Cutting ability of Norton Quantum grinding wheels

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Abstract: This paper deals with cutting ability of progressive Norton Quantum grinding wheel during grinding roll bearing steel 100Cr6 of hardness 61 HRC. Cutting ability of this wheel is compared with conventional grinding wheel and based on measurement of grinding forces as well as surface roughness. Results of experiments show that Norton Quantum grinding wheels are capable of long term grinding cycles at high removal rates without unacceptable occurrence of grinding chatter and surface burn whereas application of conventional wheel can produce excessive vibration and remarkable temper colouring of ground surface. Moreover, while Norton Quantum grinding wheel gives nearly constant grinding forces and surface roughness within ground length at higher removal rates, conventional grinding wheel (as that reported in this study) does not.

Keywords: grinding, surface roughness, grinding forces

1 Introduction

Grinding operations are vital of importance considering components functionality. These operations very often represent the final operation in which the final surface is produced. Grinding is usually performed on critical parts to improve their precision (dimensional and shape) and surface roughness. Ground parts can suffer from overtempering or overheating as well as unacceptable chatter marks due to unstable grinding process. Grinding chatter can also affect precision of produced parts. For this reason grinding technology is rapidly developed in a variety of its aspects such as grinding machines design, coolant, dressing process as well as grinding wheel to increase productivity, decrease energy and time consumption and the corresponding costs, elongate dressing intervals and enhance quality of ground parts [1, 2, 3]. Specific cutting ability of grinding wheels based on SG (seeded gel) or TG (targa gel) grains was previously studied and reported [1, 2, 3]. Grain of SG or TG grinding wheels is entirely composed of hundreds or thousands micro grains instead more rough structure of conventional alumina grains. Such structure (SG or TG) favors microchipage of grinding grain and keeps grain sharp in the long term point of view. However, microchipage take place mainly at higher removal rates [1, 2, 3] whereas lower removal rates are less recommended. Except grinding grain structure also bonding of grinding wheel undergoes the process of intensive research. The result of such effort can produce grinding wheels of unique cutting ability. Norton Quantum is a specific grinding wheel as a mixture of progressive SG grain and newly developed type of bonding. Producer guaranties longer dressing intervals, longer grinding wheel life time, lower energy consumption and stable grinding process at higher removal rates without coolant, unacceptable grinding chatter as well as surface burn [1, 2, 3]. Being so, this study verifies the abovementioned advantages of Norton Quantum grinding wheel and compares its cutting ability with conventional alumina wheel.

2 Experimental conditions

Experiments were conducted on samples made of bearing steel 100Cr6 of hardness 61 HRC. 2 pieces of dimension 100x60x10mm were prepared for long term test. Cutting process was monitored as a long term test where such aspects as grinding forces, grinding chatter and surface roughness were monitored.

Grinding Wheel: 250x20x76,2 A9960J9V (as conventional) and 3NQ60J9VQN (as Norton Quantum). Grinding machine: BPH 20. Grinding wheel was redressed by the use of single crystal dresser a_{ed} = 20 μm, v_{cd} = 25 m.s^{-1}, v_{fd} = 90 mm.min^{-1}. Cutting conditions as follows: v_c = 32 m.s^{-1}, v_f = 8 m.min^{-1}, a_p = 0,03 mm, dry grinding, grinding width 10 mm, grinding length 100 mm. Grinding in the case of conventional grinding wheel was stopped after 30 grinding cycles (passes) due to excessive grinding chatter and visible surface burn whereas Norton Quantum gives stable grinding much longer.

Grinding forces were measured by the use of dynamometer Kistler at sampling frequency 2 kHz. Two components of cutting force such as main force F_c and thrust force F_p were analyzed as a static quantities (low frequency component – low pass filter 10 Hz) and dynamic quantities expressed in its RMS values (high frequency components – high pass filter 10 Hz). Surface roughness were measured by the use of Hommel Tester T 2000 (measuring length 0,8 mm – total 4 mm) at 5 positions (10, 30, 50, 70 and 90 mm from entering edge of the workpiece). Surface roughness is expressed in such parameters as *Ra*, *Rq*, *Rz* and *Rdq* as well as the bearing ratio curves. Interval of grinding cycles in which the grinding forces, respective surface roughness were measured indicates *Tab. 1*.

Table 1

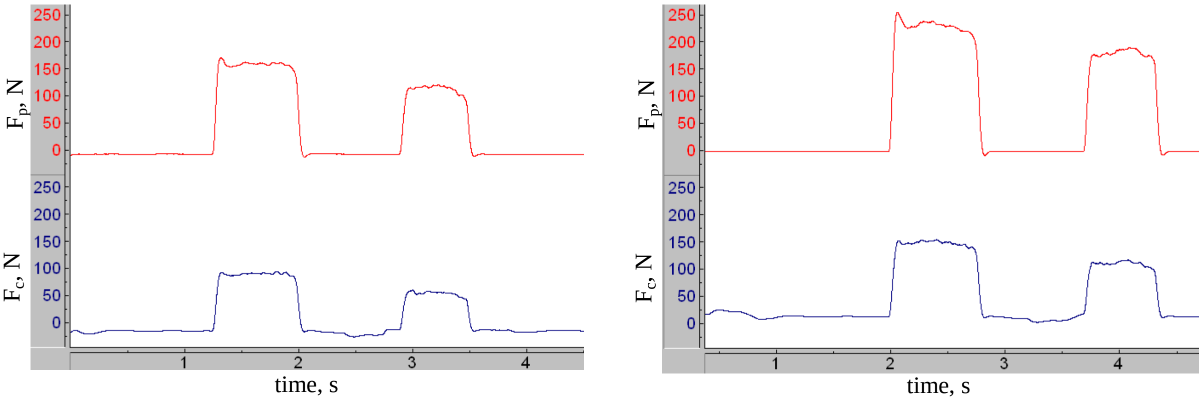
Intervals of grinding cycle in which grinding forces and surface roughness were measured

Grinding cycles (passes)	10	20	30	40	50	60
Grinding forces – conventional wheel	x	x	x			
Grinding forces – Norton Quantum wheel	x	x	x	x	x	x
Surface roughness – conventional wheel	x	x	x			
Surface roughness – Norton Quantum wheel	x	x	x	x	x	x

3 Results of experiments

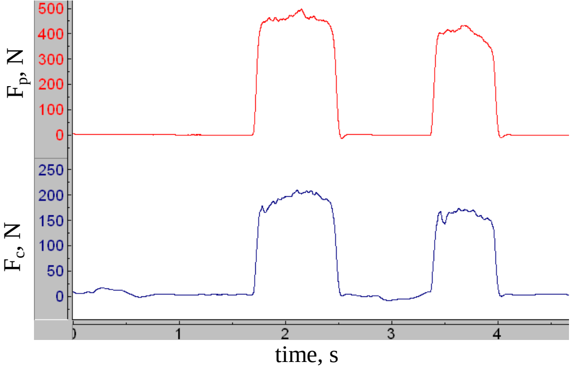
Grinding forces

Fig. 1 depicts gradual increase of grinding components for conventional grinding wheel. It can be clearly shown that high removal rates together with dry grinding process result into the loss of cutting ability after 30 passes. Static as well as dynamic components of grinding forces increase rapidly, see *Fig. 1*, *3* and *Fig. 4*. While static component of F_c increases from 105 N at 10 passes to 190 N at 30 passes, the thrust component F_p increases more remarkably from 167 N at 10 passes to 490 N at 30 passes. Moreover, static component at 30 passes is not constant within the grinding length but exhibits visible growth. The high static values indicate the high energy consumption, the corresponding excessive generation of the heat in the contact between grinding wheel and workpiece. Such grinding also produce remarkable surface burn (temper colouring due to intensive surface oxidation initiated elevated temperatures on the ground surface) together with unstable grinding evidenced by the high dynamic component of forces. Moreover, loss of cutting ability proves also increasing ration between the thrust F_p and the main F_c components, see *Fig. 5*. This increased unbalance can be viewed in either static or dynamic components. Increasing ratios between the main and thrust forces are very often associated with the grinding wheel wear, mainly generation of wear land on the grains, corresponding grain geometry and linked with intensification of friction and heat generation in the grinding wheel – workpiece contact [X].



a) 10 passes

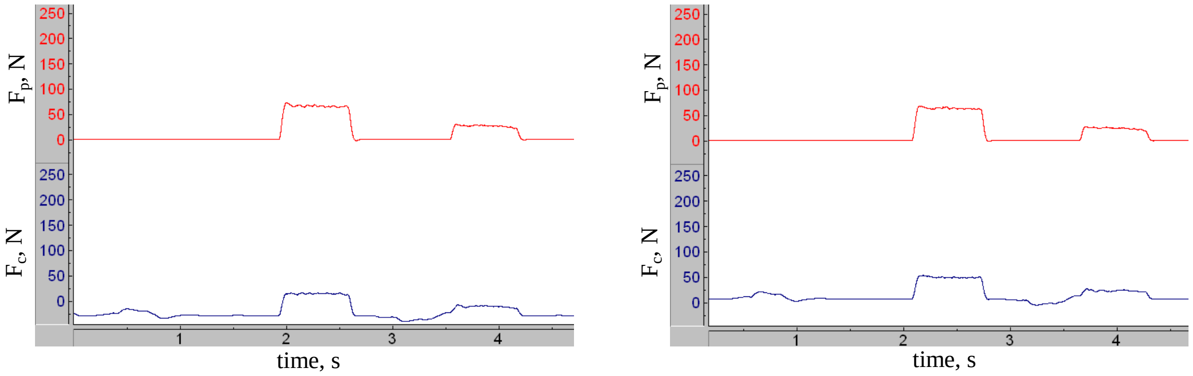
b) 20 passes



c) 30 passes

Fig. 1 Records of grinding forces for conventional grinding wheel

On the other hand, Norton Quantum grinding wheel gives much stable grinding cycles. Compared with conventional wheel, Norton Quantum produces much lower static as well dynamic components of thrust and main forces during much longer grinding cycles (60 passes). Static and dynamic components are kept nearly constant (or exhibit gentle decrease) along with grinding cycle. Moreover, the ratios between F_p and F_c (for dynamic as well as static) components stay nearly untouched. Measurement of grinding forces proves the self dressing effect of Norton Quantum grinding wheel as a result of SG grain microchipage and the specific type of grinding wheel bonding. The remarkable differences between the conventional and Norton Quantum wheels can be found not only in the phase of more developed grinding cycle (for instance after 30 passes) but can be indicated in the very early phases (after 10 passes). Both static components for Norton Quantum grinding wheel gives about 50% lower forces (compared with conventional grinding wheel), see *Fig. 1* and *Fig. 2*. Furthermore, both static components exhibit flat course along with the time and the corresponding grinding length (*Fig. 2).*



a) 30 passes *b) 60 passes*

Fig. 2 Records of grinding forces for Norton Quantum grinding wheel

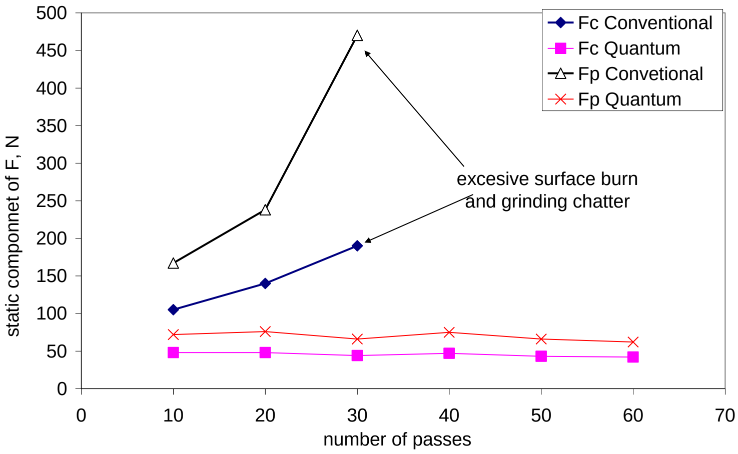


Fig. 3 Static components of grinding forces (low pass filter 10 Hz)

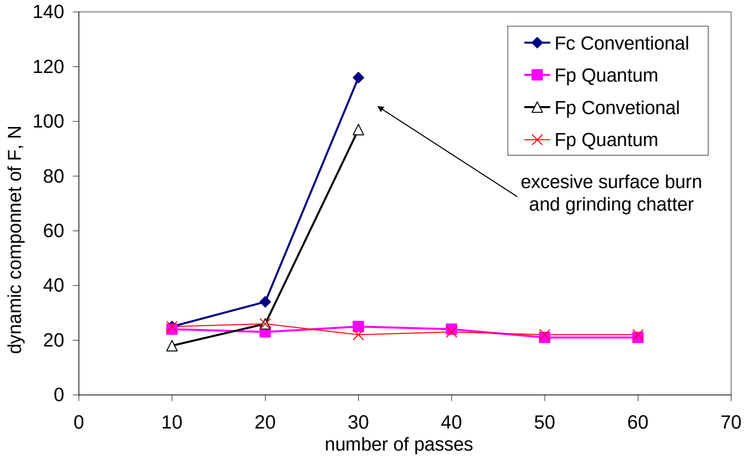


Fig. 4 Dynamic components of grinding forces (high pass filter 10 Hz)

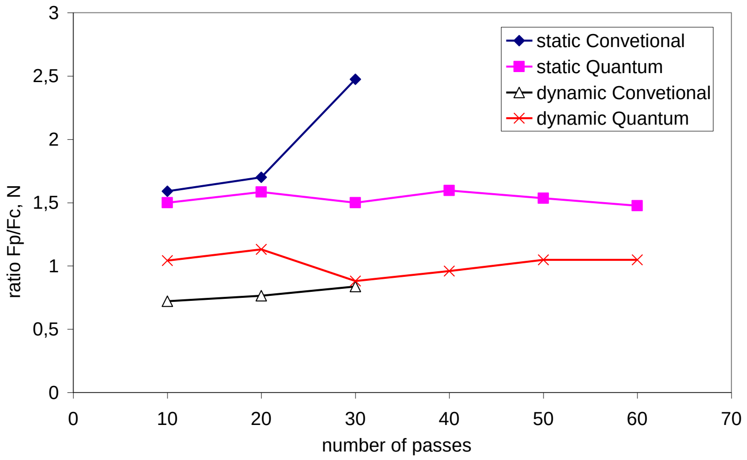
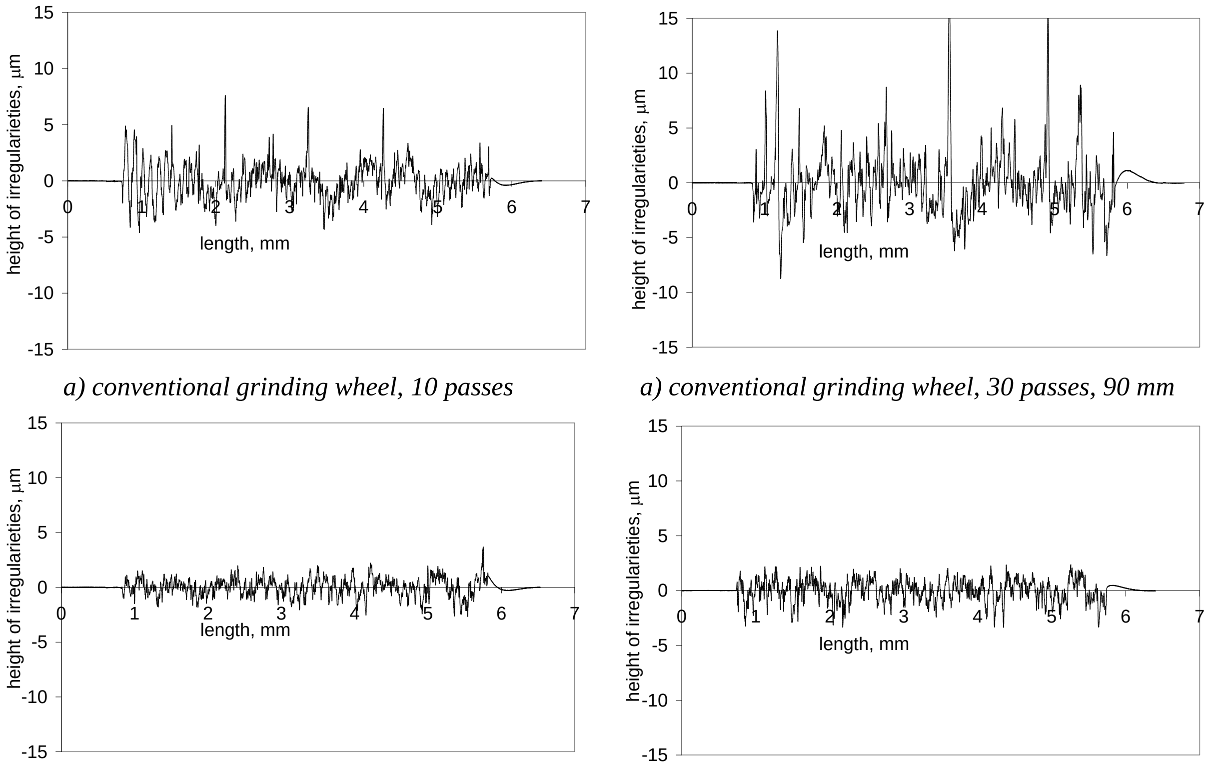


Fig. 5 Ratios F_p/F_c of static as well as dynamic components

Surface roughness

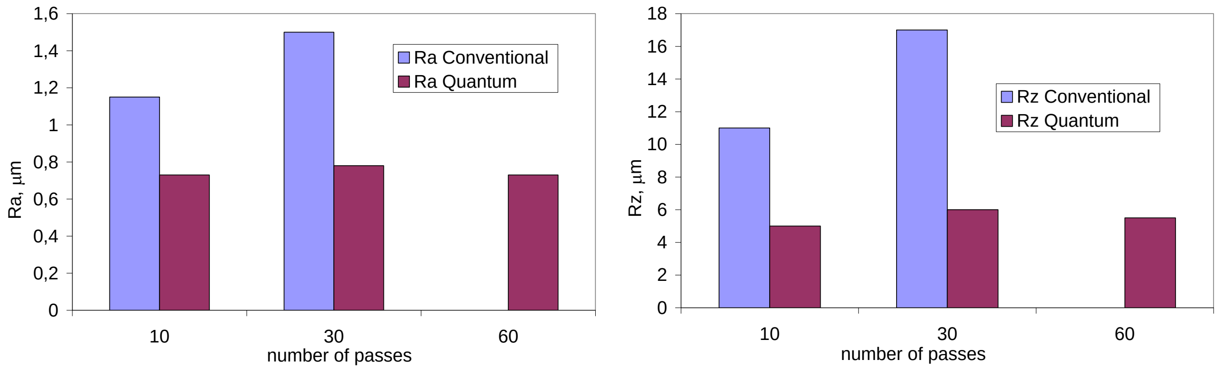
Evolution of surface roughness expressed in variable parameters corresponds with evolution of grinding forces as stated above. All analyzed parameters of surface roughness for the surface produced by conventional grinding wheel exhibit remarkable increase along with number of passes and the corresponding conventional grinding wheel wear, see *Fig. 6* and *Fig. 7*. Profile of surface roughness itself exhibits remarkable peaks especially in the final phases of grinding cycle after 30 passes). Moreover, the higher static and dynamic components for conventional wheel correspond with the higher surface roughness expressed in *Ra*, *Rz*, *Rq* and *Rdq* (see *Fig. 7*) as well as bearing ration (see *Fig. 7d*). Surface roughness produced by Norton Quantum stays either nearly untouched along with number of passes or exhibits the gentle increase (in the case of *Rqd* parameter in *Fig. 7c*). Furthermore, Norton Quantum gives more favor profile of bearing ratio curve illustrated in *Fig. 7d*. Surface roughness profile depicted in *Fig. 6* does not exhibit excessive peaks in no phase of grinding cycle as those produced by conventional grinding wheel.



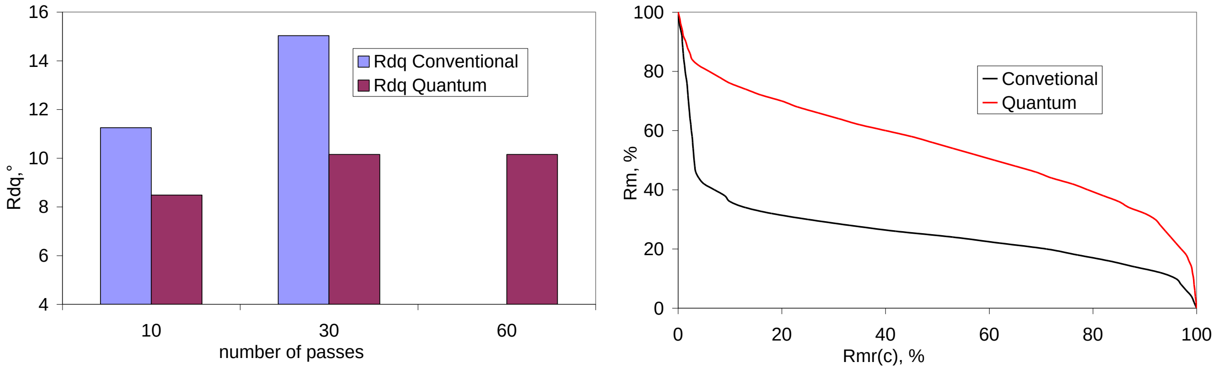
a) conventional grinding wheel, 10 passes *a) conventional grinding wheel, 30 passes, 90 mm*

c) Norton Quantum grinding wheel, 10 passes *d) Norton Quantum grinding wheel, 60 passes*

Fig. 6 Profiles of surface roughness



a) Ra *b) Rz*



c) Rdq *d) bearing ratio curves, 30 passes*

Fig. 7 Comparison of variable parameters of surface roughness

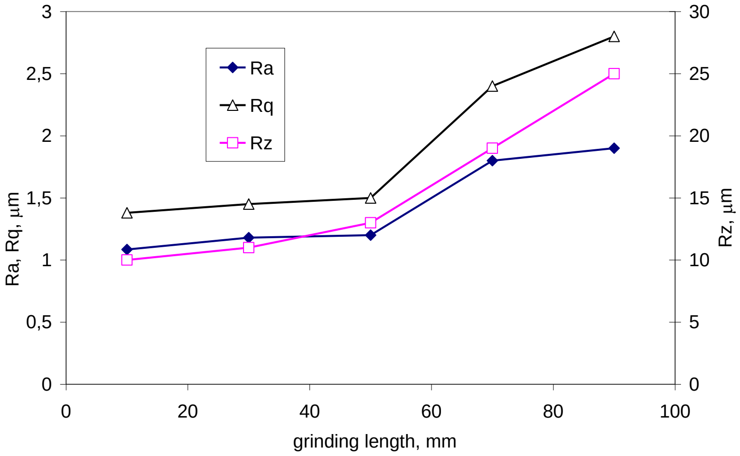


Fig. 8 Evolution of surface roughness parameters along with grinding length, conventional wheel

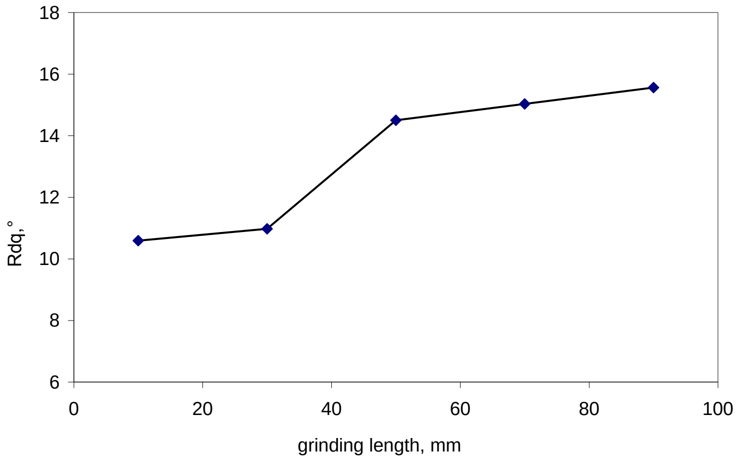


Fig. 9 Evolution of Rdq along with grinding length, conventional wheel

Unstable grinding expressed in gradual growth of static forces for conventional wheel (stated above) affects also homogeneity of surface roughness within the grinding length. *Fig. 8* a *Fig. 9* indicate that parameters of surface roughness gradually increases along with grinding length. On the other hand, Norton Quantum grinding wheel gives nearly constant state of surface roughness at all positions of grinding wheel (versus workpiece length) and all grinding cycles. Gradual increase of surface roughness illustrated by *Fig. 8* and *Fig. 9* is due to loss of cutting ability and occurrence of grinding chatter at high grinding forces.

4. Conclusions

Progressive grinding wheels based on SG or TG grains have found the high industrial relevance. Their cutting abilities are positioned between the conventional alumina and CBN wheels. Their industrial applications are more and more widely employed for a variety of grinding cycles due to potential technical and economy benefits. Their cutting abilities are still the subject of intensive research. This study only demonstrates their cutting potential expressed in such aspects of grinding as surface roughness and grinding forces. It should be also noticed that such aspects of grinding as G-ratio, surface integrity expressed in terms of stress state, structure transformations or hardness alterations have not been researched yet and should be analyzed in the near future. Application of progressive grinding wheels as those studied in this paper may contributes to intensification of grinding cycles with associated potential economy and ecology benefits.

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REFERENCES

[1] BARKHAUSEN, H.: Phys. Zeitschrift 20,1919, 201.

[2] ABUKU, S. – CULLITY, R.D.: *A Magnetic Method for the Determination of residual Stress*, Exp. Mech. 11, 1971.

[3] KARPUCHEEWSKI, B.: *Introduction to micro magnetic techniques*, ICBN 01, Hanover, 1998.

[4] ROSIPAL, M.: *Application of Barkhausen noise for study of surface integrity of machined surfaces,* PhD. Dissertation, University of Žilina, 2012.

[5] NESLUŠAN, M. – ROSIPAL, M. – OCHODEK, V.: *Analysis of some aspects of surface integrity after grinding and hard turning trough Barkhausen noise*, ICBN 09, Hejnice, 2011.

[6] MOORTHY, V. et all: *Evaluation of heat treatment and deformation induced changes in material properties in gear steeld using magnetic Barkhausen noise analysis*, ICBN 03, Tampere 2001.

[7] BRANDT, D.: *Randzonenbeeinflussung beim Hartdrehen*. PhD. Dissertation, Universität Hanover, 1995

[8] GUO Y.B. - SAHNI, J.: *A comparative study of of hard turned and cylindrical ground white layers,* Int. J. of Mach. Tool & Manuf. Vol. 44, 2004, pp. 135-145.

[9] MOORTHY, V – SHAW, B.A.: *Magnetic Barkhausen emission measurements for evaluation of depth of grinding damage*, ICBN 09, Aachen, 2009.

[10] VASHISTA, M – MOORTHY, V.: *Influence of applied magnetic field strength and frequency response of pick-up coil on the magnetic Barkhausen noise profile*, Journal of magnetism and magnetic materials, Vol. 345, 2013, pp. 208-214.

[11] NESLUŠAN, M. et. all: *Magnetic anisotropy in hard turned surfaces*, Acta Physica Polonica Vol.124, 2014, pp. 188 – 189.

[12] NESLUŠAN, M. et.all: *Application of Barkhausen noise for analysis of surface integrity after hard turning*, Manufacturing technology, Vol. 12, 2012, pp. 60-65.

[13] WANG, J.Y. - LIU, C. R.: *The effect of Tool Flank Wear on the Heat Transfer. Thermal Damage and Cutting Mechanics in Finishing Hard Turning*, CIRP Annals Vol. 48, 1999, pp. 53 – 56.