TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics and Mechanics
Vol. 56, Issue II, June, 2013

ASPECTS REGARDING THE SELECTION OF TOOLS FOR METAL CUTTING ON CNC MACHINES

Sorin ACHIMAŞ, Marian BORZAN, Tudor MORAR, Florin MOCEAN

Abstract:
The process of cutting with numeric control machines is a flexible process which provides the quickest adaptation and response to a new production task. Processing with a CNC machine is a technology where the succession of processing steps is analyzed to the level of all details regarding the tool movement, both from geometrical and technological points of view. The effect of tool geometry on the cutting process is variable therefore the geometrical parameters should be selected in a logical sequence, namely: selecting the cutter clamping system, selecting the tool support geometry and selecting the cutter geometry. Selection of cutter geometry implies the selection of following parameters: cutter shape, size, thickness and edge radius. CBN tools with defined geometry are used for cutting heat treated steel with hardness above 45 HRC, rapid steel, heat resisting steel with Ni and Co content and for powder or welding restored surfaces.

Key words: metallic carbide cutters, cutting with CNC machines, cutting with CBN cutters, measuring geometry of cutters.

1. INTRODUCTION

Selection of tools for a certain processing stage with CNC machines includes two main steps.

First, the tool is selected according to geometry, then according to technological parameters [1].

Main influence on selecting tools for CNC lathe processing, as regards the cutters geometry, is the piece geometry. Tool selection may proceed after identifying the CNC lathe, the attachment of the piece to the revolving head and the processing operations/stages.

Main objective of tool selection is to identify the complete tools (tool support and cutters) which, according to a certain criterion, would provide the geometrical and technological requirements of the processing.

For the purpose of defining the tool selection methodology according to its geometry, all geometrical parameters of the tool have to be taken into account, encoded as per ISO regulations, then analyzed and selected as relevant for processing on CNC lathes.

Considering the diversity of tools available on the market and the related information, the research in the field of selecting the most adequate tools for processing on CNC lathes is of great interest. The cutter, even if standardized, includes much geometrical and technological information, consequently the use of computerized databases in addition to company catalogues of cutting tools would be very useful.

2. ACCURACY OF PARTS PRODUCED BY CUTTING PROCESSES

2.1. General aspects

Metal cutting is a processing procedure which is important for machinery construction due to dimension and shape accuracy of the processed piece, as well as the quality of processed surfaces. In particular for individual and small series processing, metal cutting is currently the most economical processing procedure. Problems related to accuracy of finished product should be analyzed in two categories: functional and technological.

Functional accuracy concerns the size of tolerance fields for each piece and specific dimension, within the limits where the piece performs its functional purpose without doubt.

Technological accuracy regards the extensive knowledge of mechanical processing methods in order to secure a certain prescribed accuracy for pieces of various shapes and sizes, as well as of methods and devices to control the achieved accuracy. Therefore it could be said that technological accuracy has two parts: obtaining the pieces with the accuracy prescribed in the functional design and controlling the achieved accuracy.

2.2. Factors influencing the cutting process accuracy

Accuracy of a piece, processed through several stages and operations, depends on the influence of factors acting during the current process as well as factors occurring during previous processing.

Factors related to current processing are [5]:

- lack of precision of tools, devices and verification;
- wear of cutting tool;
- elastic deformation of the technological system;
- thermal deformation of the technological system;
- vibration occurring during the processing etc.
- Factors occurring during previous processing and influencing the accuracy of current processing are [5]:
- variation of tooling allowance;
- errors in piece shape and position;
- internal tensions.
- During processing, deviation from nominal geometrical parameters of the processed surface occurs, as follows [1]:
- dimensional accuracy;
- geometrical shape accuracy;
- deviations from the position of various geometric elements;
- undulations;
- roughness of processed surfaces.

2.3. Wear of cutting tools

Wearing mechanisms noticed in the case of cutting tools is wearing by abrasion, adhesion, oxidation, thermo-electric effect and corrosion. Wearing mechanisms of cutting tools are rarely acting separated; they occur simultaneously, depending on the cutting conditions.

In order to ensure proper operation of cutting tool is important to know the evolution of edge wearing.

2.4. Processing by ultra-accurate turning

This technology refers to processing hardened metal materials with hardness above 45 HRC by accurate turning. Dimensional accuracy and roughness of lathed surfaces are presented in table 1.

Table 1. Dimensional accuracy and roughness of lathed surfaces [5].

No.	Type of processing	Accuracy level	Surface roughness	Tooling allowance
1.	Rough cutting	IT 11-14	$R_a =$ 25...100 µm	$a_p > 2$ mm
2.	Semi finishing	IT 10-11	$R_a =$ 6,3...25 µm	$a_p =$ 1...3 mm
3.	Finishing	IT 7-10	$R_a =$ 0,8...6,3 µm	$a_p =$ 0,5...1 mm
4.	Fine cutting	IT 4-6	$R_a =$ 0,2...0,8 µm	$a_p <$ 0,5 mm
5.	Ultra-accurate cutting	IT 1-3	$R_a \leq$ 0,1 µm	$a_p <$ 0,1 mm
Dimensional accuracy falls within the limits of tolerances prescribed by deviations allowed for various dimensions.				

Technological parameters specific for high hardness cutting are reduced feed (s) and thin cutting depth (t). Cutting liquids are usually not used.

This technology also presents environmental advantages; processing is performed in dry environment, without producing waste with negative impact on the environment.

3. TOOL MATERIALS

Requirements imposed on tool materials are determined by the work conditions of the tool edge during the cutting process. The cutting edge of the tool is subject to mechanical, thermal and chemical stress.

Tool materials shall present the following properties: high hardness; adequate mechanical bending strength and tenacity; thermal stability; low thermal conductivity and dilation coefficient; wear resistance; workability (as good as possible) and low cost.

Tool materials complying, one way or another, with the requirements listed above and recommended for cutting on CNC machines are: hard alloys of metal carbides; coated metal carbides; ceramics; diamonds and CBN.

Conventional hard alloys are divided into three standardized usage groups (ISO), namely: P, M and K. Hard alloys with high content of TiC, named "cermets", are useful for high cutting speed in finishing operations, when the main goal is accuracy and high quality of processed surface.

The principle of coating the tool material implies the covering of their surface (hard alloys), by physical or chemical procedures, with a thin layer (3-15 μm) of high hardness and resistance to temperature and wear. The layer material may comprise carbides (HfC, ZnC), nitrides (TiN, HfN, ZxN), carbon-nitrides (TiCN), oxides (Al_2O_3) or various combinations of such.

Regarding the properties of mineral-ceramic materials, their high level of brittleness is the main impediment for their large scale usage. Such materials cannot handle shocks, in which case the edge is destroyed by cracking and breaking. The field of applications of such ceramic materials is also limited by their low bending strength.

Due to its extreme hardness, diamond is used as a tool material, both for producing abrasive tools and defined geometry tools.

Crystalline cubic boron nitride (CBN) was introduced as tool material in the early '70s, and presents hardness close to the diamond. Defined geometry tools made of CBN are used for cutting thermal treated steel with hardness above 45 HRC, heat resisting steel with Ni and Co, materials which are difficult to process with hard alloy tools. Processing with CBN tools of thermal treated materials may represent a more productive alternative for grinding [9].

4. SELECTING TOOLS FOR CUTTING ON CNC MACHINES

Selection of tool for a certain processing stage includes two basic steps.

First, the tool is selected according to geometry, then according to technological parameters. The effect of tool geometry on the cutting process is variable, therefore the geometrical parameters should be selected in a certain sequence, namely: selecting the cutter clamping system, selecting the tool support geometry and selecting the cutter geometry.

For selecting the tool geometry, the following parameters are considered:

- ☞ tool shape; this parameter determines the tool tip angle „ε_r"; number of cutting edges; volume of tool material and the chip breaker.

Figure 1 presents the standardized angles of cutting tools according to ISO.

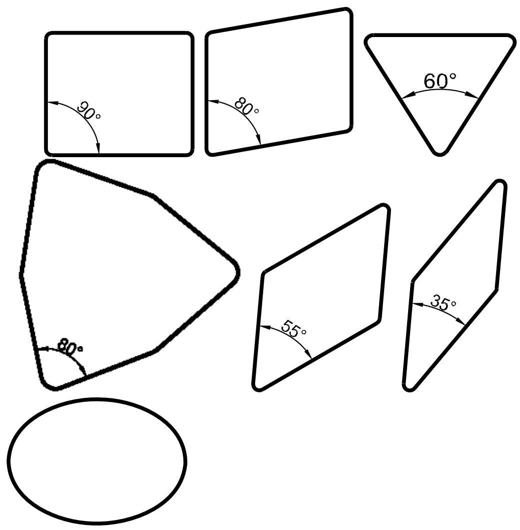

Fig. 1. Standardized geometric shape of cutting tools

The tool named "trine", with tip angle of 80°, was generated by combining the rhombic tool of 80°, stronger and with maximum 4 positions of the cutting edge, with the triangular tool, which has 3 positions of the cutting edge. Thus a strong tool was obtained, with 6 positions of the cutting edge (fig. 2).

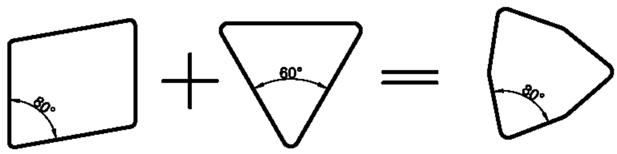

Fig. 2. Formation of trine tool [3].

Tool shape affects the tool cost and resistance to contact pressure. Cutting tool may be provided, or not, with a chip breaker, as follows:

- without chip breaker;
- with one chip breaking groove;
- with chip breaking grooves on both sides.

☞ tool size; this parameter refers to the length of cutting edge "l_m" and influences the tool cost and the maximum cutting depth "t_{max}";

☞ tool thickness; this parameter influences the tool cost and strength;

☞ tool tip radius "r_ε"; this parameter is standardized, and influences the tool durability and strength, main and radial cutting force, quality of processed surface etc.

The tool selecting order is relevant for the sequence of processing stages. As much as the main influence on selecting tool geometry is given by the piece geometry, the selection of tool material is influenced by material of the piece to be processed. Based on the above and various recommendations for selecting tools from catalogs, the following sequence according to technological parameters can be configured as presented in the diagram in figure 3. The field of cutting tools used for facing and milling is complex, however there is a trend in selecting the cutting parameters from catalogs or databases.

In such conditions, the calculation of cutting usage is actually reduced to processing the usage recommended by the tool manufacturer, in product catalogs, for each particular situation.

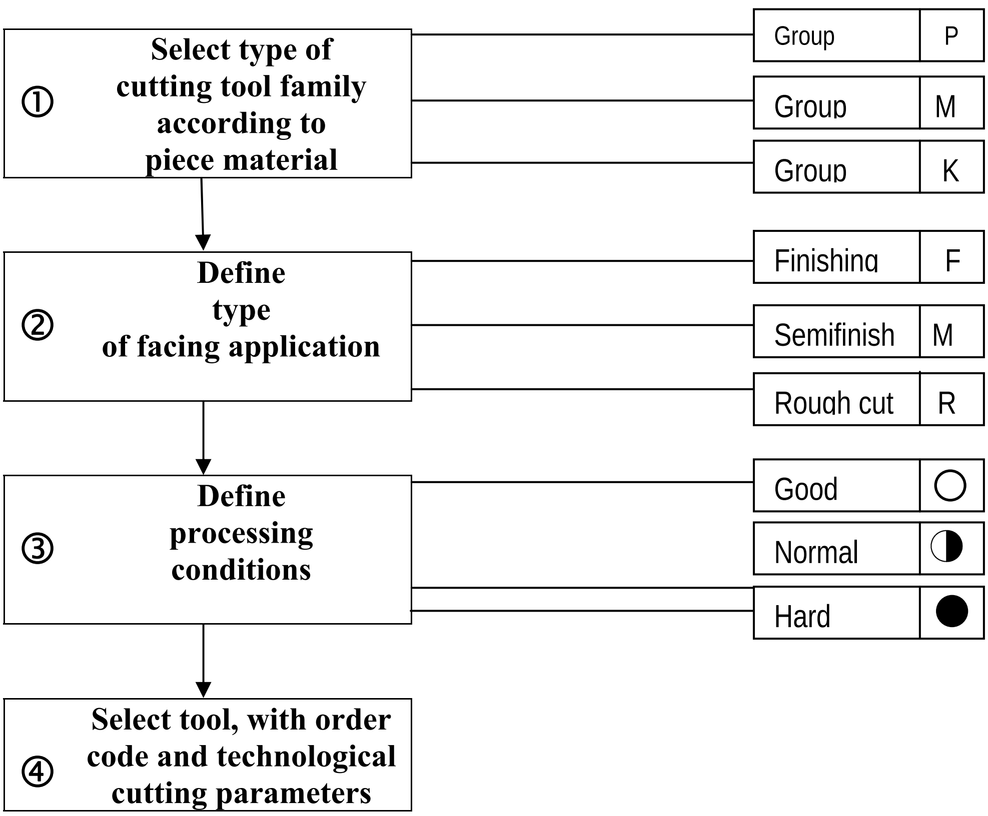

Fig. 3. Diagram of steps for selecting the tool as regards the technological parameters [3].

In order to configure cost effective cutting processes using CNC machines, the single sided optimization of cutting regime is not sufficient. The optimization of tool geometry, as well as providing optimal conditions for the process should also be taken into account [6].

For determining the actual figures for the cutting regime, the restrictions imposed by the technological system, by the tool and piece rigidity, roughness etc. should also be considered.

The shortest path to optimizing the cutting regime consists of determining the optimized cutting speed and consequently the durability. For such purpose, one of the two available optimization criteria should be adopted [6]:

☞ minimizing the incomplete operation time;

☞ minimizing the technological cost of processing.

The cutting depth and advancing step are deemed to be known and are determined according to other criteria, such as the operation time: rough cutting, finishing or according to the required roughness of processed surface. [6].

5. ADVANCED MEASUREMENT METHODS

Within the QM (Quality Management) system, the measurement technique is a component fully connected to the process of obtaining the finished product. Quality control is an important function of organizing the manufacturing process. The purpose is to foresee, detect and correct the deviations from the required quality level. There are numerous functions of quality control running at various levels of the manufacturing process. Their distribution is presented in figure 4 [4]. High quality is a significant instrument for a company to maintain its competitiveness level.

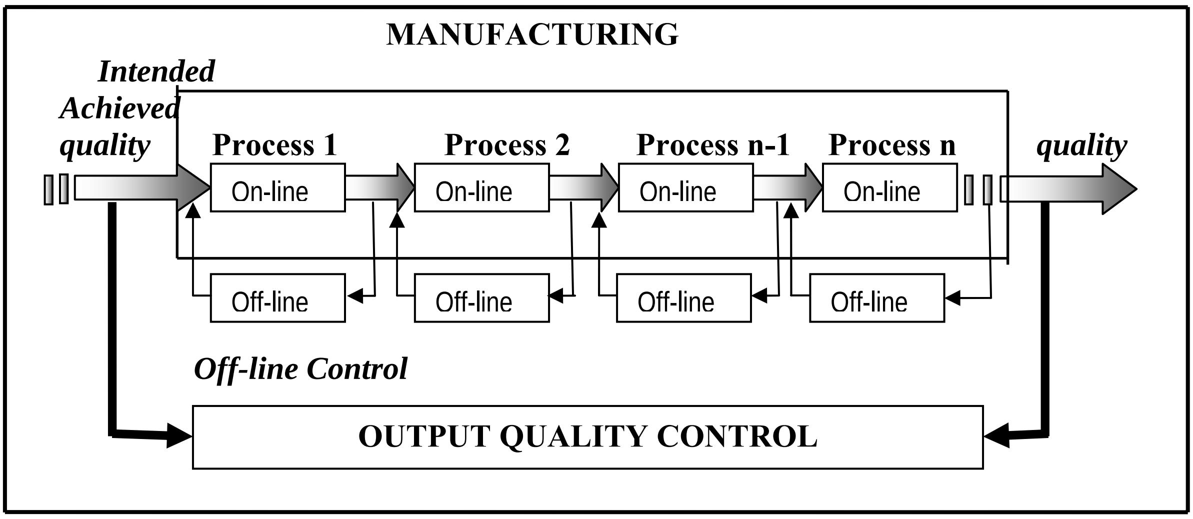

Fig. 4. Distribution of quality control functions in manufacturing

The quality control and assurance process in modern manufacturing is increasingly dependent on the performance of coordinates measurement machines [10].

The geometry study of the “trine” cutting tool with tip angle of 80°, with 6 positions of cutting edge, was performed on an “Aberlink Axiom” machine at the Technical University of Cluj Napoca and on the “IFM 1.4” machine at the Vienna Technical University.

6. MEASUREMENT PROGRAM

Inspection plan related to the “trine” cutting tool has been prepared based on the detailed drawings. Based on the said inspection plan, measurements have been performed on coordinates measurement machines.

Results of measurements performed for the “trine” cutting tool on the “Aberlink Axiom” machine at the Technical University of Cluj Napoca are presented in figure 5.

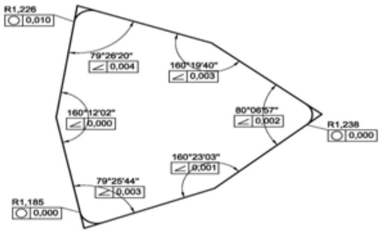

Fig. 5. Measured geometrical parameters of a “trine” tool.

According to the measurement report and the graphic presented in figure 5, the “trine” tool complies with the requirements of STAS 12046/1-81 and ISO 3685-1987.

Roughness parameters (ISO 4287-1198) for the “trine” cutting tool measured on the “IFM 1.4” machine at Vienna Technical University are presented in table 2.

Table 2

Measured roughness parameters.

Sign	**Value**	**Description**
R_L	1.00896	Ratio of true profile length to projected length
R_a	24.3 nm	Average roughness of profile
R_q	40.8 nm	Root-Mean-Square roughness of profile
R_z	515.7 nm	Maximum height of roughness profile
R_p	175.4 nm	Maximum peak height of roughness profile
R_v	340.3 nm	Maximum valley depth of roughness profile
R_c	206.8 nm	Mean height of profile irregularities of roughness profile
R_{Sm}	14084 nm	Mean spacing of profile irregularities of roughness profile
R_{sk}	- 2.30964	Skewness of roughness profile
R_{ku}	26.7958	Kurtosis of roughness profile
R_{dq}	0.0919569	Root-Mean-Square slope roughness of profile

Undulation (W) – 2nd level deviations (DIN 4760) – is generated by deviations in machine components or other factors contributing to manufacturing, vibrations, improper tool sharpening etc. and is part of the flatness tolerance.

Mean depth with mean undulation amplitude (2nd level deviations) – is the average of maximum undulation height, as per equation:

$$W = \frac{1}{n}\sum_{i=1}^{n} W_i \qquad (1)$$

Undulation parameters measured for the “trine” tool on the “IFM 1.4” machine are presented in table 3.

Table 3

Measured undulation parameters.

Sign	**Value**	**Description**
R_L	1.54665	Ratio of true profile length to projected length
W_a	2.167 μm	Average waviness of profile
W_q	2.956 μm	Root-Mean-Square waviness of profile
W_z	16.74 μm	Maximum height of waviness profile
W_p	10.68 μm	Maximum peak height of waviness profile
W_v	6.062 μm	Maximum valley depth of waviness profile
W_c	12.29 μm	Mean height of profile irregularities of waviness profile
W_{Sm}	47.07 μm	Mean spacing of profile irregularities of waviness profile
W_{sk}	1.02358	Skewness of waviness profile
W_{ku}	4.7633	Kurtosis of waviness profile
W_{dq}	1.58255	Root-Mean-Square slope waviness profile
L_c	0.807 μm	Filter wavelength for waviness profile

Total profile “P” – all irregularities forming the 1st level geometric deviations (DIN 4760). Total measured profile for the “trine” tool on the “IFM 1.4.” machine is presented in table 4.

Table 4

Measured total profile "P" parameters

Sign	Value	Description
R_L	1.6654	Ratio of true profile length to projected length
P_a	2.364 µm	Average height of primary profile
P_q	3.1 µm	Root-Mean-Square height of primary profile
P_z	16.74 µm	Maximum height of primary profile
P_p	11.93 µm	Maximum peak height of primary profile
P_v	4.816 µm	Maximum valley depth of primary profile
P_c	10.04 µm	Mean height of profile irregularities of primary profile
P_{Sm}	23.89 µm	Mean spacing of profile irregularities of primary profile
P_{sk}	1.12298	Skewness of primary profile
P_{ku}	4.88107	Kurtosis of primary profile
P_{dq}	1.68344	Root-Mean-Square slope primary profile

Statistic parameters are the following:

☞ P_P – total profile leveling depth (sum of 1st – 4th level deviations);

☞ V_P – undulation leveling depth (2nd level deviations);

☞ R_P – roughness leveling depth (3rd level deviations).

Parameters P_P, V_P and R_P represent the distance between the highest point of the profile and the mean line.

According to the measurement report presented in figures 6, 7 and 8, the "trine" tool complies with the provisions of ISO 4287-1198.

7. CONCLUSIONS

The quality of processed parts, such as to achieve zero rejected parts ("zero defects" technique) is ensured with high performance tools.

Measurements demonstrate that the "trine" cutting tool complies with the requirements of STAS 12046/1-81; ISO 3685-1987; ISO 4287-1198 and DIN 4760.

Measurement solutions presented in this paper may be also used for monitoring the tool wear and edge damages.

For a proper operation of CNC machines, the use of removable cutting tools is recommended.

Cutting with CBN tools the thermal treated materials may represent a mode productive alternative for grinding.

8. REFERENCES

[1] Borzan, M. Proiectarea asistată a sculelor pentru prelucrarea suprafețelor elicoidale riglate. Editura Casa Cărții de Ştiință, Cluj-Napoca, 1998.

[2] Bulgaru, M. ş.a. Statistica pentru ingineri. Editura Casa Cărții de Ştiință, Cluj-Napoca, 2009.

[3] Cărean, Al. Tehnologii de prelucrare cu CNC. Editura Dacia, Cluj-Napoca, 2002.

[4] Crişan, L. Metode moderne de măsurare. Editura Dacia, Cluj-Napoca, 2004.

[5] Gyenge, C. Tehnologia construcției maşinilor unelte. Editura Lito I.P., Cluj-Napoca, 1990.

[6] Julean, D. Aşchierea metalelor. Editura Dacia, Cluj-Napoca, 2000.

[7] Lăzărescu, I.D. Teoria şi practica sculelor aşchietoare. Editura Universității din Sibiu, Sibiu, 1994.

[8] Popescu S. Managementul calității. Editura Casa Cărții de Ştiință, Cluj-Napoca, 1999.

[9] Tonshoff, H.K. Cutting of hardend steel. Annals of CIRP, 2000, p. 54-66.

[10] Tulcan, A. ş.a. Sisteme de control. Editura Politehnica, Timişoara, 2006.

[11] *** ISO 9001:2001. Sisteme de management al calității-cerințe.

ASPECTE PRIVIND SELECȚIA SCULELOR LA PRELUCRAREA PRIN AŞCHIERE PE MAŞINI CNC

Rezumat:

Procesul de prelucrare pe o maşină-unealtă cu comandă numerică este un proces flexibil care se adaptează şi răspunde cel mai rapid la o nouă sarcină de producție. Prelucrarea pe o maşină-unealtă CNC este o tehnologie în care succesiunea fazelor de prelucrare sunt analizate la nivelul tuturor detaliilor privind mişcările sculei, atât din punct de vedere geometric cât şi tehnologic. Efectul parametrilor geometrici ai sculei asupra procesului de aşchiere este diferit, de aceea aceştia trebuie selectați într-o ordine logică şi anume: alegerea sistemului de prindere a plăcuței; selecția geometriei suportului sculei; selecția geometriei plăcuței.

Stadiul selecției geometriei plăcuței cuprinde alegerea următorilor parametri: forma plăcuței; mărimea plăcuței; grosimea plăcuței; raza la vârf a plăcuței. Sculele cu geometrie definită din CBN se utilizează la aşchierea oțelului tratat termic cu duritate mai mare de 45 HRC, a oțelului rapid, a oțelurilor refractare cu Ni şi Co şi a suprafețelor recondiționate cu pulberi sau prin sudură. Cuvinte cheie: plăcuțe din carburi metalice, aşchierea pe maşini-unelte CNC aşchierea cu plăcuțe CBN, măsurarea geometriei plăcuțelor aşchietoare.

Sorin ACHIMAŞ, PhD Student, Eng., Technical University of Cluj-Napoca, Department of Manufacturing Engineering, Muncii Bvd. 400641 Cluj-Napoca,E-mail: sorin_achimas@yahoo.com , Phone: 0040 264 426606.

Marian BORZAN, Univ. Prof. Dr. Eng., Technical University of Cluj-Napoca, Department of Manufacturing Engineering, Muncii Bvd. 400641 Cluj-Napoca, E-mail: Marian.Borzan@tcm.utcluj.ro, Phone: 0040 264 401647

Tudor MORAR, PhD Student, Eng., Technical University of Cluj-Napoca, Department of Manufacturing Engineering, Muncii Bvd. 400641 Cluj-Napoca, Phone: 0040 264 401731.

Florin MOCEAN, PhD Student, Eng., Technical University of Cluj-Napoca, Department of Manufacturing Engineering, Muncii Bvd. 400641 Cluj-Napoca, Phone: 0040 264 401731.