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Influence of High Speed Parameters on the Quality of Machined Surface

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***Abstract*—**The contribution is dealing with the influence of high speed parameters on the quality of machined surface. In general the principle of high speed cutting lies in achieving faster machine times with concurrent increase in accuracy and quality of the machined areas in largely irregular, mathematically hard to define shapes. High speed machining is a highly effective method of machining with the following goals: increasing of machining productivity, increasing of quality of the machined surface, improving of machining economy, improving of ecological aspects of machining. This article is based on an experiment performed by the Department of Machining and Assembly of the Faculty of Mechanical Engineering of VŠB-Technical University of Ostrava.

***Keywords*—**High speed cutting, measurement, surface integrity, surface roughness, residual stress/

I. INTRODUCTION

INCREASING competition pressure forces companies to implement organizational measures and optimize the current technology, possibly use new technologies, which include high speed machining. The high speed machining is highly efficient type of machining, where it is possible to reach large volumes of machined material per a time unit. The high speed machining thus brings us a possibility of production cost and energy savings.

II. CUTTING PROCESS DURING CONVENTIONAL AND HIGH SPEED MACHINING

It is not possible to determine the transition between conventional and high speed machining exactly, based only on determination of a certain cutting speed. We always need to take conditions that shape the cutting process into account. The determining conditions are the manner of machining and primarily the type of machined material that determine the appropriate value of the cutting speed.

Some experts are leaning towards the definition that HSC occurs in cases, when the medium temperature of cutting reaches values close to the melting temperature of machined material. In practice there is the opinion that machining by high cutting speeds takes place in the area of 600 to 1800 $m.min^{-1}$ and machining by super high cutting speeds at speeds over 18 000 $m.min^{-1}$. In case of materials that are hard to machine, like alloys of nickel or titanium, the preferred expression is power machining. [3]

According to the formulated laws of product creation efficient cutting of metal takes place only at times, when the cutting material in cutting process temperature and conditions keeps significant hardness superiority over the machined material. With increasing cutting speed the total amount of cutting process heat also increases almost in direct proportion with the increasing speed of shaving cut and intensity of shaving friction against the tool. The temperature of shaving changes suddenly, by a step, due to the plastic deformation of the shaving in the cutting plane, and increases further by friction of the shaving against front of the tool. The principle of HSC cutting processes can be explained, in comparison with conventional machining, on the Fig. 1.

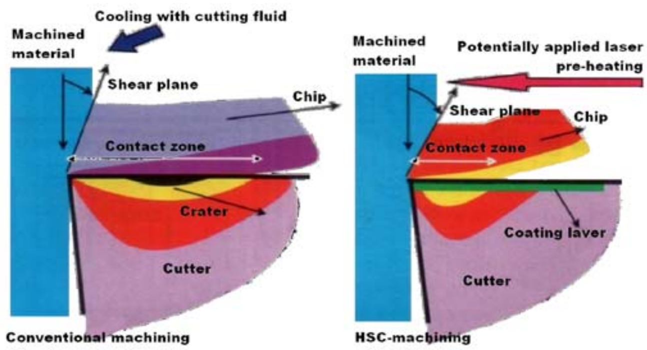

Fig. 1 Comparison of conventional and high speed machining [3]

High speed cutting performed by especially powerful, extraordinarily hard and temperature resistant cutting tools takes place with shaving temperature that is near melting temperature of the machined material. During certain cutting speeds there are sudden changes of a series of metallurgical, chemical and mechanical properties of a shaving. The shaving lowers its thrust force against the tool front. This action occurs also in case of a hardened steel shaving, which also becomes soft. Friction force and the total cutting resistance is lowered, the angle of shear plane increases, cross section of the moving

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away shaving gets thinner and the speed v_t of its departure from the contact zone increases. The created shaving becomes "red" and consequently lowers its thrusting force F_n against the tool front. On the contrary the contact zone plane becomes smaller, which limits the secondary increase in temperature due to friction of the shaving in the contact zone.

High speed machining reaches increase in material removal, quality of machined surface and life of a tool by the significant increase of cutting speed with decreased cross section of a shaving and lowered cutting force. High relative speed of the shaving with respect to the front area of a tool, together with the new quality of a cutting edge, increases the cutting process amount of heat, which is removed with the shaving, lowers heat and mechanical loading on the tool and increases its useful life. Reduction of heat flows that go into the tool, frame of a machine and the machined part gives us increase in the machined part accuracy and quality of its surface.

III. Experimental Verification of HSC Influence on Surface Quality

Within the performed experiment our target was to verify the influence of high speed cutting on the quality of machined surface. The experimental part has been performed in cooperation with the Institute of Mechanical Technology of Poznan University of Technology in Poland. Within the experimental part we have evaluated surface roughness and residual tension in relation to proposed cutting parameters and used cutting tools.

We have used the 12 050.1 material for the experiment. The work was done on the universal 5 axis CNC cutting center DMU60 MonoBlock®, with the NC turntable from the Deckel Maho company. The spindle rpm range was 1÷24 000 min-1. Heidenhain iTNC 530 was the machine control system. The optical machine probe RENISHAW OMP60, with the OMI-2 optical system was used to position a machined part.

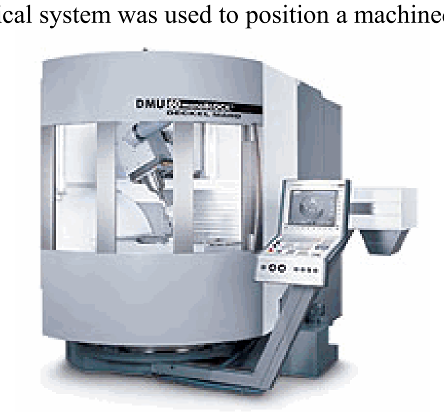

Fig. 2 The universal DMU 60 monoBLOCK® cutting center [8]

The cutter marked F4AJ1800ADN30A from the Kennametal Europe GmbH company was selected for this experiment. The cutter F4AJ1800ADN30 is a carbide four cutting edge shank cutter with the diameter 18 mm and helix rise of 30°. This cutter is suitable for high speed machining due to its rigid body and design with satisfactorily large tooth gap, which ensures removal of shavings without problems even during high cutting speeds. Primarily the cutter is intended for machining of P, M, K and S materials, and alternatively for machining of N materials.

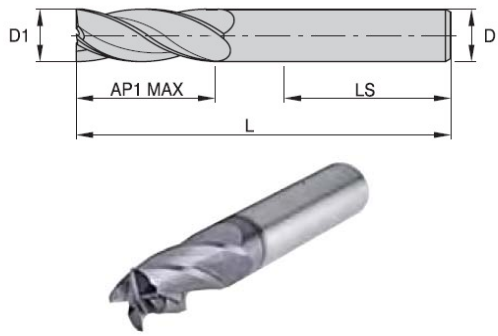

Fig. 3 The F4AJ1800ADN30 cutter [7]

TABLE I
The F4AJ1800ADN30 Cutter Dimensions [7]

D1 [mm]	D [mm]	Ap1 max [mm]	LS [mm]	L [mm]
18	18	32	48	92

The cutter has a PVD multiple layer treatment with the TiN, TiCN and TiC layers. The physically applied PVD TiN layer achieves significantly better results, considering tool cutting edge wear in comparison to the chemical CVD layering method.

The cutting parameters used during the experiment are shown in the Table II.

TABLE II
The Cutting Parameters used during the Experiment

Machined surfaces	Feed speed v_f [m.min^{-1}]	Revolutions n [min^{-1}]
Surface number 1	1	1000
Surface number 2	5	5000
Surface number 3	10	10000
Surface number 4	15	15000
Surface number 5	20	20000
Surface number 6	24	24000

The major variable in the experiment are cutting conditions. The axial cutting depth was determined with regard to application of this technology during finish to a_p= 0,25 mm, f_z = 0,25 mm. It is acceptable for finishing operations.

IV. Evaluation of Surface Roughness

The measurement of surface roughness was done on a contact measuring apparatus – the MITUTOYO SurfTest SJ-401 roughness tester in the laboratory of the Department of Machining and Assembly of the Faculty of Mechanical Engineering of VŠB-TUO Ostrava. SJ-401 is a contact (point) tester to measure surface roughness, intended for workshop use. The radius of the measuring point is 2 µm.

The following Fig. 4 shows parameters of the surface roughness for the 12 050.1 material. The 12 050.1 material was evaluated with regard to preparation of further experiments. We have evaluated the Ra and Rz roughness parameters in this experiment, both in transversal and longitudinal cross-sections in relation to the cutting movement vector.

It is apparent from the Fig. 4 that after exceeding the feed speed v_f 15 m.min^{-1}, we are achieving significantly better roughness quality results, than with lower cutting speeds. The effect of high speed cutting is confirmed in this case. The HSC cutting process is more stable than the conventional machining one, especially due to higher frequency of forced oscillations, and self-induced oscillation frequency is much higher that the inherent frequency of members of M-T-MP system. The frequency of excitation force depends for the most part on creation of shavings. During high speed machining the shavings are mostly coherent, articulate and elementary. The frequency of occurrence of shaving pieces or elements is very high, therefore the mentioned excitation force frequency is also high.

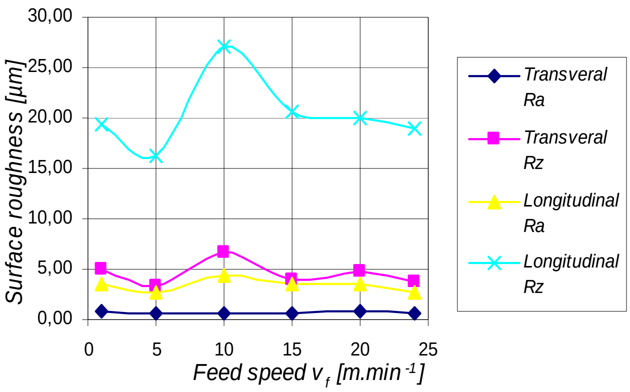

Fig. 4 Achieved the surface roughness parameters

The Fig. 4 shows that during the feed speed v_f 10 m.min^{-1} the worst surface roughness parameters were achieved. The roughness parameters improve when we exceed this speed. The best roughness parameters are of course achieved during the feed speed v_f 15 m.min^{-1}.

Both shortening of machine times and improvement in the roughness parameters were demonstrated during high speed machining. The mentioned theoretical assumptions were confirmed.

V. Evaluation of Surface Hardness

In the designed experiment the hardness test according to Brinell was performed to find a change in the hardness of sample surface layers after cutting. The designated hardness test method according to Brinell was evaluated as suitable for testing soft and medium hard materials with heterogeneous structure. The hardness test was performed at the Mechanical properties test laboratory (VTC.30), which is an integral part of the accredited VÍTKOVICE TESTING CENTER s. r. o.

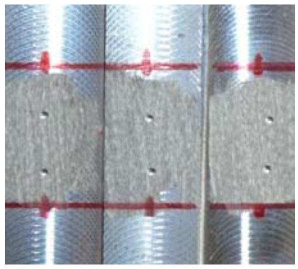

Fig. 5 Example of imprints using the hardness test

The hardness test according to Brinell was performed in accordance with the standard ČSN EN ISO 6506 Hardness Test, which became effective on September 1, 2006. The hardness value according to Brinell was determined by using tables in the standard according to used indentor, load amount and imprint diameter.

TABLE III
Table of Material 12 050.1 Hardness Measured Values

Machined surfaces	Feed speed v_f [m.min^{-1}]	HBW 2,5/187,5	
		indention 1	indention 2
Surface number 1	1	170	167
Surface number 2	5	175	180
Surface number 3	10	183	179
Surface number 4	15	182	180
Surface number 5	20	182	184
Surface number 6	24	182	175

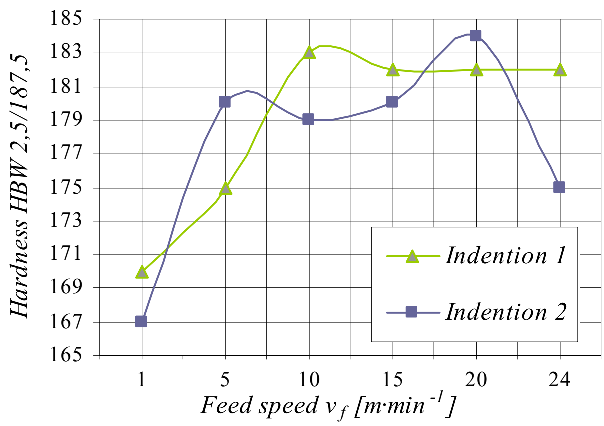

Fig. 6 Material 12 050.1 hardness values after cutting

Material hardness increases with increased feed speed to the feed speed values around v_f 10 to 24 m.min^{-1} and then remains constant. During cutting with the four tooth cutter the highest hardness was achieved at the transport speed v_f 20 m.min^{-1}, on the contrary, the lowest hardness was achieved during cutting with the transport speed v_f 1 m.min^{-1}.

VI. Evaluation of Residual Stress

The occurrence of residual stress in dependence on cutting speed, cutting movement, tool type and other parameters is therefore one of important parts of HSC machining process optimization. To evaluate residual tension after high speed cutting, it was used the magneto elastic method based on the Barkhausen noise.

The surface tension was measured to the depth of 0.1 mm. The measurement was performed by a magnetoelastic method in three independent cross sections. Measurement was performed on 3 different seats of every machined surface with step 10 mm.

The MBN amplitude curve for the four tooth cutter using the 12 050.1 material can be seen on Fig. 7.

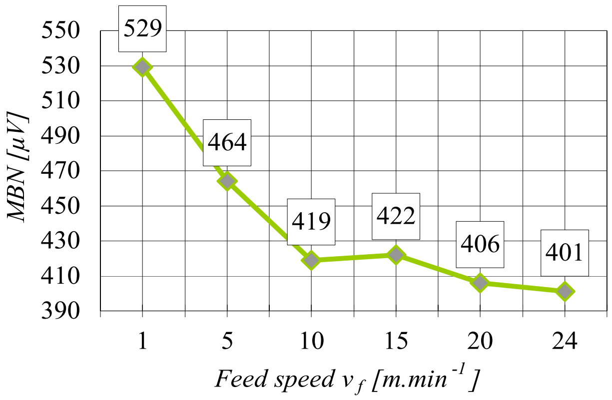

Fig. 7 The MBN amplitude curve depending on feed speed

With increasing feed speed the surface tension slowly decreases. The best tension parameter was achieved for the transport speed v_f 24 $m.min^{-1}$. Lower surface tension values were achieved during high speed cutting in comparison with cutting using lower speeds. The effect of high speed cutting has been confirmed in this case.

VII. Conclusion

Within the experimental part we have evaluated surface roughness and hardness according to Brinell in relation to proposed cutting parameters and used cutting tools. The roughness test on all planes in longitudinal and transversal directions to the transport direction vector was performed first. The measurement was performed at the Department Machining and Assembly of the Faculty of Mechanical Engineering of VŠB-TU Ostrava. Another performed test was the hardness test according to Brinell, which was performed with help of the Vítkovice a.s. testing laboratory. The measurement of the residual tension by the magnetoelastic method was performed at the laboratory of Department of Mechanical Technology.

The HSC effects were reached by optimal selection of cutting conditions. Mutual relationship of the feed speeds to spindle revolutions or cutting speed significantly differs according to machined materials and diameters and number of cutting tool edges. In the performed experiment the described high speed machining effects started to show after reaching the feed speed limit of 15 $m.min^{-1}$. It was confirmed during experimental machining of the 12 050.1 steel that even in these materials the transition from conventional machining to HSC exists.

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