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Qualitative Aspects of Machined Surfaces of High Strength Steels

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Abstract

The aim of this paper was to assess the impact of cutting speed in grinding quality of the surface layer test samples of heat-and chemically processed steel. To fulfill these objectives have been used experimental and computational methods, including statistical evaluation. Technology grinding was performed without cooling recess manner. The following were used grinding wheels-porous A9980K9V and A9980K13V. As machined materials were selected tool steel 19436.4, cemented and hardened steel 14109.4 and steel 16420.4. The hardness of steel is in the range of HRC=61÷62. The work follows the qualitative indicators to assess the integrity of the most common surface finish. These characteristics create conditions affecting the fatigue strength against wear, corrosion stability, quality and fits under.

Keywords: surface integrity; porosity; microgeometry; microhardness and surface hardening; microstructure; cutting forces

1. Introduction

Grinding is characterized mainly by their performance machining capabilities expressed a number of material, taken per unit time and achieving high quality surface. Due to the layout and operation conditions of grinding it is a very complex process. Therefore increasing efficiency, eventually optimization of grinding, it is not easy. It requires assessment and improvement not only of individual articles of the operation, but at the same time and their interaction on the final result aside [2], [3].

At present, there was a great boom in the grinding process, particularly speed. The complexity of the grinding process and a large number of input parameters of the cutting tool, Grinding wheel, attached to the theoretical and experimental study of significant problems. Research requires not only the use of new cutting materials, tools and new methods, but also consistent automation and safety and greening in machining. The conventional method of grinding begins slowly replace speed grinding way. Speed grinding can be called grinding cutting speed of 35 ms^{-1}.

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Nomenclature

a_p depth of cut [mm]
f feed motion [mm.min^{-1}]
n spindle speed [min^{-1}]
F_c tangential component of overall cutting force F [N]
F_f axial component of overall cutting force F [N]
F_p radial component of overall cutting force F [N]
K_{chs} constant of chemical composition of material
K_{mh} constant of material hardness
v_c cutting speed [m.min^{-1}]
v_f feeding speed [m.min^{-1}]

Another big important factor is the grinding wheel. The idea of seeking estate prices and high quality grinding wheels (diamond and CBN grinding wheels), which are now produced by foreign companies is not exactly on the spot. Therefore, we seek "compensation", which is financially far more acceptable in the field of use.
Finally, the effort to complete concept of quality of the surface layer (surface integrity) are starting to take off only in recent decades. It is based on technological processes and their effect on the depth and distortion of the surface layer of the workpiece. Extensive application possibilities of grinding can be broken down by fields of application, e.g. production of automobiles, turbines, bearings, instruments and so on: type grinding process, for example cylindrical grinding inner and outer, surface grinding and the like and type of technology, for example plunge, with the reciprocating shift etc. Implementation of each operation requires a corresponding tool grinding - Grinding wheel, grinding machine, ensuring dressing systems, cooling/lubrication and technological conditions that ensure compliance with user requirements. Development of methods of grinding is to be viewed comprehensively to the requirements of the finished surface (dimensional and shape accuracy, surface finish), although often respond to the challenges of a production area.

2. High strength steels

Fundamental importance of using steels with high strength lies in reducing the bearing sections stressed parts and reducing the total weight of machinery and structures. Reducing the load-bearing sections is limited by the requirement of sufficient rigidity of bodies. The basic characteristics for the assessment of materials with high strength can be as absolute values or R_{p0} R_m, 2, but as a basic criterion used to value ratio $R_{p0,\,2}$ / E, which is the rigidity of the body taken into account. Materials with a value $R_{p0,\,2}$ / E > 1/150 are high strength materials, which are often called super-materials.

Demanding for cyclically loaded machine parts, which were also reflected in significant burdens on centrifugal and inertia forces, is considered as another criterion value ratio $R_{p0,\,2}$ / ρ (ρ - density). The maximum value of this ratio is an important material requirements and where required the lowest mass structures (aircraft, etc.).

Development of advanced technology immediately associated with the development and use of new metallic materials, which have special properties, e.g. and wear resistance to high temperature, high strength and durability in aggressive environments. It is known that improving the properties of metallic materials are usually worse technological properties. To reduce the difficulties associated with making components from these materials, to develop new technological processes.

Machining, however, still remains the primary method for effective production of parts and materials from these. The principal cause of poor machinability (in this case is characterized by cutting machinability rate that corresponds to a defined tool life in machining with a defined cross section of chip and optimal design of the cutting edge on the workpiece) is difficult to machine steels and alloys is the formation of considerable forces and temperatures in the cutting zone [3].

3. Planar technology of grinding

Grinding is mainly used for machining parts with higher requirements for shape and dimensional accuracy and surface quality. With the development of efficient grinding wheels and grinding machines, the importance of extending is the original field of finishing and machining to production machining. Grinding is characterized by specific conditions of chip formation and machined surface. As a result of large plastic deformation and the external and internal friction is a part of the chip is heated enough to melt metal and create droplets, or burned (arcing). Individual abrasive grains have an irregular geometric shape, high hardness, temperature resistance, irregular cutting edge radius r_n a few thousandths of a millimeter. Abrasive grains generally have a negative angle γ_n front and back relatively large angle α_n. As the cutting speed in grinding is considered peripheral speed of grinding wheel, which is given to other methods of machining is relatively high.
Arguably, the traditional grinding now reached the limits of their best options. Material removal volume is small, hardened surface layers of ground dominated by tensile stress components [6]. Surface area to grind circuit or front wheel and the workpiece is held straight shift. Grain size and hardness of the grinding tool is chosen according to the size of contact surface between wheel and workpiece. Generally, the larger the contact surface, the grinding wheel has to be softer and thicker [2].

3.1. Experimental sample preparation

Peripheral grinding wheel speed is chosen in tough materials from 25 to 32 ms^{-1} and for brittle materials from 18 to 25 ms^{-1}. For the plane grinding wheel circumference are selected cutting conditions according to Table 2 and Table 1 according to the type of disc. For the grinding test samples were surface grinder was used BRH 20.03 F (Fig. 1). BRH 20.03 grinders are planar type grinders with horizontal spindle and rectangular desk. They are designed for sanding flat and contoured surfaces of parts made of steel, iron and other metal materials, which were required to achieve high quality and precision machining. Sharpening is mostly grinding wheel circumference. Samples can be machined by grinding because of its shape clamped directly to the electromagnetic plate or through suitable clamps to the base table. 20.03 F grinders operate in a closed automatic working cycle. To control the automatic cycle machine includes a digital indication FAGOR NV 300E company, which serves metering to track vertical and lateral displacement at work in manual mode Where the management of vertical displacement in automatic cycle. Technical parameters of the machine tool are:

- Working surface: 200x630 mm
- Dimensions of grinding wheel: ∅ 250x20-50x76 mm
- Infinitely adjustable: 1 to 30 m. min^{-1}
- Maximum Grinding spindle speed: 2550 min^{-1}

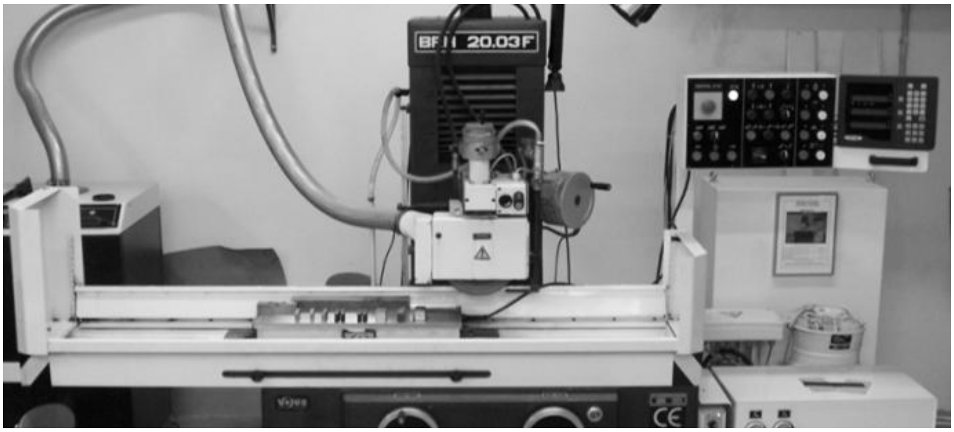

Fig. 1. Overall view for CNC machine tool BRH 20.03 F.

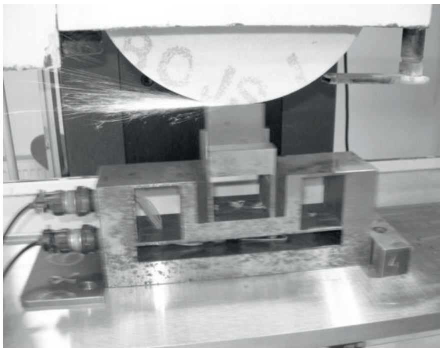

Fig. 2. Surface grinding of the sample.

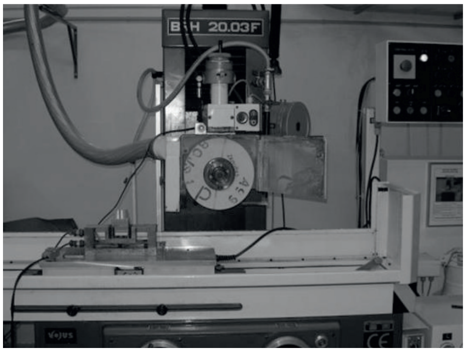

Fig. 3. A99 K80 9V OPEN F 20.03 grinding wheel.

In the process of experiments we used two types of grinding wheels-type A99 K80 9V and 13V with dimensions of 250x76x10. It is an electro corundum grinding wheels with ceramic binder with the difference in porosity. Samples used were made of steel 14 109.4, 16 420.4 and 19 436.4. Each of these samples was drawn to size 50x50x8 mm. Steel were chosen for their inferior (low) grade machinability grinding in order to verify the expected decreases of cutting force components in grinding with high porosity abrasive wheel. Steel 14 109 belongs to a group of steels for the manufacture of rolling bearings. It contains about 1.0% C, 0.8 to 1.6% Cr and about 1% Mn to enhance hardening penetration. It is characterized by high hardness, wear resistance and high compressive strength [2]. 16 420 steel contains 0.14% C, 0.27% Si, 0.75% Cr and 3.7% Ni. It is characterized by good formability as well as heat and good machinability in annealed condition. It is suitable for the production of highly loaded machine parts, which are intended to hardening and hardening to high strength and toughness in the core like shafts and gears. Steel 19 436 belongs to the alloy - chrome tool steel. It contains 1.80 to 2.05% C, then 0.20 to 0.45% Mn, 0.20 to 0.45% Si and 11.0 to 12.5% Cr. The properties of this steel [7] are as follows: very high compressive strength, low toughness, good dimensional stability during heat treatment. This steel is used for highly stressed and difficult to shape tools, shaping tools and cutting tools for example broaching or extrusion mandrels, tools, cutters for lower cutting speeds, etc.

4. Cutting forces measurement

In this paper, a simulation system for grinding freeformed surfaces was presented. In contrast to previous simulations, it calculates the process forces based on the engagement situation for each grain on the tool, but it is also sufficiently efficient to simulate multiple tool rotations in an appropriate period of time [8]. The process forces are determined by dividing each grain into small cutting wedges along the workpiece surface and then adding the forces for all the cutting wedges for all grains [8]. When operating in the grinding abrasive wheel cutting and centrifugal forces. Since cutting forces are due to centrifugal forces small, when considering the strength of the grinding wheel of their neglect. To the work component operates resultant force *F,* which is the sum of the elemental forces of individual grains. Decomposes into three components: tangential force F_c , radial force F_p and axial force F_f. These components are used to calculate: power to the wheel spindle and workpiece (force F_c), stiffness of the machine system workpiece-tool, precision machining (force F_p) and the power stroke (force F_f). Since the abrasive grains have negative face angles, we can assume that the cutting force F_p will always be greater than the force F_c. Experimental measurements confirm that the radial force F_p is about 1.5 to 3 times larger than cutting force F_c. Force F_f is quite a bit smaller than the force F_c. In doing so, cutting force in grinding is the sum of elementary forces exerted on the material the individual abrasive grains. Individual grains extend to different depths, elemental forces are therefore substantially different. Cross-sectional area has a complex shape, unlike the machining tool with defined geometry. Cutting forces in grinding is possible to determine the analytical calculation. We start from identifying the actual cross-cutting one layer of abrasive grain S_z spanning the same number of grains in the desired depth of cut, etc., grain size and structure of the disc. Measurement of cutting forces in grinding was done on two-component strain-gauge dynamometer (see on Fig. 4). Dynamometer [5] of signal curves is allowed to characterize a cutting process. It was observed that the influence of the cutting forces onto the cutter tooth is stable.

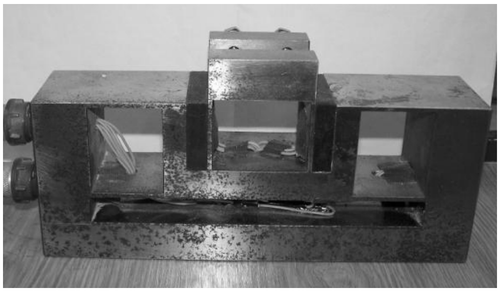

Fig. 4. Two-component strain gauge dynamometer.

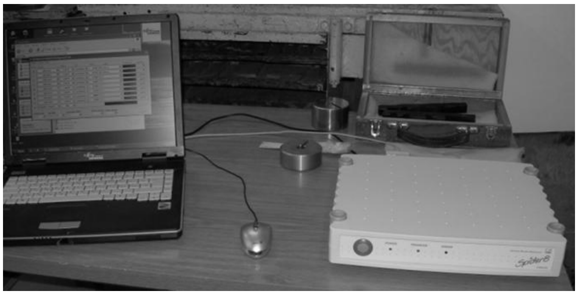

Fig. 5. Measuring device for cutting forces.

5. Results and evaluation

Measurements were performed on the surface grinder which is further described in Section 2. Technological conditions of plane grinding to an experimental measurement of cutting forces we opted for the normal conditions used in practice. For all three types of steel were the same, namely to be edited mercilessly cutting depth a_p and Feeding speed v_f: = 0.01, 0.02, 0.03, 0.04 mm and v_f = 7, 12.5, 16.5, 23.5 m.min^{-1}

For example, the traverse speed of 7 m.min^{-1}, we changed the depth of cut a_p = 0.01 to a_p = 0.04 and for all four traverse speed. From Figures 6 and 7 to see the depth of cut a_p = 0.03 mm decrease in cutting forces for the wheel A99 80K 13 V (Fig. 7), while for steel 14 109.4 occurs almost linear to the curve for both curves (Fig. 6 and 7). Steel 16 420.4 also has a linear shape of all dependences, the decrease of cutting forces F_p, some 8N. Curves for steel 19 436.4 are square (Fig. 6) and logarithmic (Fig. 7) shape with a strong decline of about 20 N. Size of cutting forces (Fig. 8 and fig 9) F_p for depth of cut 0.04 mm for steel 14 109.4 is nearly the same for both grinding wheels. A marked decrease in high porosity grinding wheel is seen for steel 16 420.4 and 19 436.4.

Size difference between the tangential component of cutting force F_c (Fig. 10 and 11) at 0,03 mm depth of cut is noticeable when comparing the graphs (Fig. 10 and 11). Radial component of cutting force exhibits the lowest values for steel 16 420.4 for the four dependence (Fig. 6, 7, 8, 9) which can also be caused by higher content of nickel (Ni = 3.7%). Conversely 19 436.4 steel shows the highest values of cutting force F_p due to the high content of chromium (Cr = 12.5%) and carbon (C = 2%). What is seen in the steel 14 109.4 [2].

It is interesting to 19 436.4 high speed steel radial component of cutting force (Fig. 6, 7, 8, 9, 10, 11, 12, 13) is the largest compared with other steels, since the tangential component of cutting force is the smallest.

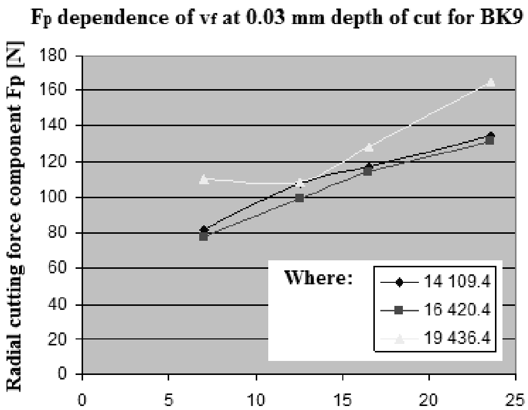

Fig. 6. Graphical dependence of radial component of cutting force.

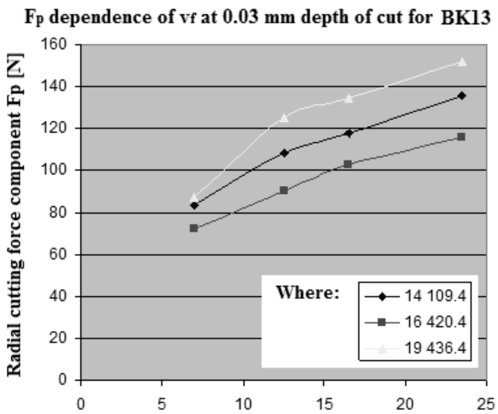

Fig. 7. Graphical dependence of radial component of cutting force.

In Figure 14 and 15 are shown records from the monitor meter SPIDER 8 where to see that the measured field samples (50 mm) there is a high shear strength at the initial contact with the grinding wheel of cropped area. In a further stroke there is a significant decrease in cutting forces (the result of sharpening) [3].

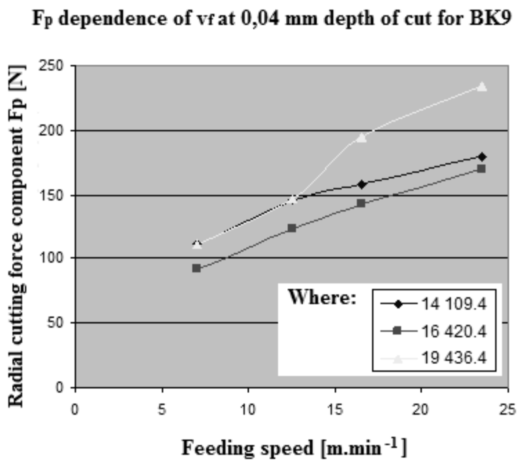

Fig. 8. Graphical dependence of radial component of cutting force.

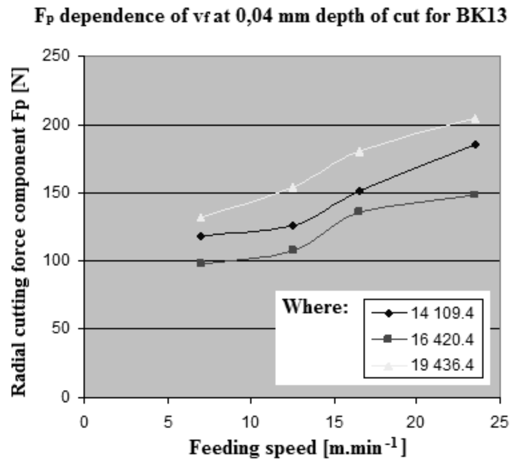

Fig. 9. Graphical dependence of radial component of cutting force.

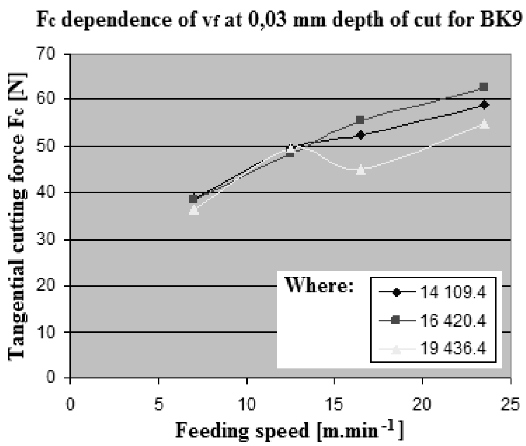

Fig. 10. Graphical dependence of F_c component of cutting force.

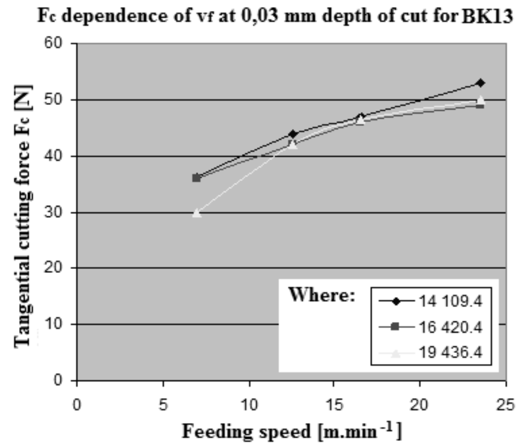

Fig. 11. Graphical dependence of F_c component of cutting force.

In developing a mathematical model based on the readings we have several options. The choice always depends on the shape and structure of the processed file is the number of input parameters to their direct, respectively indirect dependencies. In seeking to rule in several variables as in this case can be very difficult to estimate the shape of the model and therefore the methods as the method of least squares, and minimal methods to useless. For this reason, we have to estimate the mathematical model chosen to use a combination of two statistical methods namely method "Monte Carlo" and point estimators [1]. As a model formula we used the ratio.

$$F_c = C_p v_s^{\,0,7} f^{\,0,7} a_p^{\,0,6} \tag{1}$$

We decided to create a model in the form:

$$F_c = pC_p v_c^{\alpha} v_f^{\alpha} a_p^{x} \tag{2}$$

Material constant for the sharpening, we identified by a particular material. For example, the material 16 420.4, as well as for other materials, we used chemical composition and hardness of steel concrete. 16 420.4 steel has a hardness after hardening around 62 HRC, which is about 745HV. Hardness is not exactly translates to different glands, which is stamped into the steel for its measurement. Constant, we get multiple constants of chemical composition and constant hardness K_{chs2} and K_{mh}. For steel 16 420.4 us went $C_p = 13.73$.

Coefficient α gradually we chose 0.2, 0.3, to 0.8, 0.9 and the formula (3) to get a solid set of possible outcomes.

$$x = \log_{a_p} \frac{F_c}{pC_p v_c^{\alpha} v_f^{\alpha}} \tag{3}$$

We designed this method of parameter estimation and calculate the standard deviation. To consider that is an acceptable model, where the standard deviation is the smallest. The situation in the disc of porosity occurred for 9 mm cutting depth thus became the model we adopted for this situation is:

$$F_c = 53{,}245 C_p v_f^{0,5} \tag{4}$$

Two-component strain gauge dynamometer is calibrated to a value of 9.81N on weight 1kg. When is measured the components of cutting forces must take into account measurement error. Readings at various depths of cut depending on changing traverse rate rose almost linearly. While our main aim is to demonstrate experimentally and then followed by the calculation (the creation of a mathematical model) decrease in cutting force components in the porous discs. Expected experimental and interpretative aim has been to prove, of course, the main reason for this decrease of cutting forces is better heat dissipation from the cutting zone.

The evolution of the tangential force F_t, feed force F_f, and radial force F_p components is showed as a function of cutting speed. The tangential force component is approximately two times the two other force components [4].

Cutting forces were significantly increased with high speed and high feed rate [9].

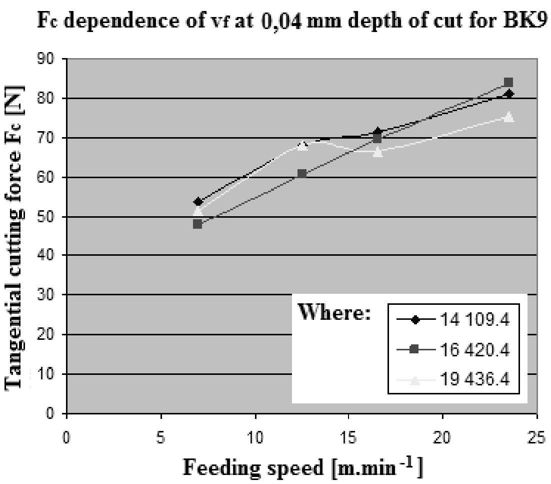

Fig. 12. Graphical dependence of F_c component of cutting force.

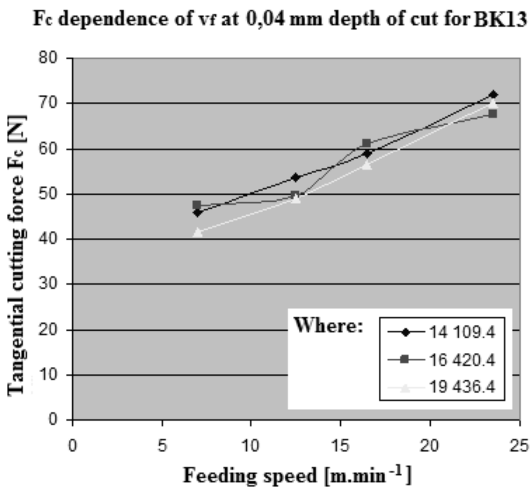

Fig. 13. Graphical dependence of F_c component of cutting force.

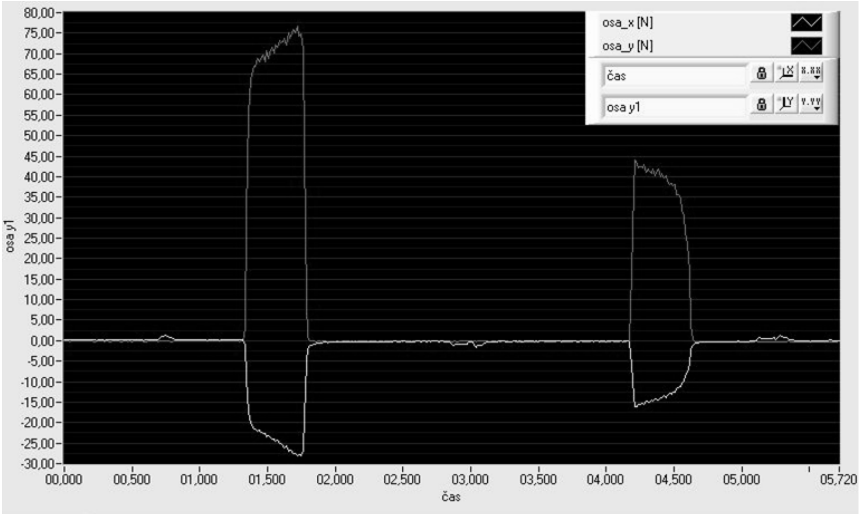

Fig. 14. Chart of the measuring device for generating forces size

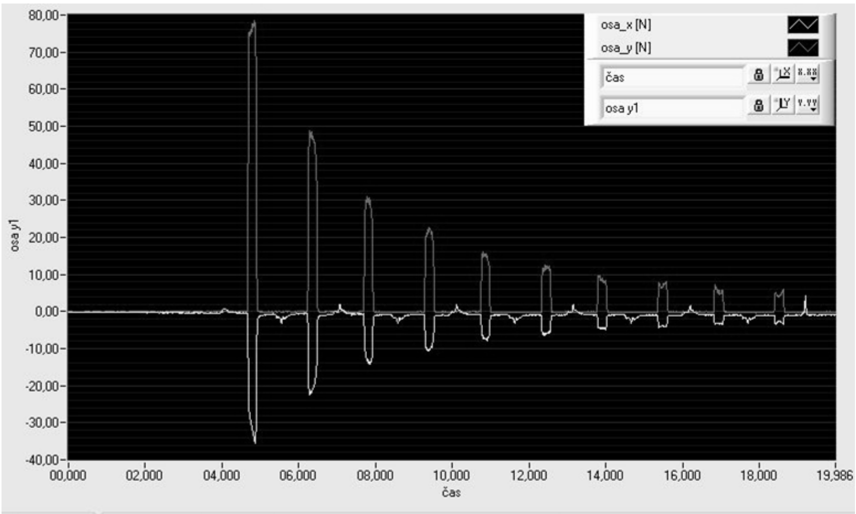

Fig. 15. Chart of the measuring device for generating forces size.

6. Conclusion

In this study, cutting force calculation method which is known the most developed force calculation method in machining processes is applied in grinding operations and cutting forces experimentally measured. Experiment shows that with the increasing depth of cut also increases value as the axial component of cutting force F_p and the tangential component of F_c in all species studied steels. In addition to the above is confirmed by the fact that there is a decrease of cutting forces in grinding with highly porous grinding wheel, unlike the wheel with a lower porosity. In the future research the authors want to deal more about static deflections of the tool. Also material behavior at the 3D shear plane along the thread root should be more studied in detail in the future. It opens the way for further research in this area to optimize the machining process in the production of their dominant functional areas.

Acknowledgements

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