

REVIEW OF THE CONSUMPTION OF THE RADIUS OF THE CUTTING INSTRUMENT, DURING THE SAWING LAMINATED PARTICLEBOARDS

Muhamet YMERI

Dr. - University of Applied Sciences
Ferizaj (Republic of Kosovo)
E-mail: muhametymeri@yahoo.com

Agron BAJRAKTARI

Prof. - University of Applied Sciences
Ferizaj (Republic of Kosovo)
E-mail: aragon.bajraktari@ushaf.net

Hektor THOMA

Prof. - Agricultural University of Tirana
Koder Kamez, 1029, Tirana Albania
E-mail: hektor.thoma@ubt.edu.al

Abstract:

The focus of this study is the examination of tool wear or the causes of tool radius increase, during sawing of melamine wood panels with CNC machines. During the tests, the following materials will be used: laminated particleboard, based on the objectives of the study, for the technological sawing operation, with dimensions 2100x2800x18mm, first quality.

As a cutting tool for sawing it is used the one in the shape of a disc, as in figure 4. Table 1, presents all the details of the cutting instrument, its geometry, the blade angle, the number of rotations, its material of construction etc.

The examination of tool wear was measured by the direct measurement method, with the help of a measuring device called Nikon NEXIV VMR-3020 CNC Video Measuring System, with the possibility of lensing up to 270 times.

While the data obtained from the measurement are presented in table no. 2, constructing an overview of the data, from the results obtained. This data was also compared by mathematical calculations, with a clear difference in consumption, between the initial radius and that after t working minutes.

From all this, a mathematical model is obtained, which serves the users to choose the right instrument for the respective wood-based material, in this case carpentry boards, for the technological operation of sawing.

Key words: *cutting instrument; measuring equipment; three dimensional CNC machine; measuring radius of the blade; laminated particleboard.*

INTRODUCTION

The permanent tendency of producers to increase the quality and production capacity makes them to invest in technology and know how (Ymeri *et al.* 2015). In the course of processing in the wood industry, as well as other fields, four criteria are of utmost importance to be taken into account: a). The material (wood or wooden material), b) Instrument - tools for processing, c) the machine which makes the processing and d) human factor, who takes part in this process (Goglia 1994). Investment in these segments is a guarantee for increase of their competitiveness in the markets. For this reason, we study the blade consumption at cutting instrument, selection of instruments with the best features, ways of their best use. Now, just as in other countries in the world, in our country also, considerable investment has been made in technology and cutting instruments, in particular in CNC technology.

In general, having in consideration the theory of cutting, one should bear in mind many important factors in massive wood cutting, because of its homogeneous composition, such as: a) direction of cutting, b) the thickness of chips (carved bits), c) angle of cutting, d) friction of the blade on the wood, e) cutting speed, f) the type of wood, g) moisture of wood, h) temperature of wood, i) consumption of the blade of cutting instrument. But it is very important and problematic at the same time the cutting of the wooden based slabs, and in particular their final surface processing. In our paper, we will mainly elaborate sawing of melamine woodworking slabs. So even in those cases when we have a lot more homogeneous composition, again the presence of different resins and glues make the sawing difficult (Jambrekovic 2004).

But in specific resistance to wood cutting, despite the impact of many factors, for us is important the study of the causes of the consumption of blade of the cutting instrument when cutting laminated particleboard (Figuric 2000). For the given process parameters, the edge geometry of the blade, can be

chosen as a compromise between the smallest possible edge angle, for the highest processing quality, and on the other hand it determines with its largest value, the favorable in terms of blade resistance consumption (Kowaluk *et al.* 2009). According to (Keturakis and Lisauskas 2010), experiments showed that for determining the influence of the sharpening angle β on the arc radius of the cutting blade ρ and the cutting force P_c is nonlinear for the cutting path up to 400m.

Regardless of the fact how the cutting instrument has been made, of the best materials, during the effective work it will face consumption of the cutting range. This causes great resistance during cutting and consequently the forces which are in vertical position to the movement of the cutting blade will grow, and they are frontal and side force of the cutting blade. The ratio between the frontal force F_o and cutting force F_p , is presented in this way:

$$F_o = c \times F_p \text{ (N)}$$

where: c is the coefficient, value of which depends on the sharpness of the blade. For sharpened blade it has the value 0.1-0.3, on average sharpened it has the value 0.5 - 0.7 and consumed over 1. The blade sharpness radius, after t effective working minutes, can be calculated: $r = r_o + \Delta r$, where: r is the range of sharpness of the cutting blade s after t minutes of effective work in (μm), r_o the initial range of cutting blade sharpness (for instruments - blades is $r_o = 4 - 5\mu\text{m}$, for saws $r_o = 6 - 10\mu\text{m}$), Δr change or increase of the initial range and that after t minutes of effective work in μm .

Based on regimes of work, the material that is processed and material of cutting instrument, the consumption can be of different forms. All these 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 wear 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.

When the cutting speed increased, the quality of the processed surface increased. The best quality of the surface was reached when the cutting speed V_c was 40m/s. (Keturakis *et al.* 2017).

Consumption of back surface, most often occurs when friction occurs between the processor and the cutting instrument. The consequences of such a habit are because the material being processed is hard, the abrasive action is great, and the cutting speed is great.

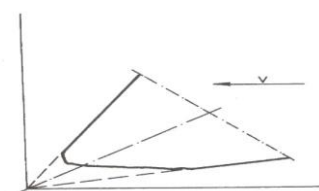


Fig. 1.
Consumption of the back surface.

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

Chest surface consumption is a consequence of the friction between this surface with chips. Consumption increases with increasing cutting speed and chip thickness. Depending on the working regime, the consumption of the chest surface can be observed in two forms: deformations on the chest surface and the appearance of the crater on this surface.

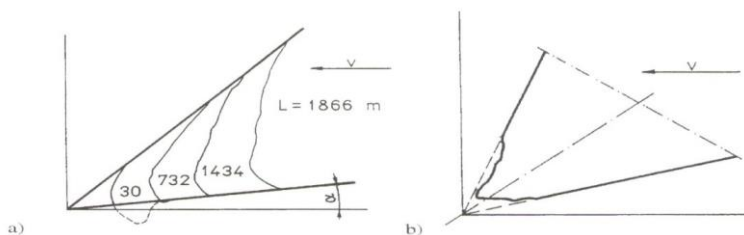


Fig. 2.
Forms of consumption of the chest surface.

On Fig. 2., forms of consumption of the chest surface have been presented: deformities on the surface of the chest and appearance of crater in this surface.

Consumption of edges of the blade 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 .

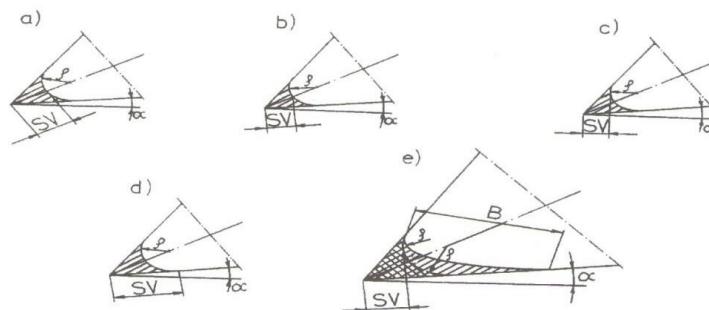


Fig. 3.
Possible forms of blade edge consumption.

Fig. 3., depicts the consumption of the blade, in the form of growth of the range of the cutting blade and possible forms of consumption.

Even though at the first glance we point out wood cutting and processing, compared to other materials seems easier, in reality it presents a quite complex process because of its anisotropy and heterogeneous composition (Lato and Quku 2008), which many scientists dealt with.

Methods of cutting tool radius wear

Amongst the main methods of testing blade consumption, in terms of duration, two groups are identified:

- **indirect methods,**
- **direct methods,**

The **indirect methods** are used for definition of wearing using measurement of another value connected to a tool wearing and having similar course e.g. cutting force, cutting power, cutting length, cutting speed, etc. The indirect methods do not inform about change of a cutting edge profile. The direct methods are divided into two groups as following:

- **First group of direct methods** - there are methods based on measurement of removed material (weighting method, the method of stamps). The methods of this group do not describe completely the cutting knife wearing, because they do not define its geometry.
- **Second group of direct methods** - there are microscopic methods based on measurement of linear dimensions chosen characteristics of a cutting knife wearing. The methods of this group describe changes in geometry of a cutting knife, e.g., decrease of a cutting-edge SV, radius of a fillet on a cutting edge r , wearing along the cutting face VF, wearing along the back part VB, width of abrasion S, KT - depth of a on a cutting face, KV - dimensional wearing.

There are many methods of this group, which are used:

- **Weighting method** - it's consisting of a measurement on very accurate scales. The weight a tool is measured before and after machining. The weight difference is a wearing. The disadvantage of this method does not give information of real cause of wearing.
- **Using a scale beam** - the scale is given on a cutting knife, which is vertically divided into two parts. Deflecting a cutting knife about a certain angle changes the position of the gravity center from the supporting point. It deflects a scale beam about an angle γ . This way is possible to define an amount of wearing.

Other methods on second group are and: **method of a cross section; method of a light beam; method of cutting quality change; method of fuel consumption change; method of change of tool temperature** and method of:

- **Measurement of a profile by a profilograph and profiloprojector** - It uses a software NIS - elements for measuring the value of wearing.
 - **Contact way**, this method based on measurement of a profile by a measurement needle. It analyses the signal and draws a shape of a cutting edge.
 - **Contactless way.**
 - **Using automatic profilometer.**

All these methods are very similar. On the basis of one parameter change we define the value of another parameter. A wood type and its properties, cutting model and so on can influence cutting quality.

MATERIALS AND METHODS

The direct method for measurement of cutting knife, used in our experiment is using automatic profilometer. The device used consist of a mocroscop and digital camera called measuring Nikon NEXIV VMR-3020. The camera was controlled by 3D softwer. The softwer is focused on high performance and fluent course of experiments. It is able to record and display multidimensional pictures in six dimensions (X,Y,Z, wave, length, time, multipoint), which is shown in tebles after muesuring.

Cutting CNC machine used for experiment

Cutting CNC machine is used for our experiment is Holzma HPP 350/4300, main saw motor power of 9kW(13.5kW option), with optimisation program, softwer CADmatic 4.0, constant speed range n of 5500(rpm), possibility feed rates $V_f = 5-130\text{m/min}$.

Cutting condtions

Cutting and feed rate values are based on the relations between tooth feed value, cutting speed, tool speed and cutter diameter (Chladil *et al.* 2019). In our case: feed rates $V_f = 5-130\text{m/min}$, in our case 28.1m/min , constant feed tool ($f_z = 0.023\text{mm}$). The cutting speed (v_c) determined by Eqs. 1 and 2 (Chladil *et al.* 2019) $v_c = \pi \cdot D \cdot n / 10^3 [m \cdot \text{min}^{-1}]$ (1) and feed rate v_f was calculated by Eqs. 2. $V_f = f_z \cdot z \cdot n [mm \cdot \text{min}^{-1}]$ (2). In this type of cutting CNC machines n is constant, is different on CNC three dimensional machines, when is possible to change rotation speed of the milling cutter.

Table 1

Parameters of cutting regime for experiment

Parameters	Value
Diameter of circular saw D(mm)	350
Number of teeth z	72
Feed per tooth f_z (mm)	0.023
Cutting speed v_c ($m \cdot \text{min}^{-1}$)	100.74
Speed range n used (rpm)	5500
Feed rate v_f ($mm \cdot \text{min}^{-1}$)	9108
Material thickness h (mm)	18
Masurement of tool wear sawing in minutes	0, 60, 180, 300

Instruments of testing equipment

Among the cutting tools of the CNC sawing machine, is the one shown in Fig. 4, which serves as the cutting tool for sawing the laminated particleboards at this machine, the main cutting disc (blade) with the following parameters is used: $\text{Ø}350 \times 4.4 \times \text{Ø}60$, $Z = 72$ teeth, with the possibility of rotation 5500/min, with two side holes $\text{Ø}Y = 14\text{mm}$ and distance between them $X = 100\text{mm}$. Also presented is the shape of the teeth of the main blade, their angles, and the way of their placement, as well as the types of materials to which these blades are dedicated. The most suitable profile of the saw blade for cutting laminated particleboards is the flat trapezoidal tooth.



Fig. 4.
Presents the blade as a sawing tool.

Table 2

The initial geometry of the saw blade instrument as well as the composition of the material

Basic dimensions	Disc saw diameter D (mm)	Disc teeth thickness B (mm)	Back angle α (°)	Chest angle γ (°)	No. of teeth	Composition of the material of instrument	Speed of rotation rot/min
Disc for sawing	350	4.4	15°	10°	72	Hard metals - hard sintered carbides from Wolfram 93.5%, cobalt 6% and tantalum-carbon 0.5%	5500

Measurements and measuring tools

With the direct method it is possible to achieve very accurate results, especially on changing the geometry of the tool after certain stages of work. We have used this method with very advanced apparatus, called measuring Nikon NEXIV VMR-3020.

CNC Video measuring System, CNC through which it is measured and then the new geometry of cutting instrument is created, because of deformations suffered, 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 300mm and laser measurements with high precision. With ideal equipment in general, the measuring coordinating 3D system, with dimensions of 300x200x150mm 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.

Device for measuring the range of consumption cutting tool, Nikon NEXIV VMR-3020 CNC Video measuring System.

Installing the blade of the cutting tool in the form of a disc for sawing, measuring tool wear radius, in our case.

RESULTS AND DISCUSSION

From direct measurements we obtain the results of the consumption of the blade radius of the tool, it is clearly observed that with the increase of consumption the radius of the blade of the cutting tool also increases.

Table 3, gives the details of the position of the cutting blade during the measurement, as seen in Fig. 5, presented in Fig. 6, the measuring device is three-axis CNC, where the base of the measuring table is 300x200mm, while during the measurement the position of the cutting tool blade is in these coordinates:

x=122.48mm, y=126.49mm and z=3.33mm), and what is most important, in the RAD note 0.007mm or 7µm, give the initial radius of the tip of the blade.

Table 3

Processed results of the cutting-edge radius condition of the cutting tool, after 0 minutes of effective work (initial condition)

Condition of the cutting blade	Effective work in t minutes	Consumption radius in µm	Corrective factor of consumption c	Position of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Sharpness	0	7	1	122.48	126.49	3.33



Fig. 6.

The edge of the cutting tool blade, when measuring in the apparatus, in the first position - sharpened, presented in Tables 2.

Table 4, gives the details of the position of the cutting blade during the measurement, as seen in Fig. 1, presented in Fig. 7, the measuring device is three-axis CNC, where the base of the measuring table is 300x200mm, while during the measurement the position of the cutting tool blade is in these coordinates: x=130.12mm, y=166.25mm and z=3.28mm), and what is most important, in the RAD note 0.017mm or 17µm, the radius of the tip of the blade is given after 60 minutes of effective work.

Table 4

Measurement of tool wear after 60 minutes of effective working time, Cutting speed $v_c = 100.74(m \cdot min^{-1})$, based in Eqs. $\Delta r = r - r_o [\mu m]$, the change the initial radius is $\Delta r = 10[\mu m]$

Condition of the cutting blade	Effective work in t minutes	Consumption radius in µm	Corrective factor of consumption c	Position of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Sharpness	60	17	1.1	130.12	166.25	3.32

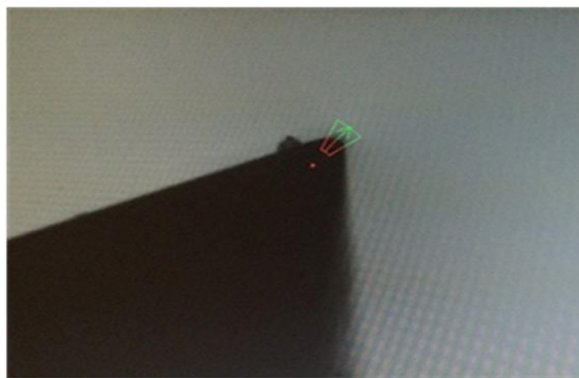


Fig. 7.

The edge of the cutting tool blade, when measuring in the apparatus, in the second position - medium sharpened, from the results presented in Tables 4.

Table 5. gives the details of the position of the cutting blade during the measurement, as seen in Fig. 1 above, presented in Fig. 8, the measuring device is three-axis CNC, where the base of the measuring table is 300x200mm, while during the measurement the position of the cutting tool blade is in these coordinates: $x=116.43\text{mm}$, $y=146.72\text{mm}$ and $z=4.29\text{mm}$, and what is most important, in the RAD note 0.029mm or $29\mu\text{m}$, give the radius of the tip of the blade.

Table 5

Measurement of tool wear after 180 minutes of effective working time, Cutting speed $v_c = 100.74(\text{m} \cdot \text{min}^{-1})$, based in Eqs. $\Delta r = r - r_0 [\mu\text{m}]$, the change the initial radius is $\Delta r = 12[\mu\text{m}]$

Condition of the cutting blade	Effective work in t minutes	Consumption radius in μm	Corrective factor of consumption c	Position of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Sharpness	180	29	1.2	116.43	146.7	4.29

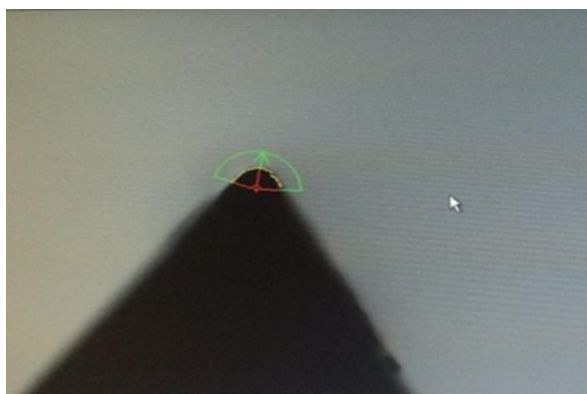


Fig. 8.

The edge of the cutting tool blade, when measuring in the apparatus, in the third position - visibly consumed, from the results presented in Tables 5.

Table 6, gives the details of the position of the cutting blade during the measurement, as seen in Fig. 1 above, presented in Fig. 9, the measuring device is three-axis CNC, where the base of the measuring table is 300x200mm, while during the measurement the position of the cutting tool blade is in these coordinates: $x=89.06\text{mm}$, $y=140.30\text{mm}$ and $z=4.24\text{mm}$, and what is most important, in the RAD note 0.033mm or $33\mu\text{m}$, give the radius of the tip of the blade.

Table 6

Measurement of tool wear after 300 minutes of effective working time, Cutting speed $v_c = 100.74(m \cdot min^{-1})$, based in Eqs. $\Delta r = r - r_0 [\mu m]$, the change the initial radius is $\Delta r = 4[\mu m]$

Condition of the cutting blade	Effective work in t minutes	Consumption radius in μm	Corrective factor of consumption c	Position of the cutting instrument blade during measuring on the apparatus plate		
				Axis X (mm)	Axis Y (mm)	Axis Z (mm)
Sharpness	300	33	1.2	89.06	140.30	4.24

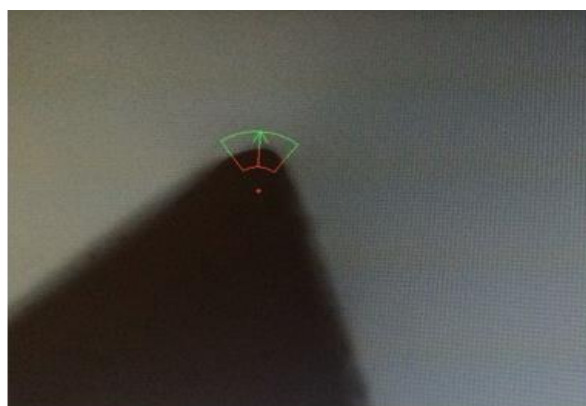


Fig. 9.

The edge of the cutting tool blade, when measuring in the apparatus, in the third position - consumed, from the results presented in Tables 6.

CONCLUSIONS

A summary of the results from measurements of tool wear after 60, 180 and 300 minutes of effective working time, Cutting speed $v_c = 100.74(m \cdot min^{-1})$, is presented in Table 7, for cutting the laminated particleboard, based in Eqs. $\Delta r = r - r_0 [\mu m]$.

Table 7

Presents the ranking relation of the state of the radius of the cutting edge, after t minutes, from the measurements made.

Condition of the cutting blade	Effective work in t minutes	Technological operation	Laminated particleboard		
			Consumption radius r in μm	The change the initial radius $\Delta r = [\mu m]$	Corrective factor of consumption c
Sharpened	0	Sawing	7	0	1
Medium sharpened	60	Sawing	17	10	1.1
Significantly consumed	180	Sawing	29	12	1.2
consumed	300	Sawing	33	4	1.2

Judging from experience, in the whole, but also based on studies of many different authors, the accurate determining of consumption of the radius of the cutting blade with indirect method (Kovač and Krilek 2011), is very difficult or even impossible. In our case we have applied the most advanced technology for such a thing, so we are giving some conclusions:

- The need to determine the level of consumption is related to determining the cutting regime, because operators of CNC machines that use cutting tools, due to the volume of work, should know that from the beginning of effective work, in stages such as in the above tables (Ymeri *et al.* 2015).

- By making direct measurements, in all cases when we work with cutting tools, composed of the same material, as well as with other same tools, as in Fig. 1, and with the same raw material, respectively particle boards, then we are sure in the time after the minutes "t" which state of blade consumption we have.

- This regime of cutting helps in a tendency for cutting ideally by the operators, given the high price in equipment, tools and raw material.
- No doubt that the permanent tendency for ideal cut saves: raw material, electrical energy, absorption of tools and machines, it also saves labour force, which is expensive to CNC machines (Ymeri 2015, Ymeri *et al.* 2015).

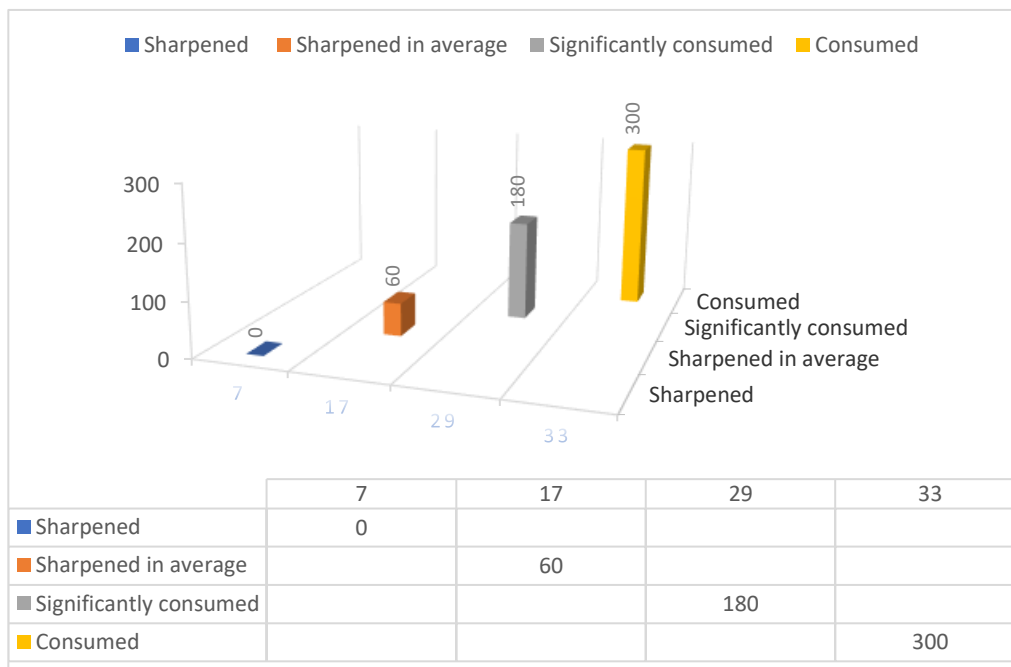


Fig. 10.
Graphic presentation of data from the Table 6.

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