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ADVANCED GRINDING FOR HIGH PRECISION OF SURFACE ROUGHNESS

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Abstract

The traditional approach to grinding is to operate within the limits of surface quality. The requirements for surface quality in grinding are higher than those in other common machining operations such as turning and milling. The surface quality of machined parts is very important for precise production and assembly. When we focus on roughness parameters after grinding, we can establish the limits of these parameters for typical grain materials: Al_2O_3, SiC, CBN, SG and others. Increasing demands on accuracy and quality of production leads to research concerned with the properties of these materials and the surface quality after grinding. This paper shows new possibilities for the ground surface with focus on surface roughness obtained under varying combinations of cutting conditions. The influence of the grinding wheel, cutting parameters and coolant on higher surface quality is assessed by roughness parameters Ra, Rz, Rt and the Material portion of a surface profile. These high-precision ground surfaces are shown to have a Nanometres (10^{-9}) unit topography demonstrating that the process is able to replace other finishing technologies such as superfinishing or honing.

Key words: *Grinding, High precision, Roughness, Surface*

1 INTRODUCTION

Each process in production is still monitored with a focus on tool life, quality of products, lower lead time and production costs. These monitored parameters of the process influence total production and profit of a company. [1] They have high importance in process validity. The quality of products and their price are decisive factors in the successful sale of company products and growth of profit. In production the machining makes the highest portion of production technologies. The various types of tools, tool materials and possibilities of cutting conditions are limiting conditions in technology process creation. The production's efforts are focused on production costs reduction and finding of optimal solution of used machine, tools, cutting conditions, workers, transport, storage and working time in component production. [2], [10]

This article shows new possibilities where we can reduced the production costs. This area of production is in machining and finishing. Reduction of production costs are given by replacement of technologies. This article shows high precision surfaces of chosen materials in surface roughness parameters evaluation. These partial results are showing new ways of grinding that we use for replacement of superfinishing or honing. These possibilities enable to us reduce machine for superfinishing or honing, tools for these operations, support material and workers. The research will be continued with others materials used in production and will be evaluated for geometrical accuracy of machined parts namely by the character of samples (circular or plane). [11]

2 GRINDING PROCESS AND EXPERIMENT

Grinding is subject to high process changes through the introduction of new technological developments. There are new types of grains developed that can grind with higher cutting speed, high feed speed and without of coolant [4]. Size and shape of abrasive grains are also developed and changed.

The surface with high precision roughness is given by relations between:

- used grinding wheel (type of grains, size of grains, bond, hardness, structure),
- material of workpiece (solidity, toughness, hardness and heat treatment),
- cutting speed of grinding wheel,
- circular speed of workpiece,
- speed of feed,
- depth of cut,
- coolant (type and concentration).

These conditions are basic input information concerning the set of cutting conditions used to achieve grinding with high precision of surface roughness. The cutting conditions – cutting speed, feed speed, depth of cut, circular speed of workpiece and coolant [3], [5] are especially important for achievement of such surfaces.

2.1 Experiment

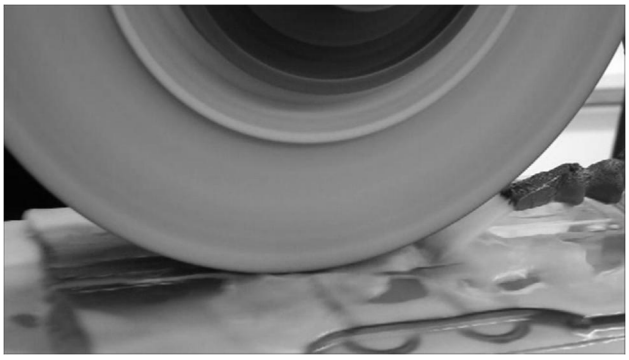
The nature of this research is the enable to current grinding processes to attain a high precision surface roughness equivalent to that obtained with other high precision technologies including superfinishing and honing, by application of common grinding wheel and cutting conditions on a traditional machine.

Our workplace has considerable experience in grinding research with particular experience in bearing steels grinding, tool steel, carbide steels and steels with heat treatment (hardening and tempering). [6] Our research also deals with grinding of non-ferrous materials including aluminium alloys EN AW range 2000, 6000 and 7000. A partial area of our research attends to the replacement of finishing operations and this article shows new information in this area.

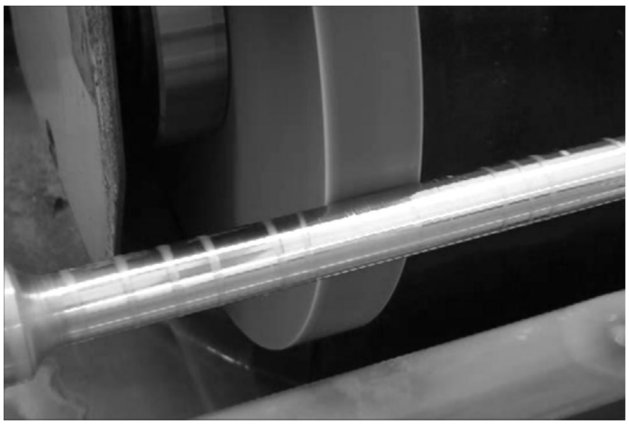
2.2 Ground materials and grinding wheel

Materials were chosen on the base of use in different areas of engineering especially in automotive industry and industry of machining machine production. These materials are:

- steel EN ISO C55E (55 HRC), 1.0535,
- ductile iron EN ISO GGG60 (50 HRC),
- bearing steel EN ISO 100Cr6 (62 HRC), 1.3505,
- steel EN ISO St 52-3 (natural), 1.057.



a) peripheral surface grinding



b) peripheral cylindrical grinding

Fig. 1 Methods of grinding

Grinding wheel used in this experiment was base on Al_2O_3 with grains consist of white corundum and this mark A99B 80K 9V – composition of tool by FEPA. Cutting conditions during grinding were:

- v_c = 40 m.s^{-1},
- v_f = 6,5 m.min^{-1},
- a_p = 0,05 mm,
- coolant – water solution with semi synthetic cutting fluid (5%),
- dressing of the wheel, single point, depth – 0,01 mm
- method of grinding is showed in Fig. 1 b) – peripheral surface grinding (traverse grinding).

In these cases with higher precision of surface roughness is necessary dressing of grinding wheel. Finer dressing increases the specific energy (formula 2.1) and decreases the roughness, whereas coarser dressing has opposite effect as shown in Fig. 2.

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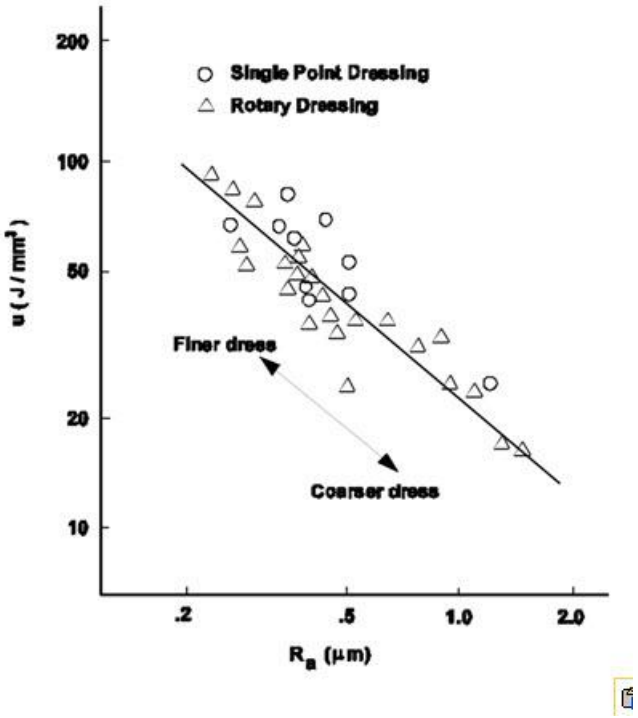


Fig. 2 Relationship between specific grinding energy and workpiece surface. [7]

$$u = \frac{P}{Q_w} \quad \left[J \cdot mm^{-3}\right], \tag{2.1}$$

where:

u…specific grinding energy,

P…grinding power,

Q_w…volumetric removal rate.

The formula (2.1) continues for grinding power and volumetric removal rate as shown in formula (2.2) and (2.3). Individual parameters are shown in Fig. 3.

$$P = F_c \cdot v_c, \tag{2.2}$$

where:

F_c…tangential component

v_c…cutting speed of wheel

$$Q_w = v_w \cdot a \cdot b = \pi \cdot d_w \cdot v_f \cdot b, \tag{2.3}$$

where:

d_w…diameter of workpiece

v_f…feed rate

b…width range of tools and workpiece

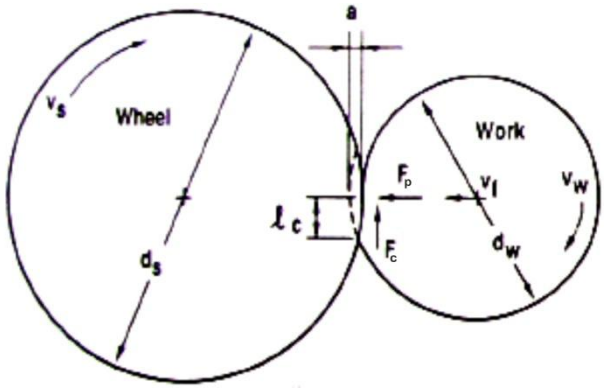


Fig. 3 Illustration of force components for plunge grinding. [7]

3 SURFACE ROUGHNESS EVALUATION

This part of the research will be focused on surface roughness after grinding of machined materials. Three basic parameters of the surface profile will be used for performance evaluation : Ra, Rz and Rt. A further parameter is the material portion of a surface profile (Abbott-Firestone curve).

The surfaces were ground with white corundum and with coolant. Peripheral surface grinding was used for plane samples of materials.

3.1 Roughness – Ra parameter

This is a commonly used parameter in engineering but for evaluation of actual surface profile it is not so informative (i.e. it presents only an average value of surface profile), however the parameter is still used to prescribe product design and remains popular in engineering applications. Shown in Fig. 4 are values of the parameter Ra for each of the surfaces of four materials ground by white corundum. The surfaces are very high precision and the process shows possibilities of replacing a further finishing operation for example superfinishing or honing..

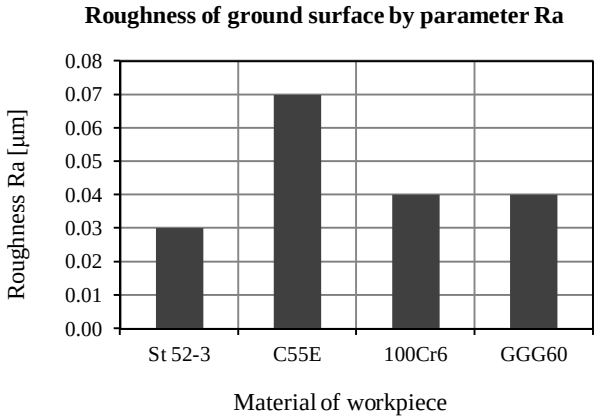


Fig. 4 Ra parameter of ground surfaces

3.2 *Roughness – Rz parameter*

This parameter is commonly used in the automotive industry and presents the distance between the lowest point of a valley and the topmpost point of a peak in the measured surface profile. This parameter volunteers actual sight on profile and his segments. In Fig. 5 you can see values of parameter Rz for each of the ground surface of four materials ground by white corundum. These values of surface roughness are also very high precision and support surface roughness quality after grinding, as in the case of parameter Ra.

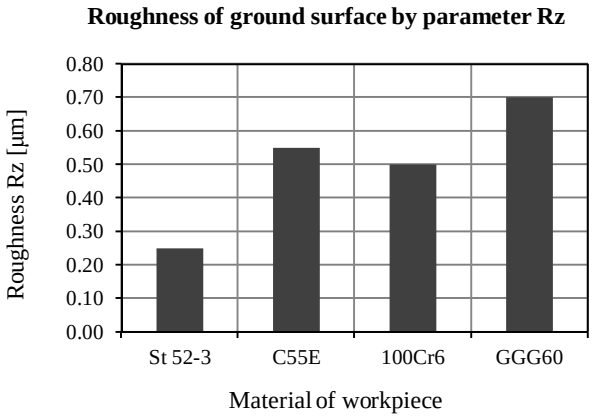


Fig. 5 Rz parameter of ground surfaces

3.3 Roughness – Rt parameter

This parameter is also commonly used in the automotive industry, and similarly to Rz this parameter is joined with material portion of surface profile. In Fig. 6 you can see values of parameter Rt for each of the surface of four materials ground by white corundum.

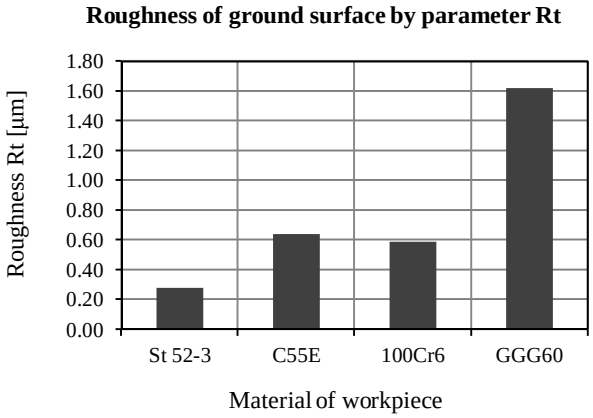
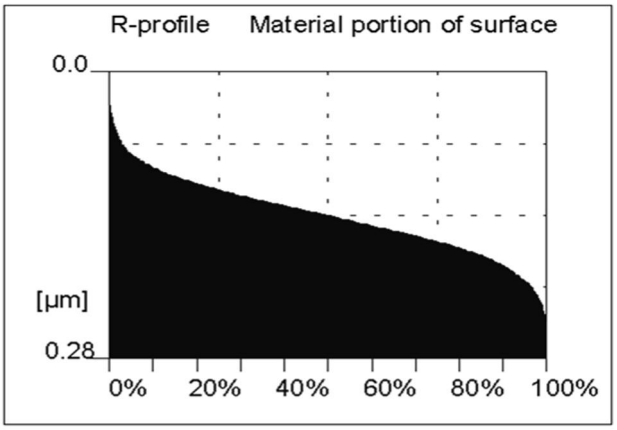


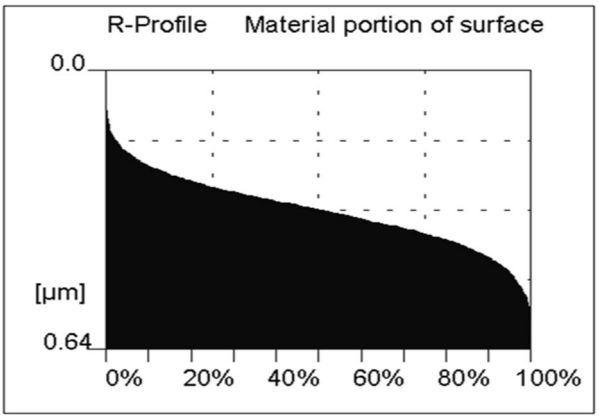
Fig. 6 Rt parameter of ground surfaces

3.4 Roughness – Material portion of surface profile

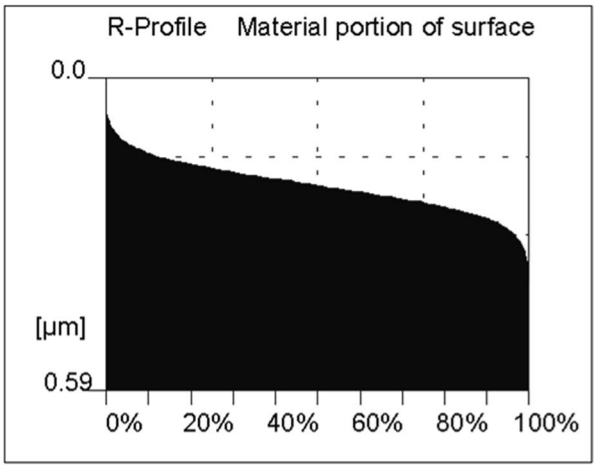
This surface profile parameter shows the percentage portion of “full material” in peaks against “short material” in the valleys of the surface profile. This parameter is important for estimatation of machined part life in the different machines, devices, vehicles and others. In Fig. 7 you can see areas of material portion of each surface profile of four materials ground by white corundum.



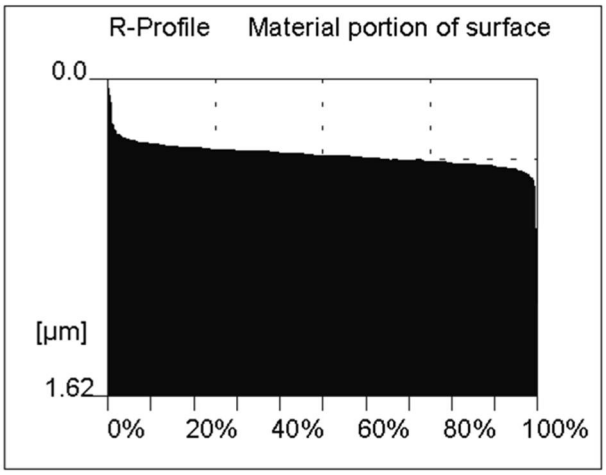
a) St 52-3



b) C55E



c) 100Cr6

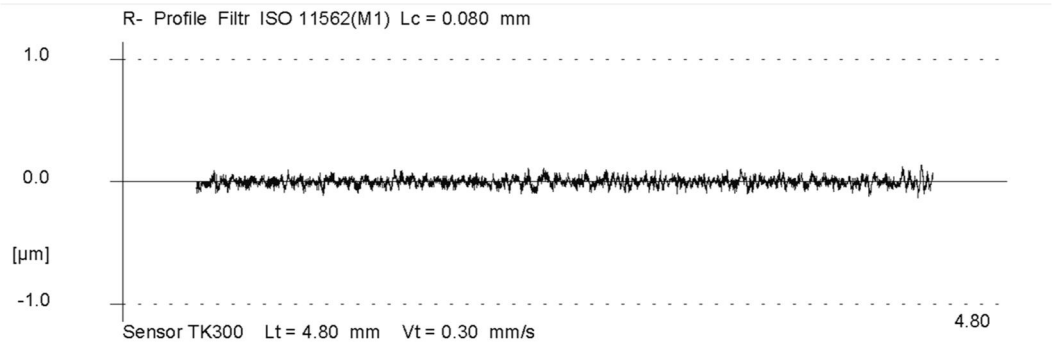


d) GGG60

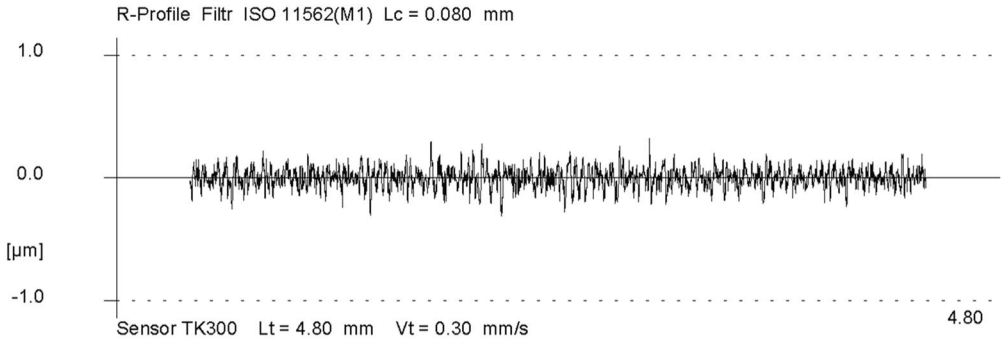
Fig. 7 Material portions of surface profiles

3.5 Roughness – Surface profile

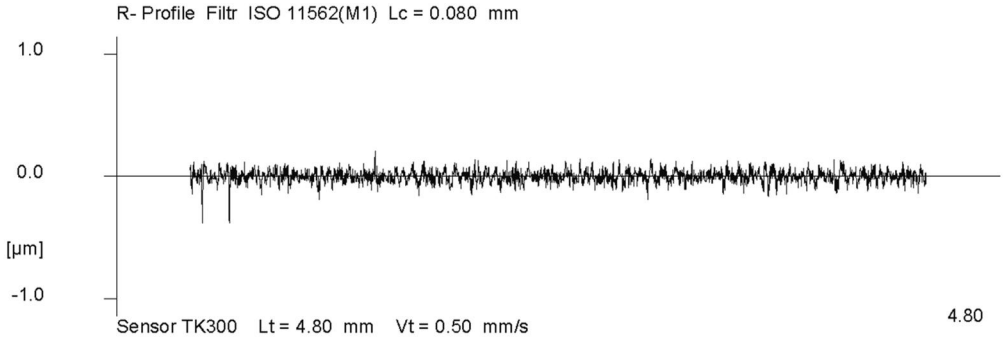
Evaluation of the surface profile determined from a range of roughness parameters is useful and better describes the surface than a single parameter.. In graphic image the profile shows a distribution of peaks and valleys in their basic measured profile, size and shape. The profile provides information about exceptions in the profile, the texture of the profile and from the profile we can determine the extent of the primary plastic deformation zone (affected zone after machining). In Fig. 8 you can see the actual profile of each of the surfaces of four materials ground by white corundum. Very small differences in profile and lower profile can be observed. This profile is obtained from the grinding method and cutting conditions used in the research.



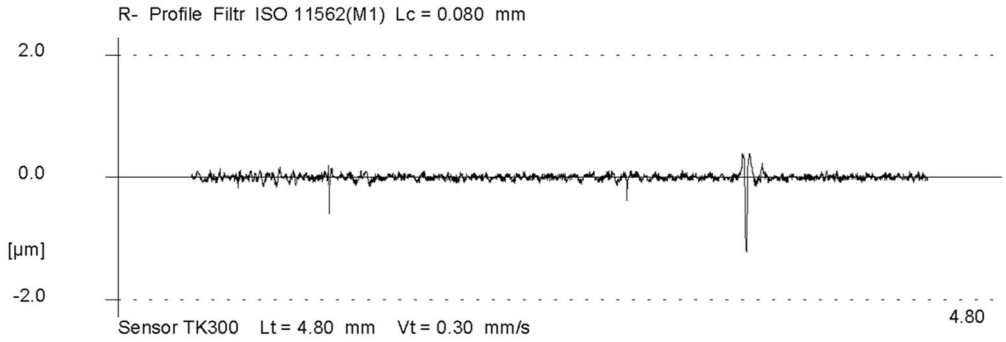
a) St 52-3



b) C55E



c) 100Cr6



d) GGG60

Fig. 8 Ground surface profile

4 RESULTS AND DISCUSSION

This paper shows new ways of grinding engineering materials. The research demonstrates that grinding is able to move limits in surface roughness quality. Our particular aim in research is focused on ground surface quality with high precision roughness. Fundamental to this work is the identification of cutting conditions during grinding that are able to deliver surfaces able to compete

with those produced by, for example, superfinishing or honing. The need to achieve higher surface quality in grinding only is very important to production. We have a normal grinding wheel that we can use to grind different surfaces of materials. In fig. 4 we can see values of parameter Ra for the ground surface. These surfaces roughness values are corresponding to those achieved in honing or superfinishing. This fact is supported from the data shown in Fig. 5 and Fig. 6. The surface profile is very much lower and corresponds with roughness parameters, seen in Fig. 8. Material portion of surface profile is an average value for this method as shown in fig. 7. Very high quality of surface roughness is also given by use of grinding wheel and cutting conditions. Very low depth of cut, very fine dressing and use of coolant are the key process conditions. There is a material removal with small depth of cut and with combination of very fine dressing. The ground material is actually in polishing process – but with grinding wheel use and so we can get these surfaces with lower values of surfaces roughness that are not in polish surface parameters (due to 80 granularity of grinding wheel). Use of these process cutting conditions results in peak reductions and a reduction of the distance between peaks and valleys (evaluation by the Rz and Rt parameters – shown in Fig. 5 and Fig. 6, these results are supported by the surface profile – in Fig. 8).

The possibilities of improving the grinding process remains. It has been shown that the widening combination of cutting conditions and tools leads to continual research in finishing and shows new ways for manufacturing technology and production. A very important part of this research and results is that of production costs. For as long as we have demands on surface quality roughness, measured by different parameters, we can continue to generate very high precision surface roughness and quality by grinding, which diminishes the need for others methods of finishing. And will result in cost savings.. We save the cost of operators, machines, support materials, energy and time but the quality has to be maintained. [8], [9], [12]

This paper shows new eventuality in surface roughness parameters namely is presenting values of surface roughness after grinding by parameter Ra at Nanometre scale. In fig. 4 we have for example Ra values 0.04 [μm] for EN ISO 100Cr6 steel – we could present this value as 40 [nm]. Certainly we should be using a measuring device capable of measuring to this scale and resenting new ways to show grinding is possible at this prefix – 10^{-9} level.

Acknowledgement

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REFERENCES

[1] Bassoli, E. etc., 2011, Grinding Micromechanisms of a Sintered Friction Material, in: *Journal of Manufacturing Science and Engineering, ASME*, Feb 2011, vol. 133., 6 pp.

[2] Holesovsky, F., Novak, M. 2010. Influence of grinding on machine parts with desing notches, in: *Manufacturing Technology* IX, UJEP, Usti n. Labem, 40-46 pp.

[3] Kocman, K. 2010. Analyza vyvojovych brousicich kotoucu na bazi mikrokrystalickeho korundu, in: *Strojirenska technologie*, vol. XV., no. 3., UJEP, Usti nad Labem, 40-47 pp.

[4] Lukovics, I., Bilek, O., Holemy, S. 2010. Development of Grinding Wheels for Tools Manufacturing, in: *Manufacturing Technology*, vol. X., no. 10., UJEP, Usti nad Labem, 10-16 pp.

[5] Marinescu, I., D., et all. 2007. *Handbook of Machining with Grinding wheels*, Boca Raton: CRC Press, 592 pp.

[6] Novak, M. 2011. Surface quality of hardened steels after grinding. in: *Manufacturing Technology*, vol. XI., no. 11., UJEP, Usti nad Labem, 55-59 pp.

[7] Malkin, S. 1989. *Grinding Technology: Theory and applications of machining with abrasives*, SME, 275pp.

[8] Kundrak, J. 2011. Alternative machining procedures of hardened steels, in *Manufacturing Technology*, vol. XI., no. 11., UJEP, Usti nad Labem, 32-39 pp.

[9] Novak M., Lattner M., Ruzicka L., Holesovsky F., 2010. Grinding and surface quality parameters at automotive parts machining, in *Manufacturing Technology*, vol. X., no. 10., UJEP, Usti nad Labem, 36-38 pp.

[10] Holesovsky, F., Novak, M. 2010. Grinding and its influence to ground surface durability. *Proceedings of International Conference on Advances in Materials and Processing Technologies*, Paris. Publisher: Amer INST Physics, Melville, NY, USA. ISBN 978-0-7354-0871-5. WOS: 000287169300158.

[11] Novak, M. 2012. Influence of the Corrosion Surrounding on Surface Quality of Ground Hardened Steels In *Key Engineerings Materials*, vol. 496: Precision Machining IV. TTP, Zurich, 25 – 30 pp., WOS:000302674400005

[12] Novak, M., Naprstkova, N., Ruzicka. L. 2012. New ways in aluminium alloys grinding. In *Key Engineerings Materials*, vol. 496: Precision Machining IV. TTP, Zurich, 132 – 137 pp. WOS:000302674400023