2025. Volume 9, Number 1 *Pages 29-37*

UOT: 621.91; 621.923; 621.95; 684.4
DOI: https://doi.org/10.30546/09085.2025.01.015

FEATURES OF DEFORMATİON OF DİSC CUTTER TEETH IN PROCESSİNG RECTANGULAR GROOVES ON CHİPBOARD

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ARTICLE INFO

Article history:
Received: 2025-03-05
Received in revised form: 2025-03-05
Accepted: 2025-04-02
Available online

Keywords: rectangular grooves; deformations; runout, cutting forces; wood materials.

JEL Classification: L60, O33

ABSTRACT

This paper presents the deformation of the teeth of disk cutters when milling rectangular grooves on chipboards depending on the processing modes. Since, depending on the cutting modes of the grooves, a significant cutting force occurs, under the influence of which deformations of the cutting teeth occur in the direction parallel to the axis of the cutter, which affects the quality of manufacturing rectangular grooves and the choice of the allowance for sharpening the teeth of the cutter. And, to develop a new technology for sharpening disk cutters, ensuring with minimal removal of the allowance, the identity of the tool profile and the elimination of its runout.

I. INTRODUCTION

Wood materials are widely used in the production of furniture for various consumer purposes, with chipboard being the leading material. Depending on the furniture design, grooves of various shapes and geometric dimensions are milled on wood boards. Most often, rectangular grooves with a depth of up to 10 mm are milled on chipboard boards. Milling rectangular grooves on chipboards uses disc cutters with different diameters and numbers of teeth. Rectangular grooves 3–10 mm wide and up to 10 mm deep are milled with disc cutters with a diameter of 100–125 mm and a count of teeth is 24.

The deformation of the cutting teeth of the cutter, along with other factors, largely depends on the choice of the tool body material. The body of the disc cutter of the KÖNİG brand, type WZ TUNGSTEN HARTMETALL with a diameter of 100 mm, having 24 teeth, which is used for cutting rectangular grooves on furniture parts, produced according to GOST 14959-79 or to GOST 5950-73, the disk hardness is 40-45 HRCэ. The material of the cutting part of the disk cutters is made according to GOST 3882-74. The shape and dimensions of the carbide plates choosen according to GOST 13833-77. The thickness of the cutter is 3.0 mm. Carbide plates of various shapes are soldered to the top of the teeth of the cutter body, after which the cutter is sharpened and the necessary geometry is ensured [5].

When milling grooves wider than 3 mm, the cutter forms it in several passes. During the first pass, the cutting teeth of the cutter on the front, rear and both end surfaces at a high rotation speed (20–100 m/s) contact the processed wood material and chips are formed. Such a pattern of contact of the teeth of disk cutters creates complex contact and force pressures on their surfaces. Therefore, at a high cutting speed, large forces arise that affect the deformation of the cutting teeth [6].

It is known that [1] in the production of furniture using wood-based materials, which are made by pressing plasticized and glued laminated mass in the form of chipboard and MDF. Therefore, when processing such materials, the deformation of the teeth of disk cutters depends on their structure and indicators of physical and mechanical properties. Since, depending on the properties of wood, the density of its structure and humidity significantly fluctuates within wide limits. Therefore, the teeth of disk cutters when milling rectangular grooves under the influence of cutting forces are subject to uneven deformation, leading to beating of the cutting tool. Analysis of the process of milling rectangular grooves with disk cutters shows that the cutting teeth of the cutter when processing chipboard are also subject to varying degrees of wear both cutting edges and on the front and back surfaces of the tool. Uneven wear of the cutting teeth leads to a change in the nature of the cutting forces, its direction, action, and trajectory, which differently affect the resulting deformations of the cutting teeth of the cutter [7].

It is known that wood materials subjected to milling have a pronounced parallel-layered structure, in which the anisotropy of mechanical properties acts on the cutting tool in two directions, i.e., parallel, and perpendicular to the planes. Therefore, when milling chipboard, its non-uniform structure leads to varying degrees of wear of the working surfaces of the cutter, under the influence of which the wear and deformation of the cutting teeth of the cutter separately differ from each other. Based on the research work carried out on milling rectangular grooves on chipboard, it was found that the study of the deformation of the cutting teeth of the cutter when processing rectangular grooves will allow us to establish the direction of reducing the deformation of the cutting teeth of the cutter to improve the quality of the processed groove [2].

II. RESEARCH METHODS

The experimental study was conducted at the furniture factory "HASANOGLU" on a machining center with a CNC portal "profi line BHT 500", the processing was carried out with KÖNİG brand cutters, type WZ TUNGSTEN HARTMETALL with a diameter of 100 mm and 24 teeth. The dimensions of the milled groove were hxb = 10x3.0 mm, the grooves were milled with a length of 50,000 m. The depth on each pass was 5 mm. The longitudinal feed rate was taken as S_{feed} = 12 m/min (S_0 = 125 mm/tooth), the rotation speed of the cutter was 20 m / s. The milling power was measured using a special setup consisting of an ACTDN24685 wattmeter, a UTT5 type current transformer and an additional resistor DV30 μA, 5000 Ohm. After measuring the milling power of chipboards, the cutting force P_z is calculated and, on its basis, the forces P_y and P_x are calculated [24,25,26,27,28].

The method of measuring the deformation of individual teeth on the side surfaces, i.e. in the axial direction of the cutter, is that the cutter is installed on the shaft of a special installation, which is shown in Fig. 1,

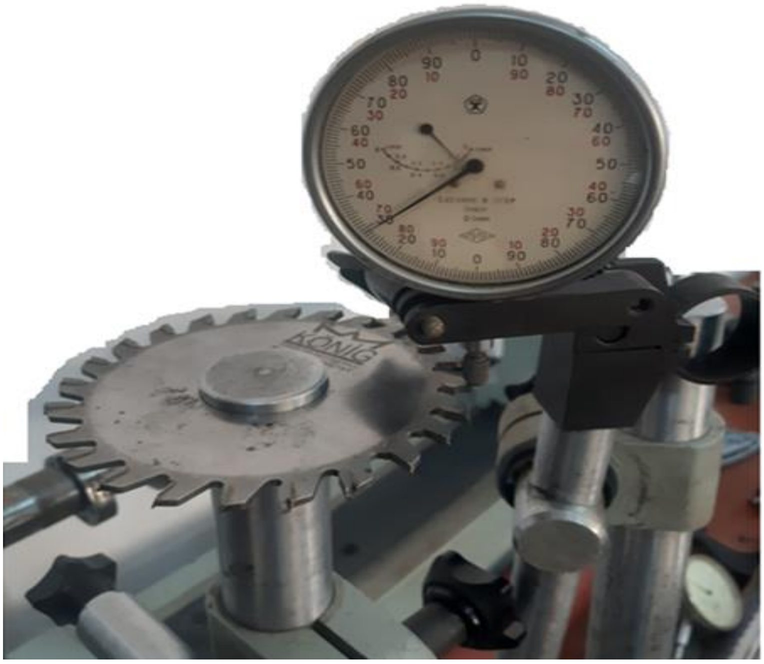

Fig.1. Device for measuring the deformation of the teeth of a disc cutter

and an indicator with micron accuracy, fixed on a tripod, touches the side surface of one tooth, the indicator readings are set to zero, after which the cutter is turned to the next tooth and the indicator measures the magnitude of its deformation. In this case, the difference in the indicator readings when measuring the next teeth is applied to the table and their deformation is calculated. After measuring the deformation of all teeth, the runout of the disk cutters is calculated to develop a technology for sharpening the cutter teeth [3,9,11]. (fig. 1).

As is known, when processing rectangular grooves with disk cutters, the cutting teeth are affected by the cutting forces that arise during the chip formation process. In this case, the cutting teeth of the disk cutters form chips within the rectangular grooves, a process that occurs in a closed milling condition. In this case, the position of the processed surface and the feed direction relative to the wood fibers are along the fibers. The scheme of milling rectangular grooves with a milled disk cutter on a machining center with a CNC portal "profi line BHT 500" is shown in Fig. 2, from which the tangential (tangent) cutting force P_z at point "0" acts along the front surface of the cutting teeth of the cutter, where the chip is formed. In this case, a normal cutting force P_y arises, which is directed perpendicularly to the cutting surface along the vertical axis of the cutter. The force P_x, which is the axial cutting force, acting along the horizontal axis of the cutter, depending on the anisotropy of the cut wood, affects the end surfaces of the cutting teeth and leads to the appearance of deformation of the cutter teeth in the axial direction (O - O) [18,19,20,21,22,23].

Since when processing rectangular grooves on chipboards, the workpiece is installed and secured on the machine table and the spindle with the tool, along with the rotational movement, performs longitudinal feed, therefore, the accuracy of the formed surface and the dynamics of the process are affected not only by the cutting forces, but also by the kinematic movements of the spindle unit of the machine. As noted above, the deformation of the cutting teeth of disk cutters when processing rectangular grooves on chipboards occurs due to the kinematics of the rotational and longitudinal movement of the machine spindle [8,13,14,15,16,17].

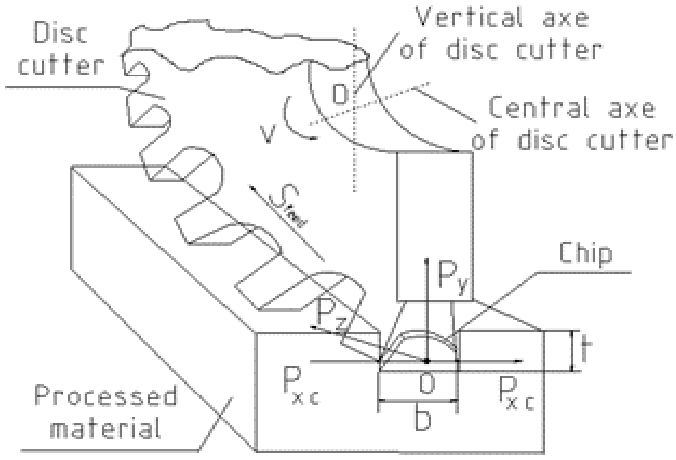

Fig. 2 Scheme of milling rectangular grooves on the machining center with CNC portal "profi line BHT 500" (the drawing was made using the LibreCAD program)

It is known that when processing rectangular grooves on furniture parts, the cutting teeth of disc cutters are affected by the cutting force "P", which consists of the following components: tangential (tangent) P_z, radial P_y and axial P_x. Considering these components of the cutting forces, the total cutting force "P" when milling with a disc cutter can be determined from the following equation [10,12]:

$$P = \sqrt{P_x^2 + P_y^2 + P_z^2},\ N \qquad (1)$$

Analysis of the process of milling rectangular grooves shows that depending on the cutting depth, the length of the arc of contact of the cutter with the surface being machined changes. Depending on the length of the arc of milling L (Fig. 3) and the depth of groove processing, the number of teeth simultaneously participating in the milling process will be different. Therefore, the value of the tangential force P_z will be determined by the following formula [4]:

$$P_z = P_{zt} * z_{cut.} \qquad (2)$$

where, P_{zt} – tangential force acting on one tooth of the cutter,

$z_{cut.}$ - the number of simultaneously cutting teeth.

$z_{cut.}$ – can be determined from the following formula:

$$z_{cut.} = \frac{L}{t_{teeth}} \qquad (3)$$

t_{teeth} – the value of the axial pitch of the teeth.

Arc length at milling rectangular grooves we determine from Fig. 3 as follows [4,8,9]

$$L = \frac{2\pi R}{360} * (\varphi_{cont} + \varphi_{out}) \qquad (4)$$

where, φ_{cont} – contact angle of the tooth of the disk cutter

$$\varphi_{cont} = \varphi_{out} - \varphi_{in} \qquad (5)$$

φ_{in} – angle of tooth entry into the material

φ_{out} – angle of tooth exit from the material.

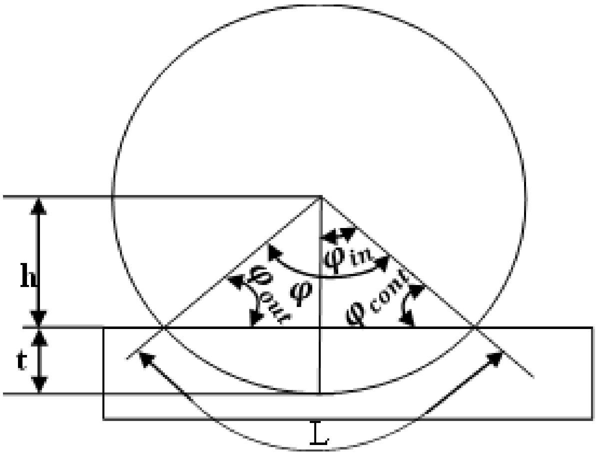

Fig. 3 Parameter diagram for cutting rectangular grooves.

III. RESEARCH RESULTS AND THEIR DISCUSSION

A rectangular groove on chipboard is milled with a disc cutter with a diameter of 100 mm, the number of teeth is 24. Considering the parameters of the cutter, the following can be calculated:

$$t_{tooth} = \frac{\pi D}{z} = \frac{3.14 * 100}{24} = 13.08mm$$

$$\varphi_{in} = arccos\frac{h}{R} \qquad (6)$$

where h – is the distance from the center of the disc cutter to the processing surface

$$h = R - t \qquad (7)$$

where, t – milling depth, mm

R – cutter radius, mm.

When processing rectangular grooves, t=10mm is taken, while

$h = 50 - 10 = 40$ мм

then from here $\varphi_{in} = arccos\frac{40}{50} = arccos0{,}8\varphi_{in} =$

$$= 36{,}87°$$

Also $\varphi_{out} = arccos\frac{h-t}{R} = arccos\frac{40-10}{50} =$

$$= arccos0{,}6 = 53{,}13°$$

We determine the number of cutting teeth simultaneously involved in cutting as follows:

$$z_{cut} = \frac{L}{t_{tooth}} \qquad (8)$$

where L is the length of the contact arc

$$L = \frac{2\pi R}{360} * (\varphi_{cont} + \varphi_{out}) == \frac{2 \cdot 3{,}14 \cdot 50}{360} * (53{,}13 + 16{,}26) == 0{,}8722 \cdot 69{,}39 = 60{,}523 \text{ мм}$$

Then $z_{cut} = \frac{60{,}523}{13{,}08} = 4{,}63$ tooth is taken as 5 teeth.

Thus, when processing chipboards with cutters of 100 mm diameter, with a processing depth of 10 mm, 4.63 teeth are simultaneously involved in cutting. We determine the quantities tangential (tangent) cutting force on the arc of contact. We determine the average tangential force on the arc of contact of the blade with the workpiece F_{xt} and the average cyclic F_{xy}:

$$F_{xt} = F_{x1} \cdot b \cdot a_{cor.} \qquad (9)$$

where, F_{x1} is the tabular tangential force for particle boards, a_{med}=0.16; density of chipboard is 700 kg/m^3, F_{x1}=8.1 N/mm^2 [4].

b – milling width per pass, equal to 3 mm,

a_{cor} – general correction factor, determined from the following equation [4]:

$$a_{cor.} = a_{tw} * a_w * a_\rho * a_\delta * a_v * a_t \qquad (10)$$

where a_{tw} –correction factor for the type of wood used to make the particleboard (on average, we take it equal to 1)a_{tw}=1;

a_w – correction factor for particleboard humidity (with humidity of 5-8% equals 0.9) a_w=0.9

a_ϱ – correction factor for blade dullness, a_ϱ = 1.7

a_δ – correction factor for the cutting angle, a_δ = 0.86

a_v – correction factor for cutting speed, a_v = 1.07

a_t – correction factor for the processing depth, a_t = 0.8

Thus $a_{cor} = a_{tw} * a_w * a_\rho * a_\delta * a_v * a_t = 1 *$

$$* 0{,}9 * 1{,}7 * 0{,}86 * 1{,}07 * 0{,}8 = 1{,}1263$$

$F_{xt} = F_{x1} \cdot b \cdot a_{cor} = 8{,}1 \cdot 3 \cdot 1{,}126 = 27{,}362$N

Total tangential cutting force is

$F_{xy} = F_{xt} * z_{cut} = 27{,}362 \cdot 5 = 136{,}81$N

F_{xy} – cutting forces are designated as the total tangent force equal to P_z. Then the normal cutting force during groove milling can be determined from the following equation

$$P_y = P_z * cos\varphi_{out} = 136{,}81 * cos53° = 136{,}81 *$$

$* 0{,}6018 = 82{,}333$N

The axial force when milling a rectangular groove 3 mm wide will be:

$P_x = P_z * cos\varphi_{in} = 136{,}81 * cos37° = 136{,}81 \cdot 0{,}7986 = 109{,}261$N

Thus, the total cutting force coming per 1 mm^2 of area during milling will be

$$P = \sqrt{P_z^2 + P_y^2 + P_x^2} == \sqrt{136{,}81^2 + 82{,}333^2 + 109{,}261^2} == \sqrt{18716{,}9761 + 6778{,}722 + 11937{,}966} =$$
$$= \sqrt{37433{,}664} = 193{,}478\ N$$

If we take into account that rectangular grooves with a width of 3 mm and a depth of 10 mm are milled, at the same time in this case the total area of the cut layer was . Based on this, when cutting a given groove, the cutting forces that arise will be: $P = b \cdot t = 3 \cdot 5 = 15\ mm^2$

$P_0 = P \cdot b \cdot t = 193{,}478 \cdot 3 \cdot 5 = 2952{,}17$ N

We calculate the total cutting forces proportionallyP_{ztot}, P_{ytot} and P_{xtot}

$P_{\text{ztot}} = P_z \cdot b \cdot t = 136{,}81 \cdot 3 \cdot 5 = 2052{,}15$N

$P_{\text{ytot}} = P_y \cdot b \cdot t = 82{,}333 \cdot 3 \cdot 5 = 1234{,}95$N

$P_{\text{xtot}} = P_x \cdot b \cdot t = 109{,}261 \cdot 3 \cdot 5 = 1638{,}93$N

As noted above, under the influence of cutting forces, the cutting teeth of disc cutters are subject to deformation, which increases the runout of the cutter, which has a negative impact on the quality and accuracy of the cuts. rectangular grooves. The deformation value of individual teeth of the disk cutter in the direction of its axis was investigated. The results of the deformation measurement of all teeth of the cutter are shown in Table 1.

Table 1. THE VALUES OF DEFORMATION OF THE TEETH OF A DISC CUTTER

Parameters of a disc cutter		Parameters of a disc cutter	
Teeth No.	The magnitude of deformation, microns	Teeth No.	The magnitude of deformation, microns
1.	0	13.	44
2.	12	14.	8
3.	16	15.	-9
4.	20	16.	25
5.	-8	17.	-33
6.	-40	18.	-11
7.	30	19.	41
8.	40	20.	-8
9.	23	21.	-2
10.	-21	22.	2
11.	30	23.	5
12.	-40	24.	-4

The measurement scheme is shown as graph in fig4.

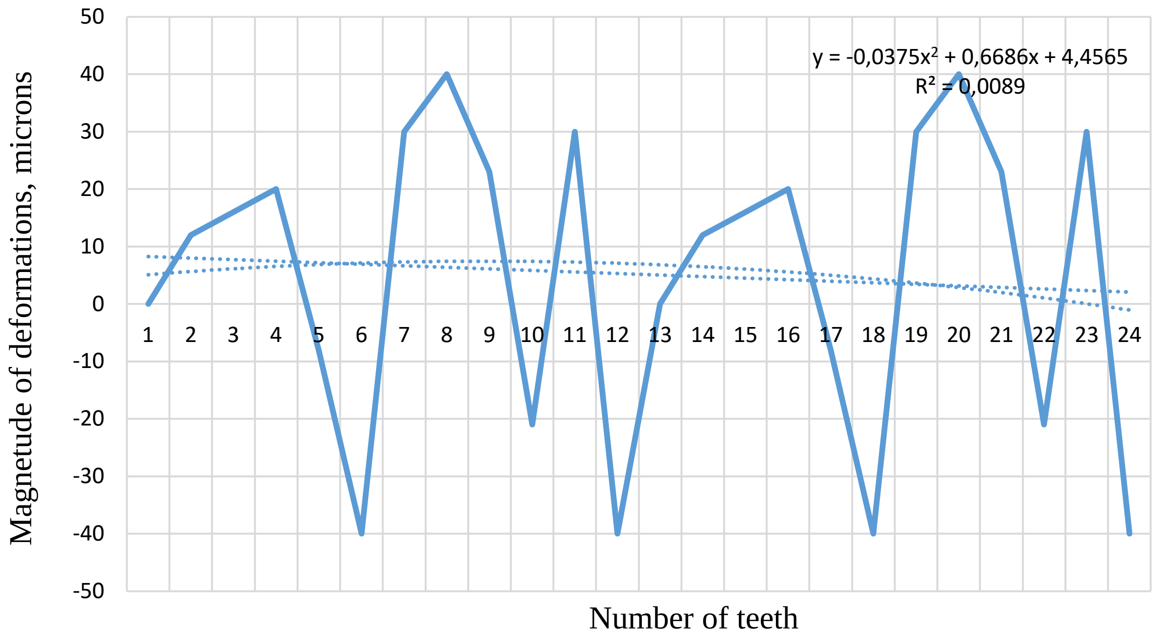

Fig4. The measurement scheme of deformation

IV. CONCLUSION

1. It has been established that when processing rectangular grooves on chipboard, the deformation of the cutter teeth along the axial direction of the tool is uneven, which shows the complexity of the process of milling wood materials, which is associated with the kinematics of the cutting process, the influence of cutting forces and the properties of the cutter material, etc.

2. When processing rectangular grooves with disk cutters, it was found that the size and signs of deformation of the cutting teeth of the cutter require the development of a new technological process for sharpening the tool to ensure the identity of the profile and eliminate the runout of the cutter, ensuring the milling of rectangular grooves with the required accuracy of the product.

ACKNOWLEDGMENT

Authors deeply thankful to managers and workers of "HASANOGLU" firm, for their support on technical areas of the furniture producing plant.

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