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ERGONOMIC APPROACH TO TEACHING ONLINE ACTIVITY USING PRINCIPLES OF AXIOMATIC DESIGN

Laurențiu SLĂTINEANU, Margareta COTEAȚĂ, Oana DODUN, Florentin CIOATĂ, Adriana MUNTEANU, Adelina HRIȚUC, Gheorghe NAGÎȚ, Andrei MIHALACHE

Abstract: *The need to carry out online teaching activities in universities has required the use of solutions that maximize the efficiency of such activities but with the maximum fulfillment of the ergonomic requirements as far as possible. In the last two years, additional demand for the development of online teaching activities has been generated by the pandemic caused by the covid virus 19. Axiomatic design principles were used to identify an equipment solution used in online teaching. In this way, it was outlined a version of the equipment that would allow the teacher to use a way to write texts and make drawings to be transmitted online, in conditions as close as possible to those of onsite teaching activity. In the future, it is intended to take steps to optimize the constructive solution of online teaching equipment.*
Keywords: *teaching online; axiomatic design; functional requirements; design parameters; workplace for teaching online.*

1. INTRODUCTION

One of the components of the teaching activities carried out with the pupils or students is teaching. In its most common form, teaching involves the face-to-face presence of the teacher and students.

Through didactic teaching, the teacher transmits to the participants a systematic set of information corresponding to a certain discipline and appreciated as useful for the respective category of participants.

However, there are situations when teaching can no longer be done through the physical presence, in the same space, of teachers and students or pupils, respectively.

Such a situation corresponded, for example, to the pandemic period caused by the aggressive presence of the covid 19 virus, when in many states, it was necessary to use online teaching activities.

Both advantages and less convenient aspects of online teaching have been noted from the beginning of its use. Note, however, that the online teaching format was also used before the pandemic period, for example, for participants who were relatively far away from teachers and who, for various reasons, could not be present at teaching activities in a classroom. There are many discussions and controversies in the literature on such issues.

Restricting the scope of observations to the situation when the online teaching activity became mandatory, we will find the requirement that this activity ensures conditions as close as possible to those of the onsite teaching activity and to allow efficient transmission of information specific to a certain matter.

Within the university teaching activities, it was necessary to carry out online the teaching activities, the seminar and project activities, and, to a relatively limited extent, specific laboratory activities. Suppose for teaching, seminar, and project activities, it is considered that acceptable conditions for online conduct could be identified. In that case, this finding is less valid in the case of laboratory activities, when it is considered more effective the participation and involvement of students themselves in handling activities of industrial equipment.

In the case of pupils, it is possible to use various other online activities, such as quizzes, various projects, and educational games. To a lesser extent, some such activities are directly usable in the case of online university teaching activities.

Sadiku appreciated that *online education* (for which the names of *distance education* or *web-based education* are still used) is considered to be the most commonly used form of distance education [1]. On the other hand, many universities' training programs have adopted online teaching and learning.

The first information about distance education seems to be about the development correspondence education programs promoted by the professors and students of the University of Chicago in the 1800s [2]. These programs aimed to increase the efficiency of teaching activities, including for students at different locations who did not have access to university buildings.

Improving the quality of online teaching has been addressed by Kearsley [3]. The analysis he developed led to the revelation of the need to consider four categories of problems that define the interaction between teacher and student.

Simon pointed out that two categories of teachers carry out online teaching activities [4]. Thus, some teachers use online and face-to-face activities but prefer the first category of activities.

The second group of teachers appreciated online teaching more. Simon's research has led to suggestions for solving the problems raised by online teaching.

A systematization of effective online teaching principles is presented in [5].

The study's authors outlined ten principles of online teaching that can help the teacher involved in educational activities achieve better results.

Some aspects of the importance of technology in online teaching activities have been researched by Mafruudloh et al. [6].

They used questionnaires and interviews to observe how teachers appreciate that they can intervene to conduct effective online teaching activities.

Bates found that online learning has become a standard form of distance education [7]. He developed an analysis of the extension of online learning and why some institutions have adopted such a way of teaching.

The emergence and spread of the Covid-19 pandemic have frequently led to the mandatory conduct of online teaching activities, and this issue has been investigated in many ways [8, 9]. On the other hand, there was a need to ensure ergonomic requirements for workplaces used in online teaching activities [10 - 12].

Sodhar et al. investigated the conditions under which, through appropriate information technology tools, solutions were identified for the proper conduct of online teaching activities during lock-down [13]. They found several applications designed to allow the efficient conduct of online teaching and learning activities.

Coman et al. researched how some universities in Romania have adapted to the requirements of pandemic coronavirus [14]. As difficulties, the technical problems, the lack of technical skills of the teachers, and the less adequacy of the teaching methods to the specific requirements of online education were highlighted.

It was also appreciated that the decreased level of interaction between teachers and students and the reduced communication between them are problems for which no adequate solutions have been identified.

The last decades have seen an expansion of so-called *axiomatic design* to solve many problems. In principle, axiomatic design starts from accepting the existence of two axioms, namely the axiom of the independence of functional requirements and the axiom of selecting, among the alternatives to solve a problem, that alternative characterized by a minimum volume of information.

In such circumstances, a proposal has been made to evaluate or develop online teaching activities using axiomatic design principles.

We will find that the approach of different teaching activities starting from the principles of axiomatic design or even increasing the efficiency of teaching processes by using axiomatic design principles have been topics that have focused the attention of researchers in various fields [15, 16].

Researchers have also made significant efforts to involve information technology in distinct activities, including teaching. Thus, e-learning platforms [16] were designed and materialized to increase the efficiency of teaching and assessment processes with the help of computer tools.

This article has been considered to identify solutions for developing online teaching activities using some principles from axiomatic design. It also started from the premise that some components of the online teaching equipment could present elements of originality that would allow the elaboration of the documentation specific to a patent application. It was appreciated that an approach to online teaching would allow a better systematization and clarification of the requirements that this way of teaching must meet and, at the same time, identify appropriate solutions for each of the identified functional requirements.

2. METOD USED AND RESEARCH STAGES

The use of axiomatic design principles for the design of manufacturing processes was proposed by the American professor of South Korean origin Nam Pyo Suh, while working at the Massachusetts Institute of Technology [17-19]. The professor then aimed at a more systematic approach to the design of manufacturing technologies and defined the two axioms that characterize the axiomatic design.

Subsequently, it was found that axiomatic design principles can be applied efficiently to solve a wide range of problems, some of which have no connection with the design of manufacturing technologies.

It was thus normal for axiomatic design to find use primarily in mechanical parts and equipment design.

However, some axiomatic design principles were found to help optimize road traffic, plan surgical operations, analyze sports or leisure activities, etc.

According to the first axiom of axiomatic design, the functional requirements that the components of a problem to be solved are independent.

As each functional requirement must be met by a specific component of the final solution, these components must also be expected to be distinct.

In such conditions, it is considered that an optimal design of the problem's solution to be solved is ensured.

As mentioned, the second axiom involves the selection of that problem-solving alternative that involves the existence of a minimum amount of information capable of ensuring the highest probability of success in applying that alternative.

When using the information axiom, it is necessary to analyze the probability of success for each of the possible alternatives, and the alternative for which there is the highest probability of successful application will be applied.

The main steps that could be considered when using the axiomatic design method could be the following:

a) Clarifying the client's needs;

b) Formulation of *zero-order functional requirements* and, frequently, *higher-order functional requirements* by taking into account increasingly detailed components;

c) Identification of *design parameters*, this involving the selection of alternatives to respond to each functional requirement adequately;

d) Defining *the process variables*, so establishing the values of some quantities that define the operation of each design parameter.

Going through the last three steps could involve successive returns and additions or corrections of alternative functional requirements, design parameters, and process variables used to characterize this situation (*zigzagging*). At the same time, *decomposition* has become commonplace for identifying lower-order requirements than the zero-order requirement.

It is considered that the client's needs (*CNi*) define the client's domain. Distinct domain names are still used – client, functional and physical domains - to define the approached issue, respectively. Of course, using the principles of axiomatic design is not always easy.

Thus, the correlation of the functional requirements with the design parameters is done in the form of *a design matrix.*

The functional requirements are entered along with the first columns, and the design parameters will be taken into account along the first line. An *X* symbol can be entered in the design matrix for that design parameter that contributes to the fulfillment of each functional requirement. If all *X* symbols are inscribed along the descending diagonal of the matrix, the design is considered optimal or *uncoupled*. If X symbols are all placed above or below the descending diagonal, we are dealing with a *decoupled design* and *a triangular design matrix*.

A third variant is the *coupled design,* when the *X* symbols are distributed both above and below the descending diagonal of the design matrix. Such a design is called coupled design, and it should suggest the existence and necessity of using ways to perfect the initial solution.

The correlation between the functional requirements *FRi*, the design parameters *DPi* and the design matrix *A* can also be expressed in the form of a matrix equation of the form:

$$\{FR\}=[A]\ \{DP\}. \qquad (1)$$

If we divide the theoretical research methods into *methods of analysis* and *synthesis* [10], we find that the axiomatic design method has a hybrid character.

It first involves analysis and then a synthesis of design parameters to reach an acceptable final solution.

3. RESULTS

Returning to the problem whose results are presented in this paper, we will consider that the client's requirement (*CN*) was to design a workplace for the teacher who must develop an online teaching activity, fulfilling as much as possible *ergonomic requirements*. The zero-order functional requirement can now be defined using the following form: *FR*0: Design a workplace necessary to develop an online teaching activity in maximum ergonomic conditions. This zero-order functional requirement could be broken down into first-order functional requirements, which will also consider workplace ergonomics requirements. The first-order functional requirements could be the following;

*FR*1: Ensure an adequate space in which the teacher conducts the online teaching activity;

*FR*2: Provide a possibility to arrange the various subsystems or objects required for online teaching;

*FR*3: Provide a position for the teacher to sit and adjust their position to ensure an ergonomic use of the teacher's body;

*FR*4: Ensure the presence of an object on which the teacher can successively write texts or figures to illustrate the content of the course taught;

*FR*5: Ensure the presence of an object or equipment that allows the information on the subject to be included in the previous functional requirement of the course content;

*FR*6: Provide a possibility to take an image of the surface of the object on which the teacher can successively inscribe texts and figures to illustrate the content of the course and which still allows the transmission of images taken over the Internet;

*FR*7: Provide the possibility of positioning the continuous imaging subsystem to ensure optimal imaging conditions corresponding to the texts and figures developed by the teacher;

*FR*8: Provide an opportunity for the teacher to take over the oral presentation of the course content and to broadcast the oral presentation via the Internet, respectively;

*FR*9: Provide an area where auxiliary materials used by the teacher in the teaching activity (books, leaflets, material samples, etc.) can be placed;

*FR*10: Provide digital processing and transmission of visual and audio information over the Internet, as well as on-screen observation of course participants and information taken by the imaging subsystem, respectively;

*FR*11: Provide connection of at least a second monitor screen for a faster transfer between two images appreciated as useful by the teacher to illustrate the course content;

*FR*12: Provide digital processing of information from imaging equipment;

*FR*13: Ensure the digital processing of audio and visual information corresponding to the oral presentation by the teacher of the course content, with a view to their transmission via the Internet;

*FR*14: Ensure the transmission of the course developed by the teacher via the Internet.

Each of the above functional requirements shall be affected by design parameters capable of contributing to the materialization of those functional requirements. Such a set of *DPi* design parameters is presented below for the example under analysis.

Zigzagging elements were also considered for some of these design parameters, justifying the preference for a certain type of design parameter.

*DP*1: Home office room;

*DP*2: Desk;

*DP*3: Adjustable office chair. Compliance with the ergonomic requirements for this office chair requires ensuring the possibility of adjusting the height of the chair in a vertical direction for more accurate positioning of the teacher concerning the height of the desk;

*DP*4: A sheet of A5 size paper. It was preferred to write the information specific to online teaching on a piece of paper, considering that the option of writing on the board the information specific to the course by the teacher would require greater mobility of the imaging subsystem;

*DP*5: Pencils and/or pens of different colors, able to ensure maximum contrast to the color of the sheet of paper used to enter the information by the teacher.

When using the whiteboard, this design parameter could be materialized by the chalk or the liquid pen used in the case of modern versions of school whiteboards. The arguments presented in *DP*4 by which it was preferred to use the sheet of paper instead of the blackboard led directly to the use of the black pencil, possibly in association with some colored pencils or some colored paste pens;

*DP*6: Video camera. The use of a mobile phone may also be considered here. Still, because during the course, there is a probability of the need to use the mobile phone for its original destination (usually, undesirable probability), it was preferred to use a specialized video camera compatible with the "Mirror" option of the software used.

An analysis of the possibilities of using different video cameras in terms of their technical characteristics and prices determined one of the authors of this paper to prefer a Logitech type video camera HD Pro C920;

*DP*7: Subsystem for positioning of the imaging subsystem along a vertical direction;

*DP*8: Microphone. The laptop microphone was used, just as the camcorder's phone (if the camcorder has one), or a separate microphone connected to the laptop could be used.

*DP*9: The flat surface of the desk;

*DP*10: Laptop;

*DP*11: Additional monitor, which can be connected to the laptop;

*DP*12: Logitech software for using the Logitech camera;

*DP*13: Google Meet software. Other software on the market (Microsoft Teams, Zoom, Skype, etc.) could be considered here. Google Meet software was preferred because of its features compared to other software;

*DP*14: Internet connection.

It is possible to proceed further with the exposition of the 2nd order functional requirements, the 2nd order design parameters, and the 2nd order process variables, respectively.

Due to the volume restrictions of this article, only a presentation of the 2nd order functional requirements specific to the video camera positioning subsystem (*FR*7) will be used.

*FR*7.1: Provide video camera positioning in a vertical direction;

*FR*7.2: Provide angular orientation of the video camera;

*FR*7.3: Ensure the possibility of using the mobile phone in case of video camera failure;

*FR*7.4: Provide the possibility of fixing the video camera to the moving subsystem along a vertical direction;

*FR*7.5: Provide opportunities for the imaging equipment to be positioned close to the edge of the desk to avoid an overly sloping position in front of the teacher as he or she writes various texts or figures on the subject for such an activity.

Table 1

The matrix containing *FRi* functional requirements and *DPi* design parameters in the case of workplace for online teaching activity.

Line no. 1	Design parameters / Functional requirements		Zero-order design parameter *DP*0													
2			Workplace for online teaching													
3			DP design parameters corresponding to the first level													
4			*DP*1: Home office room	*DP*2: Desk	*DP*3: Adjustable office chair	*DP*4: A sheet of A5 size	*DP*5: Pencils and/or pens of different colors	*DP*6: Video camera.	*DP*7: Subsystem for positioning of the imaging subsystem	*DP*8: Microphone	*DP*9: The flat surface of the office	*DP*10: Laptop	*DP*11: Additional monitor	*DP*12: Logitech software	*DP*13: Google Meet software	*DP*14: Internet connection
5 Column no. 1	2	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18
6	Zero order functional require-ment	1st order FR functional requirements	Highlighting the *DPi* design parameters corresponding to each *FRi* functional requirement													
7	*FR*0: Design a workplace necessary for the development of an online teaching activity	*FR*1: Provide adequate space for online teaching	X													
8		*FR*2: Provide a possibility to arrange the various subsystems or objects	X	X												
9		*FR*3: Make sure the teacher sits down and adjusts his/her height	X		X											
10		*FR*4: Provide a writable object	X	X		X										
11		*FR*5: Providing a writing object	X	X			X									
12		*FR*6: Providing imaging equipment	X	X				X								
13		*FR*7: Provide a possibility to position the video camera	X	X				X	X							
13		*FR*8: Provide a possibility to take the oral presentation	X	X						X						
14		*FR*9: Provide an area where auxiliary materials can be placed	X	X							X					
15		*FR*10: Provide digital processing and transmission of visual and audio information over the Internet	X	X								X				
16		*FR*11: Provide connection of at least a second monitor screen	X	X								X	X			
17		*FR*12: Provide digital processing of visual information	X	X								X		X		
18		*FR*13: Provide digital processing of audio and visual information	X	X								X			X	
19		*FR*14: Ensure that the course is broadcast online	X	X								X				X

The design parameters corresponding to the 2nd order functional requirements in the case of the 1st order functional requirement *FR*7 may be the following:

*DP*7.1: Wooden board with vertical metal column;

*DP*7.2: Subsystem through which the video camera can be positioned at an angle;

*DP*7.3: Subsystem for mobile phone positioning;

*DP*7.4: Video camera clamping screw;

*DP*7.5: Moving the wooden board on the desk or a sled that can be moved longitudinally along a horizontal direction perpendicular to the edge of the desk in front of the teacher.

A summary of the information on the first-order functional requirements and the design parameters related to these requirements is presented in a design matrix in Table 1.

The aspects mentioned concerning the components that should only allow the functional requirements of first-order have been taken into account. However, the elaboration of the design matrix can continue with the consideration of the functional requirements of second-order and, if necessary, even of the functional requirements of 3rd order, by breaking down the investigated system into smaller and smaller subassemblies or the parts of the system.

Examining the information entered in the design matrix (Table 1) leads to the finding that we deal with a decoupled design. All the *X* symbols have been included along the lower diagonal or below this diagonal.

It is also known that some of the correlations specific to the use of axiomatic design can be expressed in the form of mathematical relations.

Such a situation can be highlighted, for example, by taking into account only the 2nd order functional requirements resulting from the more detailed decomposition or analysis of the first-order functional requirement *FR*7. The actual aspects that take into account the correlations between the functional requirements, the design parameters, and the design matrix correspond (by customizing equation (1)) to the following mathematical relation:

$$\begin{Bmatrix} FR7.1 \\ FR7.2 \\ FR7.3 \\ FR7.4 \\ FR7.5 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 & 9 & X \\ X & X & 9 & X & X \\ X & 9 & X & 9 & X \\ X & 9 & 9 & X & X \\ X & 9 & 9 & 9 & X \end{bmatrix} \begin{Bmatrix} DP7.1 \\ DP7.2 \\ DP7.3 \\ DP7.4 \\ DP7.5 \end{Bmatrix} \quad (2)$$

The analysis of the information included in equation (2) shows that in the case of the first approach of the first-order functional requirement *FR*7, we are dealing with a coupled design, as *X* symbols were inscribed both above and below the descending diagonal of the design matrix.

It is found that meeting the same functional requirement involves the participation of several design parameters, which does not ensure that the requirement of the first axiom is met.

The main conclusion to be drawn from this example is the need for further design efforts to ensure, as far as possible, *the removal of the coupled design character of the solution* developed so far.

4. POSSIBLE SOLUTION

Continuation of the design of equipment that meets the functional requirements and design parameters identified above has led to the emergence of an online teaching equipment solution whose schematic representation can be seen in Figure 1. The use of a wooden motherboard can be observed, to which a vertical column has been attached.

On this vertical column can be moved a sleigh bushing that allows the vertical movement of a video camera so that on the screen of a laptop to which the video camera is connected, it can see the texts and drawings written by the teacher on a sheet of paper size A5. The equipment includes several solutions for rotating the video camera to be oriented to illustrate the course content with other objects appreciated by the teacher as useful for a better understanding of the subject approached in the teaching activity.

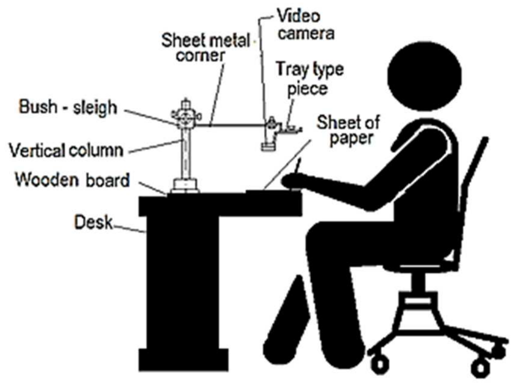

Fig. 1. Use of online teaching equipment.

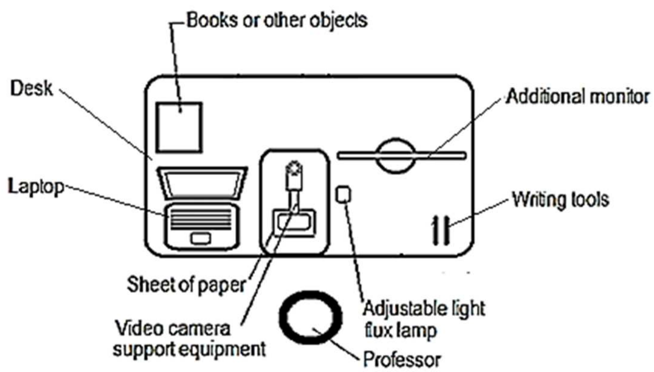

Fig. 2. Top image of the workplace.

However, the effective application of a solution of the type shown in Figure 1 has led to the conclusion that to meet ergonomic requirements, it may be necessary to use an additional light source and, at the same time, allow the change in light flux intensity within certain limits

This requirement was considered in the development of the graphical representation in Figure 2, which included the main components of the equipment usable in the online teaching activity.

It is possible to observe the use of a laptop, an additional monitor, the subsystem for taking images from the sheet of paper, and the lamp with variable light intensity. These components can be placed on the board at the top of a work desk.

5. CONCLUSIONS

The analysis of the information identified in the literature on online teaching and the equipment used for this purpose has highlighted a particular interest from researchers in how to address issues specific to online teaching and the solutions applied so far to solve those problems. It was found that there is a wide diversity of views expressed by the authors of some of the papers published so far in relation to online teaching. Due to the manifestation of the effects of the pandemic caused by the coronavirus in the last two years, the introduction of the obligation to carry out online teaching activities has involved identifying solutions that can be used in a short time and meet a maximum number of requirements.

Among such requirements were those of ergonomic organization of the workplace, i.e., the space from which the teacher had to perform the online teaching activity. One way to address such issues is to use principles from axiomatic design.

An online design matrix was designed in this way, and it revealed the possibilities of meeting the requirements derived from the first axiom of axiomatic design. The attempt to identify the design parameters related to the previously defined functional requirements led to outlining a solution related to a system capable of meeting the functional requirements and some constraints derived from the ergonomic requirements. Thus, the formulation of requirements to be met by the equipment usable by the teacher in the online teaching activity can lead to a more systematic approach to the problems related to the ergonomic organization of the workplace for online teaching. In the future, it is intended to continue research on the provision of jobs for online teaching, so that the online teaching activity becomes more efficient and convenient for the human operator (teacher) involved in that activity, as long as it allows, for sure, online conduct. of the teaching activity.

Furthermore, there have been considered for future research the context of different university-industry collaborations due to the mutual advantages for education and research activities [18]. The acceleration of digital transformation has put a high pressure on vocational trainings and lifelong learning. Thus, the presented approach should be experiment in these cases, too [19, 20].

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Abordare ergonomică a activității didactice de predare online, folosind principii din proiectarea axiomatică

Necesitatea desfășurării online a activităților de predare în universități a solicitat folosirea unor soluții care să maximizeze eficiența acestora, dar cu îndeplinirea maximal a cerințelor de natură ergonomică, pe cât posibil. Pentru identificarea unei soluții de echipament utilizabil în activitatea de predare online, au fost folosite principii din proiectarea axiomatică. Astfel, a fost identificată o variantă de echipament care să permită cadrului didactic utilizarea unei modalități de a scrie texte și a realiza desene care să poată fi transmise online, în condiții cât mai apropiate de cele ale unei activități de predare de tip față în față.

Laurențiu SLĂTINEANU, PhD, Prof., "Gheorghe Asachi" Technical University of Iași, Department of Machine Manufacturing Technology, slati@tcm.tuiasi.ro, +40723718675, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.

Margareta COTEAȚĂ, PhD, Assoc. Prof., "Gheorghe Asachi" Technical University of Iași, Department of Machine Manufacturing Technology, mcoteata@tcm.tuiasi.ro, +40752141598, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.

Oana DODUN, PhD, Prof., "Gheorghe Asachi" Technical University of Iași,, Department of Machine Manufacturing Technology, oanad@tcm.tuiasi.ro, +40747144604, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.

Florentin CIOATĂ, PhD, Assoc. Prof., "Gheorghe Asachi" Technical University of Iași, Department of Machine Tools and Tools, florentin.cioata@academic.turiasi.ro, +40742045238, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.

Adriana MUNTEANU, PhD, Assoc. Prof., "Gheorghe Asachi" Technical University of Iași, Department of Machine Tools and Tools, adriana.munteanu@academic.tuiasi.ro, +40740219923, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.

Adelina HRIȚUC, PhD. student, "Gheorghe Asachi" Technical University of Iași, Department of Machine Manufacturing Technology, hrituc.adelina3295@yahoo.com, +40751640117, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.

Gheorghe NAGÎȚ, PhD, Prof., "Gheorghe Asachi" Technical University of Iași, Department of Machine Manufacturing Technology, nagit@tcm.tuiasi.ro, +40723936351, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.

Andrei-Marius MIHALACHE, Ph.D. eng., lecturer, "Gheorghe Asachi" Technical University of Iași, Department of Machine Manufacturing Technology, andrei.mihalache@yahoo.com, +40745356715, Blvd. D. Mangeron, 59A, 700050 Iași, Romania.