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STUDY OF GRINDING WHEELS UNDER CRITICAL SPEED

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A***bstract:*** *Intensification of grinding process is recently provided by increase of cutting speed. The article describes possibilities of shaping of grinding wheels in other to get constant strength wheel. This paper also relates physical-mechanical properties of grinding wheels and presents experimental equipment. Some experimental results of using new shape grinding wheels with respect to high speeds are presented. Influence of high speed on stock removal and change of surface roughness is discussed.*
Key words: *Grinding, Wheels, Critical speed, Study*

1. INTRODUCTION

The development of finishing operation, especially grinding leads to increase of cutting speed. This trend is of course limited by construction and physical-mechanical properties of grinding materials. The grinding materials are usually two-component materials with high porosity. Nowadays, visible progress in the development of high-strength bonds is observed. The goal of present research is development of new shaped tools for high-velocity grinding (up to 100 ms^{-1}).

2. SHAPE OF CONSTANT STRENGTH WHEEL

The stress calculation is based on equilibrium of inner forces causing element of rotating wheel. First attempt was to detect stresses in the simple rotating wheel with hole under rotation. Homogenous steel material of the wheel is getting under critical angular velocity into the area of probable wheel failure – Fig. 1. This was tested in the FEM analysis program, Cosmos DesignStar. Entry conditions were angular velocity $2760s^{-1}$ and wheel dimensions 250x76x10mm. Highest stress is closer to the hole of the grinding wheel.

After determination of equilibrium equations in axis of symmetry direction, assumption of negligable effect of some high-order differential members, implementation of compatibility equations and on the assumption of Hook law for brittle materials we can obtain the relations for stress calculation.

When we assumed that exploitation of grinding wheel material is uniform, i.e., for presumption $\sigma_\rho = \sigma_t = \sigma_{Rt}$ and when we respect boundary conditions, the shape of constant strength wheel is expressed as:

$$b = b_2 \, [\exp \, (v_k^2 - v_\rho^2).\gamma \, / \, (2 \, g \, \sigma_{Rt})]. \qquad (1)$$

The shapes of rotating wheels with variable thickness are shown in Fig. 3. It is not easy to create grinding wheel with exponential shape.

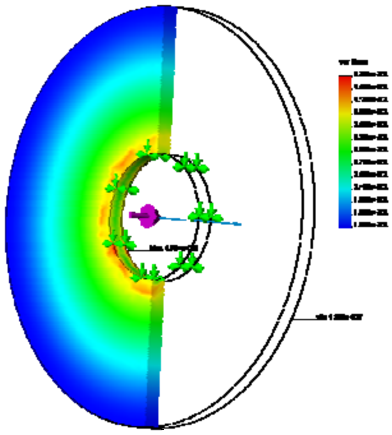

Fig.1. Simulation of simle rotating grinding wheel with hole under critical speed

Adjustment of wheels like this would be difficult too. A reasonable compromise solution of this problem are tools for high-velocity grinding which are shown in Fig. 3. Experimental tools has working part with cylindrical shape and in the breaking point (i.e., adjusting hole) has greater width.

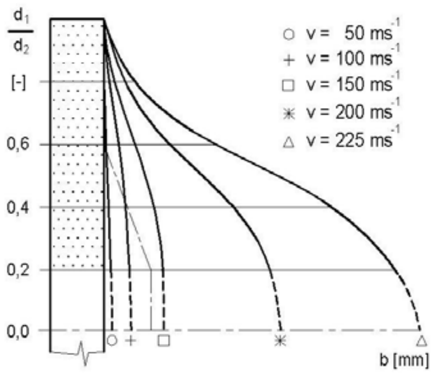

Fig. 2. Shapes of rotating wheels with variable thickness

Results of bursting test KUP grinding wheels with ceramic bond are described at Fig. 4. The grinding wheels with greater width near adjusting hole are much more suitable for high-velocity grinding. Conical clamping part contributes to higher safety (in case of breakdown of grinding wheel captures parts with maximum weight) and to higher strength (with reference to stress superposition of compression and tangential stress). With respect to stress distribution in rotating wheel the tool without hole is ideal. But there are some technical problems with clamping and adjusting of grinding wheels like this. So rotating segment wheels are much better. The limitation of this tool is compression strength limit of grinding material in conical clamping flange. With respect that compression strength limit of grinding materials is six times as much as higher than tensile strength, these tools are suitable for really high cutting speeds.

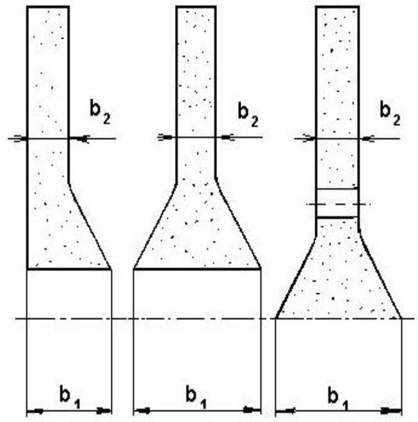

Fig. 3. Shapes of grinding wheels with conical clamping

Development trend in tool design is introduction of shaped all-metal grinding wheels for high-velocity grinding with thin layer of abrasive on the periphery. Considering equations for stress calculation we must use materials with low density such as titanium. Application of polymer materials especially composites reinforced with Kevlar or metal fibers is also possible.

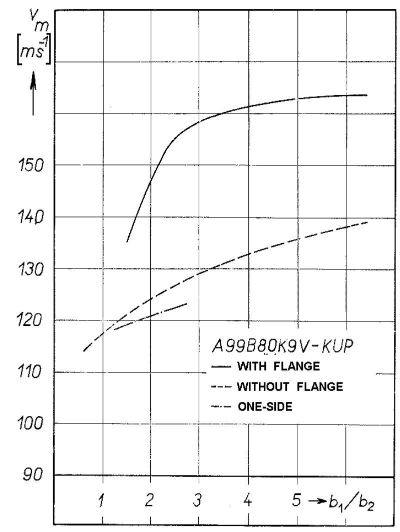

Fig. 4. Results of strength test of rotating KUP wheels

High-speed and high-power grinding could be characterized by enormous increasing of cutting speed (our experiments at UTB in Zlin was realized at speeds up to 240 ms-1) and stock removal is realized on one stroke of grinding wheel. With respect to above factors, we must determine also: strength of grinding wheel at breakdown of rotating wheel and corresponding cut-out angular velocity, specific weight and Poisson's ratio for grinding wheel as entire. Effect of grain size and hardness on the cut-out angular velocity is well known. Grinding tools with high hardness and with small grains is suitable for high-speed and high-power grinding. This fact is in conflict with high power requirement of grinding process.

The crucial factor in appreciation of grinding wheels is grinding productivity. Cutting power determines than suitability of any grinding tool for high-power grinding. We can evaluate cutting power either by some partial physical-mechanical properties of tool or by monitoring cutting properties in cutting process directly. Following springing of system machine-tool-workpiece we can define the cutting power (K) as material removal (Q) to electromotor power input (Pu):

$$K = Q / P_u \ . \qquad (2)$$

When we evaluating cutting power of grinding tool we are monitoring material removal per time unit, wheel wear, normal force, power input of grinding spindle.

When the grinding wheel stroke to workpiece it causes lockup of tool in cut. So we can note that greater lockup of wheel in cut determines worse cutting properties of tool. On the basis of this effect we have another way how to define relative machinability of grinding wheel because time and character of the lockup which is monitored, e.g., by decrease of rotation speed could be our criteria. Tools like this has also conical clamping surface (KUP) for higher safety (additional compression stress and tangential stress causes stress superposition).

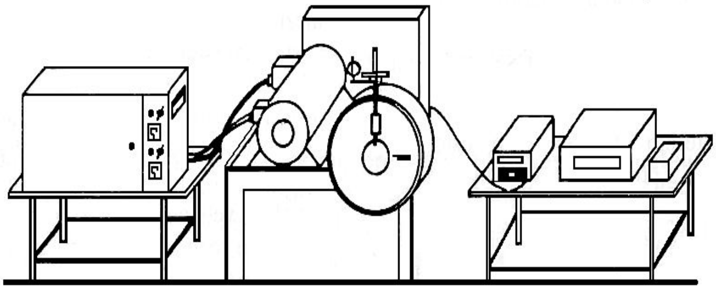

Fig. 5. Testing apparatus for grinding wheels

We developed apparatus for testing grinding wheels in order to validate this thinking (Lukovics & Sýkorová, 1999). This apparatus has stepless speed variation, accurate record of rotation speed, duration of wheel intervention and video recording of rotating grinding wheel failure.

Results of testing grinding wheels in wide range of different technological conditions which has been obtained through testing equipment developed at UTB in Zlin gives very valid research findings. This testing equipment is shown in Fig. 5. Especially evaluation of cutting power on the basis of time needed to lockup seems to have advantage because in this case the relative machinability could be characterized by only one quantity. This method of evaluation corresponds to real conditions which take place in stroke of grinding grain. Development of these techniques should ensure better and safer testing of grinding wheels. On the other hand, there are many variables which characterized grinding wheels so the definition, analysis and definite evaluation of cutting power is rather complicated. Another research projects should solve these questions.

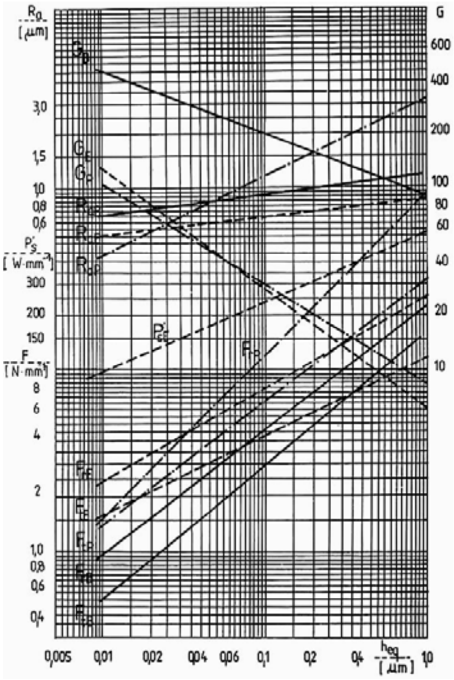

Fig. 6. Grinding diagram for synthetic corundum, semi-splintery corundum and cubic boron nitrid.

Our testing equipment allows also obtain the grinding diagram. These diagrams are important in practice grinding. They can characterize efficiency of roughing or finishing grinding. Grinding diagram for bearing materials in case of use synthetic corundum, semi-splintery corundum and cubic boron nitrid describes Fig. 6.

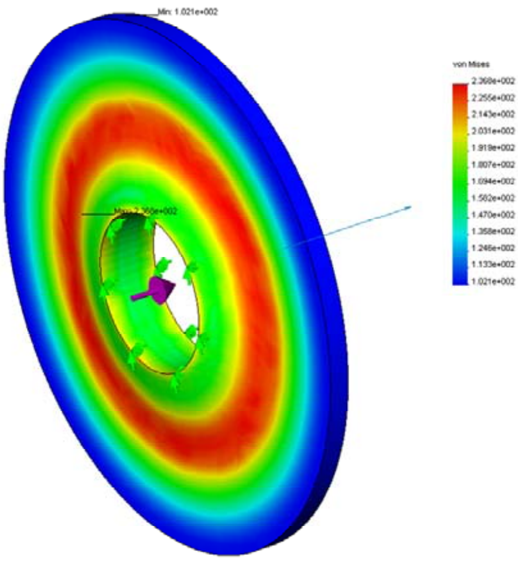

Fig. 7. FEM model of grinding wheel with lowered stress under rotation

3. CONCLUSION

The submitted article describes some possibilities of increasing strength of rotating grinding tools. This improvement is reached through some design modifications of existing grinding wheels. This article presents also possibilities of better utilization of grinding materials which in combination with development of new firmer bonds, eventually all-metal grinding tools, make possible to use speeds above 100 ms^{-1}. This results in higher productivity of grinding operations. Also shape changes in the grinding wheel lowers stress when rotating (Fig. 7.). Testing apparatus for evaluation relative machinability of grinding wheels allows very accuracy measurement of quality and usability of grinding wheels. We can choose exactly efficient grinding tool on the basis of this measurement. One of the most important contribution of this testing equipment is in serial and mass production where even small improvement is warranty for more economical production.

4. ACKNOWLEDGEMENTS

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