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Research Article

Wear Measurement of the Cutting Tool when Cutting Medium-Density Fiberboard

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Abstract

Regardless of how advanced is the technological equipment used in cutting operations, high quality cutting instruments are always a necessity. In the focus of this study is the wear of the cutting blade, namely the increase of the radius of the cutting blade. The wear of the cutting tool is measured carving MDF slabs in three dimensional CNC machines. In order to test the tool wear during the technological process of carving, first quality medium-density fiberboard slab panels of both simple surfaces, with dimensions of 2100x2800x18mm, has been used as raw material. The wear measurement is done with the direct method, through a measuring device called "Nikon NEXIV VMR-3020 CNC Video measuring System", with the possibility of lensing up to 270 times. The wear of the carving blade is measured for three effective working time periods, respectively 60, 180 and 300 minutes. The obtained results can be used to construct a mathematical model which serves the users to choose the right instrument for respective wood material.

Keywords: *Tool wear, cutting blade, carving process, CNC, video measuring system*

1. Introduction

The permanent tendency of producers to increase the production capacities and quality of product drives them to invest in better technologies and know how. Just as in other countries in the world, following the above mentioned tendency, also our country, considerable investments have been made by the wood processing industry, in particular in CNC technology and better cutting instruments (Ymeri, 2007). Investments in these segments are a guarantee for increase of their competitiveness in the markets.

In the course of the processing processes in the wood industry, as well as other fields, four criteria are of utmost importance should be taken into account: a) the material (wood or wooden material); b) the instrument - tools for processing; c) the machine which makes the processing and d) the human factor, who takes part in this process (Goglia, 1994). Considering the importance of the second criteria we have study the blade consumption at cutting instrument in order to be able to select the cutting instruments with the best features and use them in the best way.

In the theory of cutting in general, considering the wood heterogeneous composition, there are many factors influencing the solid wood cutting process such as: i) direction of cutting; ii) the thickness of chips (carved bits); iii) angle of cutting; iv) friction of the blade; v) cutting speed; vi) wood species, vii) wood moisture; viii) temperature; ix) wear of cutting tool (Dimoshi, 2006).

Considering that a big number of the wood processing facilities in Kosova are using as raw material wood based panels (particle boards and medium-density fiberboards) we are focused in the problematics of the cutting instruments used to perform cutting and the final surface processing of wooden based slabs, in particular engraving of MDF slabs. Despite the fact that in case of medium-density fiberboard slabs we have a lot more homogeneous composition of the material the cutting of the wooden based slabs and in particular their final surface processing remain problematic (Bajraktari and Marku, 2006), cause among other factors the presence of different resins and glues makes these processes difficult (Jambrekovic, 2004). In general reconstituted wood products are harder, more abrasive, and dryer than the solid wood (Sheikh-Ahmad and Bailey, 1999). Despite the impact of many factors, we focused in the study of the wear influencing factors of blade of the cutting instrument when cutting MDF slabs.

Regardless of the fact how the cutting instrument has been made, during the effective work it will face consumption of the cutting range (Nelson, 1999). This causes great resistance during cutting and consequently the forces which are in vertical position

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to the movement of the cutting blade will grow, both the frontal and side force of the cutting blade. The ratio between the frontal force F_o and cutting force $F_{p,}$ is given by the formula:

$$F_o = c \times F_p(N) \qquad (1)$$

where:
c is the coefficient, value of which depends on the sharpness of the blade. For the sharpened blade it has a value of 0.1-0.3, for average sharpening it has a value of 0.5-0.7 and for consumed blades has a value over 1.
The range of blade sharpness, after t minutes of effective work, according to Prokeś (1982), can be calculated as follows:

$$\rho = \rho_o + \Delta\rho \qquad (2)$$

where:
ρ is the range of sharpness of the cutting blades after t minutes of effective work in (μm), ρ_0 the initial range of cutting blade sharpness (for instruments - blades ρ_0 = 4-5 μm and for saw ρ_0 = 6-10 μm), $\Delta\rho$ is the change or increase of the initial range after t minutes of effective work in μm.

Based on regimes of work, the material that is processed and the material of cutting instrument, the consumption of the blade can be of different forms. All the possible consumption forms can be divided into three groups:

- Consumption of the back surface
- Consumption of the chest surface
- Consumption of edges of the blade

All the three forms of consumption represent increase of three forms torpidity of the instrument during the effective work (Goglia, 1994). We know from the practice that instrument can be unusable, if the blade is crumbled extensively.

-Consumption of the surface of the back most frequently appears when friction happens in processors and cutting instrument. Consequences of such a habit are because the material which is processed is tough, abrasive action is significant and cutting speed is high.

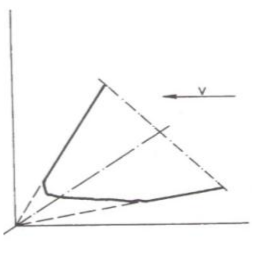


Fig.1 Consumption of the surface of the back

A typical case of such consumption is shown in Fig. 1. Such a form is a consequence of carving of abrasive materials (rough).

-Consumption of the chest surface, it is a consequence of friction between this surface and the chip. Consumption increases with an increase of cutting speed and thickness of the chips. Depending on working regime, consumption of the chest surface can be noticed in two forms: (a) deformities on the surface of the chest and (b) appearance of a crater in this surface.

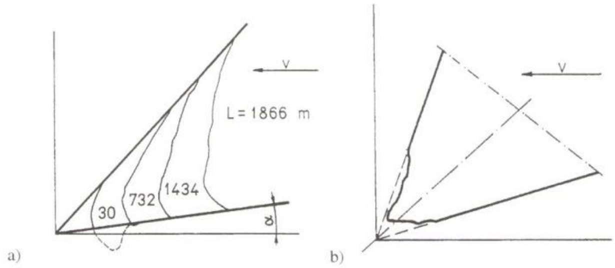


Fig.2 Forms of consumption of the chest surface

In **Fig. 2** above are shown both forms of consumption of the chest surface as deformities on the surface of the chest and appearance of crater in the surface

-Consumption of edges of the blade (Fig. 3) represents the dominant consumption of cutting instrument. Such a form appears most frequently, while such consumption is noticed with the increase of cutting blade range r.

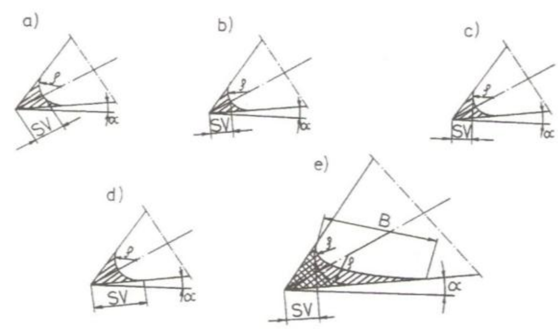


Fig.3 Possible forms of consumption of edges of the blade

Many factors have an impact on the resistance of the blade, impacts coming directly from mechanical, thermal, chemical and electrical actions into the cutting blade itself. Some of the above mentioned factors are (i) application of very high working speed; (ii) extremely sharp cutting edges of the tools; (iii) intensive abrasive wear and high working temperature, (iv) low thermal conductivity (Ratajski, *et al*., 2009). The effect of so many factors make the presenting of the blade consumption process quite complex (Pinheiro, *et al*., 2003).

Even at the first glance the cutting and processing process of wood seems easier compared to other raw materials, in reality it presents a quite complex process also because of its anisotope and heterogeneous composition (Lato and Quku, 2008; Ratajski, *et al*., 2009). When determining the cutting instrument we have to take into account all the factors that complicate wood cutting.

In terms of duration the main methods of testing blade consumption, can be divided into two groups:

1. Long term testing method (Taylor's Method)
2. Short term testing method

The safest testing method is Taylor's method, take its name from a famous American technologist, is a method which is based on long term testing. She is considered as the safest testing methods, but it is more costly.

Among the short term testing can be mentioned testing with escalation of cutting speed, testing with constant increase of cutting speed, testing by consuming 1000 details, testing of the length of the road of up to 100 m, testing for time units in duration of 1 minute, testing consumption with radioactivity and testing by creating a nest or crater at hard metals.

While to measure the changes in the geometry of the cutting instrument we can use two methods: an indirect and direct one (Rousek, *et al.*, 2009). With the indirect method it is difficult to identify the changed geometry of blade range, after t minutes of work, while it can be achieved with the direct method.

Using the direct method we have several possibilities, but the safest and clearest is the one with profile-graph and profile-projector or with more advanced CNC equipment, system programming, with direct reading of the results.

2. Materials and Methods

2.1. Instruments of testing equipment

In the wood machining processes in automatic lines, in which is installed CNC technology, it is inconceivable that in addition to product design, not to take into account the design of the cutting instrument and the structure of building his materials (Altintas, 2000). Tooling selection is always closely related to the setup and cutting conditions. When selecting tools, always should be considered two considerations. When the part setup method has been established, the tools can be selected on the basis of drawing dimensions and machining operations required. Tools are always selected on the basis of machining operations required (Smid, 2006).

Amongst the cutting instruments at the CNC machine used in the experimentation, is also the one presented in figure 4, which serves for carving, in one form is universal. A characteristic of this machine is that its cutting blade is changeable, as seen in the figure, having cutting edges into four sides, it can be used twice, once the lengthy shape and the short one, and then the two others. Those which are to be exposed in greater scale are the lengthy sides, therefore we have also made measurements of the consumption of the cutting blade range. This has been marked by letter h, the usable height of which can be used during the drafting process of the program of any constructive part of any product.

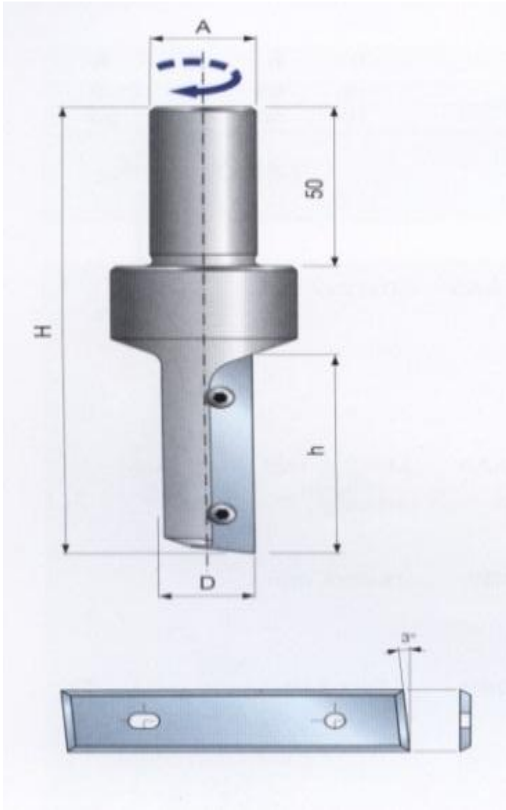


Fig.4 Carving tool (head and carving blade)

The data on the initial geometry of the instrument for carving and composition of the material is given in table 1. The cutting blade of this instrument has been measured regarding the consumption of the range.

Table 1 Data for the carving instrument in CNC machine

Name of cutting instrument	Carving - engraving instrument
Diameter of carving instrument D(mm)	20
Dimensions of cutting edge (mm)	h= 50, I=12, d= 1.5
Back angle a(°)	15°
Chest angle g(°)	10°
No. of teeth	1
Composition of the material of instrument	Hard metals - hard sintered carbides from Wolfram 93.5 %, cobalt 6% and tantalum-carbon 0.5 %
Speed of rotation rot/min	20000

2.2. Measuring system

With direct method it was possible to achieve very accurate results, especially on amendment of geometry of instrument - tool following a certain working phase. We have used this method with an highly advanced measuring equipment, called Nikon NEXIV VMR-3020 CNC Video measuring System (Nikon catalog and manual, 2014), CNC through which it is measured and then the new geometry of cutting instrument is created after few phases of effective work, which we will determine on the table.

The device is equipped with the system of lenses of high resolution, shown with long waves of 300 mm and laser measurements with high precision. With ideal equipment in general, the measuring coordinating 3D system, with dimensions of 300 x 200 x 150mm of phasing itinerary, NEXIV-3020 deals with a series of tasks of measurement, including those for mechanical parts, reshaped parts, printed parts and other various instruments. Characteristics of an 8-segment LED, lighting system and with laser lenses with auto-focus feature, thus enabling ultra-precise detection of measurement points. It is available in four models, with 5 zoom grades, to cover various shown areas and resolution demands.

Fig.5 Nikon NEXIV VMR-3020 CNC Video measuring System

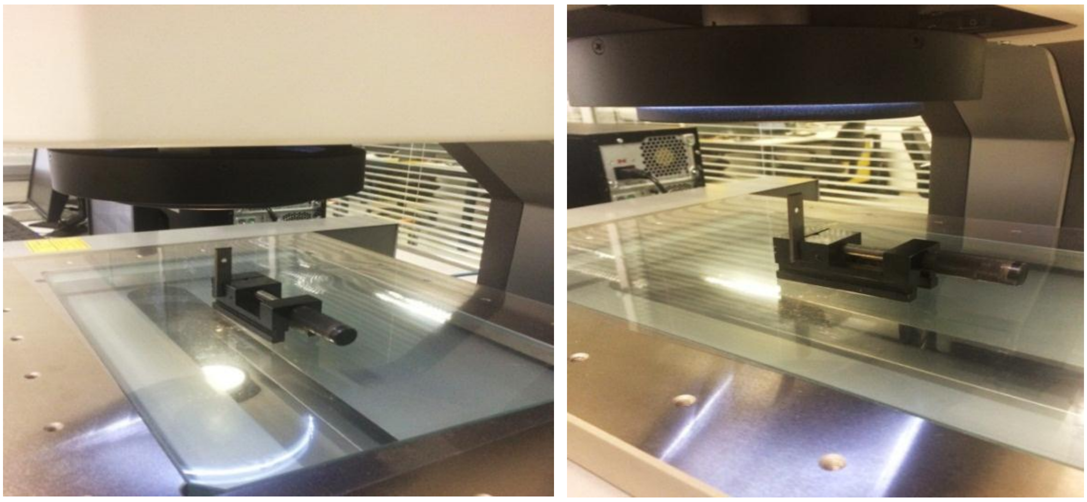


Fig.6 Installation of the blade on cutting instrument for measuring the range of consumption

3. Results and discussion

In the wood machining process with high CNC technology, the implementation of systems CAD-CAM, make it easier to identify the state of the cutting instrument in certain stages of its consumption, due to the circulation of information at the right time (Franceschi, 1994).

Through direct measurements, we can get the results of the consumption of range of the blade of the instrument. We have measured the changes in the geometry of the blade in four conditions of the blade, namely, sharpened, sharpened in average, significantly consumed and consumed.

a) The condition of the blade: sharpened

In the **table 2**, have been given details for the position of the cutting blade during measurement, as seen in the photo above, in a three-axis CNC, where the foundation of measuring table is 300 x 200mm.

Table 2 Position data of the cutting blade in condition (a) during measurement

		Nominal	Upper Tol.	Lower Tol.	Actual
1. Circle	X	121.4492	0	0	121.4492
1.Circle	Y	62.5279	0	0	62.5279
1.Circle	Z	0	0	0	0
1.Circle	POS	0	0	0	0
1.Circle	RAD	0.0071	0	0	0.0071
1.Circle	CIRLTY	0	0	0	0.0003

Table 3 State of cutting blade wear after effective work of 0 minutes

Condition of the cutting blade	Effective work in t minutes	Radius / range of consumption r in μm	Corrective factor of consumption c	Condition of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Sharpened	0	7.1	1	121.449	62.5279	0

Table 4 Position data of the cutting blade in condition (b) during measurement

		Nominal	Tol.	Tol.	Actual
1. Circle	X	116.3626	0	0	116.3626
1.Circle	Y	24.6568	0	0	24.6568
1.Circle	Z	0	0	0	0
1.Circle	POS	0	0	0	0
1.Circle	RAD	0.0178	0	0	0.0178
1.Circle	CIRLTY	0	0	0	0.0045

Table 5 State of cutting blade after effective work of 60 minutes

Condition of the cutting blade	Effective work in t minutes	Radius/range of consumption **r** in μm	Corrective factor of consumption **c**	Condition of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Sharpened in average	60	17.8	1.20	116.3626	24.6568	0

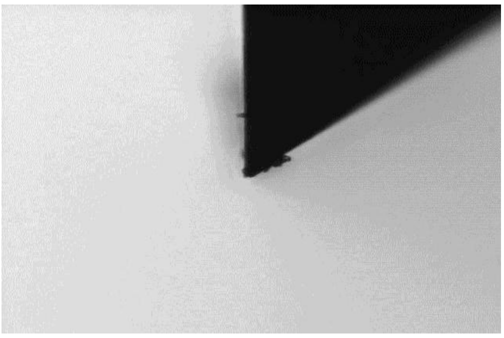


Fig. 7 Edge of the blade of cutting instrument in condition (a)

Table 6 Position data of the cutting blade in condition (c) during measurement

		Nominal	Tol.	Tol.	Actual
2.Circle	X	108.9189	0	0	108.9189
2.Circle	Y	12.7458	0	0	12.7458
2.Circle	Z	0	0	0	0
2.Circle	POS	0	0	0	0
2.Circle	RAD	0.0257	0	0	0.0257
2.Circle	CIRLTY	0	0	0	0.0078

Table 7 State of cutting blade after effective work of 180 minutes

Condition of the cutting blade	Effective work in t minutes	Radius/range of consumption **r** in μm	Corrective factor of consumption **c**	Condition of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Significantly consumed	180	**25.7**	1.40	108.9189	12.7458	0

In the photo below can be seen the geometry of the blade edge with its initial range, the value of which is presented in tables 2 and 3.

In the photo below can be seen the geometry of the blade edge with its initial range, the value of which is presented in tables 4 and 5.

b) Condition of the blade: Sharpened in average

In the **table 4**, there are given details of the position of the cutting blade during measurement and measurements after 60 min of effective working of edge of the blade

In the photo below can be seen the geometry of the blade edge with its initial range, the value of which is presented in tables 4 and 5.

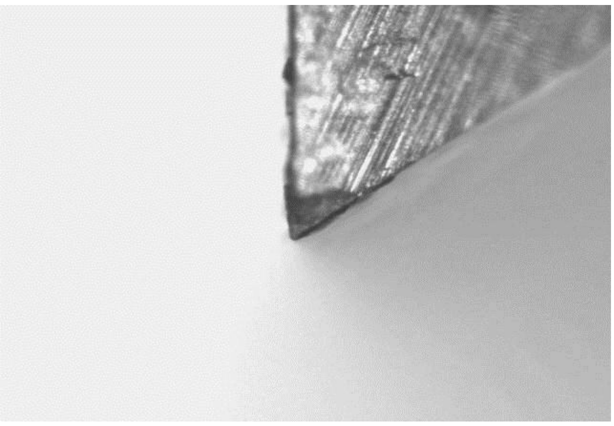


Fig.8 Edge of the blade of cutting instrument in condition (b)

c) Condition of the blade: Significantly consumed

In the **table 6**, there are given details of the position of the cutting blade during measurement and measurements after 180 min of effective working of edge of the blade

In the photo below can be seen the geometry of the blade edge with its initial range, the value of which is presented in tables 6 and 7.

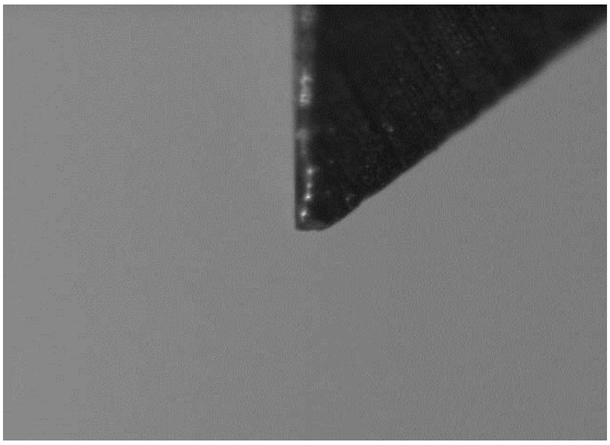


Fig.9 Edge of the blade of cutting instrument in condition (c)

d) Condition of the blade: Consumed

In the **table 6**, there are given details of the position of the cutting blade during measurement and measurements after 300 min of effective working of edge of the blade

Table 8 Position data of the cutting blade in condition (d) during measurement

		Nominal	Upper Tol.	Lower Tol.	Actual
5.Circle	X	97.4312	0	0	97.4312
5.Circle	Y	36.8926	0	0	36.8926
5.Circle	Z	0	0	0	0
5.Circle	POS	0	0	0	0
5.Circle	RAD	0.0477	0	0	0.0477
5.Circle	CIRLTY	0	0	0	0.0098

Table 9 State of cutting blade after effective work of 300 minutes

Condition of the cutting blade	Effective work in t minutes	Radius/range of consumption **r** in µm	Corrective factor of consumption **c**	Condition of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Consumed	300	**47.7**	1.55	97.4312	36.8926	0

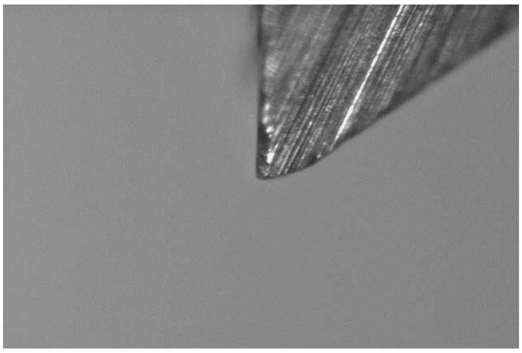


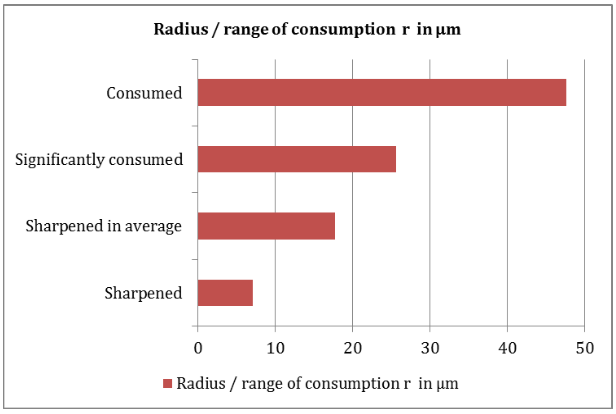
Photo 6 Edge of the blade of cutting instrument in condition (d)

Conclusions

In the table 10 are given the final results of measurements. Then the same data have also been presented in the following diagram.

Table 10 Range of wear of blade in relation to condition of the cutting blade

Condition of the cutting blade	Effective work in t minutes	Radius / range of consumption **r** in µm	Corrective factor of consumption **c**
Sharpened	0	**7.10**	1.00
Sharpened in average	60	**17.8**	1.20
Significantly consumed	180	**25.7**	1.40
Consumed	300	**47.7**	1.55



Graph 1 Graphical presentation of the data in table 10

From the data in the table 10 and graph 1 it is clearly shown that with the increase of wear stage, the range of cutting blade of instrument increases as well and not proportionally.

According to studies from many different authors the accurate determining of consumption of the radius of the cutting blade is very difficult or with indirect method even impossible (Kováč and Krilek, 2011).

In our case we have applied the most advanced technology using the direct method of measurement of the changes in the geometry of the blade. Based on the results obtained we have reached in the conclusions as follows:

1. The need for ascertaining the level of the range consumption is related with the definition of the cutting regime. The CNC machine operators need to know, that from the beginning of effective work, the range of the blade of the cutting instrument will have a certain consumption grade according to the stages given in the above tables. Based on this knowledge they can identify the volume of work to be performed with one cutting instrument.
2. Direct measurements of blade wear are showing that in all cases we are working with cutting instruments consisting of the same material and machining the same raw material, respectively MDF slabs, we can be assured of the consumption state of the cutting instrument after "t" effective minutes of working time.
3. The knowledge of the state of consumption of the cutting instrument helps the tendency to realize an ideal cutting process. This regime of cutting helps in a tendency for cutting ideally by the operators, given the high price in equipment, instruments and raw matter.
4. Taking into account the hight costs related with the cutting instruments and raw materials, undoubtedly the permanent tendency to realize ideal cutting processes results in important production costs savings, including material costs, energy costs and labour costs.

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