framework Program for Research and Technological Development (FP7).

All et al. [1] conclude that the teacher, administrator or person providing assistance to respondents when they practice game based learning should be removed from the system. Their role should only remain procedural, if so required. A precisely set industrial design should guide a respondent through a repetitive process. Authors claim that this is contrary to research completed so far where the role of the instructor or teacher is very important during the experiment. Authors of this work agree with All et al. who also continue by claiming that future research should isolate a game as much as possible. A detailed description of the implementation and characteristics of the game are as needed as the information on experimental and control groups.

The authors conclude that it would be useful to see several empirical works on the guidelines stated earlier and conclusions on the application of game based learning in higher education. What we suggest is to study efficiency at the level of courses during the entire semester and study the students' motivation. The Croatian educational system is inert, it changes very slowly, and this would be an example of good practice with actual guidelines on how to plan and implement instructional design and measure the knowledge and motivation of candidates who use game based learning as a primary source of knowledge.

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INVESTIGATION OF 3:1 AND 2:1 INTERNAL RESONANCES IN FLUID CONVEYING MICROBEAM

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Abstract: Microbeams are widely used in micro-electro-mechanical systems (MEMS). These systems are alternatives to piezo-resistive sensors because of their high sensitivity and low power consumption. Unlike with the classical theory of continuous media, in order to see the effects of the system being micro-sized, the effect of micro-structure was added to the system based on the modified couple stress theory (MCST) for fluid conveying microbeam. By using Hamilton's principle, the nonlinear equations of motion for the fluid conveying micro beam were obtained. Microbeam was investigated under electrical field and resting on an elastic foundation. It is assumed that the fluid velocity changes harmonically around a constant velocity and that the electrical field force changes harmonically with time. Approximate solutions of the system were achieved by using the multiple time scale method. 3:1 and 2:1 internal resonance cases were investigated. Detuning parameter-amplitude variation graphs were obtained, and stability areas were shown.

Keywords: fluid conveying micro beam; internal resonance; nonlinear vibration; perturbation methods; stability analysis

1 INTRODUCTION

Micro-electromechanical systems (MEMS), micro-beam-based sensors (MCSs), resonators (a micro-device formed by combining several micro-electro-mechanical systems to produce a vibration of a given frequency, usually at its natural frequency [1]), etc., have been increasingly used in recent years. These systems are attractive alternatives to piezo resistive sensors because of their high sensitivity, low power consumption and low cost. In addition, micro-mechanical systems take up less space and consume less power than large-scale machine systems. With proper serial-production techniques, such systems can be manufactured at very low cost. [2, 3, 4]

Some systems, such as MEMS and MCSs, can convey fluid. It is important to obtain the influence of the fluid and its motion on the microbeam behavior. Today, such fluid-conveying microsystems are widely used for genetic engineering, protein synthesis, micro-chemical and biological analysis, micro-sampling, drug injection, in-situ cooling of microsystems, and microfluidic transport. [5]

Several studies have been reported in the literature about microbeam-based systems. The founder of MEMS is often referred to as the famous physicist Richard Feynman. In 1959, Feynman suggested that very small devices could be produced by vaporizing or accumulating materials [6]. In Feynman's important speech the production of small machines by chemically synthesizing the materials first, then physically bringing them together in atomic order was suggested.

Nowadays, this idea has gone much further and systems in nano-dimensions are trying to be produced. There are studies in the literature about the behavior of these systems; Paidoussis et al. [7] investigated the linear and nonlinear dynamic behaviors of cylindrical beams under water flow. They studied and experimented with the energy transfer by the work-energy principle without solving the equations of motion. Then, Paidoussis et al. [8] studied the 3D dynamics of fluid carrying pipes that have one or several springs supports over their length. They compared the theoretically obtained results with those obtained experimentally. Rinaldi et al. [9] studied the dynamics of microstructures with fluid passing through them. They investigated damping, natural frequency changes and stability states. Kural et al. [10] studied string–beam transition problem and they found an approximate solution by using perturbation methods. Yurddaş et al. [11, 12] investigated nonlinear vibrations of an axially moving string having non-ideal mid-support and multi-support conditions.

The equations obtained in the above studies were based on the classical beam theory (CBT) and they are the same as those obtained in normal dimensions, except for the forces in the nonlinear order. In this case, according to the classical beam theory, there is no difference that the beam is of very small size [13]. However, some research which cannot be explained by the classical beam theory has been observed experimentally. It has been concluded that a microbeam has dimensional effects due to reasons such as impurity, crystal lattice incompatibility, shear stresses and micro cracks. Particularly in the studies carried out, it has been observed that the sliding resistance of the material increases as its dimensions decrease. [14]

Different theories have been produced for microstructures because the classical beam theory cannot explain the size effects. For example, couple stress theory and strain gradient theory. Then, modified couple stress theory (MCST), which is easier to apply, has been proposed by Yang et al. [15]. According to this theory, the tensile tensor is symmetric, and a single material dimension parameter is used. According to other theories, this advantage has been attracting many researchers' interest in the past years. Park and Gao [16] studied the properties of Euler-Bernoulli microbeams with MCST. They have already explained unexplained bending tests for epoxy microbeams. Kong et al. [17] have also investigated boundary value problems for Euler-Bernoulli microbeams

with MCST. They have shown that the new natural frequency values obtained are higher than the classical beam theory. Chen et al. [18] have developed a "Modified Couple Stress" model for bending analysis of first order shear deformation of composite layered beams. Rafiee et al. [19] studied forced oscillations that also observed nonlinear effects for simple-supported microbeams. Ke et al. [20] studied free vibrations for Mindlin microplates using MCST. They show that the size effects are quite large when the thickness of the microplates is close to the material length parameter. Atcı and Bağdatlı studied the effects of non-ideal boundary conditions on the free vibrations of fluid conveying clamped microbeams [21]. They also investigated non-ideal boundary conditions for nonlinear fluid conveying microbeams [22]. Dai et al. [23] studied nonlinear dynamic responses of microcantilevers containing internal fluid flow. They found that with the increase in flow velocity, flutter instability, pull-in instability and the combination of both can occur in this dynamical system. Nikkhah-Bahrami et al. investigated nonlinear vibrations of micropipes conveying fluid [24] and nonlinear stability of fluid-conveying imperfect micropipes [25]. Hadi Arvin presented the flap wise bending free vibration analysis of isotropic rotating Timoshenko microbeams, including the size effects [26]. Lotfi et al. [27] investigated transient behavior and dynamic pull-in instability of electrostatically-actuated fluid-conveying microbeams. Kural et al. [13] investigated nonlinear free vibration of a fixed-fixed microbeam conveying fluid resting on elastic foundation.

In this study, it is assumed that the microbeam is affected by the electrical field force and is on an elastic ground, as shown in Fig. 1. The terms originating from extensions during vibration, elastic ground, damping and electrical field strength have added an additional nonlinear property to the equations of motion. Obtained mathematical model became independent from geometry and material by making the equations of motion dimensionless. It is assumed that the fluid velocity changes harmonically around a constant velocity and the electrical field force changes harmonically with time. Under these conditions, the first two natural frequencies of the system were obtained. The resonance states of 3:1 and 2:1 are examined according to the closeness of these natural frequencies. Amplitude changes for the cases where natural frequency values will form 2:1 and 3:1 internal resonance are obtained and shown in the graphs.

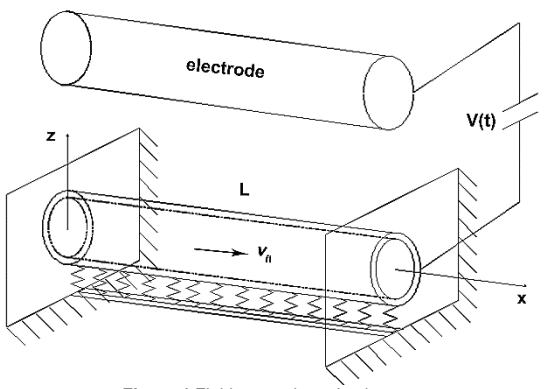

Figure 1 Fluid conveying microbeam

2 LINEAR SOLUTIONS

The equations of motion for the system discussed in this study, in Fig. 1, can be modelled as follows, [28]

$$\begin{aligned}&\ddot{w}+\beta(2v_{fl}\dot{w}'+\dot{v}_{fl}w')+(\beta{v_{fl}}^2-1)w''\\&+({V_f}^2+\Gamma^2)w^{iv}+k_1w+\varepsilon k_2w^3+\varepsilon\bar{\mu}\dot{w}\\&=\varepsilon\bar{\alpha}_2[\frac{1}{2}\int_0^1 w'^2\mathrm{d}x]w''+\varepsilon\bar{\alpha}_1V_{el}(t)^2(1+2w)\end{aligned}\tag{1}$$

Here v_{fl} is fluid velocity, β is solidity ratio, V_f is beam coefficient, Γ is microbeam coefficient, k_1 is linear spring constant, k_2 is nonlinear spring constant, μ is the damping ratio and can be accepted as $O(\varepsilon)$ ($\mu=\varepsilon\bar{\mu}$), $\bar{\alpha}_2$ is the beam elasticity coefficient. For the multiple scale method, the derivatives can be defined as,

$$T_0=t,\quad T_1=\varepsilon t\tag{2}$$

$$\frac{\partial}{\partial t}=\frac{\partial}{\partial T_0}\frac{\partial T_0}{\partial t}+\frac{\partial}{\partial T_1}\frac{\partial T_1}{\partial t}=D_0+\varepsilon D_1+\ldots\tag{3}$$

$$\frac{\partial^2}{\partial t^2}={D_0}^2+2\varepsilon D_0D_1+\ldots\tag{4}$$

We can expand "w" expression as,

$$w=w_0+\varepsilon w_1+\ldots\tag{5}$$

Then the fluid velocity and the electric voltage can be defined,

$$v_{fl}=v_0+\varepsilon v_1\sin\Omega_1t\tag{6}$$

$$V_{el}(t)=V_{AC}\cos\Omega_2t\tag{7}$$

From here, Eq. (1) becomes,

$$\begin{aligned}&({D_0}^2+2\varepsilon D_0D_1)(w_0+\varepsilon w_1)\\&+\beta(2(v_0+\varepsilon v_1\sin\Omega_1T_0)[D_0+\varepsilon D_1](w_0'+\varepsilon w_1')\\&+(\varepsilon v_1\Omega_1\cos\Omega_1T_0)(w_0'+\varepsilon w_1'))\\&+(\beta({v_0}^2+2\varepsilon v_0v_1\sin\Omega_1T_0)-1)(w_0''+\varepsilon w_1'')\\&+({V_f}^2+\Gamma^2)(w_0^{iv}+\varepsilon w_1^{iv})+k_1(w_0+\varepsilon w_1)\\&+\varepsilon k_2(w_0+\varepsilon w_1)+\varepsilon\bar{\mu}[D_0+\varepsilon D_1](w_0+\varepsilon w_1)\\&=\varepsilon\bar{\alpha}_2[\frac{1}{2}\int_0^1({w_0'}^2+2\varepsilon w_0'w_1'+\varepsilon^2{w_1'}^2)\mathrm{d}x](w_0''+\varepsilon w_1'')\\&+\varepsilon\bar{\alpha}_1{V_{AC}}^2\cos^2\Omega_2t(1+2w_0+3{w_0}^2)\end{aligned}\tag{8}$$

If the expression is separated into ranks, Order (1) and Order (ε) are obtained as follows,

$$\underline{O(1)}$$

$$D_0{}^2 w_0 + 2\beta v_0 D_0 w_0{}' + (\beta v_0{}^2 - 1) w_0{}'' + (V_f{}^2 + \Gamma^2) w_0{}^{iv} + k_1 w_0 = 0 \tag{9}$$

$$\underline{O(\varepsilon)}$$

$$\begin{aligned} &D_0{}^2 w_1 + 2\beta v_0 D_0 w_1{}' + (\beta v_0{}^2 - 1) w_1{}'' \\ &+ (V_f{}^2 + \Gamma^2) w_1{}^{iv} + k_1 w_1 = -2 D_0 D_1 w_0 \\ &-2\beta v_0 D_1 w_0{}' - 2 v_1 \sin\Omega_1 T_0 D_0 w_0{}' \\ &-\beta v_1 \Omega_1 \cos\Omega_1 T_0 w_0{}' - 2\beta v_0 v_1 \sin\Omega_1 T_0 D_0 w_0{}'' \\ &-k_2 w_0 - \bar{\mu} D_0 w_0 + \bar{\alpha}_2 (\frac{1}{2}\int_0^1 w_0{}'^2 \mathrm{d}x) w_0{}'' \\ &+ \bar{\alpha}_1 V_{AC}{}^2 \cos^2\Omega_2 T_0 (1 + 2 w_0) \end{aligned} \tag{10}$$

The first order solution can be written as the sum of the infinite number of modes,

$$w_0(x, T_0, T_1) = \sum_{m=0}^{\infty} Y_m(x) A_m(T_1) e^{i\omega_m T_0} + K.E. \tag{11}$$

This solution can be written in linear order as,

$$\begin{aligned} &(V_f{}^2 + \Gamma^2) Y_m{}^{iv} + (\beta v_0{}^2 - 1) Y_m{}'' + 2 i \omega_m \beta v_0 Y_m{}' \\ &+ (k_1 - \omega_m{}^2) Y_m = 0 \end{aligned} \tag{12}$$

Here $Y_m(x)$ solution is offered as,

$$\begin{aligned} Y_m(x) &= c_{m1} e^{i r_{m1} x} + c_{m2} e^{i r_{m2} x} + c_{m3} e^{i r_{m3} x} + c_{m4} e^{i r_{m4} x} \\ &= c_{m1} (e^{i r_{m1} x} + \frac{c_{m2}}{c_{m1}} e^{i r_{m2} x} + \frac{c_{m3}}{c_{m1}} e^{i r_{m3} x} + \frac{c_{m4}}{c_{m1}} e^{i r_{m4} x}) \end{aligned} \tag{13}$$

We can change the coefficients in this equation as follows,

$$\frac{c_{m2}}{c_{m1}} = C_{m2}, \quad \frac{c_{m3}}{c_{m1}} = C_{m3}, \quad \frac{c_{m4}}{c_{m1}} = C_{m4} \tag{14}$$

Hence,

$$\begin{aligned} &c_{m1}\{e^{i r_{m1} x} (r_{m1}{}^4 (V_f{}^2 + \Gamma^2) - r_{m1}{}^2 (\beta v_0{}^2 - 1) \\ &- r_{m1} 2\omega_m \beta v_0 + (k_1 - \omega_m{}^2)) + C_{m2} e^{i r_{m2} x} (r_{m2}{}^4 (V_f{}^2 + \Gamma^2) \\ &- r_{m2}{}^2 (\beta v_0{}^2 - 1) - r_{m2} 2\omega_m \beta v_0 + (k_1 - \omega_m{}^2)) \\ &+ C_{m3} e^{i r_{m3} x} (r_{m3}{}^4 (V_f{}^2 + \Gamma^2) - r_{m3}{}^2 (\beta v_0{}^2 - 1) \\ &- r_{m3} 2\omega_m \beta v_0 + (k_1 - \omega_m{}^2)) + C_{m4} e^{i r_{m4} x} (r_{m4}{}^4 (V_f{}^2 + \Gamma^2) \\ &- r_{m4}{}^2 (\beta v_0{}^2 - 1) - r_{m4} 2\omega_m \beta v_0 + (k_1 - \omega_m{}^2))\} = 0 \end{aligned} \tag{15}$$

In Eq. (15) coefficients cannot be zero; the inside of the parentheses must be zero. For this,

$$\begin{aligned} &r_{mn}{}^4 (V_f{}^2 + \Gamma^2) - r_{mn}{}^2 (\beta v_0{}^2 - 1) \\ &- r_{mn} 2\omega_m \beta v_0 + (k_1 - \omega_m{}^2) = 0 \qquad n = 1, 2, 3, 4 \end{aligned} \tag{16}$$

If we apply the boundary conditions, then the solution of the linear order becomes,

$$\begin{aligned} Y_{mn}(x) = c_{1mn} (& e^{i r_{1mn} x} - \frac{(r_{4mn} - r_{1mn})(e^{i r_{3mn}} - e^{i r_{2mn}})}{(r_{4mn} - r_{2mn})(e^{i r_{3mn}} - e^{i r_{2mn}})} e^{i r_{2mn} x} \\ & - \frac{(r_{4mn} - r_{1mn})(e^{i r_{1mn}} - e^{i r_{2mn}})}{(r_{4mn} - r_{3mn})(e^{i r_{3mn}} - e^{i r_{2mn}})} e^{i r_{3mn} x} \\ & + \frac{\begin{pmatrix} -(r_{4mn} - r_{2mn})(r_{4mn} - r_{3mn})(e^{i r_{3mn}} - e^{i r_{2mn}}) \\ +(r_{4mn} - r_{3mn})(r_{4mn} - r_{1mn})(e^{i r_{3mn}} - e^{i r_{1mn}}) \\ +(r_{4mn} - r_{2mn})(r_{4mn} - r_{1mn})(e^{i r_{1mn}} - e^{i r_{2mn}}) \end{pmatrix}}{(r_{4mn} - r_{2mn})(r_{4mn} - r_{3mn})(e^{i r_{3mn}} - e^{i r_{2mn}})}) = 0 \end{aligned} \tag{17}$$

The C coefficients are determined to provide the following equation.

$$\int_0^1 Y_m{}^2 \mathrm{d}x = 1 \tag{18}$$

With this solution, if the first two natural frequencies of the system will be displayed in tabular form for different conditions as follows,

Table 1 Case 1 - first two natural frequencies of system for fluid velocity changes ($V_f = 1, k_1 = 1, k_2 = 1, v_1 = 3, \varepsilon = 0.1, \beta = 0.5, \alpha_2 = 3$)

v_0	ω_1	ω_2	ω_2 / ω_1
4.300	22.708	67.486	2.972
4.350	22.637	67.421	2.978
4.400	22.566	67.354	2.985
4.450	22.493	67.287	2.991
4.500	22.420	67.219	2.998
4.550*	22.345*	67.150*	3.005*
4.600	22.270	67.080	3.012
4.650	22.193	67.009	3.019
4.700	22.116	66.938	3.027

Table 2 Case 2 - first two natural frequencies of system for fluid velocity changes ($V_f = 0.8, k_1 = 1, k_2 = 1, v_1 = 3, \varepsilon = 0.1, \beta = 0.5, \alpha_2 = 3$)

v_0	ω_1	ω_2	ω_2 / ω_1
3.500	18.210	54.063	2.969
3.550	18.138	53.996	2.977
3.600	18.065	53.929	2.985
3.650	17.991	53.860	2.994
3.700*	17.916*	53.790*	3.002*
3.750	17.839	53.719	3.011
3.800	17.761	53.647	3.020
3.850	17.682	53.574	3.030
3.900	17.602	53.500	3.039

As can be seen from the graphs, the 3:1 internal resonance is a more common problem in the studied situations, while the 2:1 internal resonance condition occurs

when the spring constant is higher. From these graphs nonlinear problem is analyzed, stability limits are plotted by using * values (critical values for internal resonance).

Table 3 Case 3 - first two natural frequencies of system for fluid velocity changes ($V_f = 0.1, k_1 = 1, k_2 = 1, v_1 = 3, \varepsilon = 0.1, \beta = 0.5, \alpha_2 = 3$)

v_0	ω_1	ω_2	ω_2/ω_1
1.150	3.027	8.032	2.653
1.200	2.893	7.873	2.722
1.250	2.750	7.706	2.802
1.300	2.598	7.531	2.899
1.350*	2.437*	7.348*	3.015*
1.400	2.265	7.157	3.160
1.450	2.081	6.956	3.342
1.500	1.885	6.746	3.579
1.550	1.673	6.527	3.901

Table 4 Case 4 - first two natural frequencies of system for fluid velocity changes ($V_f = 0.1, k_1 = 8, k_2 = 1, v_1 = 3, \varepsilon = 0.1, \beta = 0.5, \alpha_2 = 3$)

v_0	ω_1	ω_2	ω_2/ω_1
0.300	5.048	10.004	1.982
0.350	5.019	9.964	1.985
0.400	4.984	9.917	1.990
0.450	4.945	9.864	1.995
0.500*	4.901*	9.805*	2.001*
0.550	4.852	9.739	2.007
0.600	4.798	9.668	2.015
0.650	4.739	9.589	2.024
0.700	4.675	9.505	2.033

3 NONLINEAR PROBLEM AND INTERNAL RESONANCES

Examination of internal resonance states will form nonlinear order solutions. In this section, the effects of nonlinear expressions on the system will be investigated. We define the first order solution as the sum of only the first two modes as follows,

$$w_0(x,T_0,T_1) = A_1(T_1)e^{i\omega_1 T_0}Y_1(x) + A_2(T_1)e^{i\omega_2 T_0}Y_2(x) + K.E. \tag{19}$$

In this case the nonlinear order expression becomes,

$$\begin{aligned} &D_0{}^2 w_1 + 2\beta v_0 D_0 w_1{}' + (\beta v_0{}^2 - 1)w_1{}'' \\ &+(V_f{}^2 + \Gamma^2)w_1{}^{iv} + k_1 w_1 = -2D_0 D_1 w_0 - 2\beta v_0 D_1 w_0{}' \\ &-2\beta v_1 \sin\Omega_1 T_0 D_0 w_0{}' - \beta v_1 \Omega_1 \cos\Omega_1 T_0 w_0{}' \\ &-2\beta v_0 v_1 \sin\Omega_1 T_0 D_0 w_0{}'' - k_2 w_0^3 - \bar{\mu} D_0 w_0 \\ &+\bar{\alpha}_2 (\frac{1}{2}\int_0^1 w_0{}'^2 dx) w_0{}'' + F\cos^2\Omega_2 T_0 (1 + 2w_0) \end{aligned} \tag{20}$$

For simplicity, the force amplitude can be defined as follows,

$$F = \bar{\alpha}_1 V_{AC}{}^2 \tag{21}$$

we can suggest the solution of the nonlinear order as follows,

$$\begin{aligned} &w_1(x,T_0,T_1;\varepsilon) = \phi_1(x,T_1)e^{i\omega_1 T_0} + \phi_2(x,T_1)e^{i\omega_2 T_0} \\ &+W(x,T_0,T_1) + K.E. \end{aligned} \tag{22}$$

we obtain following equation if we write trigonometric expressions in complex form and write all expressions.

$$\begin{aligned} &(V_f{}^2 + \Gamma^2)w_1{}^{iv} + (\beta v_0{}^2 - 1)w_1{}'' + 2\beta v_0 D_0 w_1{}' + D_0{}^2 w_1 + k_1 w_1 \\ &= -2(i\omega_1 Y_1 + \beta v_0 Y_1{}')D_1 A_1 e^{i\omega_1 T_0} - 2(i\omega_2 Y_2 + \beta v_0 Y_2{}')D_1 A_2 e^{i\omega_2 T_0} \\ &-\beta v_1 \omega_1 Y_1{}' A_1 e^{i\omega_2 T_0} e^{i(\sigma_2 - \sigma_1)T_1} + \beta v_1 \omega_1 \overline{Y}_1{}' \overline{A}_1 e^{i\omega_1 T_0} e^{i\sigma_2 T_1} \\ &+\beta v_1 \omega_2 Y_2{}' A_2 e^{i\omega_1 T_0} e^{i(\sigma_1 - \sigma_2)T_1} - \frac{1}{2}\beta v_1 \Omega_1 Y_1{}' A_1 e^{i\omega_2 T_0} e^{i(\sigma_2 - \sigma_1)T_1} \\ &-\frac{1}{2}\beta v_1 \Omega_1 \overline{Y}_1{}' \overline{A}_1 e^{i\omega_1 T_0} e^{i\sigma_2 T_1} - \frac{1}{2}\beta v_1 \Omega_1 Y_2{}' A_2 e^{i\omega_1 T_0} e^{i(\sigma_1 - \sigma_2)T_1} \\ &+i\beta v_0 v_1 Y_1{}'' A_1 e^{i\omega_2 T_0} e^{i(\sigma_2 - \sigma_1)T_1} + i\beta v_0 v_1 \overline{Y}_1{}'' \overline{A}_1 e^{i\omega_1 T_0} e^{i\sigma_2 T_1} \\ &-i\beta v_0 v_1 Y_2{}'' A_2 e^{i\omega_1 T_0} e^{i(\sigma_1 - \sigma_2)T_1} - k_2 (A_1{}^3 Y_1{}^3 e^{i\omega_2 T_0} e^{-i\sigma_1 T_1} \\ &+3A_1{}^2 \overline{A}_1 Y_1{}^2 \overline{Y}_1 e^{i\omega_1 T_0} + 3A_2{}^2 \overline{A}_2 Y_2{}^2 \overline{Y}_2 e^{i\omega_2 T_0} \\ &+3\overline{A}_1{}^2 A_2 \overline{Y}_1{}^2 Y_2 e^{i\omega_1 T_0} e^{i\sigma_1 T_1} + 6A_1 A_2 \overline{A}_1 Y_1 Y_2 \overline{Y}_1 e^{i\omega_2 T_0} \\ &+6A_1 A_2 \overline{A}_2 Y_1 Y_2 \overline{Y}_2 e^{i\omega_1 T_0}) - \bar{\mu}(i\omega_1 A_1 Y_1 e^{i\omega_1 T_0} + i\omega_2 A_2 Y_2 e^{i\omega_2 T_0}) \\ &+\frac{\bar{\alpha}_2}{2}(e^{i\omega_1 T_0}(A_1{}^2 \overline{A}_1 \overline{Y}_1{}'' \int_0^1 Y_1{}'^2 dx + 2A_1 A_2 \overline{A}_2 \overline{Y}_2{}'' \int_0^1 Y_1{}' Y_2{}' dx \\ &+2A_1{}^2 \overline{A}_1 Y_1{}'' \int_0^1 Y_1{}' \overline{Y}_1{}' dx + 2A_1 A_2 \overline{A}_2 Y_2{}'' \int_0^1 Y_1{}' \overline{Y}_2{}' dx \\ &+2A_1 A_2 \overline{A}_2 Y_1{}'' \int_0^1 Y_2{}' \overline{Y}_2{}' dx) + e^{i\omega_2 T_0}(A_2{}^2 \overline{A}_2 \overline{Y}_2{}'' \int_0^1 Y_2{}'^2 dx \\ &+2A_1 A_2 \overline{A}_1 \overline{Y}_1{}'' \int_0^1 Y_1{}' Y_2{}' dx + 2A_2{}^2 \overline{A}_2 Y_2{}'' \int_0^1 Y_2{}' \overline{Y}_2{}' dx \\ &+2A_1 A_2 \overline{A}_1 Y_1{}'' \int_0^1 \overline{Y}_1{}' Y_2{}' dx + 2A_1 A_2 \overline{A}_1 Y_2{}'' \int_0^1 Y_1{}' \overline{Y}_1{}' dx)) \\ &+F(A_1 Y_1 e^{i\omega_1 T_0} + A_2 Y_2 e^{i\omega_2 T_0}) + K.E. + S.O.T. \end{aligned} \tag{23}$$

Here we need a state of solvency to eliminate the concepts that make secularism. We will examine the resolvability conditions in separate sections for different states of internal resonances.

3.1 The Case Where the Fundamental Parametric Resonance and the 3:1 Internal Resonance Conditions are Together

In this case, the fluid velocity change frequency is taken as the critical forcing frequency. The frequency of the electric voltage change was chosen so as not to create any secularity.

$$\begin{aligned} &\omega_2 = 3\omega_1 + \varepsilon\sigma_1 \\ &\Omega_1 = 2\omega_1 + \varepsilon\sigma_2 \\ &\Omega_2 \not\approx 0, \omega_1, 2\omega_1 \end{aligned} \tag{24}$$

Since the homogeneous equation has non-simple solutions, the nonhomogeneous equation can only accept

solutions with a solvability condition. Hence, the following conditions must be met for secularity-forming terms,

$$\begin{aligned}
&\int_0^1[-2(i\omega_1 Y_1+\beta v_0 Y_1')D_1A_1+\beta v_1\omega_1\overline{Y}_1'\overline{A}_1e^{i\sigma_2T_1}\\
&+\beta v_1\omega_2 Y_2'A_2e^{i(\sigma_1-\sigma_2)T_1}-\frac{1}{2}\beta v_1\Omega_1\overline{Y}_1'\overline{A}_1e^{i\sigma_2T_1}\\
&-\frac{1}{2}\beta v_1\Omega_1 Y_2'A_2e^{i(\sigma_1-\sigma_2)T_1}+i\beta v_0v_1\overline{Y}_1''\overline{A}_1e^{i\sigma_2T_1}\\
&-i\beta v_0v_1Y_2''A_2e^{i(\sigma_1-\sigma_2)T_1}-k_2(3A_1^2\overline{A}_1Y_1^2\overline{Y}_1\\
&+3\overline{A}_1^2A_2\overline{Y}_1^2Y_2e^{i\sigma_1T_1}+6A_1A_2\overline{A}_2Y_1Y_2\overline{Y}_2)-\overline{\mu}\,\mathrm{i}\,\omega_1A_1Y_1\\
&+\frac{\overline{\alpha}_2}{2}(A_1^2\overline{A}_1\overline{Y}_1''\int_0^1Y_1'^2\mathrm{d}x+2A_1A_2\overline{A}_2\overline{Y}_2''\int_0^1Y_1'Y_2'\mathrm{d}x\\
&+2A_1^2\overline{A}_1Y_1''\int_0^1Y_1'\overline{Y}_1'\mathrm{d}x+2A_1A_2\overline{A}_2Y_2''\int_0^1Y_1'\overline{Y}_2'\mathrm{d}x\\
&+2A_1A_2\overline{A}_2Y_1''\int_0^1Y_2'\overline{Y}_2'\mathrm{d}x)+\mathrm{F}\,A_1Y_1]\overline{Y}_1\mathrm{d}x=0
\end{aligned}\tag{25}$$

$$\begin{aligned}
&\int_0^1[-2(i\omega_2Y_2+\beta v_0Y_2')D_1A_2-\beta v_1\omega_1Y_1'A_1e^{i(\sigma_2-\sigma_1)T_1}\\
&-\frac{1}{2}\beta v_1\Omega_1Y_1'A_1e^{i(\sigma_2-\sigma_1)T_1}+i\beta v_0v_1Y_1''A_1e^{i(\sigma_2-\sigma_1)T_1}\\
&-k_2(A_1^3Y_1^3e^{-i\sigma_1T_1}+3A_2^2\overline{A}_2Y_2^2\overline{Y}_2+6A_1A_2\overline{A}_1Y_1Y_2\overline{Y}_1)\\
&-\overline{\mu}\,\mathrm{i}\,\omega_2A_2Y_2+\frac{\overline{\alpha}_2}{2}(A_2^2\overline{A}_2\overline{Y}_2''\int_0^1Y_2'^2\mathrm{d}x\\
&+2A_1A_2\overline{A}_1\overline{Y}_1''\int_0^1Y_1'Y_2'\mathrm{d}x+2A_2^2\overline{A}_2Y_2''\int_0^1Y_2'\overline{Y}_2'\mathrm{d}x\\
&+2A_1A_2\overline{A}_1Y_1''\int_0^1\overline{Y}_1'Y_2'dx+2A_1A_2\overline{A}_1Y_2''\int_0^1Y_1'\overline{Y}_1'dx)\\
&+FA_2Y_2]\overline{Y}_2\mathrm{d}x=0
\end{aligned}\tag{26}$$

From here, the simplest form of our equations is obtained as follows,

$$\begin{aligned}
&D_1A_1+\overline{A}_1e^{i\sigma_2T_1}K_{11}+A_2e^{i(\sigma_1-\sigma_2)T_1}K_{12}-\overline{A}_1^2A_2e^{i\sigma_1T_1}K_{13}\\
&+A_1K_{14}+A_1^2\overline{A}_1K_{15}+A_1A_2\overline{A}_2K_{16}=0
\end{aligned}\tag{27}$$

$$\begin{aligned}
&D_1A_2-A_1e^{i(\sigma_2-\sigma_1)T_1}K_{21}+A_1^3e^{-i\sigma_1T_1}K_{22}+A_2^2\overline{A}_2K_{23}\\
&+A_2K_{24}+A_1A_2\overline{A}_1K_{25}=0
\end{aligned}\tag{28}$$

The K expressions in the equations defined as follows,

$$\begin{aligned}
K_{11}&=\frac{[(\beta v_1\omega_1-\frac{1}{2}\beta v_1\Omega_1)\int_0^1\overline{Y}_1'\overline{Y}_1\,\mathrm{d}x+i\beta v_0v_1\int_0^1\overline{Y}''\overline{Y}_1\,\mathrm{d}x]}{(-2i\omega_1\int_0^1Y_1\overline{Y}_1\,\mathrm{d}x-2\beta v_0\int_0^1Y_1'\overline{Y}_1\,\mathrm{d}x)},\\
K_{12}&=\frac{[(\beta v_1\omega_2-\frac{1}{2}\beta v_1\Omega_1)\int_0^1Y_2'\overline{Y}_1\,\mathrm{d}x-i\beta v_0v_1\int_0^1Y_2''\overline{Y}_1\,\mathrm{d}x]}{(-2i\omega_1\int_0^1Y_1\overline{Y}_1\,\mathrm{d}x-2\beta v_0\int_0^1Y_1'\overline{Y}_1\,\mathrm{d}x)},\\
K_{13}&=\frac{(3k_2\int_0^1\overline{Y}_1^3Y_2\,\mathrm{d}x)}{(-2i\omega_1\int_0^1Y_1\overline{Y}_1\,\mathrm{d}x-2\beta v_0\int_0^1Y_1'\overline{Y}_1\,\mathrm{d}x)},\\
K_{14}&=\frac{[(-\overline{\mu}\,\mathrm{i}\,\omega_1+\mathrm{F})\int_0^1Y_1\overline{Y}_1\,\mathrm{d}x]}{(-2i\omega_1\int_0^1Y_1\overline{Y}_1\,\mathrm{d}x-2\beta v_0\int_0^1Y_1'\overline{Y}_1\,\mathrm{d}x)},\\
K_{15}&=[-3k_2\int_0^1Y_1^2\overline{Y}_1^2\,\mathrm{d}x+\overline{\alpha}_2(\frac{1}{2}\int_0^1\overline{Y}_1\overline{Y}_1''\int_0^1Y_1'^2dxdx\\
&+\int_0^1\overline{Y}_1Y_1''\int_0^1Y_1'\overline{Y}_1'dxdx)]/(-2i\omega_1\int_0^1Y_1\overline{Y}_1\,\mathrm{d}x-2\beta v_0\int_0^1Y_1'\overline{Y}_1\,\mathrm{d}x),\\
K_{16}&=[-6k_2\int_0^1Y_1\overline{Y}_1Y_2\overline{Y}_2\,\mathrm{d}x+\overline{\alpha}_2(\int_0^1\overline{Y}_1\overline{Y}_2''\int_0^1Y_1'Y_2'dxdx\\
&+\int_0^1\overline{Y}_1Y_2''\int_0^1Y_1'\overline{Y}_2'dxdx\\
&+\int_0^1\overline{Y}_1Y_1''\int_0^1Y_2'\overline{Y}_2'dxdx)]/(-2i\omega_1\int_0^1Y_1\overline{Y}_1\,\mathrm{d}x-2\beta v_0\int_0^1Y_1'\overline{Y}_1\,\mathrm{d}x)
\end{aligned}\tag{29}$$

$$\begin{aligned}
K_{21}&=\frac{[(\beta v_1\omega_1+\frac{1}{2}\beta v_1\Omega_1)\int_0^1\overline{Y}_2Y_1'\mathrm{d}x-i\beta v_0v_1\int_0^1\overline{Y}_2Y_1''\mathrm{d}x]}{(-2i\omega_2\int_0^1Y_2\overline{Y}_2\mathrm{d}x-2\beta v_0\int_0^1\overline{Y}_2Y_2'\mathrm{d}x)},\\
K_{22}&=\frac{(-k_2\int_0^1Y_1^3\overline{Y}_2\mathrm{d}x)}{(-2i\omega_2\int_0^1Y_2\overline{Y}_2\mathrm{d}x-2\beta v_0\int_0^1\overline{Y}_2Y_2'\mathrm{d}x)},\\
K_{23}&=[-3k_2\int_0^1Y_2^2\overline{Y}_2^2\mathrm{d}x+\overline{\alpha}_2(\frac{1}{2}\int_0^1\overline{Y}_2\overline{Y}_2''\int_0^1Y_2'^2\mathrm{d}x\mathrm{d}x\\
&+\int_0^1\overline{Y}_2Y_2''\int_0^1Y_2'\overline{Y}_2'\mathrm{d}x\mathrm{d}x)]/(-2i\omega_2\int_0^1Y_2\overline{Y}_2\mathrm{d}x-2\beta v_0\int_0^1\overline{Y}_2Y_2'\mathrm{d}x),\\
K_{24}&=\frac{[(-\overline{\mu}\,\mathrm{i}\,\omega_2+\mathrm{F})\int_0^1Y_2\overline{Y}_2\mathrm{d}x]}{(-2i\omega_2\int_0^1Y_2\overline{Y}_2\mathrm{d}x-2\beta v_0\int_0^1\overline{Y}_2Y_2'\mathrm{d}x)},\\
K_{25}&=[-6k_2\int_0^1Y_1Y_2\overline{Y}_1\overline{Y}_2\mathrm{d}x\\
&+\overline{\alpha}_2(\int_0^1\overline{Y}_2\overline{Y}_1''\int_0^1Y_1'Y_2'\mathrm{d}x\mathrm{d}x+\int_0^1\overline{Y}_2Y_1''\int_0^1\overline{Y}_1'Y_2'\mathrm{d}x\mathrm{d}x\\
&+\int_0^1\overline{Y}_2Y_2''\int_0^1Y_1'\overline{Y}_1'\mathrm{d}x\mathrm{d}x)]/(-2i\omega_2\int_0^1Y_2\overline{Y}_2\mathrm{d}x-2\beta v_0\int_0^1\overline{Y}_2Y_2'\mathrm{d}x)
\end{aligned}\tag{30}$$

If the complex amplitudes are expressed in polar form and written into the real and imaginary parts of the coefficients, the "amplitude phase modulation equations" for the uniform regime state can be simply written as,

$$\begin{aligned}\text{Re\_1} \Rightarrow\ & a_1\cos\gamma_{11}K_{11R} - a_1\sin\gamma_{11}K_{11I} \\ & + a_2(\cos\gamma_{13}\cos\gamma_{11} + \sin\gamma_{13}\sin\gamma_{11})K_{12R} \\ & + a_2(\cos\gamma_{13}\sin\gamma_{11} - \sin\gamma_{13}\cos\gamma_{11})K_{12I} \\ & - \frac{1}{4}{a_1}^2 a_2\cos\gamma_{13}K_{13R} + \frac{1}{4}{a_1}^2 a_2\sin\gamma_{13}K_{13I} \\ & + a_1K_{14R} + \frac{1}{4}{a_1}^3K_{15R} + \frac{1}{4}a_1{a_2}^2K_{16R} = 0\end{aligned} \tag{31}$$

$$\begin{aligned}\text{Im\_1} \Rightarrow\ & \frac{1}{2}a_1\sigma_2 + a_1\sin\gamma_{11}K_{11R} + a_1\cos\gamma_{11}K_{11I} \\ & + a_2(-\cos\gamma_{13}\sin\gamma_{11} + \sin\gamma_{13}\cos\gamma_{11})K_{12R} \\ & + a_2(\cos\gamma_{13}\cos\gamma_{11} + \sin\gamma_{13}\sin\gamma_{11})K_{12I} \\ & - \frac{1}{4}{a_1}^2 a_2\sin\gamma_{13}K_{13R} - \frac{1}{4}{a_1}^2 a_2\cos\gamma_{13}K_{13I} \\ & + a_1K_{14I} + \frac{1}{4}{a_1}^3K_{15I} + \frac{1}{4}a_1{a_2}^2K_{16I} = 0\end{aligned} \tag{32}$$

$$\begin{aligned}\text{Re\_2} \Rightarrow\ & -a_1(\cos\gamma_{11}\cos\gamma_{13} + \sin\gamma_{11}\sin\gamma_{13})K_{21R} \\ & - a_1(\cos\gamma_{11}\sin\gamma_{13} - \sin\gamma_{11}\cos\gamma_{13})K_{21I} \\ & + \frac{1}{4}{a_1}^3\cos\gamma_{13}K_{22R} + \frac{1}{4}{a_1}^3\sin\gamma_{13}K_{22I} \\ & + \frac{1}{4}{a_2}^3K_{23R} + a_2K_{24R} + \frac{1}{4}{a_1}^2a_2K_{25R} = 0\end{aligned} \tag{33}$$

$$\begin{aligned}\text{Im\_2} \Rightarrow\ & a_2[\frac{3}{2}\sigma_2 - \sigma_1] - a_1(-\cos\gamma_{11}\sin\gamma_{13} \\ & + \sin\gamma_{11}\cos\gamma_{13})K_{21R} - a_1(\cos\gamma_{11}\cos\gamma_{13} \\ & + \sin\gamma_{11}\sin\gamma_{13})K_{21I} - \frac{1}{4}{a_1}^3\sin\gamma_{13}K_{22R} \\ & + \frac{1}{4}{a_1}^3\cos\gamma_{13}K_{22I} + \frac{1}{4}{a_2}^3K_{23I} + a_2K_{24I} \\ & + \frac{1}{4}{a_1}^2a_2K_{25I} = 0\end{aligned} \tag{34}$$

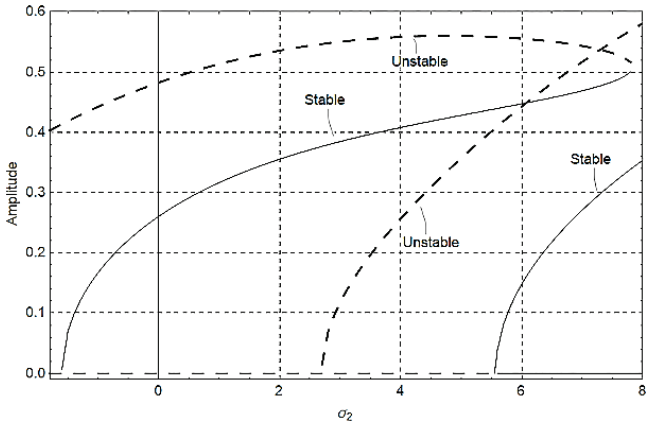

Figure 2 Change of the amplitude a_1 according to the detuning parameter σ_2 (Case 1)

By using the marked natural frequency values for cases 1 to 3 and the equations obtained for the cases where the fundamental parametric resonance due to the fluid velocity and the 3:1 internal resonance coincide, the graphs that show the variations of the amplitudes depending on the fluid velocity detuning parameter (σ_2) are plotted in Figs. 2-7.

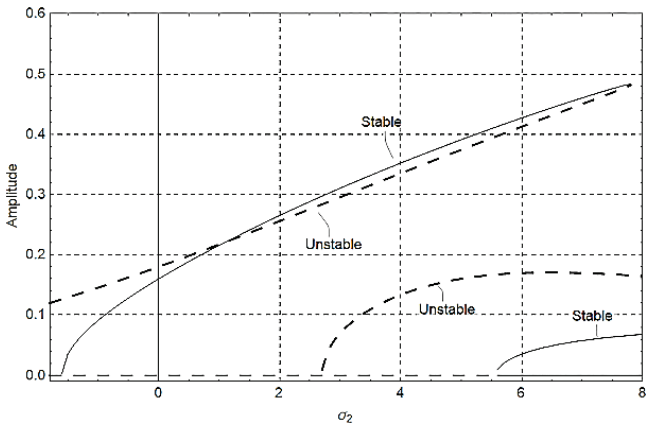

Figure 3 Change of the amplitude a_2 according to the detuning parameter σ_2 (Case 1)

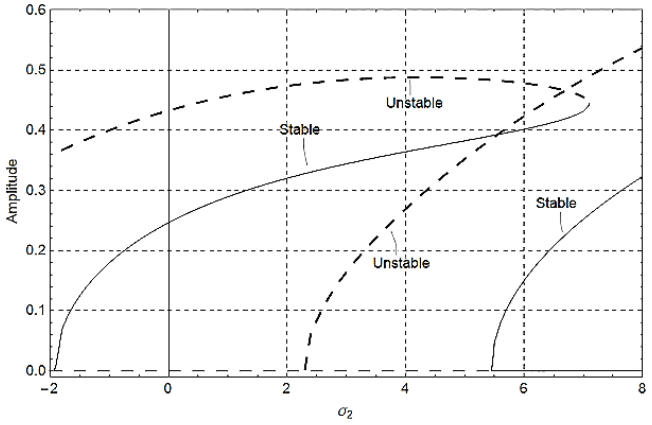

Figure 4 Change of the amplitude a_1 according to the detuning parameter σ_2 (Case 2)

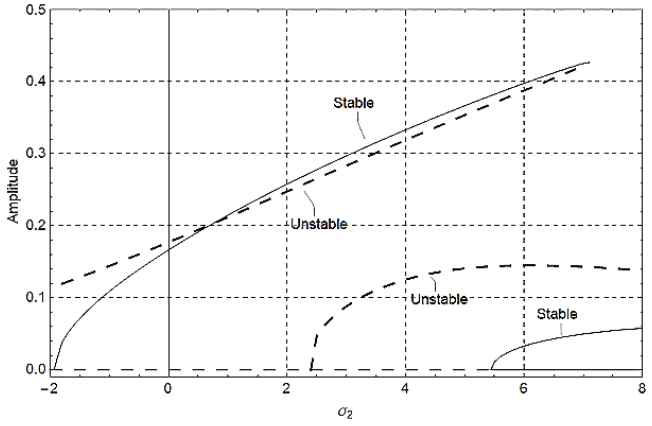

Figure 5 Change of the amplitude a_2 according to the detuning parameter σ_2 (Case 2)

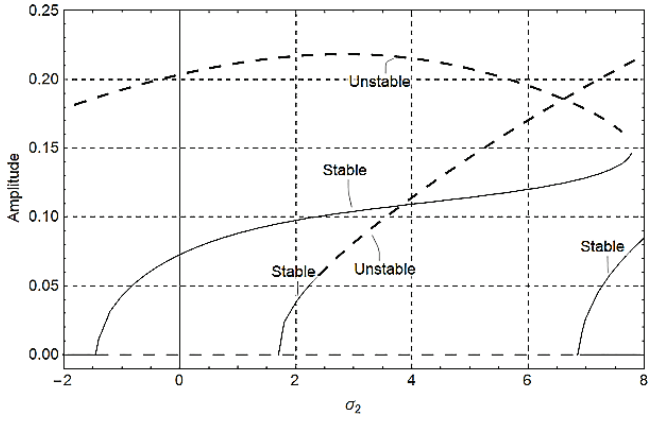

Figure 6 Change of the amplitude a_1 according to the detuning parameter σ_2 (Case 3)

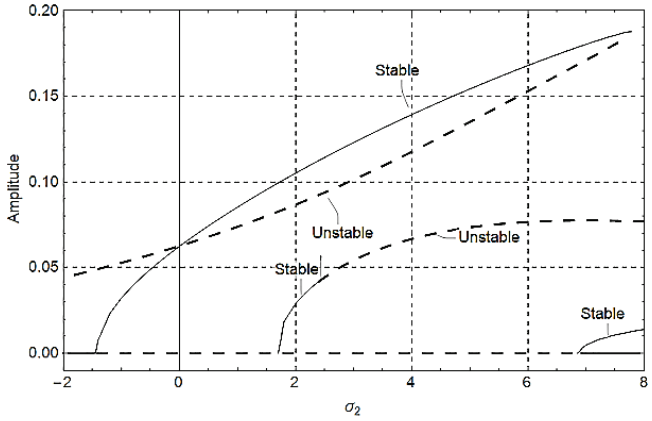

Figure 7 Change of the amplitude a_2 according to the detuning parameter σ_2 (Case 3)

In these graphs, force amplitude and damping ratio are taken as 1 ($F=1,\mu=1$). Figs. 2 and 3 show the first and second mode amplitude changes depending on the detuning parameter for case 1. Figs. 4 and 5 show the first and second mode amplitude changes depending on the detuning parameter for case 2. Figs. 6 and 7 show the first and second mode amplitude changes depending on the detuning parameter for case 3. Stable and unstable roots of the amplitudes and stability regions can be seen from these graphs. Beam coefficient is 1, 0.8 and 0.1 in these graphs respectively. When beam coefficient decreases, the amplitudes also decrease, but unstable regions become wider in detuning parameter axis.

3.2 The Case Where the Dominant Resonance and 2:1 Internal Resonance Conditions are Together

In this case, the fluid velocity change frequency is taken as the critical forcing frequency. The frequency of the electric voltage change was chosen so as not to create any secularity.

$$\begin{aligned}&\omega_2 = 2\omega_1 + \varepsilon\sigma_1\\ &2\Omega_2 = \omega_1 + \varepsilon\sigma_2\\ &\Omega_1 \not\approx 0, \omega_1, 2\omega_1\end{aligned} \tag{35}$$

When similar operations are performed in this case, amplitude phase modulation equations are obtained as follows,

$$\begin{aligned}&\mathrm{Re\_1} \Rightarrow a_1K_{11R} + \frac{1}{4}a_1{}^3K_{12R} + \frac{1}{4}a_1a_2{}^2K_{13R}\\ &+2(\cos\gamma_{11}K_{14R} - \sin\gamma_{11}K_{14I})\\ &+a_2(\cos\gamma_{12}K_{15R} - \sin\gamma_{12}K_{15I}) = 0\end{aligned} \tag{36}$$

$$\begin{aligned}&\mathrm{Im\_1} \Rightarrow a_1\sigma_2 + a_1K_{11I} + \frac{1}{4}a_1{}^3K_{12I} + \frac{1}{4}a_1a_2{}^2K_{13I}\\ &+2(\cos\gamma_{11}K_{14I} + \sin\gamma_{11}K_{14R})\\ &+a_2(\cos\gamma_{12}K_{15I} + \sin\gamma_{12}K_{15R}) = 0\end{aligned} \tag{37}$$

$$\begin{aligned}&\mathrm{Re\_2} \Rightarrow a_2K_{21R} + \frac{1}{4}a_1{}^2a_2K_{22R} + \frac{1}{4}a_1{}^2a_2K_{23R}\\ &+a_1(\cos\gamma_{12}K_{24R} + \sin\gamma_{12}K_{24I}) = 0\end{aligned} \tag{38}$$

$$\begin{aligned}&\mathrm{Im\_2} \Rightarrow -a_2\sigma_1 + a_2K_{21I} + \frac{1}{4}a_1{}^2a_2K_{22I}\\ &+\frac{1}{4}a_1{}^2a_2K_{23I} + a_1(\cos\gamma_{12}K_{24I} - \sin\gamma_{12}K_{24R}) = 0\end{aligned} \tag{39}$$

From the equations obtained for the case where the dominant resonance and 2:1 internal resonance coincide, the graphs that show the variations of the amplitudes depending on the fluid velocity detuning parameter (σ_2) are plotted as follows,

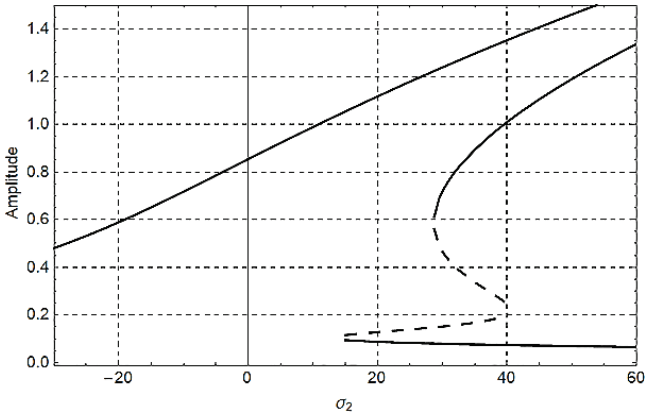

Figure 8 Change of the amplitude a_1 according to the detuning parameter σ_2 (Case 4-1)

In these graphs, force amplitude and damping ratio are both taken as 8 ($F=8,\mu=8$) for case 4-1 and force amplitude is taken as 2 and damping ratio is taken as 8 ($F=2,\mu=8$) for case 4-2. Figs. 8 and 9 show the first and second mode amplitude changes depending on the detuning parameter for case 4-1. Figs. 10 and 11 show the first and second mode amplitude changes depending on the detuning parameter for case 4-2. Stable and unstable roots of the

amplitudes and stability regions can be seen from these graphs. The stability limits become clearer as the force is decreased. In case 4-1 amplitude curves show a different structure. Dominant resonance has more effect on stability regions when force has a higher value. Structures in Figs. 8 and 9 are the combination of internal and external resonance cases. From cases 4-1 and 4-2, we can see that when force amplitude decreases, the amplitudes slightly decrease.

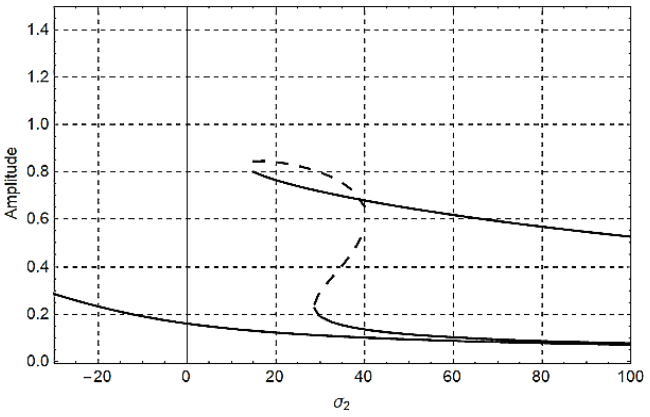

Figure 9 Change of the amplitude a_2 according to the detuning parameter σ_2 (Case 4-1)

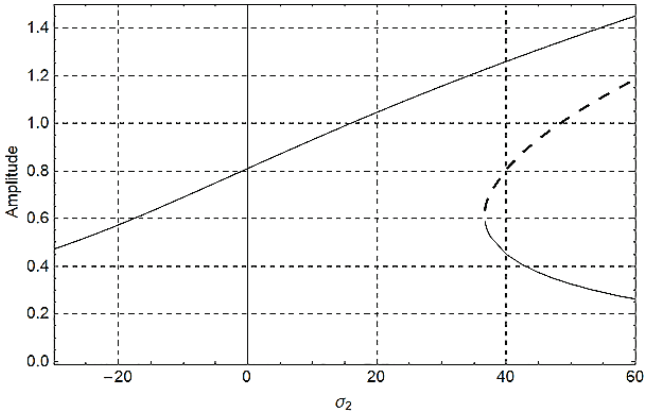

Figure 10 Change of the amplitude a_1 according to the detuning parameter σ_2 (Case 4-2)

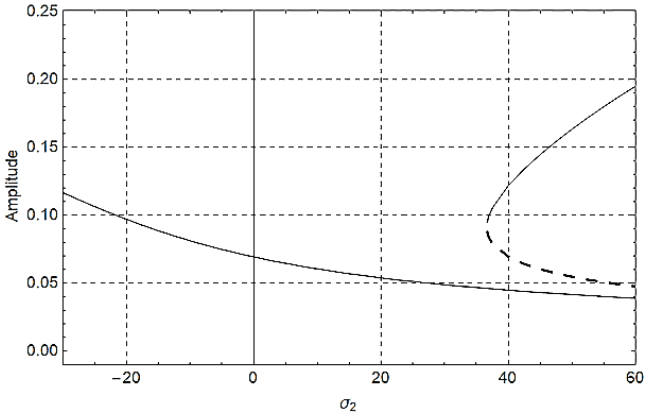

Figure 11 Change of the amplitude a_2 according to the detuning parameter σ_2 (Case 4-2)

4 CONCLUSIONS

The transverse vibrations of a microbeam conveying fluid have been investigated. The method of multiple scales and modified couple stress theory have been applied to obtain approximate solutions. First two natural frequencies and possible 3:1 and 2:1 internal resonance cases have been calculated and represented in tables. For the nonlinear problem, 3:1 and 2:1 internal resonances have been investigated. For case 1, when $v_0 = 4.550$, $\omega_1 = 22.345$ and $\omega_2 = 67.150$, for case 2, when $v_0 = 3.70$, $\omega_1 = 17.916$ and $\omega_2 = 53.790$, for case 3, when $v_0 = 1.350$, $\omega_1 = 2.437$ and $\omega_2 = 7.348$ 3:1 internal resonance case can occur. For case 4, when $v_0 = 0.500$, $\omega_1 = 4.901$ and $\omega_2 = 9.805$, 2:1 internal resonance case can occur. For these cases amplitude phase modulation equations have been obtained and by solving these equations stability borders have been drawn. At certain critical values of fluid velocity, 3: 1 or 2: 1 internal resonance states can occur. These critical fluid velocities have been evidenced in the graphs by the unstable regions that can cause significant problems in terms of system operation. The fluid velocity should not be close to the critical value so that the system can operate safely. As the beam coefficient increases, the critical velocity values at which internal resonances occur are reduced. While the critical velocity of 3:1 internal resonance is about 4.5, when the beam coefficient is 1, this value drops to about 1.35 when the beam coefficient is 0.1. Using more rigid materials will make the system safer again. But if fluid velocity is high enough for internal resonance case in rigid microbeam (Case 1), amplitudes are higher than less rigid microbeam cases.

This work can be developed in many ways:

1) Different resonance interactions such as the combination of total and difference type resonances, different internal resonances, resonances arising from interactions with more than one mode can be considered.
2) Application problems in which boundary conditions are not ideal can be considered.

ACKNOWLEDGEMENTS

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Preliminary communication

DISTANCE EDUCATION WITH MOODLE IN ENGINEERING EDUCATION: ONLINE PROGRAMMING ASSIGNMENTS COMPILATION

Mümine KAYA KELEŞ, Abdullah Emre KELEŞ

Abstract: The concept of distance education systems is a concept that applies to all levels of education, including universities. The use of distance education systems has increased considerably in universities today. Many faculties in many universities use distance education systems for their courses. The purpose of this paper is to design and develop a system that can be used to upload lecture notes and assignments online via the Internet, to do online exams, to provide a compilation control of all the assignments written, especially in the C programming language, by instructors who are primarily in the Engineering Department, then all instructors in the universities using the Moodle platform. Moreover, the aim of this paper is to design and develop a system in which the students primarily in the Engineering Department using the Moodle platform and then students in all the universities can follow the course contents, upload the assignments, and discuss their questions about the course with their instructors and their friends. As a result of this paper, a scheme is provided to easily compile, run and grade the programming assignments (source codes) given in the Programming courses using the Moodle website collected in a single place.

Keywords: compilation, distance education, engineering education, Moodle, programming language.

1 INTRODUCTION

Knowledge has become the most important factor in determining the competitiveness and development levels of societies in the today's economy. The rapid development and widespread use of the Internet and information technology has made the Internet the world's largest source of information that millions of people use every day [1]. The rapidly developing information technology has led to the diversification of distance education types and the spread of distance education based on the Internet. In the transition to the information economy, the development of human resources and lifelong education are of primary importance by using every field of information technology from education to health [2]. While the developing and changing of technological structures enables the development of widespread and common solutions in global education, at the same time it leads to the rapid increase of expectations from individuals and the evaluation of the quality of education in international standards [3].

The aim of this paper is to develop a distance education website with the Moodle [4] platform for the Engineering Departments of the Faculty of Engineering and Natural Sciences of the Adana Science and Technology University. In addition, the Moodle system, which has an important place in the education system, focuses on the types of services developed by distance learning individuals in order to meet their information needs and it also aims to explain the virtual classes that the information sources present to the users by transferring them to the electronic medium. In this study, the Moodle system was used not only for distance education, but also for supporting a more formal education. In particular, the programming language courses are the courses taught in almost every department at the engineering faculty. For this reason, there is a need for systems that will facilitate the teaching of such courses, the evaluation and grading of assignments and exams.

Recommendations are given to information specialists so that the information needs of the individuals who receive distance learning can be met at the highest level. The difficulty in the learning of programming languages such as the C programming language is mainly due to the fact that the programming efficiency of students is at a basic level. One of the most common ways to improve the cognitive skills of students in programming languages is to give them appropriate programming assignments. However, unfortunately, lecturers need to spend a lot of time and effort in evaluating and grading the programming assignments of their students. That is due to the fact that the manual approaches (such as hardcopy and CD) that evaluate the output of programming assignments are costly, time consuming, and not flexible, but systems that can automatically perform the assessment can eliminate these problems. Within the scope of these proposals, it is aimed to create a compilation module in order to compile the C programming language assignments given in the programming language courses which have an important place in the engineering education. This compilation module is designed to be run with the help of a GNU Compiler Collection (GCC) [35] system. This GCC system contains the C programming language and other compilers and is designed as part of the GNU project.

There are some universities in the Engineering Departments such as Computer Engineering, Industrial Engineering, Civil Engineering, Electrical and Electronics Engineering, Machine Engineering, Software Engineering, etc. in Turkey that offer distance learning by using Moodle. Some of these universities are; Atılım University Faculty of Engineering [6], Başkent University Faculty of Engineering [7], Bilkent University Faculty of Engineering [8], Eskişehir Osmangazi University Faculty of Engineering [9], ODTU Faculty of Engineering [10], Pamukkale University Faculty of Engineering [11], Boğaziçi University Computer Engineering Department [12], and Çukurova University

Computer Engineering Department [13], Ege University Computer Engineering Department [14]. However, these universities did not add modules that compile programming assignments to their distance education websites.

In the distance education system developed within the scope of the study, it is ensured that the compilation of programming assignments can be easily integrated into the Moodle distance education system. Thus, the programming assignments will be collected in one place, compiled and run, and scored in the same place.

2 MATERIAL AND METHOD

This paper is organized as follows: the first part explains the installation of the Moodle system, the second part explains the collection of the tasks to be compiled and the creation of the system pages, and the third part explains the coding of the compilation processes with GCC.

Firstly, the Moodle system [4] is the environment where the instructors will create lessons, the students will be enrolled in classes, the forms in which the discussions about the lesson will be carried out, the lecture notes and assignments can be loaded. Moodle is an open source software platform consisting of the initials of Modular Object-Oriented Dynamic Learning Environment. It is a web-based, free and dynamic tutorial-driven tool for educators focused on content creation and interaction. It is a software package for building web-based courses and websites. Moodle is a preferred education system in the education sector. The reasons for this include the ease of use of Moodle, being an open source code, and containing a wide range of service options.

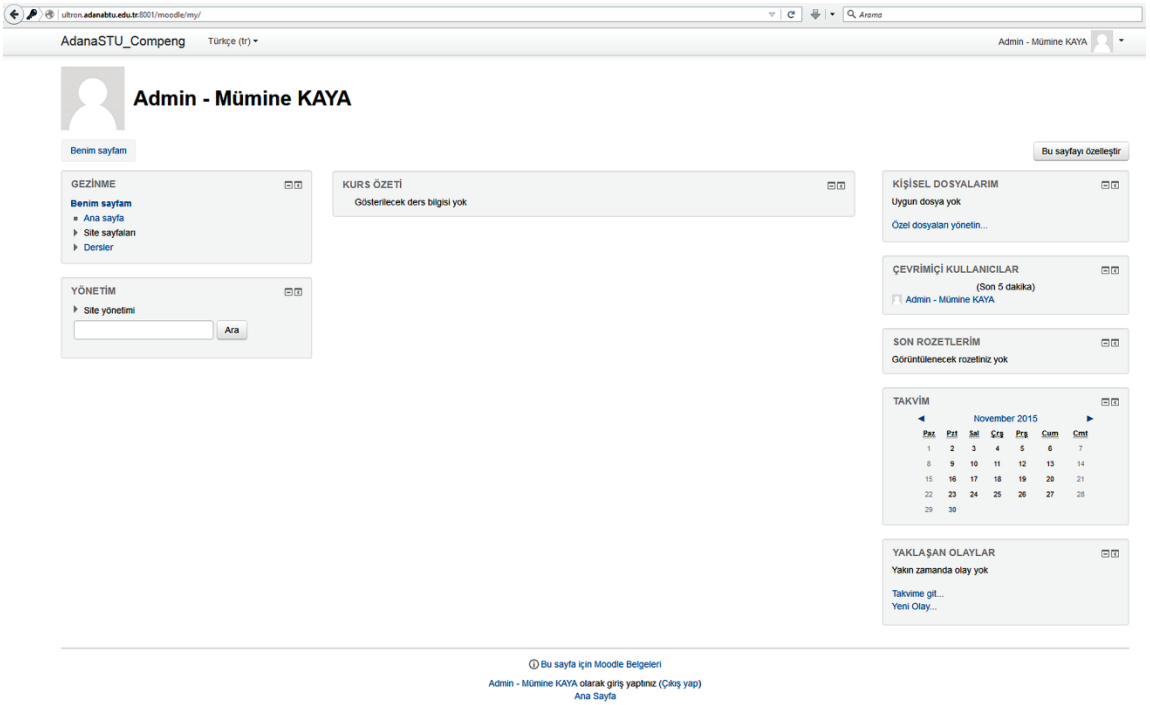

Figure 1 Moodle homepage of the Engineering Departments

Moodle's open source and modular architecture allows for the development of new extensions. At the same time, hundreds of extensions available in Moodle offer significant advantages to the Moodle users and administrators in the distance learning applications. One of these extensions is the online compilation plug-in. The online compilation, which is also included among the main objectives of this article, includes C codes. In this paper, an online C compiler developed plug-in/extension for Moodle has been presented. With the development of this plug-in/extension, it is possible for Moodle users to freely compile and run their C source codes installed on the server. In addition to the other major benefits of Moodle, this plug-in/extension provides an efficient execution of the C lessons and the compilation of C source codes, without any compiler installed on each computer in computer labs where the programming lessons will be run.

For using Moodle and its new extension, Apache [15], MySQL database [16], Perl [17] and PHP [18] have installed the server where Moodle has been installed. Once the required software has been installed, Moodle is ready and operational for the Engineering Departments as shown in Fig. 1.

Then, the GNU Compiler Collection (GCC) [5] was used to compile assignments written in the C programming language which constitutes a significant part of this study. The GCC system contains the C programming language and other compilers designed as part of the GNU project. Within the scope of this study, GCC was used in order to control, compile and run/execute programming assignments written in the C programming language.

The Distance Learning Website is run on the server computer and is available for the use of the department lecturers and students.

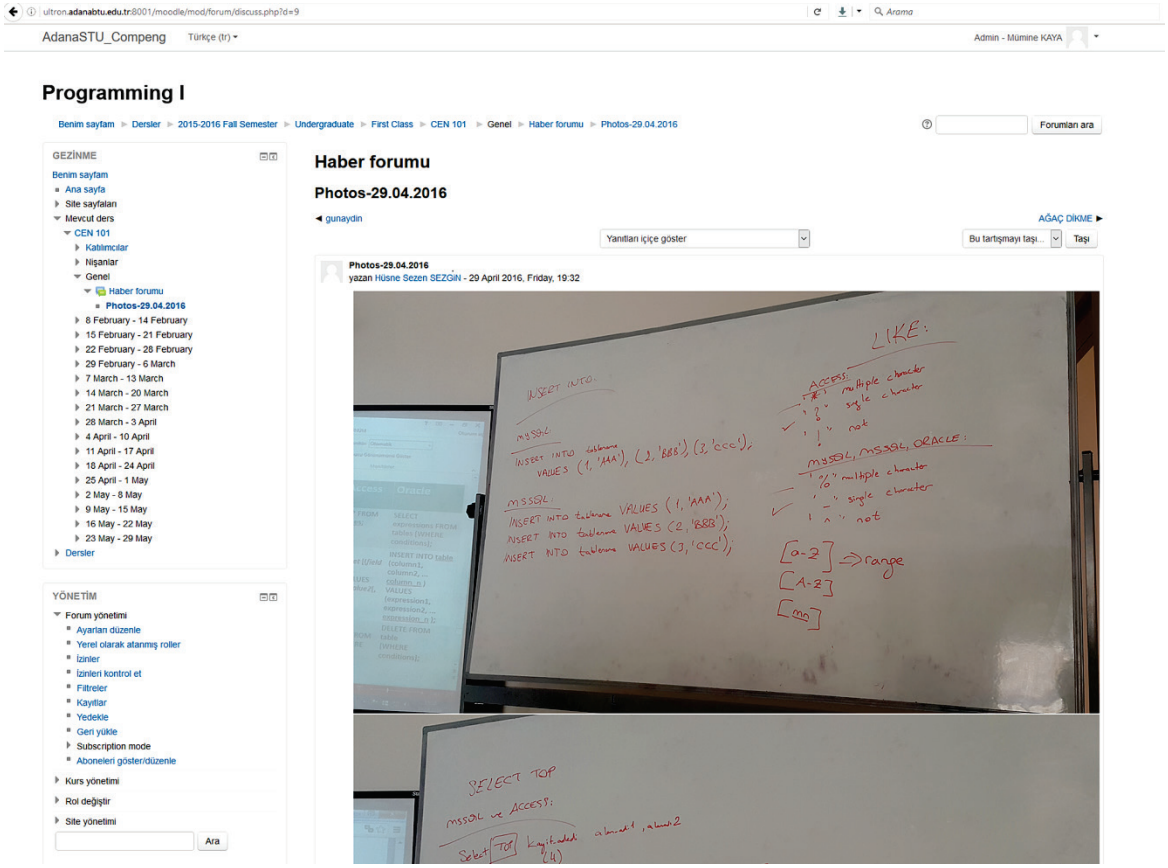

Figure 2 Moodle News Forum webpage

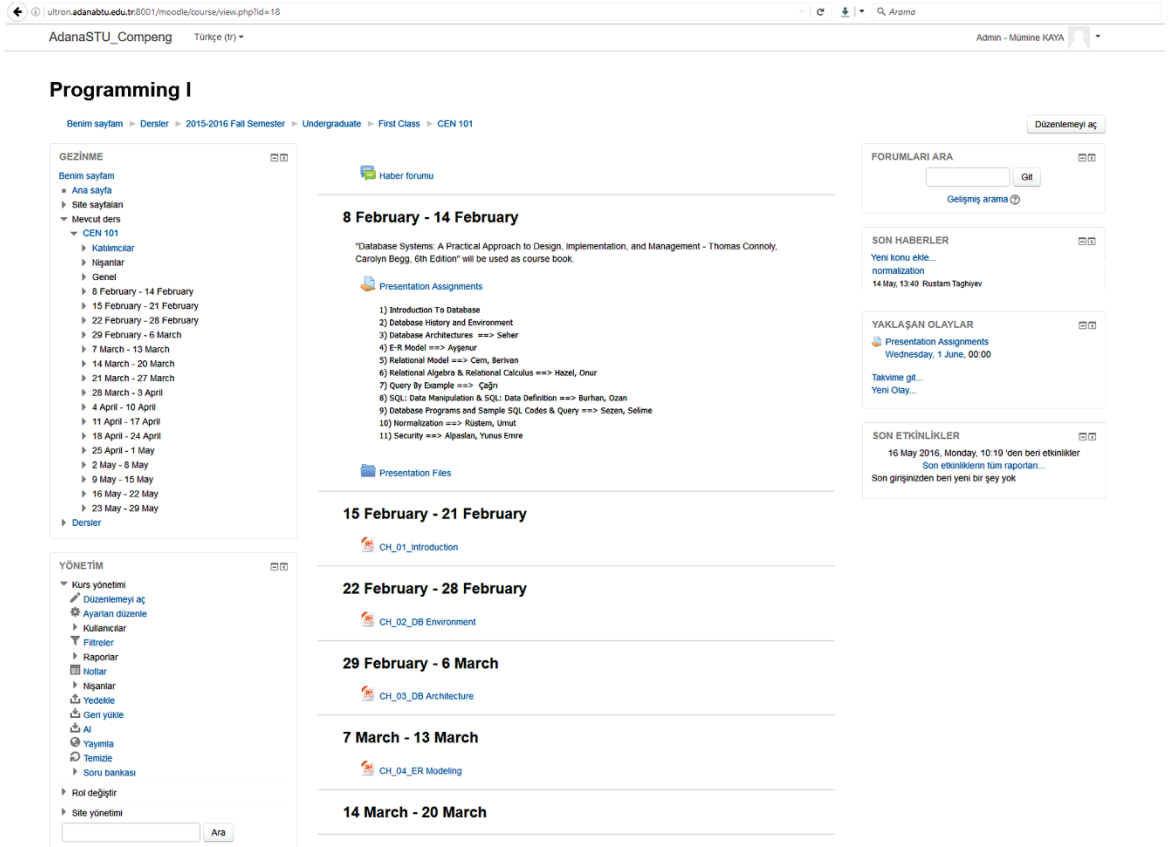

Figure 3 Assignment plug-in webpage

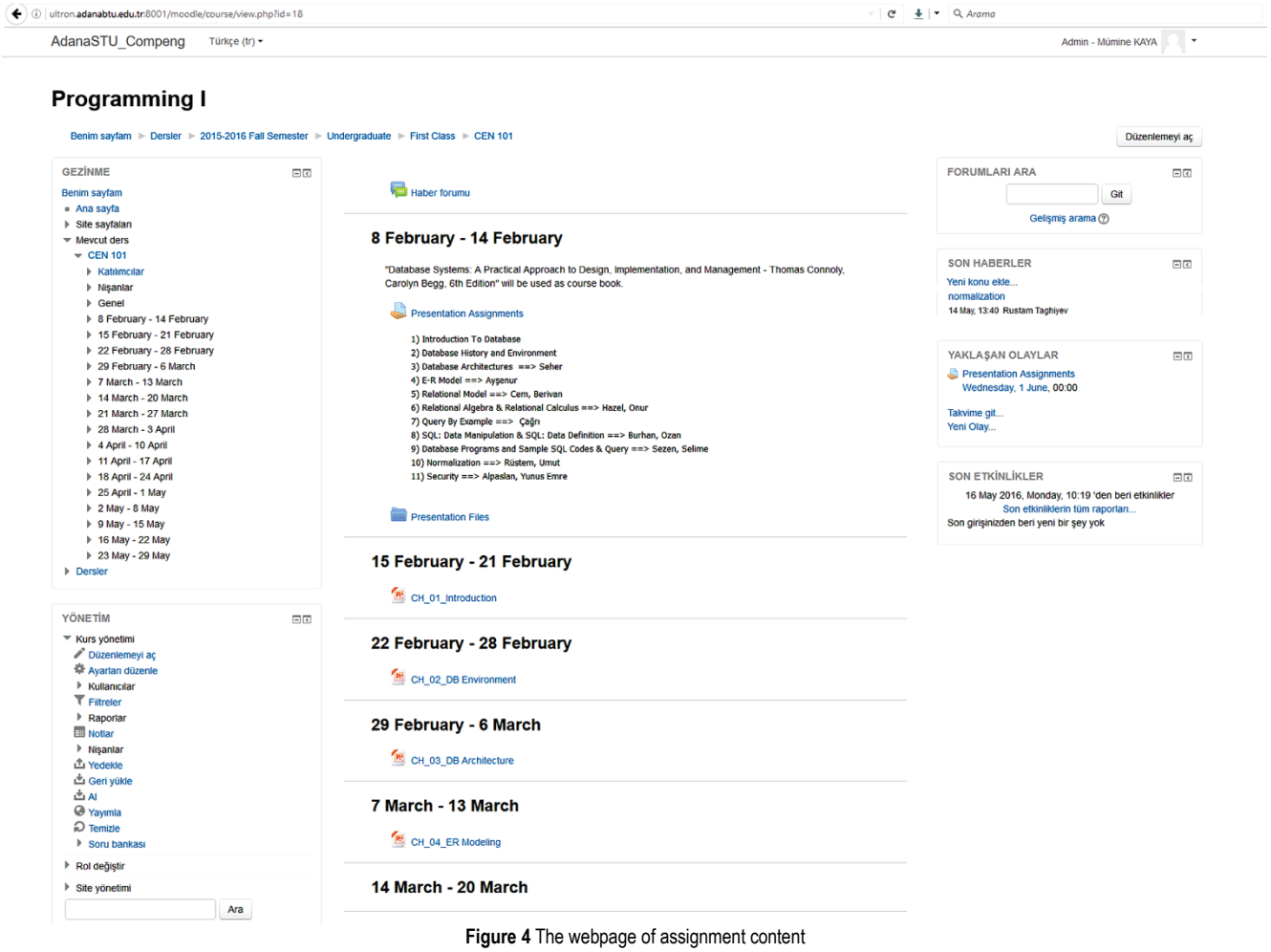

Figure 4 The webpage of assignment content

Programming assignments are given through the Moodle system as in Fig. 3, that is, assignments are given to the students in Moodle and the students upload their assignments to Moodle. The assignment contents can be accessed by the users registered in the course as shown in Fig. 4.

The instructor of the course can collectively access the submitted assignments via the "Tüm gönderimleri görüntüle/puanla" ("View/post all submissions") link as shown in Fig. 5. This way, the instructors can view the contents of the assignments.

The section that forms the main part of this study starts from this point. Instructors who give the courses can compile the source codes of the programming assignments written in the C programming language sent by the students with the "Derle" ("Compile") button, which is on the "Ödev İçeriği" ("Assignment Content") webpage shown in Fig. 4, online via the Moodle system with the help of GCC. An effective HTML result webpage that has been compiled is developed as shown in Fig. 6 and placed on the Internet. After pressing the "Derle" ("Compile") button on this webpage, the system will automatically direct the user to a separate compilation webpage for each assignment.

As shown in Fig. 7, the source code written in the submitted assignment and the compilation information of the compiled assignment can be accessed via a separate HTML webpage. When the "Programı Çalıştır" ("Run Program") button is clicked for the compiled assignment, the program is executed and it can be reached as the result/output of the compiled assignment as shown in Fig. 8. When doing this operation, the user can input the information requested by the user in a separate input file on this webpage, and the system can compile the source code written in the C programming language which is sent by the student considering this file, and it presents the output/result of the compiled assignment to the user. Thus, the results are evaluated and reported.

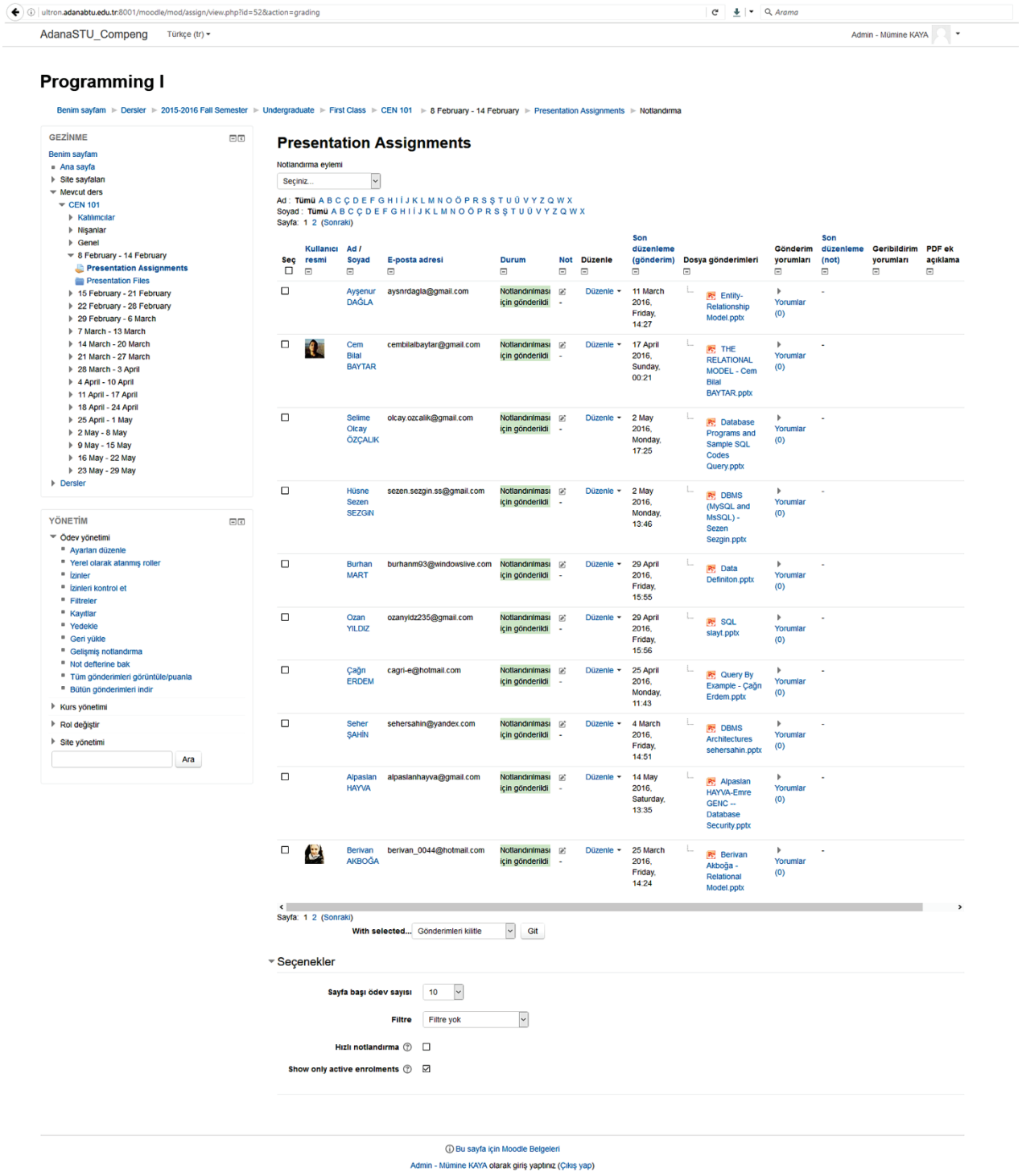

Figure 5 Webpage of submitted assignments

AD	SOYAD	ÖDEV LINKI
Abdulaziz	Ravshanbekov	odev1_150101022.c Derle
Deniz Furkan	Kanbak	odev1_150101011.c Derle
Dilara	Nihadioğlu	odev1_150101019.c Derle
Ercan	Gürsoy	odev1_150101020.c Derle
Halit	Tunçel	odev1_150101012.c Derle
Ömer Faruk	Ünaldı	odev1_150101010.c Derle

Figure 6 Assignment compilation webpage

Figure 7 Compiled assignment information webpage

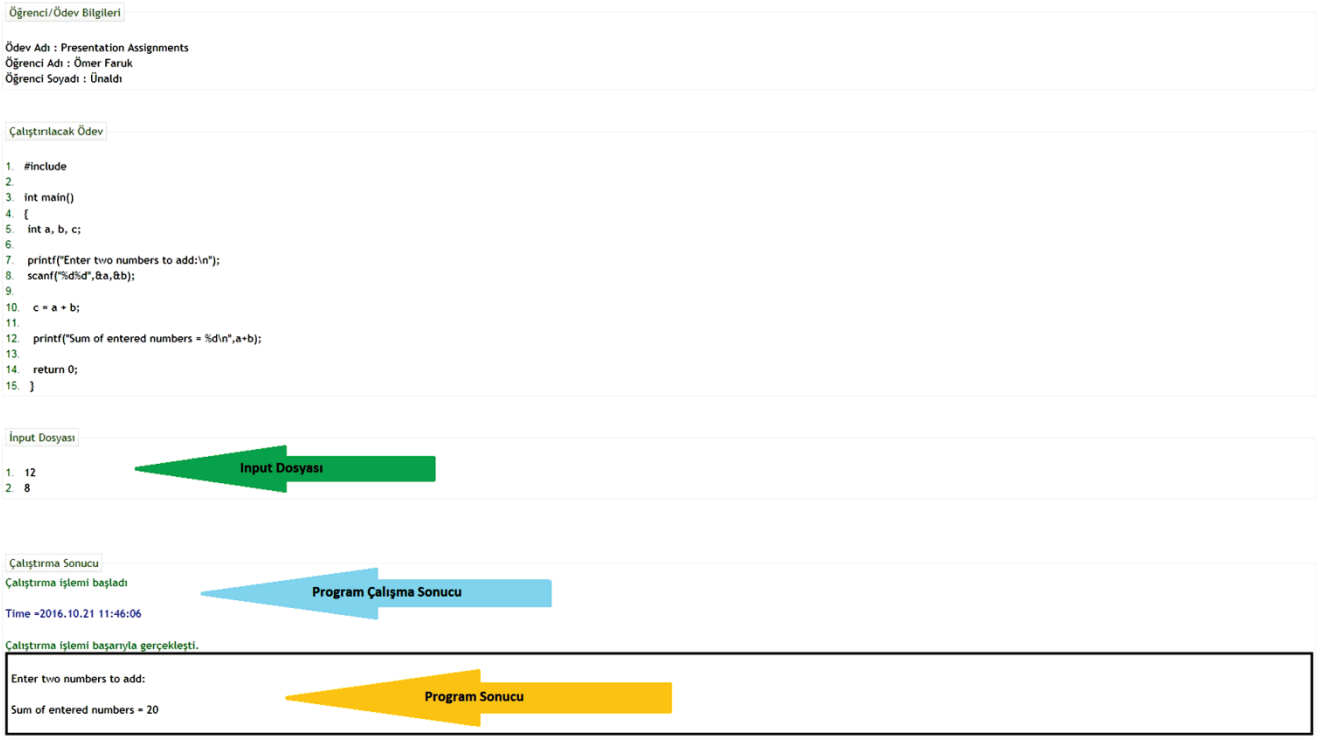

Figure 8 Compiled assignment result webpage

3 CONCLUSION

The aims of the study explained in the Introduction part of this paper were achieved. For this reason, it is thought that this paper contributes to many areas.

With this study, it was ensured that students will be able to follow course content from a specific place, submit their assignments in time, and facilitate the follow-up of course attendance; the lecturers will be able to share their lecture notes from a specific place, collect and compile the submitted assignments in one place, and do the grading more quickly and easily. While ensuring this, care has been taken to ensure that all situations that may arise are taken into account. Not only the code was compiled, but also the compiled code was executed and the results were produced. A separate section was prepared for the cases where information is requested from the user, which is an important criterion to be considered, and users can upload a

file containing the information requested by them to the system. Thus, the compilation and result generation processes can work efficiently and correctly.

As a result of this paper, lecturers can gain time to evaluate assignments and speed up the process of making lessons more efficiently by bringing students who send erroneous assignments to the courses.

With the compilation of the programming assignment module added to the Moodle distance learning website, the instructor can easily compile and run the students' programming assignments, observe and interpret the outputs/results of the assignments' source code and grade them.

Another contribution of this paper is the fact that distance education is independent of the place. For example, students who cannot attend classes due to illness or any similar excuse can follow the lecture notes and course videos uploaded to the system and the contents of the course, and can be informed of the assignments that are given.

It is possible to design systems that accelerate and facilitate information access with the techniques performed in this study.

As a future work, we plan to use the online assignment compilation module not only on the Moodle distance education system, but also on an independent platform. In addition to this, we plan to prepare a separate module for the similarity detection of assignments to each other on the Moodle distance education system. We are thinking of designing this module to show the similarity results on the webpage where the assignments are compiled.

4 ACKNOWLEDGMENT

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[4] Moodle - Modular Object Oriented Dynamic Learning Environment; See http://moodle.org/

[5] GCC - The GNU Compiler Collection; See http://gcc.gnu.org/

[6] Atılım University Engineering Faculty Moodle Web Page; See http://moodle.atilim.edu.tr/

[7] Başkent University Engineering Faculty Moodle Web Page, http://moodle.baskent.edu.tr/course/index.php?categoryid=259

[8] Bilkent University Engineering Faculty Moodle Web Page, https://moodle.bilkent.edu.tr/2017-2018-fall/course/category.php?id=8

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[14] Ege University Computer Engineering Department Moodle Web Page, http://sorubank.ege.edu.tr/~moodle/login/index.php

[15] APACHE; See http://www.apache.org/

[16] MYSQL; See http://www.MySQL.com/

[17] PERL; See http://www.perl.org/

[18] PHP; See http://www.php.net/

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Preliminary communication

POWER OPTIMIZATION IN PARTIALLY SHADED PHOTOVOLTAIC SYSTEMS

Zehan KESİLMİŞ, Halil EROL, Mahmut UÇMAN

Abstract: The Power-Voltage characteristic of a photovoltaic (PV) array exhibits non-linear behaviour when exposed to uniform solar irradiance. Maximum Power Point (MPP) tracking is challenging due to the varying climatic conditions in a solar PV system. Moreover, the tracking algorithm becomes more complicated due to the presence of multiple peaks in the power voltage characteristics under the condition of partial shading. This research is devoted to the Stochastic Beam Search (SBS) based algorithm and Stochastic Hill Climbing (SHC) for a maximum power point tracking (MPPT) at a partial shading condition in the PV system. To give a partial shading effect over the entire array of a PV system, a mast is placed in front of the modules. The modules in the array are connected in such a way that one does not need to rewire the electrical connection during the rearrangement of modules. It is validated that the power generation performance of an array under a moving shading condition is increased. Furthermore, it is observed that the SHC method outperforms the SBS method in the MMP tracking.

Keywords: partial shading; photovoltaic; MPPT; stochastic beam search; variable neighbourhood search

1 Introduction

Among the available alternative energies, photovoltaic (PV) is one of the most promising energy sources. The PV power generation has attracted attention in recent years due to a decrease in the prices of PV panels. Moreover, developments in smart grids provide opportunities for load control and dispatch of storage units that make the solar PV more valuable to the grid operation. According to the statistics, during the past decades, the world PV industry has grown on average for 30% annually [1]. The commercial PV modules' conversion efficiency is still rather low. Besides that, the P/V characteristics are non-linear and highly weather dependent [2, 3].

A PV array is the power generating unit, consisting of any number of PV panels. When a PV array is exposed to uniform solar irradiance, the array Power/Voltage (P/V) and Current/Voltage (I/V) characteristic presents non-linear behaviour. The optimal operating voltage point of the PV array is called the Maximum Power Point (MPP). MPP is defined as the point at which the PV array supplies maximum power at this particular voltage. The Maximum Power Point Tracking (MPPT) system's aim is to improve and optimise the use of the photovoltaic systems and to maximize the array efficiency in order to guarantee maximum power production.

When the PV array is subjected to the uniformly solar irradiance, it is simple and usual to determine the MPP. Due to some environmental effects, for example, a rapidly varying irradiance or changing weather condition such as clouds etc., shading occurs on the PV panels and the optimal voltage point might vary. When one or more of the PV modules in the array receives a lesser amount of solar irradiance, the PV array experiences a partially shaded condition (PSC). If PSC occurs, the generating current of the entire PV array being limited due to the shaded module and the P/V curve become characterised by multiple peaks and analysis becomes more complicated. Therefore, the conventional MPPT algorithms fail to identify the Global Maximum Power Points (GMPP) among the local point, which leads to a reduction in the overall efficiency of the PV system, distinguishing the absolute MPP and local MPP [4, 5].

A bypass diode is connected parallel to each of the PV modules to permit the excessive current from the un-shaded module to flow through.

In literature, various computational algorithm-based MPPT methods, such as the neural network [6], fuzzy control [7], Differential Evolution (DE) [8, 9], neural network-based modified Incremental Conductance (IC) algorithm and Particle Swarm Optimization (PSO) [10] etc., can be found. For tracking the global MPP, all these methods have shown to have a good performance. However, each has its own limitations. For example, most of them require experienced skills in setting the parameters used for the MPPT algorithm. For some algorithms, the processing time is long. Furthermore, most of them take a relatively long time to reach the global MPP. Some other methods such as the interconnection method [11], voltage compensation method [12] and multilevel dc-link inverter [13], etc. have also been proposed to solve the partial shading problem. Unfortunately, either their tracking speed is slow or their control process is complex. The stochastic search theory-based algorithms are generally used for the computation of MPPs. In the stochastic search, the theory uses the iterative process to control the operating voltage of the PV array according to the update scheme of the individual algorithm.

In this paper, a PV system is constructed that consist of a microcontroller, a buck DC/DC converter and a serial connected four panel PV array. The microcontroller collects the current and voltage data from the PV system. For the PV system operating under the PSCs, Stochastic Beam Search (SBS) and Stochastic Hill Climbing (SHC), algorithms are applied for the maximum power point tracking. The advantage of these methods is that they have a simple control structure. Moreover, under different shading patterns, they have the ability to quickly track the global

MPP. Moreover, there is no need to use expensive irradiance sensors.

2 MAXIMUM POWER POINT TRACKING

The solar cell equivalent circuit can be modeled as in Fig. 1. The representation of the solar cell as in Fig. 1 is generally known as a one-diode model.

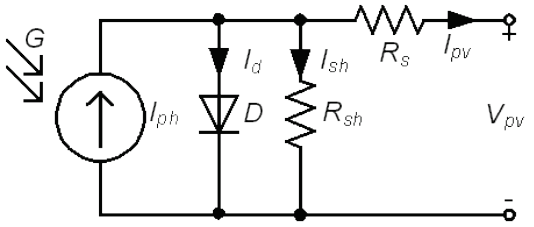

Figure 1 Single diode model of a solar cell

The equivalent PV cell model is composed of a diode and photo current source, series (R_s) and parallel resistors (R_p). The p-n junction leakage current in the solar cell is mainly modeled as a parallel resistor, R_p. The R_s is used to symbolize the metal base contact resistance within the semiconductor layer [14]. The diode D has I/V characteristic which is described by the Shockley diode equation as shown in eq. (1).

$$I_d = I_s \left(e^{\frac{q\left(V_{pv}+R_s I_{pv}\right)}{aKT}} - 1 \right) \tag{1}$$

where the current flowing through the diode D is defined as I_d , the diode reverse bias saturation current is defined as I_s, the ideality factor of the diode D is defined as a, K is the Boltzmann constant (1,3806503 × 10^{-23} J/K), cell's operating temperature in the degree Kelvin is defined as T and q is the electron charge (1,60217646 × 10^{-19} C).

By using the general model of the solar cell, the derivation of the I/V characteristic of the solar cell is done as in Eq. (2).

$$I_{pv} = I_{ph} - I_s \left[e^{\frac{q(V_{pv}+I_{pv}R_S)}{aKT}} - 1 \right] - \frac{V_{pv} + I_{pv}R_s}{R_{sh}} \tag{2}$$

where I_{pv} is the solar cell terminal current, I_{ph} is the the solar cell light dependend current, V_{pv} is the terminal voltage of the solar cell, R_{sh} is the equivalent parallel resistance and R_s is the equivalent series resistance. The resistances R_s and R_{sh} in Eq. (2) can be obtained iteratively by making the maximum power calculated from the model to coincide with the peak power from the datasheet at MPP [15].

A PV panel under a constant uniform irradiance has an I/V characteristic like the one shown in Fig. 2.

As seen in Fig. 2, the I/V cure has a unique Maximum Power Point (MPP) which the array operates with maximum efficiency and produces maximum output power. A MPPT system is a device employing a controller to achieve both the function of the MPP output and tracking by sampling the power output of the array with the highest possible speed.

In this work, a system designed for the MPPT algorithm comparison is described. This system is comprised of a PV array, a microcontroller, and a buck type DC/DC converter. Arduino Uno R3 is used as microcontroller which collects the current and voltage data from the PV prototype. The buck type DC/DC converter consist of a 2 N-channel MOSFET (IRF540), a 100 μH toroid coil and half-bridge MOSFET driver (IR2104).

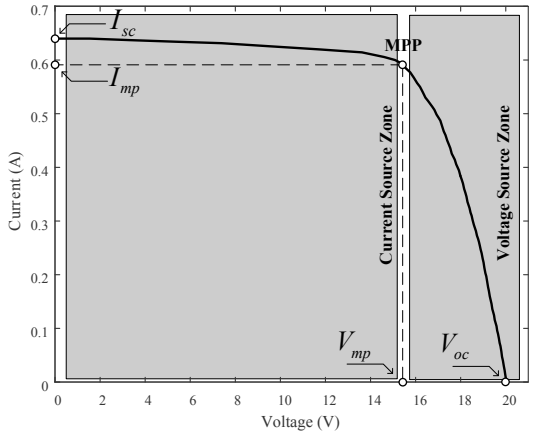

Figure 2 I_V characteristics of a PV cell under no shading

Here, the PV voltage and current are sampled and converted by a built-in analog to a digital converter (ADC). The output current (I_{pv}) is measured by the ACS712 current sensor which has a measuring capacity of ±2.5 A. The microcontroller generates a duty ratio D and the DC/DC converter is activated. In the experimental setup, the load resistance is chosen as R_o = 0.5 Ω and P_L = 30 W. The value of load resistance is capable of absorbing the power generated by a PV module.

The microcontroller is programmed to generate a signal in a pulse width modulation (PWM) with a 62 kHz frequency and 8 bit resolution. The value of the PWM signal is denoted as D and the value of D is between 1/255 and 1. The relationship between the input voltage and output voltage; the input current and output current for the buck type DC/DC converter can be modeled as

$$I_o = DV_{in}, \quad I_{in} = DI_o \tag{3}$$

Moreover, the relationship between the input and output resistances can be found by using the Eq. (3) as

$$R_{in} = \frac{R_o}{D^2} \tag{4}$$

If the range of D is used in Eq. (4), one can get the input resistance R_{in} range as $0{,}5\Omega \le R_{in} \le 32{,}5\ \text{k}\Omega$. The experimental results indicate that the R_{in} range can span a whole space of V_{oc} and I_{sc}. The occupied/unoccupied ratio of the signal D in the pulse width modulation can be found as

$$\sqrt{\frac{R_o}{R_{in\max}}} < D < \sqrt{\frac{R_o}{R_{in\min}}} \quad (5)$$

The PV array characteristic is modeled by a superposition of each of the individual PV module characteristics. When the panels are operated under the same condition, both will have the same amount of current. However, if somehow a PSC occurs, the current generated by the shaded module will be lesser. Since modules are connected in series, this will cause a drop in the generated current and the entire PV array current will be limited. With a bypass diode, the excess current by the unshaded PV module is permitted to flow through the external diode so that limitation imposed by a shaded module can be prevented. Moreover, the formation of hot spots in the PV array can be prevented by a bypass diode. Generally, hot spots are formed due to the PSC when the solar cells become reverse biased. At the same time, the PV module gets hotter, dissipating power in the form of heat. It is undesirable for the hot spots to exceed the sustainable power limit of the PV cells. If the hot spots' heat exceeds the sustainable power limit of the PV cells, it will cause permanent damage to the PV module and the array will be open circuited [16].

2.1 Stochastic Beam Search Algorithm

The local beam search algorithms may suffer from getting concentrated on a small region of the whole search space. To overcome this problem, a variant of the local search, Stochastic Beam Search algorithm, is developed. It is similar to the stochastic hill climbing method. The stochastic beam search selects β successors at random, instead of choosing the best β from the pool of candidate successors. The probability of choosing a given successor is an increasing function of its value. Lowerre (1976) first used this search technique in the artificial intelligence area to solve the speech recognition problem. Later, Sabuncuoğlu and Karabük (1998), Ow and Morton (1988) and Sabuncuoğlu and Bayiz (2000) applied it to job shop scheduling problems [17].

Table 1 Pseudo code for the **SBS Algorithm**

```
Inputs: P/V data, iteration_count, starting_points
Output: Power
for i = 1 to starting_points
|       Power_initial(i) ← Random(P)
end
Power = max(Power_initial)
for i = 1 to iteration_count
|       Power_new ← Neighbor(Power)
|       if Power_new ≥ Power then
|       |       Power ← Power_new
|       end
end
return Power
```

While using the beam search algorithm, one must take into account two important issues: (1) how the search tree representation is done and (2) how the search methodology is applied. In our study, theoretically, we have 255 different node values. However, using so many node values requires more memory and more work force. Moreover, it does not assure more benefit. Therefore, by trial and error, six node points are found as optimum. The pseudo code for the SBS algorithm is given in Tab. 1.

2.2 Stochastic Hill Climbing Algorithm

The Stochastic Hill Climbing (SHC) algorithm is an improved version of the hill climbing algorithm. The strategy of the Stochastic Hill Climbing algorithm is randomly selecting a neighbor for a candidate solution and only accepting it if it results in an improvement. The greater of the neighbor power value is selected as the active power and is compared to the next randomly assigned power value [18]. A pseudo code for the stochastic climbing algorithm is given in Tab. 2.

Table 2 Pseudo code for the SHC Algorithm

```
Inputs: P/V data, iteration_count
Output: Power
Power ← Random(P)
for i = 1 to iteration_count
|       Power_new ← Random(P)
|       if Power_new ≥ Power then
|       |       Power ← Power_new
|       end
end
return Power
```

3 RESULTS AND DISCUSSION

Three different conditions are analyzed for different shading patterns or conditions (SC). These are SC1 when the array is operated under the same conditions without shading, wherein SC2 and SC3 are at different shading conditions. In SC2, the characteristic is obtained by shading one by one out of the four PV panels at midday, while in SC3 it is obtained with the same condition but after midday. SC1 has one peak value, while others have multiple peaks. The solar irradiance values for each shading conditions are given in Tab. 3.

Table 3 Solar Irradiance Values for different shading conditions

Solar Irradiance Values (W/m^2)				
	Panel1	Panel2	Panel3	Panel4
SC1	1000	1000	1000	1000
SC2	1000	1000	1000	160
SC3	1000	1000	400	160

The obtained I/V and P/V curves for each shading conditions (SC1-3) are given in Figs. 3 and 4, respectively.

In the shadowing experiments, the shadow of a pillar the height of 1.5 m above the panels is over-shaded naturally by the movement of the Sun in the four hour time period when the data were collected. The collected data is processed in MATLAB by the Stochastic Beam Search (SBS) and the Stochastic Hill Climbing (SHC) algorithms. The process is repeated 100 times for every condition and the results are averaged.

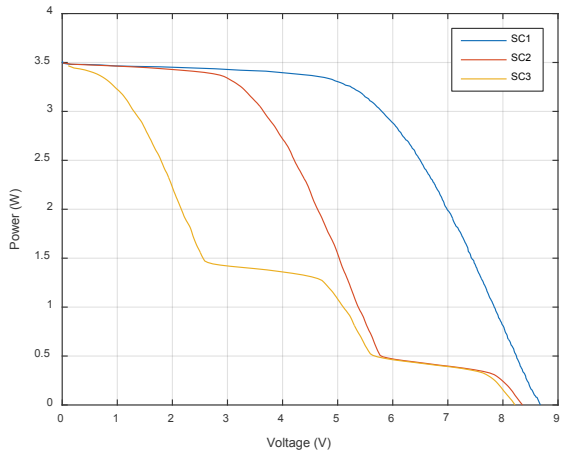

Figure 3 The I/V characteristic curve of the Photovoltaic Array

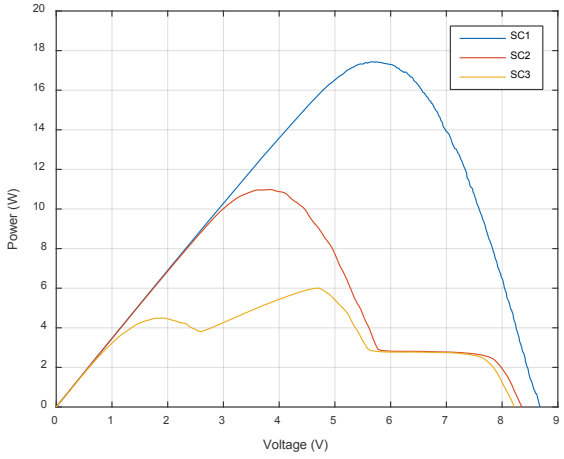

Figure 4 The P-V characteristic curve of the Photovoltaic Array

The obtained power comparison is given in table 4. As it can be seen from Tab. 4, the maximum power point found by the Stochastic Hill Climbing algorithm is higher than the Stochastic Beam Search algorithm.

Table 4 Ideal and calculated power values

Obtained Power Values (W)			
	Ideal value	Stochastic Beam Search	Stochastic Hill Climbing
SC1	17,44	17,02	16,07
SC2	10,98	10,22	10,38
SC3	6	5,02	5,16

The convergence rate and average calculation time values are given in Tab. 5. The convergence rate represents how many times the algorithms can capture real values. The success rate of SHC is generally better than the SBS algorithm. The average step size is for how many points the algorithm checks to get the best of all, that is, the number of iterations. It can be seen from table 3 that the algorithms check nearly the same amount of data points for SC1. However, for SC2 and SC3, SHC visits more data points. Thus it requires more time.

Table 5 Success rates of algorithms

	Algorithm	Convergence Rate (%)	Average Time
SC1	SBS	97,61	48 µs
	SHC	92,18	47 µs
SC2	SBS	93,03	49 µs
	SHC	94,53	45 µs
SC3	SBS	83,69	48 µs
	SHC	86,03	44 µs

4 CONCLUSIONS

In this paper, the Stochastic Beam Search and Stochastic Hill Climbing algorithms are compared for three PSCs. The SBS algorithm only showed a good convergence rate for the SC1 condition. By using the same conditions, the results prove the advantage of the SHC algorithm to ensure the rapidity and stability of the output PV power for the partial shaded conditions. The SHC algorithm has the following advantages: accurate MPP tracking performance, the capability of dealing with both the PSC and uniform insolation conditions. The experimental results on an 18 W prototype PV system showed that the SHC algorithm can be used for partial shading conditions.

Acknowledgment

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Preliminary communication

SATELLITE-BASED HYPERSPECTRAL IMAGING AND CARTOGRAPHIC VISUALIZATION OF BARK BEETLE FOREST DAMAGE FOR THE CITY OF ČABAR

Nikola KRANJČIĆ, Robert ŽUPAN, Milan REZO

Abstract: After enormous amount of ice rain during 2014 huge damage was done in forests in Croatia, especially in the city of Čabar area. Damage of forests is reflected in wide spread of bark beetle. Bark beetle damaged forest have different spectral range from healthy forest. Copernicus satellite land monitoring imagery enables distinguishing healthy from unhealthy forest. In this paper, the width of bark beetle infection spread in forests in the city of Čabar area using satellite images and semi-automatic classification will be determined.

Keywords: bark beetle; city of Čabar; Copernicus; forest damage; satellite images; semi-automatic classification

1 INTRODUCTION

In the first days of February 2014 a huge amount of ice rain fell in the area of Gorski kotar. The consequence of such weather is enormous damage on forest ecosystem with instant damage reflected in broken and pulled out trees. The aftermath of broken trees is the progressed infestation of bark beetles [10]. To prevent further infestation, the damaged forest should be cut down. This is a serious task because of the wide area infected. The first task is to determine which trees are infected. To do so, the easiest way is using satellite imagery. In this paper, the classification on training site located in the city of Čabar area will be presented. Municipality of Čabar is located on 28,205 hectares of which 94% are forests. [11].

1.1 Characteristics of Spruce Bark Beetles

The Republic of Croatia can be separated in three geographic regions: lowland, mountain area, and the Mediterranean. In mountain area we can find spruce, beech and fir trees. Čabar is located on 650 to 1,200 meters above sea level and therefore is placed in mountain region covered with spruce and fir forests [11]. Fig. 1 shows spruce distribution in the city of Čabar area. As shown in Fig. 1, the whole area of the city of Čabar is covered with mainly spruce forest and this area is convenient for research of bark beetle damage. According to [1], in spruce forest spruce bark beetles have a great role and we can distinguish two different types of spruce bark beetles. Main characteristic of bark beetle damaged spruce forest is first yellow treetop, then red treetop, and eventually the infected tree is dead [1]. Fig. 2 represents spruce forest infected with bark beetle. There are other symptoms, such as dispersal of green needles and dripping resin out of tree bark. However, in this paper the main focus will be only on color changing symptom because it is very easy to distinguish different colors on satellite images.

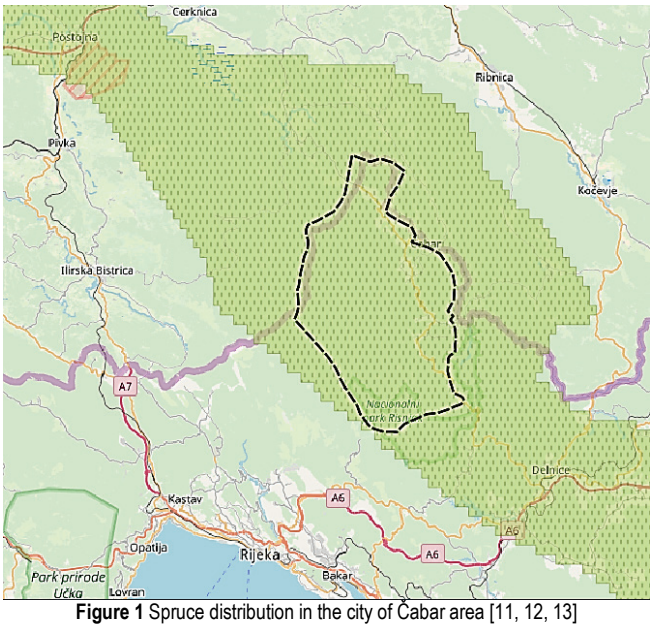

Figure 1 Spruce distribution in the city of Čabar area [11, 12, 13]

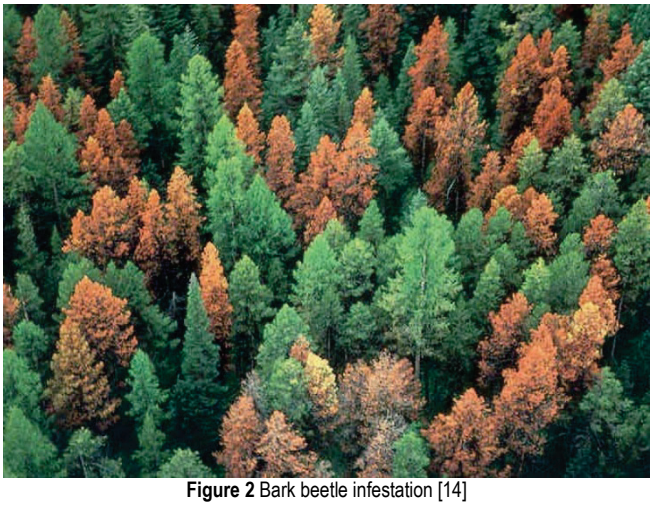

Figure 2 Bark beetle infestation [14]

1.2 Copernicus Program – Sentinel Satellite Mission

Copernicus, previously known as GMES (Global Monitoring for Environment and Security), is the European Program for the establishment of a European capacity for Earth Observation [16]. Within the Copernicus program, ESA (European Space Agency) is developing a new family of missions called Sentinels. Each Sentinel mission is based on a constellation of two satellites to fulfil revisit and coverage requirements, providing robust datasets for Copernicus services. These missions carry a range of technologies, such as radar and multi-spectral imaging instruments for land, ocean and atmospheric monitoring [17]. There are several Sentinel missions already operable and some are in development. In this paper, the data acquired from Sentinel 2 mission will be used. The SENTINEL-2 mission orbit is sun-synchronous, multispectral high-resolution imaging mission for land monitoring, to provide, for example, imagery of vegetation. Sentinel 2A was launched on June 23, 2015 [17]. Sentinel 2A contains multispectral imager (MSI) covering 13 spectral band (443 nm – 2190 nm) with a swath width of 290 km and spatial resolution of 10 m, 20 m and 60 m [18]. List of corresponding bands, ranges and names is listed in Table 1.

Table 1 Name, spectral range (nm) and spatial resolution (m) of corresponding Sentinel-2 MSI [2]

Band (m)	Range (nm)	Name
B1 (60)	443±10	Aerosol
B2 (10)	490±32.5	Blue
B3 (10)	560±17.5	Green
B4 (10)	665±15	Red
B5 (20)	705±7.5	Red-edge 1
B6 (20)	740±7.5	Red-edge 2
B7 (20)	783±10	Red-edge 3
B8 (10)	842±57.5	NIR_{wide}
B8A (20)	865±10	NIR_{narrow}
B9 (60)	945±10	Cirrus
B10 (60)	1375±15	Water Vapor
B11 (20)	1610±45	SWIR 1
B12 (20)	2190±90	SWIR 2

2 SEMI-AUTOMATIC CLASSIFICATION

Classification is analysis technique for remotely sensed image processing. It contains three types of methods: supervised, unsupervised and hybrid. The common classification algorithms contain the *K*-means, the parallelepiped, ISODATA, maximum likelihood classifier and minimum distance to mean [3]. In QGIS there is available plugin called Semi-Automatic Classification Plugin for supervised classification. In this plugin there are three different classification algorithms:

- minimum distance,
- maximum likelihood,
- spectral angle mapping.

2.1 Minimum Distance

Minimum distance classification is probably the oldest and simplest approach to pattern recognition, namely *template matching*. In a template matching we choose class or pattern to be recognized, such as healthy vegetation. Unknown pattern is then classified into the pattern class whose template fits best the unknown pattern. Unknown distribution is classified into the class whose distribution function is nearest (minimum distance) to the unknown distribution in terms of some predetermined distance measure [4].

2.2 Maximum Likelihood

Maximum likelihood algorithm is considered the most accurate classification scheme with high precision and accuracy [3], and because of that it is widely used for classifying remotely sensed data. Maximum likelihood classification is method for determining a known class of distributions as the maximum for a given statistic. An assumption of normality is made for the training samples. During classifications all unclassified pixels are assigned to each class based on relative probability (likelihood) of that pixel occurring within each category's probability density function [5].

2.3 Spectral Angle Mapping

Spectral image mapper is a spectral classifier that is able to determine spectral similarity between image spectra and reference spectra by calculating the angle between the spectra, treating them as vectors in a space with dimensionality equal to the number of bands used each time [6]. Small angles between the two spectrums indicate high similarity, and high angles indicate low similarity [6].

3 DATASETS AND METHODOLOGY

The study area is located in the Republic of Croatia, in the city of Čabar area. It is located in the north part of Gorski kotar near Slovenian border. The whole area mostly consists of spruce and fir forests. According to [1], bark beetle infestation is best seen in spring and summer, where healthy spruces and fir have green treetops and the infected ones have orange/red treetops. Therefore, from the official Copernicus site [19], Sentinel-2 images were obtained for late July, precisely on July 22, 2016. It is important to choose imagery which has little or zero cloud coverage. Since only bands 2, 3, 4, 8 are needed for analysis, the other bands were dismissed. Bands 2, 3, 4 are needed for true image representation as shown in Fig. 3. Bands 3, 4 and 8 are necessary for calculating RGI and NDVI as shown in Eq. (1) and Eq. (2). The result after merging all bands into one raster image is true color image of our training area as shown in Fig. 3.

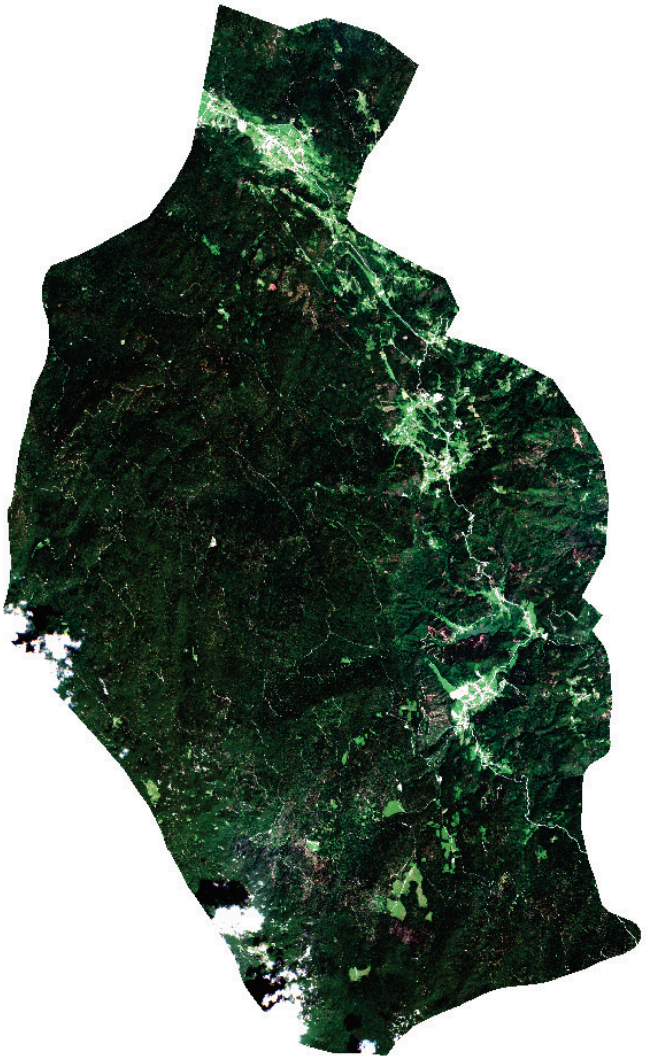

Figure 3 Training area – the city of Čabar area

Fig. 3 represents several things. First, the cloud coverage is minimum and should not affect analysis. Second, the buildings (city, villages, roads) reflect differently than vegetation. Likewise, it shows that the healthy vegetation is easily detected by plain sight as it reflects in green, while infected vegetation is brown/orange/red. To confirm this theory, the red-green index is calculated. It is sensitive to conifer tree mortality according to [7], and this is shown in Fig. 4. Moreover, according to [7], normalized difference vegetation index is calculated and it is sensitive to green (healthy) vegetation as shown in Fig. 5. Red-green index is calculated from Eq. (1) and normalized difference vegetation index from Eq. (2).

$$RGI = \frac{B4}{B3} \tag{1}$$

$$NDVI = \frac{(B8 - B4)}{(B8 + B4)} \tag{2}$$

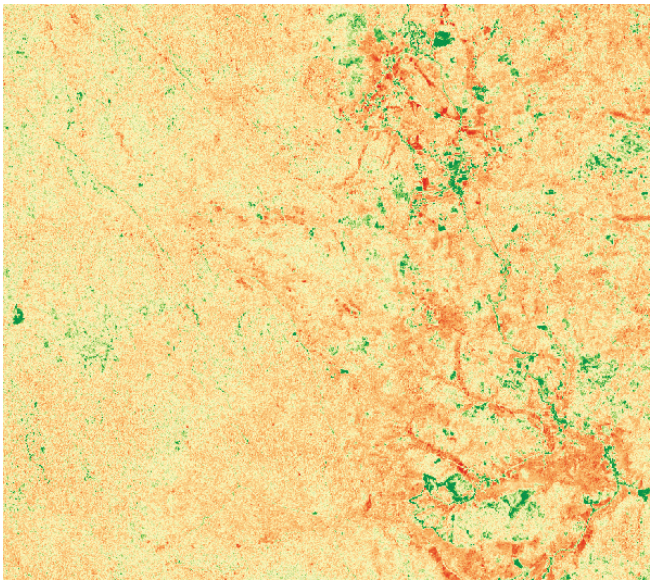

Figure 4 Red-green index

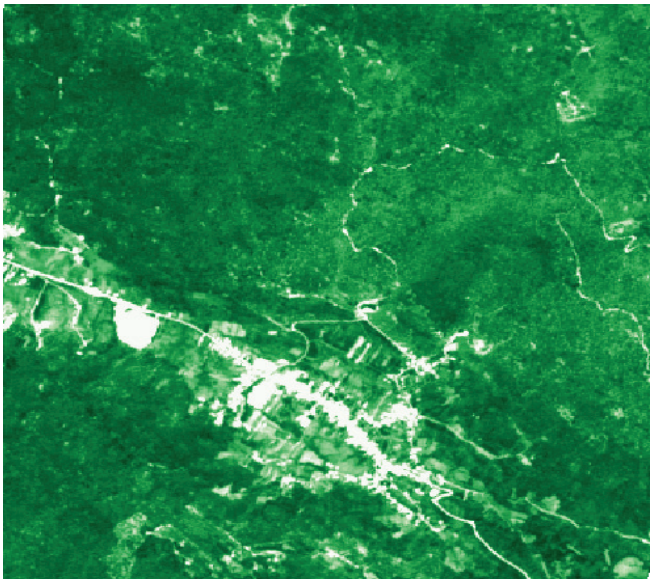

Figure 5 Normalized difference vegetation index

Fig. 4 shows green areas, which represent infested forest, and yellow – red pixels represent healthy vegetation. In Fig. 5, white/very bright pixels which represent buildings (houses, roads, etc.) and green pixels can be separated. There are dark green pixels and they represent healthy forest, while light green pixels represent unhealthy forest. Since it has been determined that there are infested spruce trees in the training area, supervised classification can be done. As mentioned earlier, the maximum likelihood algorithm is currently most accurate classification method and it is going to be used on training site. First step is to manually choose reference pixels throughout the training site. Having features in training site in mind, four different macro classes have been proposed. First class contains buildings (city, village, roads, etc.). Since some of the objects are smaller than the size of one pixel, QGIS plugin joins pixels in class based on average value of pixel and on

predefined threshold. Second class contains vegetation such as meadows and lawns. Third class represents healthy forest, and the forth class represents bark beetle infested/damaged forests. Fig. 6 shows spectral signature of obtained classes and shows the spectral plot and reflectance of each class. If looked at closely, it can be seen that first class differs from the other three classes and therefore classification for the first class can be expected. As it regards other three classes, they are slightly different one from another but classification should also give satisfying results.

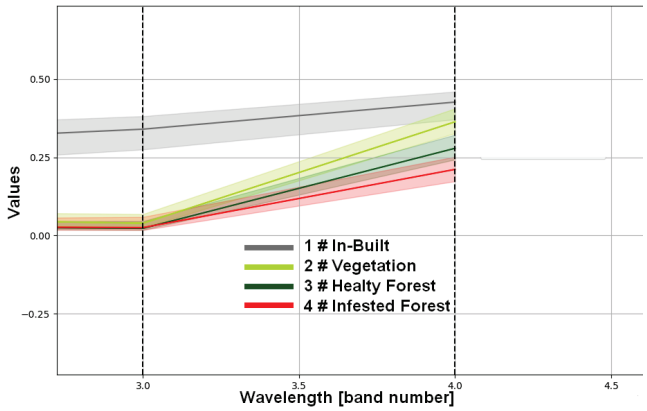

Figure 6 Spectral signature plot

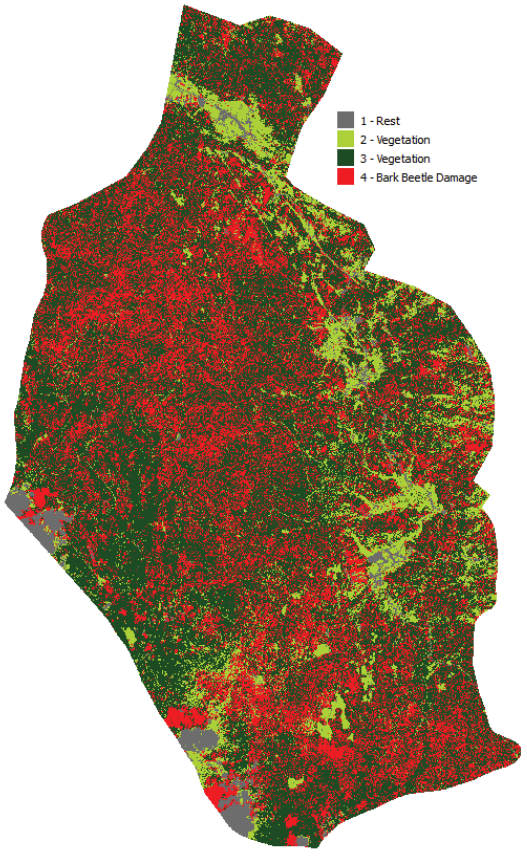

Figure 7 Training site after classification

The availability of a large number of remote sensing variables has caused the difficulty to select useful variables [8]. Thus, it becomes very important how to select the remote sensing variables that significantly contribute to increasing accuracy of distinguishing land use and land cover classification types [8]. When the number of remote sensing variables is relatively small, simple and traditional methods, such as bar graph spectral plots and feature space plots, are usually utilized [8]. If selected classes have spectral plot such as shown in Figure 6, the classification can start and should give good results. If selected classes have spectral plots that are very near each other or overlapping, classification can start but the results may not be as expected. Overlapping spectral plot of classes may occur if one of the class samples has been joined to the other class and vice versa so one should be very careful when assigning samples to classes. After it has been determined that obtained classes have satisfying spectral plot, the classification starts. Maximum likelihood algorithm in QGIS is time consuming so the final result is available in couple of hours. Later, the classification training site looks as shown in Fig. 7.

4 RESULTS

After successful classification a lot of training area is populated with damaged forest. Results of classification can be presented in numbers as shown in Tab. 2.

Table 2 Number of pixels per class and corresponding area

Class No.	Pixels per class	Area (ha)	Percentage (%)
1	5,937	813.12	3.2
2	33,788	2933.02	11.5
3	50,858	13,692.87	53.5
4	138,820	8,134.33	31.8
Total	229,405	25,573.43	100.0

Official data available online [11] shows the difference between total area of the city of Čabar in 2,631.57 hectares. This could be the result of imperfect vector data acquired from web page [13]. Tab. 2 and Fig. 7 show the correspondence between class number in Tab. 2 and legend entry in Fig. 7. Therefore, class number 4 represents unhealthy forest or, as shown in Fig. 7, bark beetle damage. Based on the conducted analysis, over 31% of the city of Čabar area is populated with unhealthy forest. It cannot be concluded from satellite images if the damage is from bark beetle or for some other reason. But official records of bark beetle infestation [20] reflect that around 4,000 hectares of public forests are infected with bark beetle. Official data for municipality Čabar says that 4,187 hectares or forested area is in private property [9] and it can be assumed that 10 - 25% is infested with bark beetle. If these two values are added up, the result is around 5,000 hectares of infested forest. This value is different from the value given in Table 2 because not all of the damage comes from bark beetle. However, it can give a good overview on damaged forest and their location.

5 CONCLUSION

After huge amount of ice rain in Gorski kotar in 2014 there was an outburst of bark beetles which attack primary spruce and fir forest. To prevent further development of disease, infected trees must be cut down. However, the detection of such trees is difficult due to the large area infected. With Copernicus program being developed and its Sentinel satellite missions, it has become a lot easier to track down unhealthy forests. Using satellite images and proper tools to classify these images useful information about damaged forests can be obtained. However, it should be taken into consideration that such classification cannot always produce helpful information so one should be very careful when using such classification results. Nevertheless, if classification results are combined with results obtained on the field, quality map, which allows us to track down infested forest with higher accuracy, can be produced.

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Subject review

THE PROSPECTS FOR ECOSYSTEM SERVICES PROVISION IN FRAGILE STATES' URBAN AREAS

Antonija BOGADI

Abstract: In fragile states context of climate change vulnerability, poverty and lack of infrastructure, the ability of ecosystem services to provide for numerous human needs is indispensable. The focus of this paper is describing the prospects for ecosystem services provision in fragile states' urban areas. This paper presents a distinct approach by analyzing actors with capacity to provide ecosystem services in urban areas: government, international partners and citizens. Using infrastructure investments data from Asian Development Bank, African Development Bank and World Bank, obstacles for ES provision are related to weak and fragmented governments, non-transparency and low access to international funds and insufficient involvement of citizens. The work presented here argues for ecosystem services implementation as a valid part of solution for fragile states' difficulties and has implications for future studies of governance measures for providing ecosystem services in urban areas.

Keywords: actors; climate change; ecosystem services; urban areas

1 INTRODUCTION

A few tens of countries in the world are confronting extreme, internally and externally caused difficulties in their development. Those countries are called "fragile states" and they are mostly dealing with rapid population growth combined with high population density, climate change, low economic and social resilience, government instabilities often linked with internal and external conflicts [1].

The most serious predicted climate change impacts in fragile countries are extremes of precipitation and temperature, more frequent and intense storms, and sea-level rise. When this is combined with the issues stated above, it is clear that fragile states are countries most vulnerable to climate changes. Those areas are already struggling with problems connected to climate change and it is most probable that these will worsen in the future.

According to recent thinking, ecosystem-based adaptation concept is seen as one of the answers for adapting to the emerging and irreversible impacts of climate change. The advantage of ecosystem-based adaptation is that it generates various additional co-benefits, such as climate change mitigation, food provision, and increasing environmental knowledge. Moreover, it is cost-effective alternative or a complement to traditional, engineering-based approaches. The premise of this article is that such a multi-beneficial intervention could be a proper, satisfactory way for climate change adaptation in fragile countries.

As the need for carefully managed ecosystems mostly occurs in the cities [2], due to the variety of actors and conflicting interests, the focus of this paper is to describe the circumstances in ecosystem services provision in fragile states' urban areas.

Governance measures used to provide ecosystem services in cities elsewhere in the world are not effective in the context of fragile states, because different stakeholders are involved and governments are fragmented and too weak to carry out major responsibilities for their implementation. The role of international development partners with their funding and knowledge is an important factor, but the access to those resources is often nontransparent and overly politically conditioned. It appears that the best strategy for ecosystem services implantation in urban areas is a switch to long-termed political actions, introducing policies focused on city-wide impacts, implementing combination of regulating, provisioning and cultural ecosystem services, and good cooperation with local communities in using local knowledge and practices.

2 FRAGILE STATES AND VULNERABILITY TO CLIMATE CHANGE

The Fund for Peace Fragile States Index is an annual ranking of 178 countries based on their levels of stability and threats [3]. Every country is ranked based on the key political, social and economic fragility indicators developed from social science research.

Sixty countries with the highest fragility are considered "fragile". World Bank estimates that more of the quarter of world's population lives in fragile states, with a majority of people surviving on less than US$1.25 per day, highest rates of children dying before the age of five, and highest maternal deaths rates [4].

The gap between fragile sates and other developing countries is widening and projections show that fragile states will constitute an even larger share of low-income countries [4]. This is a world's major sustainable development issue and development models for narrowing the gap need to be fundamentally different than in other countries due to the different context of risks.

Due to the combination of frequent natural disasters, high population density and low resilience to economic shocks fragile sates are expected to be worst affected by climate change.

Tab. 1 compares the country's fragility rank from The Fund for Peace's Fragile States Index and a country's

vulnerability rank to climate change from The Centre for Global Development [3, 5].

The countries are ranked according to vulnerability to changes in extreme weather, vulnerability to changes in sea level rise, overall climate change impact only from climate drivers, and vulnerability to climate change from climate drivers plus economic development and governance [5].

Tab. 1 demonstrates the ranks of 20 countries which are most vulnerable to those categories. When the fragility rank (shown in brackets) is added to the country's rank, it is clear that the countries suffering from overall climate change impact only from climate drivers (with no socio-economic drivers) and vulnerability to climate change impacts from climate drivers and socio-economic drivers are also fragile states.

The share of fragile states in the 20 countries most vulnerable to changes in extreme weather and changes in sea level rise is not significant, because only population at risk and the probability of extreme weather and sea level rise are measured and defined as vulnerability [5].

When including other factors in calculating impacts and vulnerability, like urge for changing the residence, agricultural productivity loss, economic development and governance strength, it is obvious that fragile states are most at risk, mainly because they mostly depend on agriculture and are economically and organizationally weak. To present the strong connection between fragility and vulnerability more clearly, fragility category [3] is added to each fragile country.

Table 1 Countries' fragility rank and a country's vulnerability rank to changes in extreme weather, rise of sea level, climate change impacts form climate drivers and general climate change impacts. (Data derived from [3, 5])

	Vulnerability to changes in extreme weather: Population at risk from changes in extreme weather (rank 2015)	Vulnerability to changes in sea level rise: Population at risk from sea level rise (rank 2015)	Overall climate change impact from climate drivers only: extreme weather; change in the probability of residence; change in agricultural productivity (rank 2015)	Vulnerability to Climate Change from climate drivers, economic development and governance (rank 2015)
1	China	India	Central African Republic (3)	Myanmar (26)
2	Djibouti (39)	Bangladesh (36)	Burundi (15)	Bangladesh (36)
3	India	China	Sudan (4)	Ethiopia (24)
4	Kenya (20)	Indonesia	Bangladesh (36)	Sudan (4)
5	Somalia (1)	Philippines (54)	Rwanda (32)	Burundi (15)
6	Mozambique (42)	Nigeria (13)	Senegal (59)	Vietnam
7	Bangladesh (36)	Vietnam	Ethiopia (24)	Zimbabwe (16)
8	Sri Lanka	Japan	Myanmar (26)	Niger (19)
9	Ethiopia (24)	United States	Malawi (44)	Malawi (44)
10	Vietnam	Egypt, Arab Rep.(38)	Niger (19)	Congo Rep. (31)
11	Bolivia	United Kingdom	Lesotho (66)	Madagascar (56)
12	Hong Kong (China)	Korea, Rep.	Zambia (49)	Central African Republic (3)
13	Cuba	Myanmar (26)	Chad (7)	Chad (7)
14	Madagascar	Brazil	Mali (29)	Mali (29)
15	Honduras	Turkey	Guniea Bissau (17)	Guinea (12)
16	Thailand	Malaysia	Zimbabwe (16)	Cambodia (46)
17	Zambia (49)	Germany	Congo Rep. (31)	Haiti (10)
18	Colombia (67)	Italy	Vietnam	Zambia (49)
19	Zimbabwe (16)	Mozambique (42)	Cambodia (46)	Senegal (59)
20	China	Thailand	Guinea (10)	Guinea Bissau (17)

	Fragile state rank	Fragility category
	1 - 8	very high alert
	9 -16	high alert
	17 - 38	alert
	39 - 67	high warning

3 ECOSYSTEM SERVICES AND CLIMATE CHANGE ADAPTATION

Current discussions on cities facing the upcoming climate changes raise the understanding that cities need to be increasingly adaptable to changes, such as less foreseeable rainfall and temperature regimes [6]. Ecosystem-based adaptation concept has a potential to contribute to sustainable urban development and it is getting growing attention from academic and governmental bodies [7-11].

Ecosystem-based adaptation uses ecosystem services to help people adapt to the various effects of climate change [12]. That approach is a cost-effective alternative or a complement to traditional, engineering-based solutions, with an advantage of generating various co-benefits; among others climate change mitigation and food provision (Tab. 2). This relatively new concept could raise human resilience to climate change with natural and managed ecosystems [2], noting that the need for managed ecosystems usually occurs in the cities.

Use of ecosystem services could provide better management of storm-water runoff, lowered incidents of combined storm and sewer overflows, water capture and conservation, flood prevention, storm-surge protection, defense against sea-level rise, accommodation of natural hazards (e.g., relocating out of floodplains), and reduced ambient temperatures and urban heat island (UHI) effects. Low levels of formal employment in fragile state cities put a high level of dependency on the provision of other ecosystem services, such as water, fuel, and food production, from areas within cities as well as nearby natural areas [13, 14].

In fragile states context of climate change vulnerability, poverty and lack of infrastructure, the ability of ecosystem services to provide for numerous human needs is indispensable [15].

4 GENERAL OBSTACLES OF ECOSYSTEM SERVICES PROVISION IN URBAN AREAS

The focus of this paper is to describe the circumstances in ecosystem services provision in fragile states' urban areas for climate change adaptation.

Fragile states are increasingly urbanizing, but those settlements are marked by extreme social inequity, weak governance structures, poor infrastructure and services delivery, limited environmental regulation, and low scientific capacity regarding ecosystem services and biodiversity, all of which impacts biodiversity loss and ecosystem services provisioning [13].

Table 2 Ecosystem services and their benefits. The Millennium Ecosystem Assessment [16] and The Economics of Ecosystem Services and Biodiversity [17] grouped ecosystem services in four categories: provisioning, regulating, habitat and cultural services.

Ecosystem service	Ecosystem service benefit
Provisioning ecosystem services	Material products obtained gained from ecosystems, including genetic resources, food and fiber, and fresh water.
Cultural services	Non-material benefits that users receive from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, supporting knowledge systems, social relations, and aesthetic values.
Supporting or habitat services	Services necessary for the production of all other ecosystem services, like biomass production, nutrient cycling, water cycling, provisioning of habitat for species, and maintenance of genetic pools and evolutionary processes.
Regulating services	Benefits attained from the regulation by ecosystem processes, including the regulation of climate, water, and some human diseases.

Biodiversity concerns, crucial for ecosystem services provision, are often treated as less important and not relevant to other urban issues such as poverty, unemployment, and access to food, energy, water, sanitation, and housing. Where urban biodiversity interventions are carried out, they are most often neglecting multiple benefits of ecosystem services and are focusing just on single ecosystem service [13].

Geographical gap in knowledge is also an obstacle for ecosystem services provision in urban areas. Most scientific studies of ecosystem services in cities are performed and published in Europe, North America and China [18], so there is insubstantial understanding of the urban ecosystem services needs and management in large regions in South Asia, Africa and Latin America.

The economic values of ecosystem services are most often derived from conventional economic accounts (e.g. cost-benefit analysis, supply and demand relations), which are not taking in account changes in human well-being outside a market. Those effects are called environmental externalities, which can be either negative (e.g., pollution) or positive (e.g., ecosystem services).

Therefore, due to economic valuation of ecosystem services the 'hidden' economic costs of the transformation of ecological infrastructure to build infrastructure are made visible.

For example, avoided cost methods show that loss of urban vegetation can lead to bigger energy costs for cooling, loss of vegetation in the city, increase the dependence on costly water purification technologies. Likewise, lack of ecosystem services such as air purification, noise reduction, carbon sequestration and regulation of water flows also contribute to significant economic costs [19].

Regardless of abundant research of economic benefits of ecosystem services implementation, management decisions are still mainly based on economic information so ecosystem services with unclear economic value are regularly depreciated [19].

5 ACTORS RESPONSIBLE FOR ECOSYSTEM SERVICES PROVISION

Ecosystem services implementation policies and regulations used in developed world cannot be useful in the fragile states' context of informality and poverty. It is important to recognize the actors, understand their relationships and responsibilities in order to develop appropriate strategies for effective ecosystem services provision.

This paper identifies state bodies, international agencies and local community as most important actors. A brief analysis of their responsibilities and domains of actions is given further in the text.

5.1 Government

Government is the most important actor in enabling the successful ecosystem services provision, but such a role is problematic in fragile states due to their relatively low stability and capacity. Government needs to play a number of different roles in order to efficiently manage ecosystem services provision:

- **Good governance procedures** should be provided both within its own institutions and between government and other actors. There is often disconnection and lack of effective communication between local and national levels of government, and between government and other actors, and failure of national policy to be implemented on the local scale.
- **Correct policies and regulations** should be aiming at facilitating investments in providing ecosystem services, like monitoring mechanisms for sustainable harvesting of ecosystem resources, sanctions for those harming ecosystem services implementation process, mechanisms for conflict resolutions among the actors with different interests, and controlling corruption.
- **Long term commitment and planning** are important in ES provision, especially for adaptation to climate change purposes and they need to be undertaken at the right time because putting investments in climate adaptation on hold may cost more in the future due to reconstruction costs, i.e. flood regulation.

5.2 International Development Partners

International development partners, such as international development funds, foreign embassies and export credit agencies, are crucial in financing the ecosystem services provision projects in fragile states.

The data presented here is gathered to describe the general context of financing climate change adaptation projects in fragile states that are relevant for providing ecosystem services and it originates from international development funds, mostly from World Bank Clean Investment Fund, African Development Bank and Asian Development Bank.

Many international funds are created to enable access to finance, such as the UNEPs Green Climate Fund, World Bank's Clean Investment Fund, Global Environment Facility fund, but fragile states often have trouble getting these sources [20-22]. One of the biggest sources of international finance is Global Environment Facility, which set up the Least Developed Country Fund, aimed for providing least developed countries with financial support for their climate change adaptation strategies.

Although such mechanisms should enable unconditional access to finance for least developed countries, they are regularly blocked to do so. Those mechanisms require many checks and monitoring systems regarding rigorous good governance requirements (with the intention to weaken "undesirable" regimes) which are preventing fragile states from accessing them [23].

World Bank Clean Investment Fund Expenditure and Global Environment Fund Expenditure data show that even if there is a high availability climate change adaptation financing, the percentage that goes to fragile states is low. The percentage that is destined to ecosystem based climate adaptation projects is even lower, because fragile states seem to be limited in their capacity to access international financing mechanism [1, 4].

Further challenges occur even when project is already funded and in implementation. The projects are often planned by the international donors, with their interests, outcomes and goals, without including the thoughts of local community or government until the evaluation stage [24].

Furthermore, the long term projects often fail after the official project end, because authorities responsible for different components of the project are not nested enough in government bodies after funding partner leaves [24, 13].

5.3 Local Community

It is often unclear in fragile states how the responsibilities for the ecosystem services management are divided between the various governmental bodies. In an environment with such a fragmented government, frequently the local community, local individuals and international development partners are taking over a determinant role in managing the provision of ecosystem services.

Ecological knowledge at the local level exists and it is used in informal and small scale management of urban ecosystems, as case studies of places in Asia and Africa suggest [24, 15]. The potential of local knowledge and practices could be encouraged through citizen initiatives and ecological stewardship [25-27], e.g. learning arenas connected to projects in which civil society groups, government, and volunteers collectively take part in environmental stewardship.

Those programs are showing that education and effective public participation seem to be crucial in facilitating ecosystem services in the long term and could support more formal governance and management of ecosystem services.

6 CONCLUSION

Fragile states are coping with rapid population growth, high climate change impacts vulnerability and serious political instability, which leads to social inequity, and ecological and economical degradation. Ecosystem-based adaptation concept uses ecosystem services to help people adapt to the various effects of climate change [12]. It is a strategy convenient for implementation in fragile states because it has multiple co-benefits, like cultural services and climate change mitigation.

To develop ecosystem services provision in the urbanized areas, it is necessary to preserve and upgrade ecosystem functioning on city scale. Due to the high level of governance informality and instability, conventional policy and regulatory measures used successfully to provide ecosystem services in cities elsewhere in the world may not be effective in the context of fragile states.

Through literature review, three main groups of actors are identified as responsible for ecosystem services provision in fragile states: government, international development partners and local communities.

Governments are weak and fragmented, and the crucial step for ecosystem services provision is generating

continued, long-term political actions and extending municipal boundaries for greater control over land-use change, and introducing policies with wider, metropolitan or even regional impact [13].

While international resources and funds exist, there is a need for increasing access and transparency of process on governments procuring these opportunities [13].

Local knowledge and practices could have an important role in ecosystem services implementation and maintaining programs, and they can be integrated through strengthening and involving citizens. It is important to combine providing regulating ecosystem services for climate change adaptation with other ecosystem benefits, especially food provision, supporting knowledge systems and social relations, because it will be accepted, used and maintained in a better way within local community.

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Professional paper

CHANGING OF VISCOSITY AND THERMAL PROPERTIES OF OLIVE OIL WITH DIFFERENT HARVESTING METHODS AND WAITING PERIOD

Cihangir SAGLAM, Fulya TAN, Turkan AKTAS

Abstract: The aim of this paper is to determine how different harvesting methods of olives and the waiting period before the extraction of the extra virgin olive oil affect the viscosity and some thermal properties, namely thermal conductivity and thermal resistivity. Olive trees in the Aegean region of the western part of Turkey were harvested by using six different harvesting methods: by hand, harvesting by a beating pole on a synthetic fabric, harvesting by a beating pole on a platform, harvesting by machine on a synthetic fabric, harvesting by machine on a platform and direct collecting of dropped olives by hand. Olive oil samples were obtained in certain intervals between the harvesting and processing that was made by using a laboratory type system. The viscosity values of oil samples were measured by using a vibro-viscometer. The thermal conductivity and thermal resistivity of oil samples were measured simultaneously by using the KD2 Thermal properties analyzer. As a result, viscosity, thermal conductivity and thermal resistivity values changed related to the harvesting method and the waiting period after harvesting to obtain olive oil. While viscosity (dynamic) and thermal conductivity values increased with the increase of the waiting time, thermal resistivity values decreased. The lowest viscosity and thermal conductivity values and the highest resistivity values were found for oils that were obtained from olives harvested by hand.

Keywords: dynamic viscosity; extraction time; harvesting methods; olive oil; thermal conductivity; thermal resistivity

1 INTRODUCTION

Olives are traditionally hand harvested, a process that is not only tedious and laborious, but represents the major proportion of the costs of production. Harvesting by hand is accomplished by three techniques: collection of the fallen fruit from the ground, "milking", or the stripping of fruit with half open hands from limbs which fall into picking bags or onto nets below the tree, and beating limbs with large sticks to dislodge fruit, which is also collected on nets. Mechanical harvest of olives has been used to a limited extent in more intensive orchards.

As it is known, the harvesting method has an important effect on the quality of olives, especially in the production for table consumption. Some researchers showed that the harvesting method also has an important effect on the quality of olive oil. Although a number of studies have reported the effects of irrigation on yield parameters under conditions and varieties, there is a shortage of the influence of the harvesting method on oil quality. The effect of irrigation on the oil quality of the fruit obtained from both the mechanical and hand harvesting methods in addition to the yield parameters was also researched [4]. They found that when fruit was picked carefully by hand so that no injuries were inflicted, free fatty acids levels were substantially reduced, peroxide was reduced and the total polyphenol content was increased.

The degradation of oil quality related to increased irrigation could potentially be aggravated by damage to the fruit caused during harvesting. It was reported that the effect of the temperature on the experimental data on thermal conductivity and dynamic viscosity of some vegetable oils such as cotton seed, rice and corn in addition to olive oil was present [2]. They found that the thermal conductivity decreased slightly with the increase in temperature for all samples researched. Moreover, they reported that a rise in temperature led to a sharp decrease for this property for all samples.

The greatest deterioration of olive oil is due to the poor handling of olives during the time between harvesting and processing. The storage of olive fruits is carried out by simple heaping in fruit piles while they wait for their processing. These fruits develop all kinds of degenerative processes in a short period. Oil samples obtained from them show characteristics of hydrolytic and oxidative deteriorations confirmed by their high acidity values, or the peroxide value. To avoid this situation, the industry is currently reducing the interval between harvesting and processing through an increase in the milling capacity [5].

For this reason, olives should be crushed within the first 24 or 36 hours after picking. In spite of this situation, in many olive production countries, the waiting period between harvesting and processing has been longer than this mentioned period.

The viscosity value of a liquid is an important parameter for designing the piping in a plant, or transporting crude oil or a chemical agent through a pipeline. Measuring the viscosity has played an important role in, to say nothing of the petrochemistry industry, a wide range of industries such as the food, printing (ink), medical drug, or cosmetics industries, as well as in the quality control during a production process or in various research and development stages for the improvements of quality and performance.

The oxidative stability of oils is determined by thermal analyses. For this reason, thermal properties of oils are important factors that are evident of oxidation.

The increase of viscosity in olive oil shows the increase of the lipid oxidation [3]. Furthermore, the increase of thermal conductivity, namely decrease of thermal resistivity shows the low thermal stability and increase of lipid oxidation in oil. For this reason, the aim of this paper is to determine how the harvesting methods of olive and the waiting period

before the extraction of the extra virgin olive oil affect the viscosity and certain thermal properties, namely the thermal conductivity and thermal resistivity of olive oil.

2 MATERIALS AND METHODS

2.1 Harvesting Methods and Obtaining Olive Oil Samples

Olive trees in the Aegean Region of the western part of Turkey were harvested by using the six methods of harvesting; by hand, harvesting by a beating pole on a synthetic fabric, harvesting by a beating pole on a platform, harvesting by a machine on a synthetic fabric, harvesting by a machine on a platform and direct collecting of dropped olives by hand. Olive oil samples were obtained in certain intervals between harvesting and processing. Olive oil was obtained as soon as harvesting was finished. Then, every day for seven days olive samples harvested by six different methods were processed into oil. Until the extraction time, olives were stored in a cold room with +4°C temperature and 70-75 % relative humidity conditions, and during the waiting period, olives were exposed to air. Olive oil samples were processed by using a laboratory type system. This system was designed as similar to big scale olive oil production systems (Fig. 1).

To obtain olive oil by using this system, production steps were carried out as below:

- Separation of dirt and leaves,
- grinding of olives and their pits into paste which goes onto the press,
- malaxation by slow mixing of the paste which allows the oil - water emulsion to coalesce in the malaxation tank that was under constant temperature (30 °C). Small microscopic oil droplets join together into large drops with this process,
- pressing of the paste. The press separates out the olive juice and oil by using an additional filter.

The thermal properties of food show its ability to conduct, store, and lose heat. These properties are inherent to today's food processing and preservation practices. Thermal properties are important for modelling processes (microwave heating, extrusion, freezing, etc.), the engineering design of the processing equipment, calculating the energy demand, and the development of sterilization. Apart from processing and preservation, thermal properties also affect the sensory quality of foods, as well as the energy saving from processing [6]. Kinetic studies speak of the thermal decomposition and thermal stability of the commercial edible oils by using the thermogravimetric method [7]. The obtained results indicate that these parameters were dependent on the composition of fatty acids, being influenced by the presence of natural and artificial antioxidants. According to the thermogravimetric curves, the following thermal stability sequence was suggested: corn > sunflower > soybean > rice > soybean + olive > sunflower + olive > canola > olive; while the activation energy indicated the following stability order: sunflower > corn > soybean > rice > soybean + olive > canola > sunflower + olive > olive. It can be said that according to these results, olive oil that contains unsaturated fatty acids is more unstable compared to others.

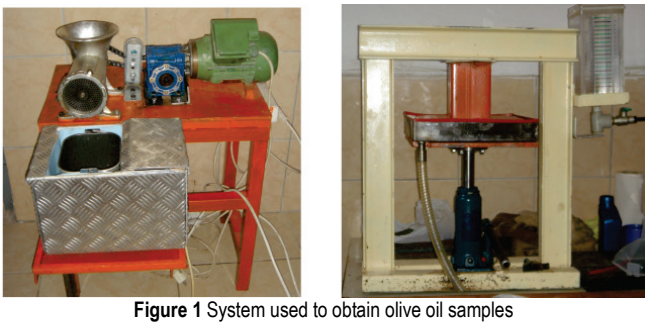

Figure 1 System used to obtain olive oil samples

2.2 Viscosity Measurements

In this research, the viscosity of oil samples was measured by using a vibro-viscometer (*AND, SV-10 model*). This type of viscometer measures viscosity by controlling the amplitude of the sensor plates immersed in a sample and by measuring the electric current to drive the sensor plates. As seen in Fig. 2, to perform the measurement, thin sensor plates were first immersed into a sample. When spring plates are vibrated with a uniform frequency, the amplitude varies in response to the quantity of the frictional force produced by the viscidity between the sensor plates and the sample.

The vibro-viscometer controls the driving electric current to vibrate the spring plates in order to make uniform amplitude. Since the frictional force of viscidity is directly proportional to viscosity, the driving electric current (driving power) for vibrating the spring plates with a constant frequency to make uniform amplitude is also directly proportional to the viscosity of each sample.

The vibro-viscometer measures the driving electric current to vibrate the sensor plates with a uniform frequency and amplitude, and then the viscosity is given by the positive correlation between the driving electric current and the viscosity (AND company catalogue).

2.3 Thermal Conductivity Measurements

KD2 Thermal properties Analyzer (Decagon Devices, Inc., Pullman, WA) that used the line heat source technique was used to determine the thermal conductivity and thermal resistivity values [1, 6]. The probe length was 60 mm and its diameter was 1.27 mm. This analyser gives direct readings of thermal conductivity and thermal resistivity with 5% accuracy.

Thermal conductivity is the ratio of heat flux density to temperature gradient in a material. It measures the ability of a substance to conduct heat.

Thermal resistivity is computed as the reciprocal of thermal conductivity [6]. Namely, it can be formulated as below:

$$R_s = \frac{1}{k_s} \tag{1}$$

Where: R_s is the thermal resistivity of oil samples (m CW^{-1}) and k_s is the thermal conductivity of the sample (W $m^{-1}C^{-1}$).

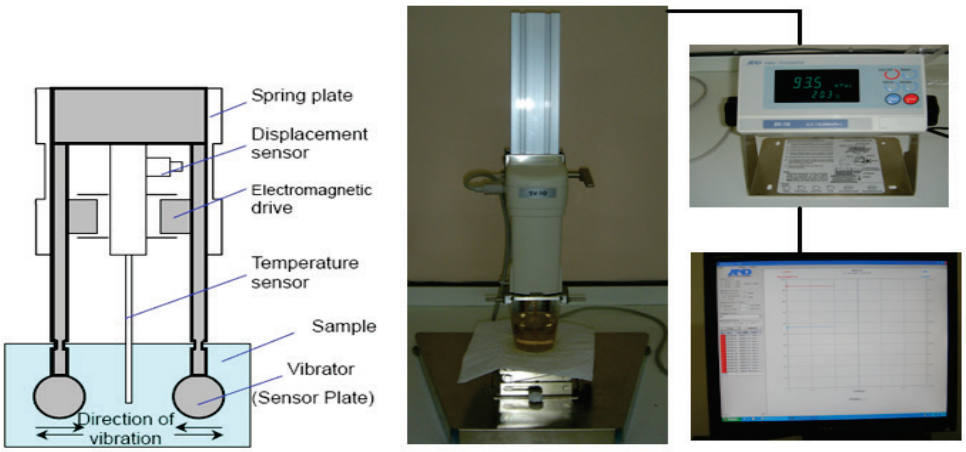

Figure 2 Detection part of the Vibro-viscometer (AND company catalogue) (a), viscosity measurements of olive oil samples, (b) Measurement steps of viscosity

3 RESULTS AND DISCUSSION

According to the measurements performed previously, the dynamic viscosity value of olive oil at 20 °C is given as 84 µPa·s, while soybean and corn oil viscosity values are 65.69 µPa·s in the same conditions [8]. As understood from these figures, the viscosity of olive oil is rather high compared to other vegetable oils.

As seen in Tab. 1 and Fig. 3, viscosity values of olive oil samples that were obtained for seven consecutive days after harvesting increased day by day for all samples that were harvested by using a different method. While the viscosity of samples that were obtained on the first day (harvesting day) were found to be almost the same for all harvesting methods; especially the viscosity of oil samples that were obtained by using the spontaneously dropped olives proved to be getting higher compared to others.

Table 1 Results for the dynamic viscosity of olive oil samples as a function of the harvesting method and waiting period

		Consecutive days during which olive oil was obtained after harvesting							
Harvesting Methods		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
Beating pole (1)	to ground (1G)	79.4	81.7	82.2	87.8	87.8	90.1	98.4	98.9
	to platform (1P)	74.04	85.85	86.7	87.2	87.4	87.7	92.3	93.8
Machine (2)	to ground (2G)	79.6	81.3	81.8	83.1	85.1	85.7	90.4	94.3
	to platform (2P)	76.6	81.1	81.8	85.8	86.6	88.7	91.2	93.3
By hand (3)	-	75.8	82.9	85.4	87.2	87.3	87.9	91.4	92.2
Spontaneously dropped olive	-	72.8	83.8	85.4	89.1	90.4	91	97.1	109

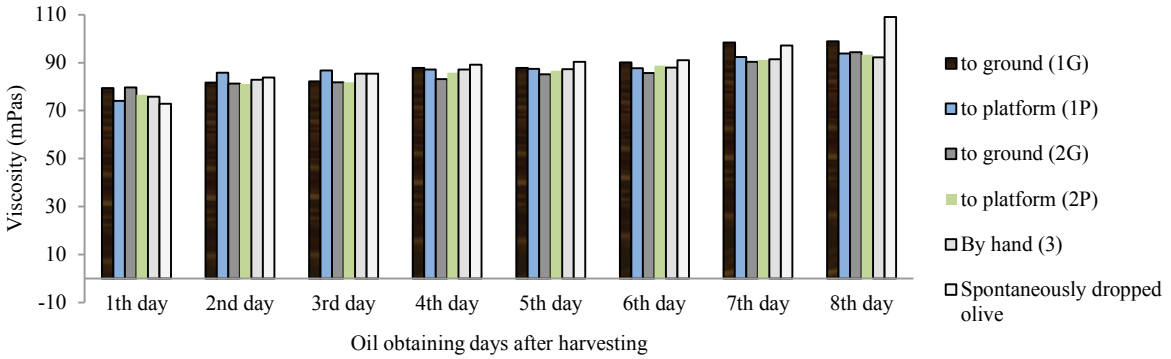

Figure 3 Changing of the viscosity values related to the harvesting method and the oil obtaining time after harvesting

As seen in Tab. 1 and Fig. 3, low viscosity values throughout the waiting period were obtained for oil samples that were produced from olives which were collected by hand, harvested using a machine to direct ground and to a special platform. The increase of viscosity values with a waiting period and related to the harvesting method can be explained in the sense that there is a possibility that a protein-polymerised phenol complex (sometimes the culprit

in a persistently cloudy olive oil), can lead to an increase of viscosity [9].

As seen in Tab. 2 and Fig. 4, thermal conductivity values of oil samples that were obtained just after harvesting were found to be the lowest for all harvesting methods. Conductivity values increased day by day. Lower values were generally found for oil samples that were obtained after harvesting by hand, while bigger values were determined for samples that were obtained from spontaneously dropped olives. These values for olives that were harvested by a beating pole were also found to be generally higher.

Table 2 Results for the thermal conductivity of olive oil samples as a function of the harvesting method and waiting period

Harvesting Methods		Consecutive days during which olive oil was obtained after harvesting							
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
Beating pole (1)	to ground (1G)	0.152	0.156	0.156	0.158	0.161	0.161	0.163	0.165
	to platform (1P)	0.153	0.156	0.157	0.158	0.158	0.159	0.164	0.165
Machine (2)	to ground (2G)	0.153	0.155	0.155	0.158	0.160	0.161	0.163	0.164
	to platform (2P)	0.150	0.155	0.156	0.158	0.160	0.160	0.161	0.164
By hand (3)	----------	0.149	0.154	0.156	0.156	0.158	0.159	0.161	0.162
Spontaneously dropped olive	----------	0.154	0.155	0.155	0.156	0.156	0.160	0.161	0.164

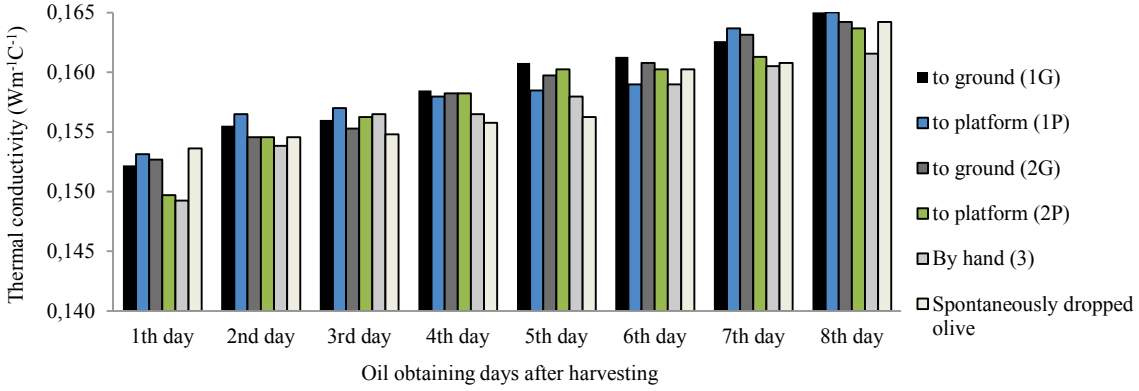

Figure 4 Changing of the thermal conductivity values related to the harvesting method and the oil obtaining time after harvesting

Table 3 Results for the thermal resistivity of olive oil samples as a function of the harvesting method and waiting period

Harvesting Methods		Consecutive days during which olive oil was obtained after harvesting							
		1st day	2nd day	3rd day	4th day	5th day	6th day	7th day	8th day
Beating pole (1)	to ground (1G)	6.57	6.43	6.41	6.31	6.22	6.2	6.15	6.05
	to platform (1P)	6.53	6.39	6.37	6.33	6.31	6.29	6.11	6.06
Machine (2)	to ground (2G)	6.55	6.47	6.44	6.32	6.26	6.22	6.13	6.09
	to platform (2P)	6.68	6.47	6.4	6.32	6.24	6.24	6.2	6.11
By hand (3)	----------	6.7	6.5	6.39	6.39	6.33	6.29	6.23	6.19
Spontaneously dropped olive	----------	6.51	6.47	6.46	6.42	6.4	6.24	6.22	6.09

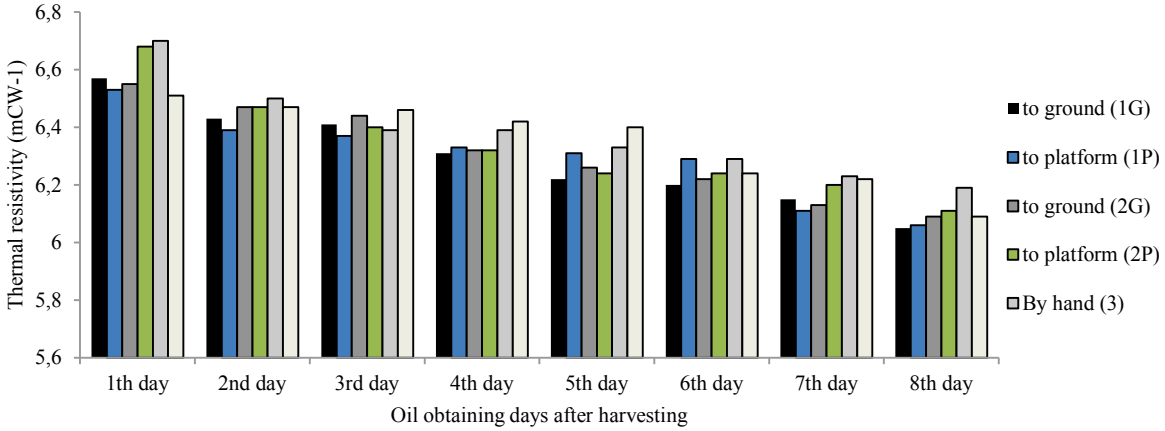

Figure 5 Changing of the thermal resistivity values related to the harvesting method and the oil obtaining time after harvesting

As seen in Tab. 3 and Fig. 5, the thermal resistivity values of oil samples that were obtained just after harvesting were found to be the highest for all harvesting methods. The resistivity values decreased day by day. Higher values were generally found for oil samples that were obtained after harvesting by hand, while lower values were determined for samples that were obtained from spontaneously dropped olives.

These values for olives that were harvested by a beating pole and a machine (to ground) were also found to be generally lower compared to oil samples that were produced by olives that were harvested by hand and harvested by a machine to the platform.

4 CONCLUSIONS

As a result, viscosity, thermal conductivity and thermal resistivity values changed related to the harvesting method and the waiting period after harvesting to obtain olive oil. While viscosity (dynamic) and thermal conductivity values increased with the increase of the waiting time, thermal resistivity values decreased. The lowest viscosity and thermal conductivity values and the highest resistivity values were found for oils that were obtained from olives harvested by hand. The reason behind this situation can be explained in the sense that the percentage of fatty acids in oil samples increased with the increase of the waiting period for olives after harvesting as a result of oxidation due to the exposure of olives to air for a longer time. It can also be said that less bruising occurs on olives that were harvested by hand and a machine (especially the use of a platform to drop olives on it decreased the bruising and tearing of skin).

This situation ensures the prevention of more oxidation of olive trees, which is the oxidative deterioration of these tears on the fruits.

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Professional paper

BUSINESS PROCESSES AS BUSINESS SYSTEMS

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Abstract: Business process is the foundation of the work organization of every business. It is a set of different activities or tasks that are carried out in a certain order and use certain resources of an organization with the aim of fulfilling the mission or the purpose of its existence. As each business process is defined by parameters such as output quality, speed, cost, added value and the like, it is logical that they are the cornerstone of achieving competitive advantage. It is therefore important to monitor and analyze them in order to remove any drawbacks in their performance before endangering the survival of a company. Business process is a structured, analytical, inter-functional set of activities that require continuous improvement. It represents a repetitive flow of activities with a clearly defined beginning and end, and in more or less constant intervals, creates value for the buyers.

Keywords: business process, process orientation, company as a system, knowledge management

1 INTRODUCTION

Business process is a set of business activities put together with a goal of creating added value for a specific customer or market. It can be also defined as:

- a closed set of activities taken as a response to a certain event, with the purpose of generating an output;
- everything that is required to ensure that the person interested in a business process gets an expected outcome;
- interaction between people, equipment, methods and regulation with the goal of achieving a certain business objective.

Basic elements of a business process are the following: the goal, available resources, activities, indicators, focus on the buyer, and the process holders.

Managing business processes is carried out by means of the following activities: formation of business processes, their execution, and measuring their success.

The goal of managing business processes is the continuous improvement of business processes based on measuring the results of performance of the existing business processes.

Well-defined business processes accelerate work, increase inner order, decrease expenditures, support the increase of the products/services quality as well as the general organizational activities and skills.

2 HISTORICAL DEVELOPMENT AND THE ORIGINATORS OF BUSINESS PROCESS INITIATIVE

Business processes have not only existed since the times when work started being performed in an organized manner; their existence and importance were recognized at the transition of the 19th and the 20th century, if not earlier.

The concept of business processes appeared for the first time and was studied into more detail at the beginning of the 1920s, related to the methods and analysis of the procedures.

At the end of the 18th century, with the rise of the industrial revolution, a more significant emphasis was given to the organization of business processes.

Through history, entrepreneurs continually changed their production processes and in that way contributed to, first of all, progress of their manufacture or craft workshops, industry itself, and in the end, the civilization at large. [1]

As far as production is concerned, it can be said that with the appearance of scientific management, production processes came to be investigated and improved.

At that time, processes were implicit and they were not automated.

Quality control approach, which started with W.A. Shewart and W. E. Deming who conducted strict analysis and control of production processes, is what significantly contributed to development of the process initiative.

Although they, just like their predecessors, place emphasis only on production processes but not the cross-functional processes, it was possible to observe production activities from the very beginning to the completion.

In the course of the 1960ies and the 1970ies, through the quality movement, Japanese companies gave a significant contribution. They developed quick and efficient processes in numerous industries: new product development, logistics, production and marketing. [1]

Value chain model was developed by M. E. Porter who looked at a business company as a comprehensive set of all activities carried out to design, produce, promote, deliver and support the production line.

Value chain model represents the highest level of observation of a business activity within a certain organization, i.e. among organizations.

As opposed to this model, the process model was, above all, directed at the optimization of activities within an organization.

Besides the value chain model, significant contribution was also made by the Total Quality Management (TQM) concept.

This concept was a product of Japanese companies that wished to improve the quality of their products so they could be competitive to American producers. It represents further development and continuation of the quality control concept.

Total Quality Management concept can be defined as an approach to improvement of efficacy and flexibility of a company as a whole.

It entails numerous methodologies like quality function development, reduction of variability, self-evaluation and application of ISO standards, lean manufacturing, statistic processes control etc.

The key feature and value of the total quality management approach is focus on customers and business processes. Besides, its important characteristics are the practice of benchmarking, i.e. the employees' involvement. [1]

Paying attention to business processes reached its peak at the beginning of the 1990s with the appearance of business processes reengineering. This refers to a managerial philosophy which is based on thorough consideration and radical redesigning of business processes to achieve dramatic improvements in critical contemporary measurements of success, such as expenditure, quality, service and speed.

Reengineering of business processes can be defined as the formation of brand new and efficient business processes, independent of former practice. Philosophy of reengineering of business processes is characterized by four fundamental words: thorough, radical, dramatic and processes. Their goal was radical improvement of productivity between 70% and even up to 95%. Additionally, this philosophy implied questioning of the logic of existing business processes and often demanded start with a clean slate and in many ways also an empty and clear mind, capable of thinking outside the restrictions of the existing systems and assumptions as well as questioning them. Reengineering was most often conducted top-down and was focused on the cross-function processes. It was based on the application of information technology, which significantly differentiated it from the former development approaches. Due to its particularity and potentially big benefits, it attracted a lot of attention in the business world, so in 1993 up to 66% of American companies applied one of the forms of business processes reengineering, while in 1995 its application reached peak and was implemented in even 78% of the researched companies.

Although reengineering became extremely popular in a very short time span, it soon became clear it was just another managerial delusion. Namely, more than 50% of business process reengineering projects in the USA and approximately 70% of the same projects in Europe ended in failure. [1]

2.1 Process Orientation Concept

Each organization consists of business processes. These processes are of implicit nature or are simply inherent to the organization from its very start. Each business activity can be considered a part of a certain process which determines sequencing of its performance, i.e. positioning within a wider organizational system. While within an organization numerous activities are held in different areas and on various hierarchical levels, it is possible to identify the existence of several business processes which, in a certain way, determine the very organization itself.

The business process orientation represents a new business philosophy which facilitates not only the vertical but also the horizontal flow of information and resources needed for the accomplishment of organizational objectives. It observes organization from the customer's point of view. It is focused on the activities within or among organizations that create added value, i.e. it is focused on the activities contained within business processes. Process orientation is characterized by the greater connection and coordination of different departments within an organization into an interrelated unit. By doing that, roles of each individual activity and its impact on the organization as a whole are taken into account.

Process orientation offers a horizontal perspective of business activities and facilitates coordination of organizational systems with business processes. It tends to make the processes themselves transparent and in that way advance the organization. One can say this is not only about the new approach to business, but an entirely new way of thinking about organizations and how business is performed within them. [1]

3 PINCIPLES OF BUSINESS PROCESSES CONSTRUCTION

A process can be defined as "a course, a route and a way in which something becomes or is, a development, an approach". The latest ISO 9001:2008 standard came into power at the end of 2008, more precisely on November 15 2008. It is a more refined version of ISO 9001:2000, which in addition to the supplemental interpretations of already existing requirements does not offer any major alterations. To be more precise, the process approach and basic requirements stay unaltered, but there is an array of improvements.

Some improvements refer to defining 'outsourcing', taking measurements wherever applicable, the greater role of the environmental impact, taking bigger responsibility of a product up to the point of its recycling, giving more significance to the member of the board in charge of monitoring the quality management system, enhancing the compatibility with the existing ISO 14001:2004 standard and the facilitation of its conduct.

In addition to the requirements stated in standard ISO 9001, standard ISO 9004:2009 gives instructions on considering the effectiveness and performance of the quality management systems and consequently the potential of efficiency improvement.

In comparison to ISO 9001, the goals of the customers' satisfaction and quality of a product are extended to satisfaction of the interested parties and the ability of organization.

It can be applied to all the processes in an organization. The goal of this international standard is achieving a lasting improvement, measured in terms of satisfaction of customers and other interested parties. [4]

3.1 The Competency Model

In the course of business process building within an organization, a number of problems will arise. They can be divided into a few groups regarding their causes: 1. Lack of the critical mass of know-how; 2. Opportunism; 3. Insufficient willingness to change; 4. Deficient motivation. To overcome these problems up to an adequate extent, and remove their causes, it is necessary to adhere to the competency model which is obvious in at least two cases: 1) in case of finding and choosing methodology for building business processes, and 2) in case of team-work at building business processes.

The choice between the already existing or the construction of one's own methodology for building business processes is not an easy task at all – the authors are not willing to present or publish their solutions so in the course of building one's own methodology, the problem of verification of one's own solutions' validity will arise.

Considering the effectiveness, we distinguish at least three groups of teams:

1) **Unsuccessful teams** are those whose work achievements are worse than the sum of the proficiency, abilities and competences of each individual member. Associates within such a team give inferior results when working as a group than individually.
2) **Average teams** are those whose results correspond to the exact sum of the proficiency, abilities and competences of each individual member. Such teams are not profitable, they are too expensive and of no value to an organization.
3) **Successful** teams are those whose results surpass the sum of the proficiency, abilities and competences of each individual member.

When choosing a team leader, it is important to take into account their leadership competence. On the other hand, when choosing team members, the most important thing is detailed knowledge of the technology of the course of the process or the part of the process, as well as having the ability of comparative analysis and resolving the conflict between what is important and what is not. [2]

3.2 Principle of Consistency

Regardless of whether we have accepted an already existing one or built our own methodology of business processes building, we need to master the methodology entirely.

The methodology of our choice needs to be applied to all the processes the building of which we have opted for in compliance with the chosen methodology. The processes differ, above all, in their nature and the level of complexity. They have a certain structure. Their simpler elements or components, on the lower level, are sub-processes, i.e. process steps.

Besides having to build the processes by implementing the methodology we have opted for, it is equally necessary to consistently apply them in processing all the elements of a certain process. That is because it often happens that the exit from one of the processes simultaneously represents the entry into another process. It regularly happens that the exit from one process step simultaneously makes the entrance into the next process step of the same process. Thereby we assure recognizability, simple perception of correlations between many business processes of a single business system.

It is exactly those reciprocal correlations among various business processes, that synergy that we recognize as a process approach.

3.3 Principle of Originality

The international standard ISO 9001:2000 does not suggest any methodology for building business processes. Related literature mainly does not offer a comprehensive methodology for the following reason: the authors who have built their own methodology are not keen on publishing the solutions they came to through research. Thus, quality managers and teams that have the role to build the business processes often resort to the partial or complete implementation of the other people's readily available solutions when building business processes. However, readily available, universal solutions do not exist.

Copying other people's solutions or making smaller adjustments and their adoption as one's own optimal solutions are a deceit and in practice they will cause the entropy of the process structure and consequently the business system itself. [2]

3.4 The Principle of Systematization

The process in itself is a system, a specific logical structure. It is composed of its elements, sub-processes, process steps, and activities arranged in the logical sequence of progression.

The building of the business processes indirectly represents the building of entire business systems that consist of the sequences of subsystems such as:

- subsystem of organizational structure,
- documentation subsystem,
- information subsystem,
- communication subsystem,
- administration subsystem,
- process substructure and alike.

It is necessary to build and arrange all the above mentioned subsystems of a business system. To administer the processes, it is needed to:

- implement them into a functional organizational scheme,
- have a clearly defined system of informing within the process structure frame,
- document all the processes by the principle of sequence,
- have an efficient communication system. [2]

3.5 Principle of Rationality

One of the most important features of every process is its reliability. Reliability is defined as a probability of a process functioning correctly at a certain time. To ensure the conditions for reliable functioning of a built business process in time dynamics is a complex task because processes are subject to the influences of various variables. The workforce (i.e. staff conducting the process) want an efficient way of uninterrupted process regulation so as to reduce deviations from a goal. To ensure the efficient mechanisms of regulation, the following will help:

- each result of a product's characteristic needs to be associated to one or a few process variables,
- the means of adequate adjustment of the process variables need to be provided, and
- there needs to be a predictable, clear relation between the extent of the modification in setting the process variable and the resulting extent of the outcome on the product's characteristic [2].

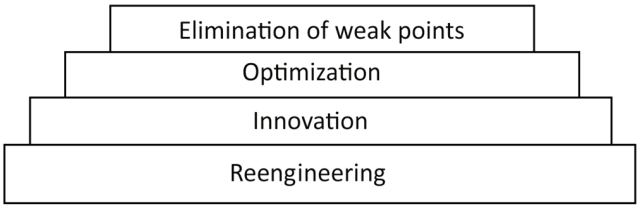

Figure 1 Mechanisms of achieving the rationality process considering the extent of intervention, duration and the risk [7]

4 MANAGING THE BUSINESS PROCESSES

Business process is a sequence of logically connected activities that utilize the company's resources. Its ultimate goal is to satisfy the customers' need for products and services of an adequate quality and price, in an adequate time frame, while simultaneously achieving a certain value.

The international organization for standardization (ISO), by the principles of quality control that the ISO 9001 standard is based on, also encourages the acceptance of the process approach for the management of an organization. Moreover, it makes a regulation which states that the company wanting to operate efficiently has to identify all its activities and resources that participate in them, link them. and manage them accordingly.

The major features of business processes are the following:

- each process has an end goal,
- each process has its owner,
- each process has a beginning and an end,
- inputs go into the process and outputs come out of it,
- it is composed of the activities that can be performed sequentially,
- success of the process can be easily determined based on the input and output,
- for the process to survive it needs to have known inner and outer suppliers and consumers, and
- process improvement is inevitable. [5]

4.1 Components of a Business Process

We can differentiate three logical components of a business process:

- managerial informational process,
- operational process,
- managerial process.

The managerial informational process refers to the component of the entire managerial system which relates to a specific business process.

The operational system is created by humans and it consists of people, equipment, organization, politics and procedures, everything that is aimed at ensuring efficient work of an organization.

The managerial process is also created by humans, and it consists of staff, authorities, an organization, politics and procedures with a goal of planning and controlling activities taking places within an organization. [5]

5 BUSINESS PROCESSES MANAGEMENT CONCEPT

Conducting business brings a lot of pressure all over the world due to big competition, business environment changing fast and ever more demanding customers. There are three trends that contribute to this pressure and they are as follows:

1) Globalization
2) Technological, legislative and regulatory modifications
3) Organizations getting more agile and flexible.

Management of business processes combines the managerial approach with adequate technology with the goal of improving the company's performance. Business Process Management (BPM) is a methodical approach to business improvement based on modeling, metrics, analysis, improvement and process management.

Managing business processes relies on the business approach of managing modifications for improving business processes with the ultimate goal of achieving business objectives in the course of which the modifications entail the entire life cycle of a process: from designing and modeling to execution, analysis and optimization of the process.

By managing business processes one accomplishes:

- improved quality,
- shorter time span,
- lower costs,
- improvement,
- lower risk of conducting business. [6]

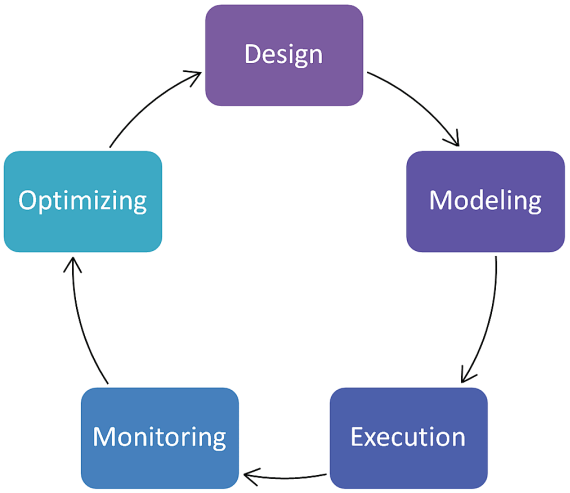

Figure 2 Life cycle of business process management [7]

6 MODELING AND MONITORING BUSINESS PROCESSES

Modeling and monitoring business processes is of vital importance for the success of the initiatives related to managing business processes. Activities within the phases of a business process management life-cycle develop a clear definition and understanding of business processes that lead to their improvement and optimization. [3]

6.1 Business Processes Modeling

There are two approaches to business processes modeling:

1) Graphic methods (static modeling)
2) Simulation modeling (dynamic modeling).

Graphic modeling of business processes implies formation of diagrams that show the activities of a business conduct and the sequence in which they take place. When creating a business process model, standardized graphic elements are used. This facilitates the communication between the participants at the monitoring phase.

Business process modeling also enables the following:

- defining key business processes,
- modeling all the processes or specific ones into detail,
- identification of the processes that need some improvement, and
- modeling new processes before they are implemented.

Simulation modeling of business processes: simulation is a useful tool for modeling and altering business processes. Simulation enables the inclusion of accidental variables into the model of a process, experimenting with the model, and the anticipation of the impact of modifications on the model's performances that are characteristic of simulation modeling.

Besides the obvious advantages that could arise from the implementation of a discrete simulation in making the proposal for the improvement of the existing processes, it also has certain disadvantages:

- long and expensive development of a model,
- complex evaluation of the model and its testing,
- necessary knowledge of a big number of methods and tools,
- the result of simulation experiment is not the optimal solution, and the choice of the best solution depends on the evaluation and decision of the members of a project team. [3]

6.2 Business Processes Analysis

Analysis of business processes enables their better understanding and its logical consequence is more efficient setting, connecting and execution of the activities that make that specific business process.

By analyzing business processes one finds activities that do not add value, redundant activities, inadequate use of technology, inappropriate rules and procedures, ways of giving feedback, and connections between the missing processes.

Steps necessary during the process analysis are as follows:

- defining the goal of activities and analyzing the steps that constitute the activities,
- detecting whether the activity adds value or not,
- defining measurement criteria for the results of the activities,
- determining the knowledge needed to perform the activity,
- defining who the activity is performed by,
- defining the costs, resources, time span of the activity, and
- process simulation. [3]

7 MANAGING KNOWLEDGE

The key to the successful accomplishment of any activity lies in the human factor quality. It comes out of the quality of the staff's education and the foundation of their education manifests in people's readiness to put their knowledge into the function of a change.

That is the reason why knowledge and science are not only the main developmental resources of the 21st century but also why the 21st century has been declared the century of knowledge.

Knowledge represents a complex concept that has been discussed by academics, managers, analysts and philosophers for many decades now.

Explicit knowledge represents everything that is coded and documented and can be relatively easily transferred to others. It is processes, procedures, drawings, graphs or all that has been written in a comprehensible way and is easy to transfer. People continually externalize such knowledge and make it accessible to other people. It is also called formalized knowledge.

Tacit or implicit knowledge represents what people have in their head and it is not easy to define. [5]

7.1 Importance of Knowledge Management

Nowadays, in order to become and stay competitive, organizations have to efficiently and effectively create, secure and distribute organizational knowledge. According to estimates, the biggest portion of knowledge, 50-95%, both explicit and experiential, is transferred through verbal, direct communication. At the same time, a big portion of knowledge is being lost so companies mainly use approximately 20% of their organizational knowledge.

Organizations have to manage knowledge for the following reasons:

- science and new technologies continually bring changes,
- knowledge grows rapidly and consequently more and more complex business and managing problems arise,
- values of an organization depend on knowledge management,
- a company creates competitive advantage. [5]

7.2 Goals of Knowledge Management

The purpose of knowledge management is to maximize effectiveness of organizational activities related to knowledge. It has to follow, encourage and facilitate all the activities related to knowledge, it has to enable and continually improve the knowledge infrastructure, create, renew, build and organize the knowledge, as well as efficiently distribute and implement the company's knowledge.

Goals:

- improvement of the process of knowledge documentation, keeping it within an organization, securing the access to the existing knowledge and supporting the process of the exterior knowledge assembling;
- modifications of the organizational culture, improvement of communication and cooperation, improvement of education, training and introduction of new employees, personal development improvement;
- transforming tacit knowledge into explicit, improvement of the knowledge exchange, improving the innovations management, acceleration of the innovations' creation process;
- decrease of prices and expenditures, increase of productivity;
- selling knowledge, increase of the organization's growth;
- development of new business areas, decrease of business risks;
- boosting the employee satisfaction and motivation, improvement of product quality, boosting the customers' satisfaction and/or quality of service;
- better planning, product/service delivery within a deadline. [5]

8 COMPANY AS A SYSTEM

Systems theory is a science that studies systems and laws that govern them. It was born out of the need for finding scientific and practical methods that could help scientifically analyze and solve problems that cannot be solved by traditional and common methods developed in other scientific areas, as they do not give satisfactory results.

Organization as an idea refers to a system in which people participate in an organized manner in order to achieve the system's goal.

There are various theories of organization:

- classical theory of organization,
- neoclassical theory of organization,
- modern theory of organization,
- early system approach, and
- modern system approach.

8.1 Cybernetic Model of a Company

Analysis of cybernetic model of a company says there are two important subsystems. The first one refers to the transformational part, and the other one to managerial mechanism.

8.2 Company and General System Theory

Organization or a company as a complex system can be divided into the following subsystems:

- subsystem of goals and values,
- managerial subsystem,
- technical subsystem,
- psychological subsystem and
- structural subsystem. [4]

9 CURRENT STATE AND TRENDS IN BUSINESS PROCESSES MANAGEMENT

Managing business processes is constantly changing and developing. At the Garter's congress in 2008, results of the current situation in the business processes' management were presented.

The results show five current trends in business process management:

1) Managing business processes together with service oriented architecture,
2) Managing business processes becomes directed by events in order to support the nature of business activities administered by events,
3) Increase of focus on processes based on knowledge,
4) Enabling social computing,
5) Moving towards dynamic business applications.

The trend most discussed about is the first one mentioned above. Global market is not static and current business environment demands continuous evolution of businesses processes management.

Business conducting trends set in front of the company process the goal of shifting from the traditional, static automation to the flexible automation in which the adjustments of the business processes in real time make part of the expected daily operations [4].

9 CONCLUSION

The most successful global companies can thank their success mostly to the practice of managing business processes and knowledge management. By applying both IT and the knowledge of staff, it is possible to accomplish a system for managing knowledge. That system deeply changes the way employees work. Accordingly, each employee becomes the instrument of knowledge that participates in creating, distributing, applying and evaluating knowledge. Besides creating more motivated employees, managing knowledge within organizations leads to higher accessibility of expert knowledge as well as faster and higher quality solutions of customers' demands. Long term success of companies also largely depends on the quality of managing business processes. Managing business processes improves competitiveness and the level of a company's innovativeness and therefore leads to faster and more flexible reactions of a company in volatile market conditions.

What is important for creating the process orientation is the implementation of adequate IT applications; therefore, the real value of IT depends on the way it supports business processes of a company. Consequently, knowledge management and business processes management lead to significant organizational benefits.

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ARTICLE TITLE ONLY IN ENGLISH (Style: Arial Narrow, Bold, 14pt)

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Ivan HORVAT, Thomas JOHNSON (Style: Arial Narrow, Bold, 11pt)

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Keywords: keywords in alphabetical order (5-6 key words). Keywords are generally taken from the article title and/or from the abstract. (Style: Arial Narraw, 8pt)

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1 ARTICLE DESIGN (Style: Arial Narrow, Bold, 10pt)

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(Tab 6 mm) The article is written in Latin script and Greek symbols can be used for labelling. The length of the article is limited to eight pages of international paper size of Letter (in accordance with the template with all the tables and figures included). When formatting the text the syllabification option is not to be used.

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1.1 General guidelines (Style: Arial Narrow, 10pt, Bold, Align Left)

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The document format is Letter with margins in accordance with the template. A two column layout is used with the column spacing of 10 mm. The running text is written in Times New Roman with single line spacing, font size 10 pt, alignment justified.

Article title must clearly reflect the issues covered by the article (it should not contain more than 15 words).

Body of the text is divided into chapters and the chapters are divided into subchapters, if needed. Chapters are numbered with Arabic numerals (followed by a period). Subchapters, as a part of a chapter, are marked with two Arabic numerals i.e. 1.1, 1.2, 1.3, etc. Subchapters can be divided into even smaller units that are marked with three Arabic numerals i.e. 1.1.1, 1.1.2, etc. Further divisions are not to be made.

Titles of chapters are written in capital letters (uppercase) and are aligned in the centre. The titles of subchapters (and smaller units) are written in small letters (lowercase) and are aligned left. If the text in the title of the subchapter is longer than one line, no hanging indents.

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Typographical symbols (bullets), which are being used for marking an item in a list or for enumeration, are placed at a beginning of a line. There is a spacing of 10pt following the last item:

- Item 1
- Item 2
- Item 3

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The same rule is valid when items are numbered in a list:

1. Item 1
2. Item 2
3. Item 3

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1.2 Formatting of pictures, tables and equations (Style: Arial Narrow, 10pt, Bold, Align Left)

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Figures (drawings, diagrams, photographs) that are part of the content are embedded into the article and aligned in the centre. In order for the figure to always be in the same position in relation to the text, the following settings should be defined when importing it: text wrapping / in line with text.

Pictures must be formatted for graphic reproduction with minimal resolution of 300 dpi. Pictures downloaded from the internet in ratio 1:1 are not suitable for print reproduction because of unsatisfying quality.

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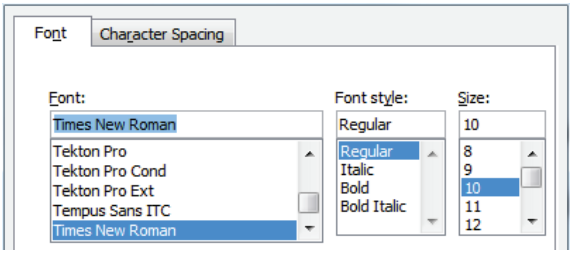

Figure 1 Text under the figure [1]
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The journal is printed in black ink and the figures have to be prepared accordingly so that bright tones are printed in a satisfactory manner and are readable. Figures are to be in colour for the purpose of digital format publishing. Figures in the article are numbered with Arabic numerals (followed by a period).

Text and other data in tables are formatted - Times New Roman, 8pt, Normal, Align Center.

When describing figures and tables, physical units and their factors are written in italics with Latin or Greek letters,

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Table 1 Table title aligned centre
(Style: Arial Narraw, 8pt, Align Centre)

	1	2	3	4	5	6
ABC	ab	ab	ab	ab	ab	ab
DEF	cd	cd	cd	cd	cd	cd
GHI	ef	ef	ef	ef	ef	ef

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Equations in the text are numbered with Arabic numerals inside the round brackets on the right side of the text. Inside the text they are referred to with equation number inside the round brackets i.e. ".... from Eq. (5) follows ...." (Create equations with MathType Equation Editor - some examples are given below).

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$$F_{\text{avg}}(t,t_0)=\frac{1}{t}\int_{t_0}^{t_0+t}F\big(q(\tau),p(\tau)\big)\,\mathrm{d}\tau, \tag{1}$$

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$$\cos\alpha+\cos\beta=2\cos\frac{\alpha+\beta}{2}\cdot\cos\frac{\alpha-\beta}{2}. \tag{2}$$

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Variables that are used in equations and also in the text or tables of the article are formatted as *italics* in the same font size as the text.

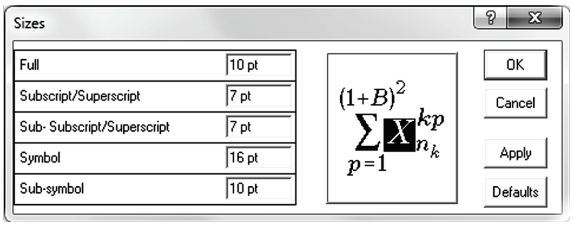

Figure 2 The texts under figures
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Figures and tables that are a part of the article have to be mentioned inside the text and thus connected to the content i.e. „ … as shown in Fig. 1…" or „data from Tab. 1…" and similar.

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Article that is offered for publication cannot be published beforehand, be it in the same or similar form, and it cannot be offered at the same time to a different journal. Author or authors are solely responsible for the content of the article and the authenticity of information and statements written in the article.

Articles that are accepted for publishing are classified into four categories: original scientific papers, preliminary communications, subject reviews and professional papers.

Original scientific papers are articles that according to the reviewer and the editorial board contain original theoretical or practical results of research. These articles need to be written in such a way that based on the information given, the experiment can be repeated and the results described can be achieved together with the author's observations, theoretical statements or measurements.

Preliminary communication contains one or more pieces of new scientific information, but without details that allow recollection as in original scientific papers. Preliminary communication can give results of an experimental research, results of a shorter research or research in progress that is deemed useful for publishing.

Subject review contains a complete depiction of conditions and tendencies of a specific domain of theory, technology or application. Articles in this category have an overview character with a critical review and evaluation. Cited literature must be complete enough to allow a good insight and comprehension of the depicted domain.

Professional paper can contain a description of an original solution to a device, assembly or instrument, depiction of important practical solutions, and similar. The article need not be related to the original research, but it should contains a contribution to an application of known scientific results and their adaptation to practical needs, so it presents a contribution to spreading knowledge, etc.

Outside the mentioned categorization, the Editorial board of the journal will publish articles of interesting content in a special column. These articles provide descriptions of practical implementation and solutions from the area of production, experiences from device application, and similar.

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Article is written in the English language and the terminology and the measurement system should be adjusted to legal regulations, standards (ISO 80 000 series) and the SI international system of units. The article should be written in third person.

Introduction contains the depiction of the problem and an account of important results that come from the articles that are listed in the cited literature.

Main section of the article can be divided into several parts or chapters. Mathematical statements that obstruct the reading of the article should be avoided. Mathematical statements that cannot be avoided can be written as one or more addendums, when needed. It is recommended to use an example when an experiment procedure, the use of the work in a concrete situation or an algorithm of the suggested method must be illustrated. In general, an analysis should be experimentally confirmed.

Conclusion is a part of the article where the results are being given and efficiency of the procedure used is emphasized. Possible procedure and domain constraints where the obtained results can be applied should be emphasized.

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The literature is cited in the order it is used in the article. Individual references from the listed literature inside the text are addressed with the corresponding number inside square brackets i.e. "… in [7] is shown …". If the literature references are web links, the hyperlink is to be removed as shown with the reference number 8. Also, the hyperlinks from the e-mail addresses of the authors are to be removed. In the literature list, each unit is marked with a number and listed according to the following examples (omit the subtitles over the references – they are here only to show possible types of references):

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