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RESIDUAL STRESS MEASURING AT CONVENTIONAL AND HIGH-SPEED MILLING

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Abstract

At the moulds and swages making happens to rise of residual stress in consequence of heat process. These problem is very significant especially at modern technology like high – speed hard milling (HSC), when happens to extreme conditions from mechanical and heat aspects. Residual stress rise depending on cutting speed, feed, tool type and other parameters is therefore one of the most important part of optimizing of he HSC process.

This paper deals with evaluation of residual stress after high – speed and conventional milling. For a measuring residual stress were select two different methods. It was method measuring by method of Barkhausen noise and hole-drilling method.

Abstrakt

Při výrobě forem a zápustek dochází ke vzniku zbytkových napětí v důsledku tepelného zpracování a obrábění. Tento problém je obzvláště významný u moderních technologií jako vysokorychlostní tvrdé frézování (HSC), kdy dochází k extrémním záběrovým podmínkám jak z mechanického, tak i z tepelného hlediska. Vznik zbytkových napětí v závislosti na řezné rychlosti, posuvu, typu nástroje a dalších parametrech je proto jednou z důležitých součástí optimalizace procesu HSC obrábění.

Tento článek se zabývá vyhodnocením zbytkových pnutí po vysokorychlostním a konvenčním frézování. Pro měření těchto pnutí byly zvoleny dvě různé metody. Byla to metoda měření pomocí Barkhausenova šumu a metoda odvrtávací.

1 INTRODUCTION

Residual stresses are defined like stress, which are in material without incidence outer load. Their rise is linked to production technology and material adjustment. Big problem have residual stress, whereas their influence is able to be bestead and harmful too. Tension stress are considered for harmful. Compressive stress contrariwise improve material fatigue properties and hold under rise and development of furface rents. High levels of residual stress and with them connected relaxation processes generally influence solidity characteristics of material and thay can lead to unstability form and qulities of components surface.

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2 PRINCIPLE OF HIGH – SPEED CUTTING

At raising of cutting speed into areas of high – speed machinig happens to markedly different tramps in comparison with conventiona cutting. At using of high – speed cutting by very hard and heat resistant tool, the chip temperature nears of fusing temperature of mechanided material. At definite cutting speed happens to sudden change of metallurgical, chemical and mechanical chip character. At passage through by cut plain suddenly raise temperature in whole chip cross – section. The chip go turn red and it soften and lower its thrust pin power on tool face. The same action occurt also in case of hardened steel chip, which soften also. Frictional force go down and general cutting resitance, the angle of cut plain extend, chip cross section reduce and raise departure chip speed from contact zone. Surface of contact zone decrease thereby confines secondary chip temperature rise, which rises friction in contact zone. Thanks to all this parameters hasn't chip time hand over heat into mechanided tools and into worpiece too. That is why the heat transfer into tool and workpiece minimizes and most heat postneuritic at machining leaves together with chip. Whole this process results in, that the also at globaly considerable generated heat confines the tool wear and raise surface integrity. Cutting force decline and heat flow decrease into workpiece also results in increasing of accuracy machinig. It follows, that at election of machinig acceptable strategy is possible enhance quality of mechanided surface also at minimum tools radius.

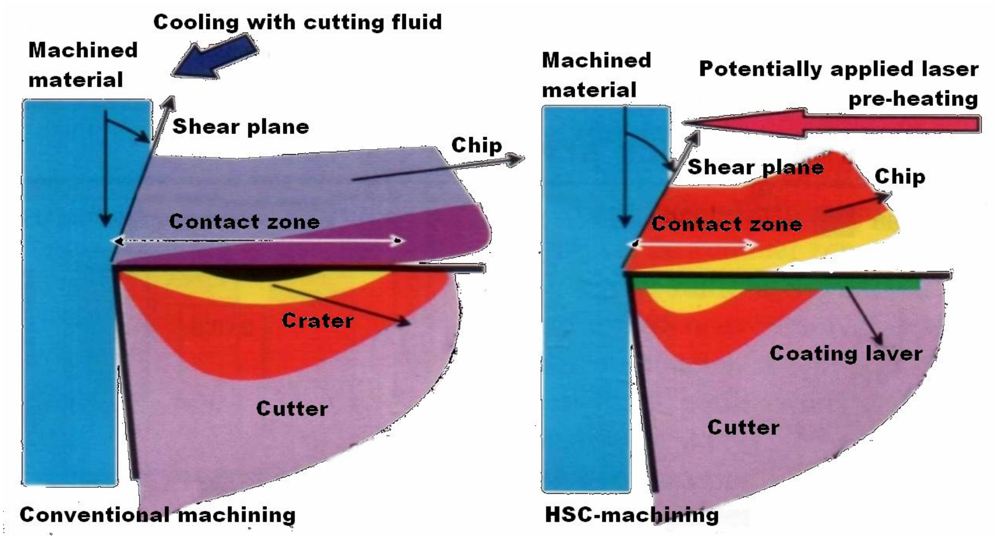

Fig. 1 Comparison of conventional and high speed cutting process

3 MEASUREMENT OF SURFACE RESIDUAL STRESS

Residual stress is such that the stays in components also after removal reason, which caused it. This tension, created outer causes after technological operation are distributed unevenly and find only in definite volume mechanided material. Residual stress rise mainly for these reasons:

- mechanical effects question unstable plastic deformation,
- thermal gradient at heat processing, shanking, machining, environment refrigeration and the next causes implicate unstable heating and resulting cooling,
- unstable structural change developed temperature concurrence and stress condition in consequence of technologica operation (transformation phasic, precipitation of new structural components, grains sizes change, etc.),
- chemical sources above all absorption, diffusion and all of chemical response between workpiece, tool and envinment.

3.1 Measurement principle of residual stress by Barkhausen noise

Barkhausen noise is effect exploited in one's from magneto ignition methots measurement of residual stress in workpiece surface. In its following make use of frequence 0,5 – 250 KHz and measures in tangential magnetic field. This method works on principle material responses on magnetic field at whose incidence on materil happens to change of Weiss domains orientation. It is possible to introduce of domains like magnetic areas, which are similar magnets stick, from which piles every ferromagnetic material. Every domain magnetizes along crystallography marked directions.

To the orientation change does not become continuously but after definite steps, which in inductor circumambient magnetize metal display like turbojet strokes. This way postneuritic strokes is possible after thickness acoustic watch. The domains way are effecteds by present and stress lay and detract by way to easy orientation in direction magnetization. From the figure 2 is perceptible, that at materials like are iron, majority steel, cobalt is intensity of compressive stress of Barkhausen noise decline and tension stress is escalate. Deph in which measurement proceedsat common applications moves at intervals 0,01 mm – 1,5 mm and sensing surface is several mm^2.

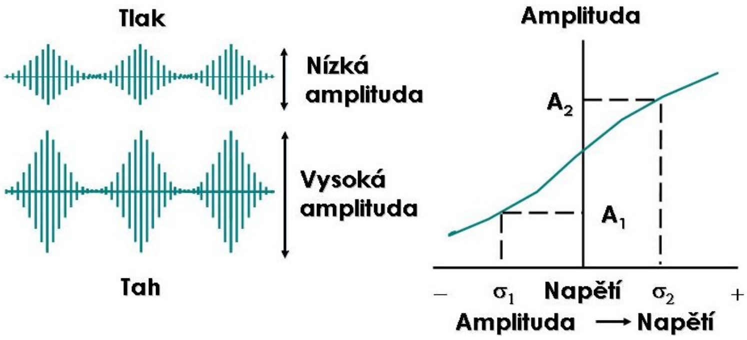

Fig. 2 Stress influence on sensing signal Barkhausen magnetic noise

Principle is small proportions hole drilling and it causes vacation of residual stress acompanied by deformations in the hole surrounding. Released deformation are measured and on their base is evaluation original residual stress. Hole-drilling method is in basic form standardized by ASTM E 837. Biaxial tensity (macroscopic stress) is measured on the material surface to the depths 0,5 – 1,5 mm, whereas can be evaluate change of tension derection to the depths. This method is make us for wide range of ecercises and materials, regarding to small demage of measurement sample is often referred to as like semi-destructive.

4 IMPLEMENTATION OF EXPERIMENT

The aim of experiment was acknowledge of theory – better surface quality at increasing of feed speed. On the basis needs of high turns of machine center spindle was for experiment implementation select universal five axis CNC cutting center DMU60 MonoBLOCK with NC turntable from the Deskel Maho company. This machine centre is on Institut of Mechanical Technologies from Poznan University, where we experiment performed in terms of program CEEPUS. Thank you very much of prof. Stanislaw LEGUTKO, DSc., PhD., MSc., Eng. for facilitation these examinations.

Fig. 3 The universal DMU 60 monoBLOCK® cutting center

4.1 Cutting tool

Election of right edge tool belongs to among priority elements, which make possible HSC machining. To avoid the potential of sudden breaking of the tool inserts as a result of mechanical or thermal shocks, as well as to reduce wear, the applied cutting materials must exhibit high resilience, high surface hardness and high resistance to chemical attack, mainly against oxidation. The high quality of cutting edge, typical for blades of HSC tools and their ingenious surface coating increases the resistance of their cutting faces to abrasion and diffusion wear. Moreover, the deposit forms an additional thermally insulating layer, which has a favourable contribution to reducing the share of process heat transferred to the tools cutting edge.

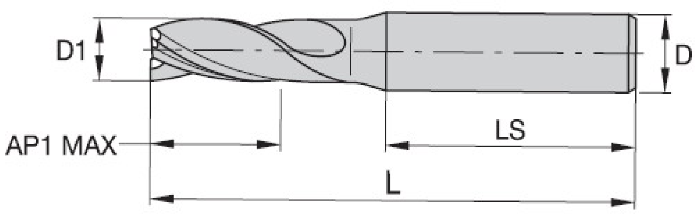

Fig. 4 Used milling cutter F3AH1800ADL30 including of all sizes

where:

D1 – cutting diameter of tool 18 mm,

D – diameter of tool shank 18 mm,

AP1 MAX – maximum of usable longitude of cutting tool part 26 mm,

LS – applicable tool shank length 48 mm,

L – tool total length 92 mm**.**

To implementation of examinations was select milling cutter from Kennametal Europe GmbH Company with marking F3AH1800ADL30. It is concerned about carbide cutting tool with three edges and its diameter is 18 mm and spiral rise is 30º. 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.

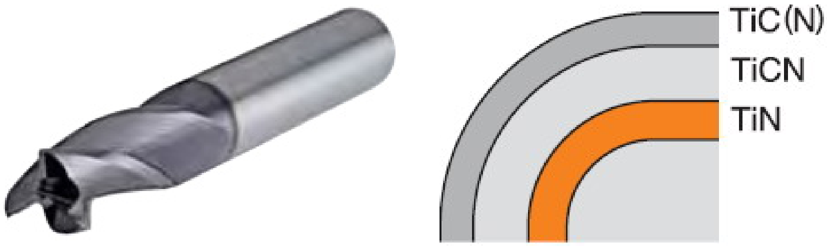

Fig. 5 Used milling cutter F3AH1800ADL30 with coating specifications

4.2 Mechanided material

For these examination was select referential material 12 050.1. This material is carbonic steel to refinement and surface martempering. Material starting position was normalization.

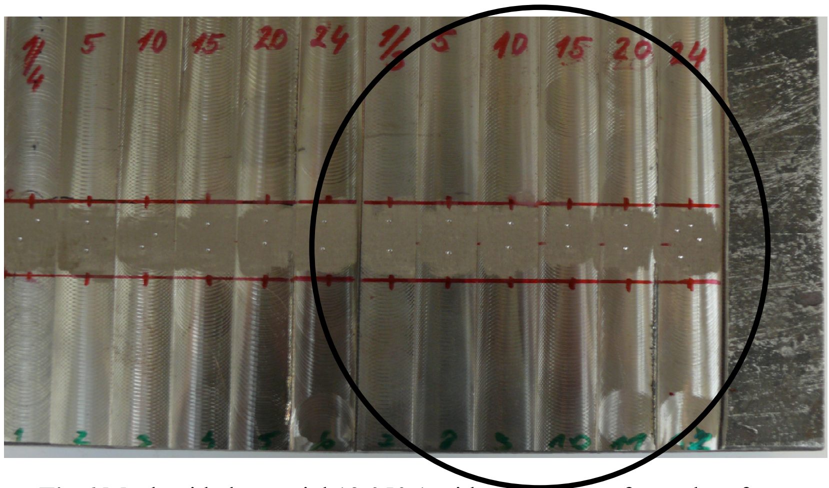

Fig 6 Mechanided material 12 050.1 with setting out of tested surfaces

4.3 Experiment characteristics

Intention of experiment was raising of feed speed v_f from 1m.min^{-1} up to 24 m.min^{-1}. It was used maximum rotational speed of spindle, which is given to offer CNC milled centre. Next selected characteristic was: axial depth of cut a_p = 0,25 mm (it is acceptable for finishing operation) and fz = 0,33 mm. Concrete cutting parameters are in the table 1

Tab. 1 Cutting parameters used at experiment

Mechanided surface	v_f [m.min^{-1}]	n [min^{-1}]	v_c [m.min^{-1}]
Surface 7	1	1000	56
Surface 8	5	5000	283
Surface 9	10	10 000	565
Surface 10	15	15 000	848
Surface 11	20	20 000	1131
Surface 12	24	24 000	1357

5 RESIDUAL STRESS EVALUATION

5.1 Evaluation of residual stress by Barkhausen noise method

Measurement was performed on 5 different seats of every machined surface with step 10 mm, whereas from measurement was blockout start surface of tool into cut. After findings of residual stress was select depth 0,1 mm. From the next graph no. 5.1 is perceptible negative incidence of low parameters v_f to surface residual stress. The best result was achieved at parameter v_f = 10 m.min^{-1}. The next values arent so favourable, but they are lower than v_f = 1 m.min^{-1}. This measurement was performed with the aid of Vladisla Ochodek, MSc.

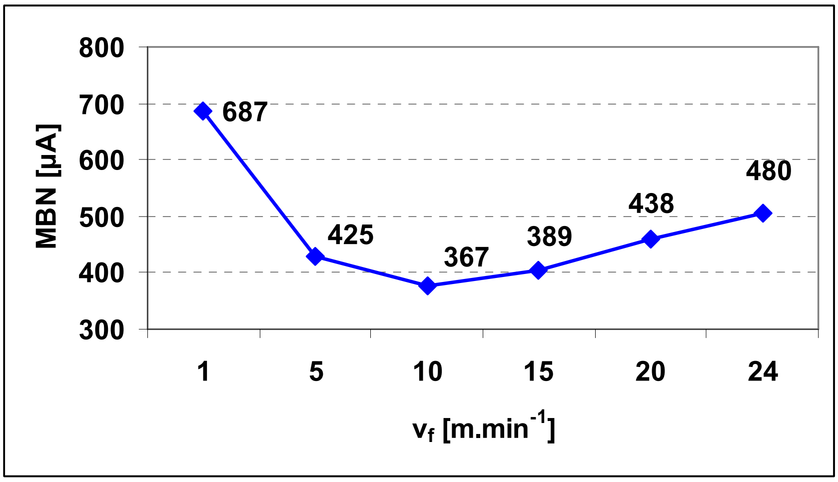

Fig. 7 Process of residual stress depending on feed speed by Barkhausen noise

5.2 Residual stress evaluation by hole-drilling method

Residual stress measurement by hole-drilling method was performed on two machined surfaci. It was survace 7 (v_f = 1 m.min^{-1}) and surface 10 (v_f = 15 m.min^{-1}). The deep of hole was 1,5 mm and it was used drill Φ1,5 mm. For measurement was used special strain-gauge gridge rosette type RY61 1,5/120S its drawing is on the figure 8. It is rectangular rosette with the marked circle in the centre for hole drilling. Rosette stick on workpiece surface whereat is common giaxial stress from residual stress, which tensiometers of rosetto after glued-on non-measurable. After drilling of circular hole in the middle of glued rosette will get in its invirons to vacation and redistribution of deformation and stress, which on single tensiometers rosett will mete.

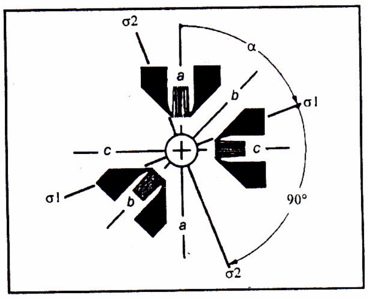

Fig. 8 Strain gauge gridge rosette RY61 1,5/120S

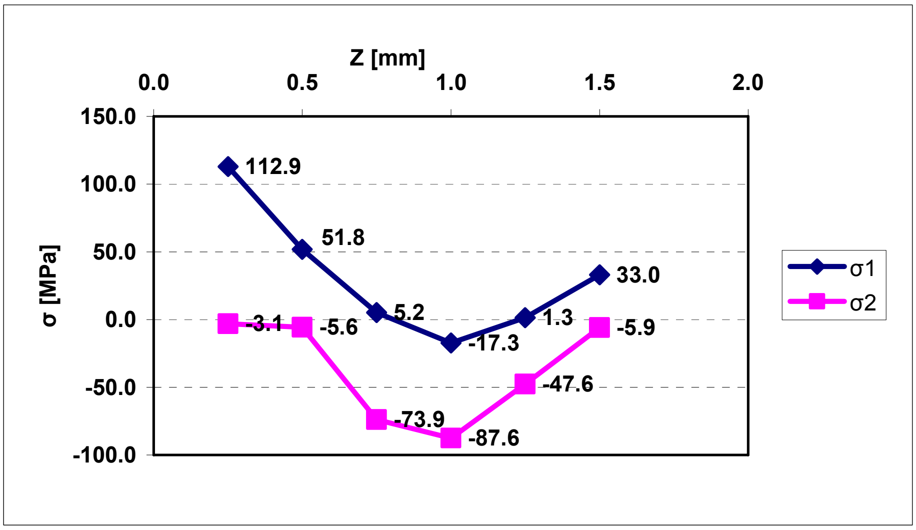

Fig. 9 Eluation of residual stress measurement by integral method on the surface 7

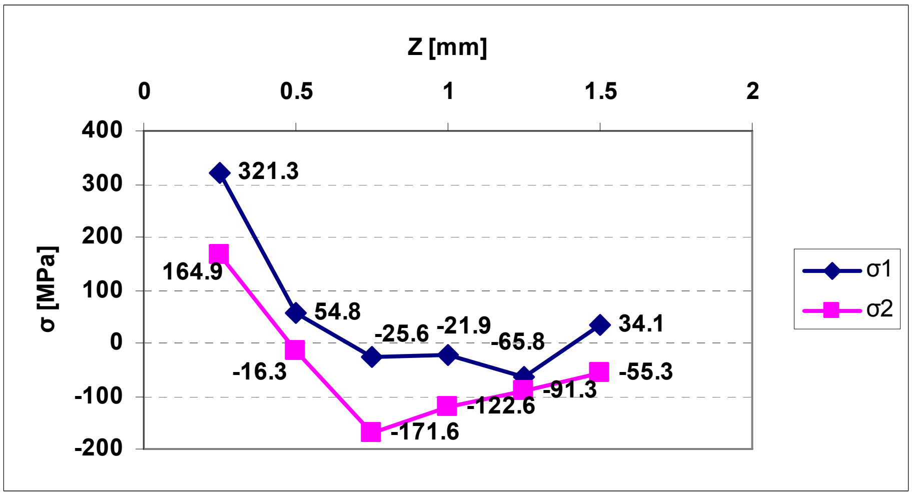

Fig. 10 Eluation of residual stress measurement by integral method on the surface 10

6 CONCLUSIONS

The paper describes shortly the results of measurement of residual stresses after conventional and HSC milling. The aim of the measurement was to determine the magnitude of results after conventional milling and compare it with HSC milling.

For the measurement were used two different methods of residual stress determination. It was measurement with principle of Barkhausen noise and a semi-destructive hole-drilling method, which make it possible to measure also the courses of residual stresses under the surface of the component. At the results scoring with using of Barkhausen noise method were measured results inscribed directly into a graph. Procedure and method of hole-drilling method evaluation are given by the US standard ASTM E 837-01. Both methods are very used for residual stress evaluation. Measuring records serve as base to determination of machined surface qualities.

REFERENCES

[1] SKOPEČEK, T. et al. *Fundamentals of high speed cutting - HSC.* University of West Bohemia Press, 2005. ISBN 80-7043-410-4.

[2] PETŘKOVSKÁ, L.; NOVÁKOVÁ, J.; BRYCHTA, J. Influence of growing feed speed to machined surface quality. In *CEEPUS Scientific reports AMO 09. Kranevo, Bulgaria, 24-28 June, 2009.* Ed. Aleksandar MAKEDONSKI, p. 541-546 + sborník na CD. ISSN 1313-4264.

[3] DOBRÁNSKÝ, J. Observation fo production process capacity by injection moulding. In *Scientific bulletin*. 2007, Vol. 7, No. 1, p. 197-201. ISSN 1224-3264.

[4] MACURA, P. *Experimentální metody v pružnosti a plasticitě*. Ostrava : VŠB-TU Ostrava, 2006. ISBN 80-7078-934-4. 106 s

[5] DANIŠOVÁ, N.; VELÍŠEK, K.; KOŠŤÁL, P. Automated tool changing system in the intelligent manufacturing and assembly cell. In. *ISCCC 2009 : Proceedings of the 2009 International Symposium on Computing, Communication and Control*. October 9-11, 2009, Singapore. - Singapore : International Association of Computer Science and Information Technology Press, 2009. ISBN 978-9-8108-3815-7.

[6] LEGUDKO, S.; SOBCZAK, A.; ČEPOVA, L.; SADÍLEK, M. Analysis of Selected Parameters of the Surface Layer Formed as the Result of Burnishing of Gear Wheels. *Technologické inženýrstvo – Technological engineering.* Scientific-Technical Society by University of Žilina, Vol. VI, number 2/2009, pp. 48 – 51, ISSN: 1336-5967.

[7] KRATOCHVÍL, J.; ČEP, R.; OČENÁŠOVÁ, L.; Diagnostic of Cutting Edge During Machining. In *The International Conference of the Carpathian Euro-Region Specialists in Industrial Systems. Baia mare 21.-23. May 2008* . Ed. Universitatii de Nord din Baia Mare, 2008, s. 500. ISSN 1224-3264

[8] JAMBOR, J.; MAJERÍK, J. Hard Die&Mould Milling Process with CAD/CAM System Catia V5R18 Support. In *Annal of DAAAM for 2009&Proceedings of the 20th International DAAAM Symposium Intelligent Manufacturing & Automation: Focus on Theory, Practice and Education : World Symposium*. Vienna, 2009, p. 1465-1466. ISBN 978-3-901509-70-4.

[9] Kennametal Europe GmbH, Neuhausen am Rheinfall, Švýcarsko. Milling Tool Catalog 6050 – metric [online]. 2006 [cit. 2009-01-15]. s. 580. Dostupný z WWW:< https://www.kennametal.com/images/repositories/PDFs/milling_metric_finalr.pdf >.

[10] Technotools OHG, Haferwende, Germany. DMU 60 monoBLOCK® [online]. [cit. 2009-01-15]. Dostupný z WWW:< http://www.strojcar.cz/images/60mono.jpg&imgrefurl=http://www.strojcar.cz/cz/technicke_vybaveni.html&h=247&w=250&sz=9&tbnid=Sw5M5L8DpHgdkM:&tbnh=110&tbnw=111&prev=/images%3Fq%3DDMU%2B60%2BmonoBLOCK&usg=__gSzyR5aPDgrwVS4GmyHO4oGnXEA=&ei=6LyxS5XsE9ud-AaH_OCqAg&sa=X&oi=image_result&resnum=4&ct=image&ved=0CBcQ9QEwAw.