

CUTTING FORCES WHEN GRINDING PARTS FROM MARTENSITE AGING STEELS WITH HIGHPOROUS ABRASIVE, BORAZON AND DIAMOND WHEELS

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ABSTRACT

Object of research. The article investigates the cutting forces when grinding martensitic-aging steels with highly porous grinding wheels.

The problem to be solved is the regularities of the change in the magnitude of the cutting forces when grinding maraging steels with highly porous CBN wheels.

Main scientific results. The studies were performed on martensiticaging steel H8K18M14. As a result of the experiments, it was found that when grinding wheels made of materials such as electrocorundum, CBN (borazon) and diamond, a significant role is played by the values of the cutting force, which increase during processing.

During the experiment it was found out: the cutting forces P_y and P_z in the width of the allowable modes, which are most often used in circular and flat grinding, can reach the following values: with the structure of the wheel 26 come to values from 2.714 N to 30.721 N and with the structure of the wheel 40 come to values from 2.49 N to 28.185 N. Reducing the grain size of the wheel, let's obtain the effect of increasing the energy costs of the grinding process, by increasing the magnitude of the cutting forces.

If to compare the cutting forces that occur when grinding different wheels, it is possible to note the following: in comparison with electrocorundum wheels when using wheels with KNB cutting forces are reduced by 20–25 %, and when grinding with diamond wheels, the effect of cutting forces is reduced by 25–30 %. When grinding with highly porous wheels, the cutting force is 15–20 % higher than when grinding with wheels of normal porosity.

The area of practical use of research results – grinding technology for maraging steels.

Innovative technological product – relationship between processing modes and the magnitude of cutting forces when grinding maraging steels.

Scope of application of an innovative technological product – mechanical engineering technology.

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1. Introduction

1.1. The object of research

The object of research is the process of grinding martensitic-aging steel.

Martensitic-aging steels are ultra-high-strength steel alloys, a special class of low-carbon steel, which demonstrate excellent strength and toughness compared to most other steels, but have the same ductility. Their strengthening is achieved by using elements that differ favorably from carbon: nickel, cobalt and molybdenum. These elements cause the dispersion hardening of the martensitic iron-nickel matrix during aging, hence the name of steels. Such steels can be used in machine building, aircraft construction, space technology. They go to the manufacture of rocket engine housings, aircraft chassis parts, stamped assemblies and fasteners.

Martensitic-aging steel differs from other steel alloys in that it is strengthened not by the presence of carbon, but by the deposition of a special set of other intermetallic compounds. The absence of carbon and the use of intermetallic precipitation allows martensitic-aging steels to achieve a combination of high strength and toughness while maintaining a relatively high ductility [1].

Martensitic-aging steels have their properties not because of carbon, but because of the deposition of intermetallic compounds in the aging process. The main alloying element, nickel, is from 15 to 25 % (by weight). Secondary alloying metals such as cobalt, molybdenum and titanium are added to produce intermetallic precipitates.

The use of martensitic-aging steel in industry: for products with high strength with sufficient ductility and toughness, high resistance to small plastic deformations, brittle and fatigue failure, which are used in mechanical engineering, instrumentation and tool industry.

Due to the low carbon content, martensitic aging steels are well processed. Before aging, they can also be subjected to cold rolling. Martensitic aging steels are well welded, but after welding must be re-aged to restore the original properties.

During heat treatment, the metal expands by a small amount, and therefore during its processing, the expansion is often not taken into account. Due to the high content of alloying additives, the steel has a high annealing. Because plastic martensites are formed during cooling, cracks are absent or insignificant. Steels can be nitrided to increase the hardness and subsequent polishing of the surface.

Stainless steel types of martensitic-aging steels have medium corrosion resistance. Corrosion resistance can be increased by cadmium plating or phosphating.

To obtain the exact size and the required surface roughness of parts made of martensitic-aging steels, a prerequisite will be the grinding operation.

1. 2. Problem description

At present, highly porous abrasive grinding wheels have become quite widespread.

In the manufacture of wheels and other abrasive tools between the individual particles of the abrasive and the ligament formed voids - pores. The internal structure, namely: the quantitative ratio and relative position of the grains, bonds and pores is called the structure of the grinding wheel. The most important characteristic of the structure of the circle is the volume of grains in the abrasive tool.

The role of the pore in the abrasive wheel is to create space for the placement of cut microchips. However, due to the small size of the "natural" pores, they perform their function satisfactorily only in light grinding modes, when the chip is small. At intensive modes, especially at deep grinding, and also at grinding of highly plastic materials – heat-resistant alloys on the basis of nickel, titanium and color alloys when the sizes and quantity of shavings grow, "natural" pores are not enough for placement of shaving which "sticks" on a circle surface. , leading to its salinity, and as a consequence, to a decrease in the cutting ability and stability of the circle. This shortcoming of standard circles was eliminated by creating highly porous circles on a ceramic bond.

Fig. 1 shows a comparison of the structures of ordinary (*a*) and highly porous (*b*) Borazon (CNB) wheels on a ceramic bond. Highly porous wheels, in contrast to the usual ones, contain, in addition to "natural" pores, specially obtained large pores.

Large pores perform two main functions:

- increase in intergranular space, and practically each grain has "own" pore for placement of shavings;

- improving the supply of lubricating and cooling fluid (or air during dry grinding) in the area of contact of the wheel with the part through the connected pores under the action of centrifugal forces.

The main advantages of highly porous abrasive wheels in comparison with ordinary wheels include such properties as their increased efficiency during work on various grinding operations. When using them, productivity increases, forces and temperature in the cutting zone decrease, the risk of grinding defects (burns) decreases or is eliminated, and the physical and mechanical condition of the surface layer of the machined part improves. Also, the advantages of highly porous abrasive wheels include a combination of increased wear resistance with guaranteed provision of flawless grinding (due to the presence of artificial pores in the abrasive wheel) in a wide range of

processing modes. Ability to combine roughing and finishing, achieving high removal of materials at high cutting speeds and better chip removal, reduces the likelihood of salting the wheel, grinding without the use of lubricating and cooling fluids [2].

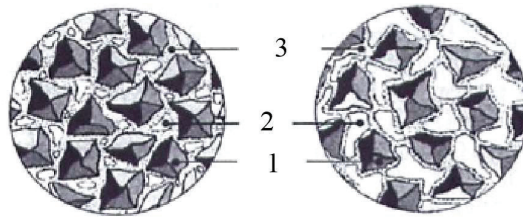


Fig. 1. The structure of borazon (CNB) wheels on a ceramic bond:
a – ordinary; *b* – highly porous; 1 – borazon grain; 2 – pores; 3 – ligament

Therefore, the task of investigating the laws of changes in cutting forces during grinding by these wheels is urgent.

The cutting forces that occur during the grinding process show the amount of energy consumption of this treatment. The grinding machine, or rather its elastic part of the system, is deformed under the influence of cutting forces, and this clearly affects the accuracy of the grinding operation. Variable cutting forces due to errors in the geometric shape of the part can cause vibration and vibration loads on the elastic system of the grinder.

1. 3. Suggested solution to the problem

In [3], the influence of force and temperature factors on deformations during cutting is considered. The issue of grinding with highly porous wheels made of superhard materials was not considered.

In [1], martensitic-aging steel and in contrast to other steel alloys were considered. Issues related to the influence of cutting forces were not considered.

In [2], the general information, manufacturing technology and operational properties of highly porous abrasive grinding wheels are considered. Issues related to the influence of cutting forces were not considered.

In [4], the theory of metal grinding is considered. Issues related to the influence of cutting forces were not considered.

In [5], the problem of determining the bond retention energy of individual abrasive grains protruding above the bond of an abrasive tool is considered, the method of calculating the bond grain strength is analyzed, based on the laws of the theory of contact of elastic bodies. Issues related to the influence of cutting forces were not considered.

In [6], the scheme of chip formation during grinding is considered. Issues related to the influence of cutting forces were not considered.

In [7], the issues of abrasive grain strength were considered. Issues related to the influence of cutting forces were not considered.

In [8], the model of grain vertex distribution on the working surface of the grinding wheel is considered. Issues related to the influence of cutting forces were not considered.

In [9], the mathematical modeling of cutting modes at processing of materials by abrasive tools is considered. Issues related to the influence of cutting forces were not considered.

In [10], the determination of the amount of heat given off by a metal grain during its movement along its trajectory during cutting is considered. Issues related to the influence of cutting forces were not considered.

In [11], martensitic-aging steel, its unique properties and applications are considered. Issues related to the influence of cutting forces were not considered.

In [12], the state of the surface of the part is considered during processing by grinding. Cutting forces are not considered.

In [13], the process of parametric optimization of AISI D3 steel during abrasive machining is considered. Cutting forces are not considered.

In [14], surface finishing is considered. Cutting forces are not considered.

In [15], parametric optimization of the cylindrical grinding process by the Taguchi method is considered. Cutting forces are not considered.

In [16], the issue of studying the modes of grinding of steel EN31 of various hardness is considered. Cutting forces are not considered.

In [17], multifactor optimization is considered when grinding EN19 steel. Cutting forces are not considered.

In [18], parametric optimization is considered by the criterion of surface roughness when grinding AISI 100 steel. Cutting forces are not considered.

In [19], the effect of material porosity on the grinding process with CBN wheels is considered. Cutting forces are not considered.

The aim of the research is to determine the values of cutting forces depending on the processing modes and characteristics of highly porous wheels for the use of the obtained regularities in the design of circular and flat grinding operations.

2. Materials and methods of research

Investigations of cutting forces were carried out on the example of parts of martensitic-aging steel H8K18M14 using highly porous grinding wheels – abrasive (electrocorundum), cubic boron nitride (CBN) and diamond. The method of the planned experiment was used in the research. The cutting forces were measured using a dynamometer (UDM 50) according to standard strain gauge measurements methods [20].

3. The results of experimental research

As a result of experimental studies it was found that when grinding martensitic-aging steel circles of diamond, electrocorundum and CBN cutting forces in the structure of the circle 26 come to values from 2.7 N to 30.7 N, and in the structure of the circle 40 come to values from 2.49 N to 28.2 N. This can be seen below, in Fig. 2–4.

For grinding wheels made of electrocorundum, diamond and CBN, changing their grain size from 25 to 8, it is possible to see an increase in the amount of cutting forces from 2–2.5 times, respectively.

This phenomenon can be explained as follows: reducing the grain size of the grinding wheel, let’s observe a significant increase in the number of cutting grains per unit area of the wheel, and this is visible in the area of contact of the grinding wheel with the workpiece. This reduces the force load on a single grain, which cannot compensate the increase in the number of grains. This is what causes a significant increase in cutting forces. It should be noted that the cutting forces also increase due to friction between the grinding surface and the bond of the wheel when using fine-grained wheels.

As a result of the research, it was possible to experimentally determine the existing relationship between the cutting forces P_y and P_z , which averages 1.75, i.e. the same as when grinding circles of normal porosity.

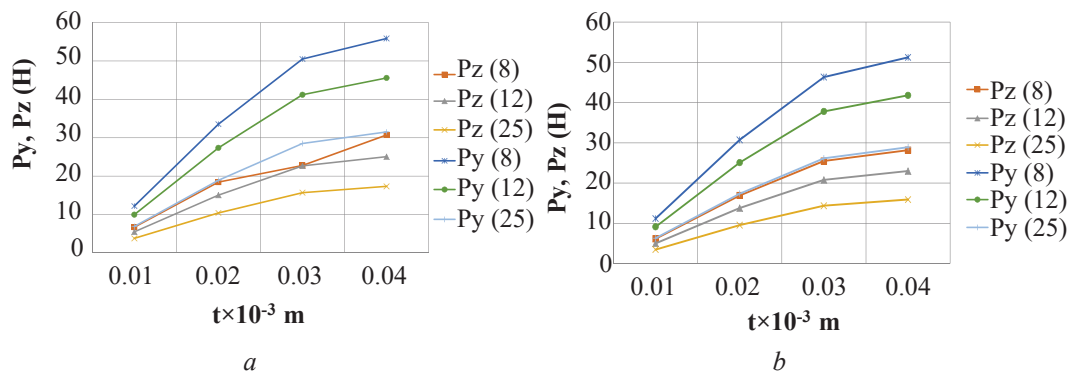


Fig. 2. The dependence of the change in the magnitude of the force P_y and P_z martensitic-aging steel H8K18M14 on the depth of grinding with different wheel structure.
 Modes: $a - N_{str}=26$; $b - N_{str}=40$; $V_w=35$ m/s; $V_d=0.25$ m/s; $S=6$ mm/stroke;
 wheels ceramic (electrocorundum): 1 – 25A8 SM1K, 2 – 25A12 SM1K, 3 – 25A25SM1K

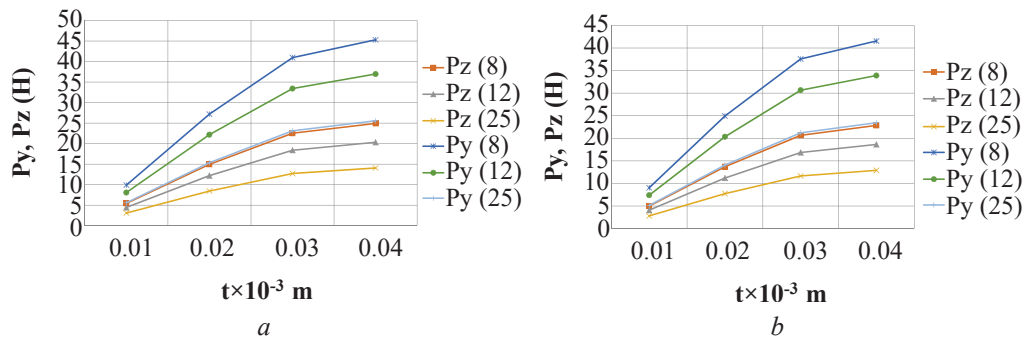


Fig. 3. The dependence of the change in the magnitude of the force P_y and P_z martensitic-aging steel H8K18M14 on the depth of grinding with different wheel structure. Modes: $a - N_{str}=26$; $b - N_{str}=40$; $V_w=35$ m/s; $V_d=0.25$ m/s; $S=6$ mm/stroke; CNB wheels: LO 80/60C10 100 %; LO 120/100 C10 100 %; LO 250/200C 10 100 %

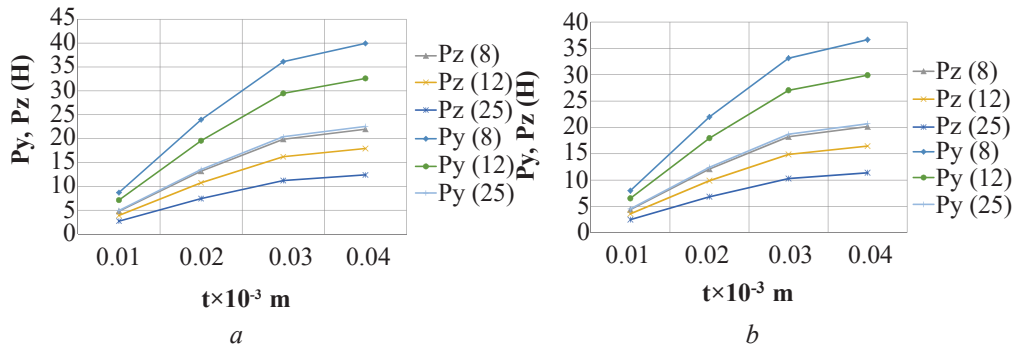


Fig. 4. The dependence of the change in the magnitude of the force P_y and P_z martensitic-aging steel H8K18M14 on the depth of grinding with different wheel structure. Modes: $a - N_{str}=26$; $b - N_{str}=40$; $V_w=35$ m/s; $V_d=0.25$ m/s; $S=6$ mm/stroke. Diamond wheels: ASO80/60S10 100 %; ASO120/100C10 100 %; ASO250/200C10 100 %, where V_w is the speed of rotation of the wheel, V_d is the speed of the longitudinal feed, S is the value of the cross feed

4. Discussion

During the experiment it was found out: the cutting forces P_y and P_z in the width of the allowable modes, which are most often used in round and flat grinding, can reach the following values: when the structure of the circle 26 come to values from 2, 714 N to 30,721 N, and when the structure of the circle 40 come to values from 2,490 N to 28,185 N.

Reducing the grain size of the wheel, let's obtain the effect of increasing the energy costs of the grinding process, by increasing the magnitude of the cutting forces.

If to compare the cutting forces that occur when grinding with different wheels, it is possible to note the following: in comparison with electrocorundum wheels when using CBN circles, the cutting forces are reduced by 20–25 %, and when grinding with diamond wheels, the effect of cutting forces is reduced by 25–30 %.

It should be noted that the cutting forces increase with increasing longitudinal feed and cutting depth, and with increasing speed of rotation of the wheel is the opposite – the magnitude of the cutting forces decreases.

If to compare the research data with the work [2], where grinding with highly porous wheels is considered, then it should be noted that these studies are a significant addition and expansion of the field of these studies, since they are devoted to maraging steels, which is practically not considered anywhere.

The results obtained in these studies cannot be mechanically transferred to other steels. Experimental correction is necessary to use the research results in relation to other steels.

The results obtained are explained by the fact that the distance between the cutting grains in highly porous circles is somewhat larger than in ordinary ones. This leads to the fact that the

chip thickness increases, which leads to an increase in cutting forces on each grain. Knowledge of the power characteristics of the grinding process is necessary to perform high-precision machining with a surface roughness of no more than $Rz=0.25 \mu\text{m}$

5. Conclusions

On the example of grinding martensitic-aging steel H8K18M14 it can be argued that in the process it is necessary to choose wheels that have the maximum grain size, which is only permissible to meet pre-existing requirements for surface roughness.

Given the conditions of labor protection, it is necessary to choose the speed of rotation of the circle at least 30 m/s or slightly higher.

When using wheels with CNB when grinding, it is necessary to know that the cutting force is 20–25 % less than when grinding with electrocorundum wheels.

When grinding diamond wheels, keep in mind that the cutting force is 30 % less than when grinding with electrocorundum wheels.

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