Investigation of the influence of certain factors on the quality of processing during hard grinding

A Sergeevich*1, N Belonogova1, V Sergeevich1, V Byzov1 and A Mikhailova2

1Department of the Applied Mechanics and Engineering Graphics, Saint-Petersburg State Forest Technical University, 5 Institutskiy Lane, Saint-Petersburg 194021, Russian Federation
2Department of the Economics, Accounting and Analysis of Economic Activities, Saint-Petersburg State Forest Technical University, 5 Institutskiy Lane, Saint-Petersburg 194021, Russian Federation

*Corresponding email: 910sav@gmail.com

Abstract. The surface roughness of wood products has a direct impact on many technological and operational properties of parts as a whole and is an important production factor, which is associated with the consumption of materials and the technical and economic efficiency of many technological operations such as gluing, grinding, varnishing, etc. We must not forget about the aesthetic properties of wood - reflective and absorbing ability, which is directly affected by surface roughness. The urgency of the problem of obtaining the required quality of the treated wood surface is now becoming increasingly important in connection with the increasing requirements for the quality of woodworking products and obtaining the greatest economic effect for the enterprise. A polished surface is formed as a result of the simultaneous action of many factors. The main ones are geometric factors, plastic and elastic deformations that accompany the grinding process. From a geometric point of view, the roughness is created due to the copying of the path of the cutting tool of a certain geometric shape on the wood surface. Plastic and elastic deformations occurring during the cutting process strongly distort the microrelief resulting from the action of geometric factors.

1. Introduction
One of the most important characteristics of the sandpaper as a cutting tool is the amount of free intergranular space [1-4]. It is known, that the chips cut off from the product during grinding must be located in the depressions between the protruding parts of the abrasive grains. Domestic and foreign researchers note that the salting of the sandpapers occurs due to overflow of intergranular cavities with chips [5-11]. The quality of processing is characterized by the roughness of the treated surface and the accuracy of the dimensions of the product.

2. Methods and Materials
The process of material removal during grinding of wood can be represented as separate volumes of material turned into chips with one square centimeter of an abrasive tool. When machining with a cylindrical grinding tool, this volume has the shape of a chip obtained when milling. The horizontal section of such a volume is equal to the feed per 1 cm² of abrasive tool (Uz) with a feed angle of 90°. Reducing the feed angle at a constant feed rate leads to the fact that the thickness of the removed chips...
decreases, tending to zero (figure 1), and with a constant thickness of the removed chips, the feed speed increases, tending to infinity (figure 2).

When processing with a flat-shaped grinding tool, the volume of material turned into chips with one square centimeter of an abrasive tool at a feed angle of 90° is a rectangular prism whose length is equal to the width of the workpiece, height - depth of cut and width - feed per 1 cm² (figure 3). The change in the thickness of the removed chips and the feed rate when changing the feed angle has the same dependence.

![Figure 1](image1.png)  ![Figure 2](image2.png)

Figure 1. The effect of the feed angle on the thickness of the cut chips with a constant supply of the workpiece.

Figure 2. The effect of the feed angle on the feed rate of the workpiece at a constant thickness of the removed chips.

Let us consider schematically the process of formation of the roughness of the processed surface and the accuracy of processing during hard grinding with a sandpaper of wood products.

A polished surface is formed as a result of the simultaneous action of many factors. The main ones are geometric factors, plastic and elastic deformations that accompany the grinding process. Consider the formation of the surface roughness of the grinding parts. From a geometric point of view, roughness is created due to the copying of the path of the cutting tool of a certain geometric shape on the wood surface to be treated. Plastic and elastic deformations occurring during the cutting process strongly distort the microrelief resulting from the action of geometric factors.

Let us consider the geometric pattern of the formation of the surface roughness of wood products during hard grinding with a sandpaper. Unlike milling, in which there is a solid cutting line, there is no solid cutting line when grinding. Figure 3 shows part of the contact surface of the sanding belt with the workpiece.

In the process of cutting, abrasive grains of the sandpaper remove elementary chips with a section $Bl$ on the surface of the product, $B$ is the width of the chips removed by an individual grain, $l$ is the length of the chips. The number of grains involved in the cutting determines the number of chips removed from the surface of the product. To remove chips from the entire $H_1$ section, it is necessary that a certain number of grains be involved in the work. Imagine that abrasive grains (figure 4) began cutting wood. After moving the first row of grains a certain distance, the abrasive grains of the second row will come into operation, and after a while, the grains of the third row will come into operation. In some way, the grains of all rows will go through joint contact with the product, and then in the same order in which they started cutting they will begin to get out of contact. From the presented scheme it can be seen that on the surface of the product elementary areas are removed, offset from each other. To remove a certain layer of wood, continuous application of such scratches is necessary. The scheme examined the embedding of abrasive grains into a perfectly smooth surface. For the closest approximation to the actual chip formation process, it is necessary to consider the insertion of abrasive grains into a rough surface, and the grains themselves are randomly located on the surface of the grinding skin (figure 4). Grinding is a spatial phenomenon, not a planar one.
Figure 3. The effect of the feed angle on the thickness of the cut chips with a constant supply of the workpiece.

Figure 4. The geometric pattern of the formation of roughness of a polished surface. 1 - initial surface roughness before cutting; 2 - grinding sand; 3 - the first row of abrasive grains; 4 - the second (adjacent) row of abrasive grains; 5 - profile of the treated surface; $B$ is the width of the chips removed by a single grain, $l$ is the length of the chips.
In the contact zone, the treated surface is not in contact with only one row of abrasive grains, but with several. Let us consider the following example. With a product feed speed of 20 m / min and a contact grinding cylinder diameter of 120 mm, the sanding belt moves at a speed of 30 m / s. The length of the contact arc is 8 mm. The product will advance by 8 mm during 0.0004 min. During the same time, the grains of the sanding belt pass a path equal to 720 mm. This means that with an average distance between grains of 0.3 mm, 2400 rows of grains pass through the contact zone of the product, significantly reducing the height of the bumps created by the first row of abrasive grains (Figure 4). Obviously, the higher the speed of the sanding belt or the lower the feed speed of the part, the faster the roughness decreases and the more the belt grinding conditions approach the cutting conditions with a continuous blade.

If we mentally reduce all rows of abrasive grains (in our case 2400 rows) into one plane, then with some approximation we can assume that a cutting contour is formed, the irregularities of which are completely copied in the contact zone onto the surface to be treated. The smaller the irregularities of the cutting contour, the closer it comes to the solid cutting blade and the cleaner the surface will be. The same cutting contour can be created in various ways. Unambiguous factors in this sense can be considered an increase in the speed of movement of the sanding belt, a decrease in the number of graininess of the sandpaper and an increase in the time of abrasive action. Therefore, the more grains involved in the cutting, the cleaner will be the surface.

When forming the dimensions of products by hard grinding due to the limited rigidity of the “machine-tool-component” system, it is squeezed as a result of the action of cutting forces. In this regard, the actual thickness of the removed layer is slightly less than that set using the measuring tool. The increase in cutting forces as a result of uneven thickness of the layer to be removed, the heterogeneity of the wood, the wear of the skin, etc. increases the release in the system. Thus, there is an unsteady process of cutting wood, which reduces the accuracy of processing.

3. Results and Discussion
To increase the accuracy of processing, it is necessary to reduce the squeezing in the system. Reducing the squeezing is possible by increasing the rigidity of the technological system or reducing cutting forces. Cutting forces can be reduced by increasing the cutting speed or reducing the feed rate.

Typically, the machines use the maximum cutting speed, so the possibility of its increase is negligible. Reducing the feed rate or grit of the grinding tool leads to a decrease in processing performance. Therefore, it is advisable not to reduce productivity to divide the processing process into two stages:

1) The stage removal of allowance;
2) The stage of the final formation of the size of the part and the roughness of its surface.

The second stage is called the smoothing operation. During the through processing, smoothing may consist in re-passing the part through the machine, installing several aggregates one after another or supporting the sanding belt of a special design (figure 5). The design of the support allows you to divide the contact zone into two sections, on one of which the sanding belt removes the allowance, and on the other, the final size of the part and the roughness of the processed surface are finally formed. With positional processing, smoothing is carried out by establishing a special grinding cycle. The peculiarity of the cycle lies in the fact that at the end of processing, the supply of the part is turned off or slows down and the part is smoothed over time.

When smoothing by repeated passage of the part through the machine, the elastic system “machine-tool-component” returns to its original position. This reduces the spin in the system and with it the depth of introduction of abrasive grains into the treated surface. The same thing happens when smoothing in the case of positional processing. Smoothing by other methods is based on the fact that at the second stage of processing a layer of material of small thickness is removed. In this case, the cutting forces cause a slight depreciation of the “machine-tool-component” system, which allows to achieve high precision machining.
By using a sandpaper of lower grain size on the second and third grinding cylinders compared to the grain size of the skin on the first cylinder or by increasing the abrasive time of the grinding tool on the workpiece, we achieve high quality surface finish.

![Diagram of grinding process](image)

**Figure 5.** Hard grinding patterns with smoothing operation. 1 - grinding cylinder; 2 - workpiece; 3 - contact cylinder; 4 - sanding belt; 5 - ironing; 6 - inclined support of the sanding belt; 7 - horizontal support of the sanding belt.

4. Conclusions
The smoothing operation allows the hard grinding of a coarse-grained sandpaper with high processing performance and low rigidity of the system "machine-tool-component" to reduce the roughness of the treated surface and improve the accuracy of processing wood products.

References
[1] Onegin V and Bartashevich A 2016 Principal physics of gloss of the varnished wood. *Works of Belarusian State Technological University: Forestry and Woodworking Industry* [Trudy...
Belorusskogo gosudarstvennogo tekhnologicheskogo universitet: Lesnaya i derevooobrabatyvayushchaya promyshlennost – in Russian] vol 184 chapter 2 pp 225-229

[2] Gdalevich A 1994 Finishing with petal circles [In Russian: Final'naya obrabotka lepestkovymi krugami] (Moscow) p 112

[3] Bratan S 2000 Identification of parameters of removal at the combined grinding Progressive technologies and systems of mechanical engineering (Materials of the international collection of scientific works Donetsk: Donetsk state technological university) [Materialy mezhdunarodnogo sbornika nauchnyh trudov – in Russian] pp 24-32

[4] Ostrovskij V 1981 Theoretical basis of the grinding process [In Russian: Teoreticheskie osnovy processa shlifovaniya] (Leningrad) p 144

[5] Brinksmeier E et al 2006 Advances in Modeling and Simulation of Grinding Processes CIRP Annals -Manufacturing Technology vol 55 chapter 2 pp 667-696

[6] Cai G, Feng B, Jin T and Gong Y 2002 Study on the friction coefficient in grinding Journal of Materials Processing Technology vol 129 pp 25-29

[7] Sergeevichchev A 2015 The analysis of destruction of abrasive grains when grinding wood and wood materials Higher Institutions News: Forest Magazine [Izvestiya Vysshikh Uchebnykh Zavedenii: Lesnoj zhurnal – in Russian] vol 5 pp 7-15

[8] Carranoa A and James B 2005 Geometric Modeling of Engineered Abrasive Processes Taylor Journal of Manufacturing Processes vol 7 chapter 1 pp 17-27

[9] Sergeevichchev A and Semenov A 2018 The analysis of ways to increase the resistance of abrasive belts in the processing of wood and wood materials News of the St. Petersburg forest technical academy [Izvestiya Sankt-Peterburgskoj lesotekhnicheskoj akademii – in Russian] vol 222 pp 213-227

[10] Sanev V, Kamenev B and Sergeevichchev A 2018 Wood cutting [In Russian: Rezanie drevesiny] (St. Petersburg: Lan’) p 456

[11] Hromchak I 1996 Abrasive processing of plate materials on mineral binders [In Russian: Abrazivnaya obrabotkaplitnyhmaterialovnamineral'nyhvyazhushchihh](L'vov) p 47