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INFLUENCE OF CUTTING PARAMETERS ON INTEGRITY SURFACE AT HIGH SPEED OF CUTTING

VLIV ŘEZNÝCH PARAMETRŮ NA INTEGRITU POVRCHU PŘI VYSOKÝCH RYCHLOSTECH ŘEZÁNÍ

Abstract

The contribution is dealing with the quality of the machined surface after high speed cutting. Development in the area of manufacturing techniques, cutting tools and industrial materials is mostly evaluated from the point of view of influence on economical and ecological aspects of machining. If we consider full utilization of new tool materials and machine outputs that are several times higher in comparison with the classical ones, we should consequently ask, whether this amount of energy transferred to cutting edge of these tools will not influence surface properties of a machined surface significantly. Many research institutions have been working on these questions of influence of technological processes on the properties of machined parts. 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.

Abstrakt

Příspěvek se zabývá kvalitou obrobeného povrchu po obrábění vysokými řeznými rychlostmi. Vývoj v oblasti výrobní techniky, řezných nástrojů a strojírenských materiálů je většinou hodnocen z hlediska vlivu na ekonomické a ekologické aspekty obrábění. Uvažujeme-li plné využití nových nástrojových materiálů a příkonů strojů, které jsou několikanásobné ve srovnání s klasickými, vystává následně otázka, zda to množství energie převedené na břit nástroje neovlivní výrazněji vlastnosti obrobeného povrchu. Problematikou vlivu technologických procesů na vlastnosti povrchové vrstvy obrobku se zabývala a nadále zabývá řada pracovišť. Tento článek vychází z experimentu realizovaného Katedrou obrábění a montáže Fakulty strojní VŠB-Technická univerzita Ostrava.

1 INTRODUCTION

Surface integrity is a term that involves several considerations such as surface finish and freedom from cracks, chemical range, thermal damage and adverse residual stress. The first of these (surface finish) is by far the most important for finishing operations. The others are mainly a concern relative to ground surfaces. High speed machining can be characterized by the fact the area of the primary plastic deformation is reduced to a narrow band remaining in the shear plane; this contraction is due to the impact of high-speed cutting.

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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.

2 INFLUENCE OF CUTTING CONDITIONS ON QUALITY OF MACHINED SURFACE AFTER HSC

The quality of a surface needs to be understood as an integral characteristic of a machine part. The quality of the machined surface is characterized by:

- the geometry of the machined surface (dimensional accuracy, variations of geometrical shape and position, undulation, roughness and others),
- physical-mechanical properties of the surface layer – hardness, solidification and residual tension,
- physical-chemical state of the surface.

The state and quality of a surface layer of machined metal influences fatigue strength, wear resistance, anticorrosion stability, fitting quality etc. Study of the surface layer properties helps to evaluate influence of technological processes and work conditions on machined part surface layer quality.

During high speed machining there is narrowing of the primary plastic deformation area to the narrow belt in the shear plane due to machining speed. This plastic deformation is very small and almost does not intrude under the cutting plane. A size of surface layer solidification is then influenced by the tertiary plastic deformation only. Using of the HS technology lowers the intensity of solidification of the surface layer and the solidification depth remains very small. [3]

Another advantage of the high speed machining is decreased ratio of heat that is transferred to a machined part. The surface layer is less heat stressed, which eliminates disadvantageous tensile stress on the machined part surface (creation of cracks). Decreasing of the surface temperature also eliminates structural changes in the surface layers. This is especially important in hardened materials, where the high surface temperature would cause yielding and loss of hardness. [3]

The shape accuracy and roughness of a machined part depends also on stability of the cutting process. In order to achieve stability the frequency of forced and self-induced oscillations must differ from the inherent oscillation frequency of any determinant system member. Then resonance cannot occur. [3]

There is focus on surface topography, especially in finish machining, during high speed machining. The HS technology itself does not have a large influence on the surface topography, unlike many factors occurring within the process. It is primarily static and dynamic rigidity of the whole system, which consists of a tool, a machine and a machined part. Dynamic loading of the M-T-MP (Machine-Tool-Machined Part) system by cutting forces has fundamental influence on stability of cutting process and consequently the accuracy of a machined part and quality (integrity) of machined surface as well. [3]

Influence of cutting speed and depth in high speed cutting is similar as for conventional machining. However, in HS machining values of these parameters depend a lot on many factors, and must be always strictly maintained within a certain range. A suitable strategy of material removal must be employed, especially during machining of shaped planes. A cutting depth may significantly change in corners and sharp turns. This suitable strategy of material removal is enabled by sophisticated CAD/CAM systems. Wrong strategy of material removal can affect whole stability of cutting process.

3 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}. The DMU 60 MonoBlock® cutting center is one of highly productive machining tools with required accuracy. The modular monoBLOCK® concept provides necessary rigidity and also offers optimum ergonomics and user friendliness. 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. 1 The universal DMU 60 monoBLOCK® cutting center [6]

We have used a cutter from the Kennametal Europe GmbH company for this experiment. Kennametal is one of the leading world companies that supplies tools, machining components and modern materials used in manufacturing processes. Specifically, we used the cutter marked F4AJ1800ADN30.

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. The tool is also suitable for finish cutting. Primarily the cutter is intended for machining of P, M, K and S materials, and alternatively for machining of N materials.

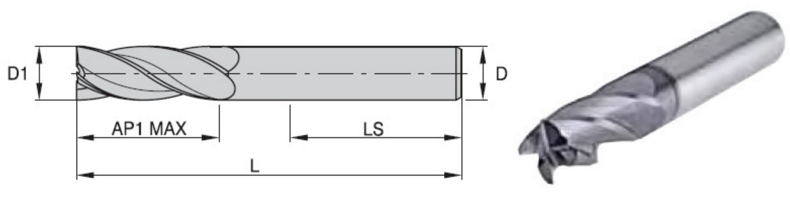

Fig. 2 The F4AJ1800ADN30 cutter [5]

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 mentioned coatings are usually used for hard and dry machining.

The coating systems for high speed cutting must be as thin as possible, often < 10 µm, since higher thicknesses increase curvatures of cut edges, which affects accuracy, roughness and cutting process in general.

Tab. 1 The F4AJ1800ADN30 cutter dimensions [3]

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

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. The cutting parameters used during the experiment are shown in the table 2.

Tab. 2 The cutting parameters used during the experiment

Machined surfaces	feed rate v_f $m \cdot min^{-1}$	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

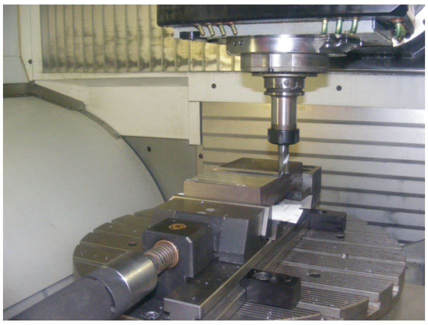

Fig. 3 The milling of sample

3.1 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.

Fig. 4 The SurfTest SJ-401 roughness tester [7]

The following Fig. 5 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. 5 that after exceeding the movement speed v_f 15 m/min, 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.

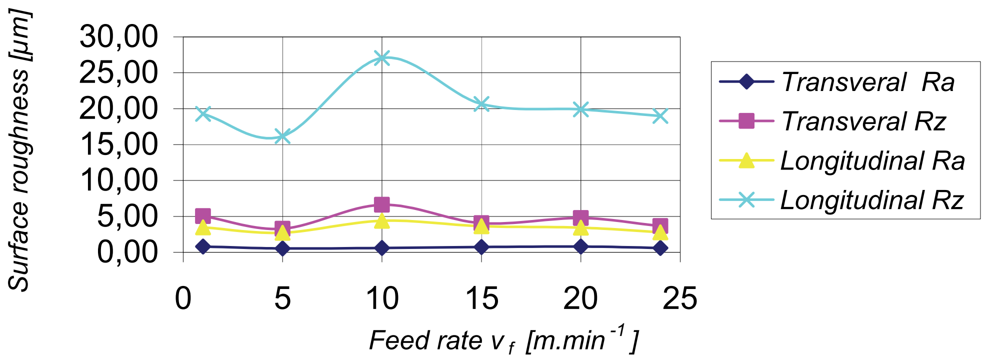

Fig. 5 The surface roughness parameters achieved with the 12 050.1 material

3.2 Measurement of Residual Tension

The residual tension is a tension that remains in the part surface after removal of causes that created it. There is occurrence of residual tension during machining due to heat processing and machining. This problem is especially significant in modern technologies, like hard high speed cutting (HSC), where we encounter extreme cutting conditions both from mechanical, and heat point of view. The occurrence of residual tension 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, we have used the magneto elastic method based on the Barkhausen noise. The Barkhausen noise phenomenon was described in 1919 for the first time. The arrangement used by prof. Barkhausen is shown on the Fig. 6. [2]

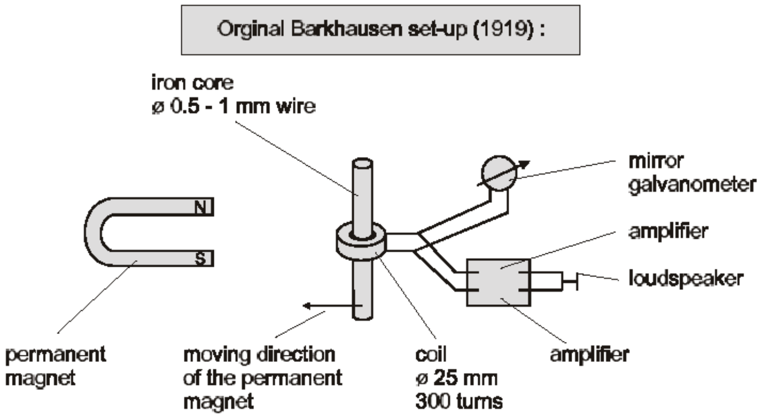

Fig. 6 The original Barkhausen arrangement [2]

If we bring near or take away a magnet from a core, we will hear rustling or cracking noise in a loudspeaker. This noise is related to discontinuities in the magnetization process of a ferromagnetic material. The ferromagnetic materials can be imagined as consisting of small magnetic areas, similar to bar magnets, so called domains. Each domain gets magnetized along its crystallographically distinctive directions. The domains are separated by borders (so called walls) one from another. Outside magnetic field causes movement of the domain walls. The wall movement is reflected in the whole magnetization of a sample. If a coil with conductive wire is placed near the sample in the period, when the domain wall is moving, then the related change in sample magnetization induces an electrical pulse in the coil. [2]

The Barkhausen noise magneto elastic method can be used in the following areas:

- measuring of residual tension, provided that micro structural parameters move within reasonable (stable) limits,
- measuring of structural changes, provided that level of tension moves within reasonable limits again,
- testing of defects that can cause changes in tension or microstructure.

5 CONCLUSIONS

A significant parameter that influences the level of Barkhausen noise is a metallurgy structure. This phenomenon can be described by using a concept of hardness. Intensity of a signal continuously decreases with increasing hardness. The measurement of Barkhausen noise then provides information about micro structural state of material to us. The mutual relationship of roughness and level of Barkhausen noise will be researched in further experiments performed at the Department of Machining and Assembly of the Faculty of Mechanical Engineering of VŠB-TUO.

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