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Ivan MRKVICA*, Vladislav OCHODEK, Ryszard KONDERLA*****

INFLUENCE OF THE RESIDUAL STRESS IN SURFACE LAYER OF WORKPIECE BY MEANS OF TOOL´S GEOMETRY AND TOOL´S SETTING

OVLIVNĚNÍ ZBYTKOVÉHO NAPĚTÍ V POVRCHOVÉ VRSTVĚ OBROBKU ŘEZNOU GEOMETRIÍ NÁSTROJE A JEHO NASTAVENÍM

Abstract

The article deals with an influence of the tool geometry and set-up, of the milling head, on tension in the surface layer of workpiece. It describes, whether the tool brings the residual stress to the surface and its measurement by the magnetoelastic method based on the Barkhausen noise principle. The correct choice of the tool and cutting parameters can highly influence surface layer of the component and extend so its lifetime and increase itsreliability. In this way we try to fulfil the growing requirements on the machine component.

Abstrakt

Článek se zabývá vlivem geometrie a nastavení nástroje, konkrétně frézovací hlavy, na napětí v povrchové vrstvě obrobku. Popisuje, zda nástroj vnesl do povrchu zbytkové napětí, a jeho měření magnetoelastickou metodou založenou na principu Barkhausenova šumu. Volbou správného nástroje a technologických parametrů obrábění lze příznivě ovlivnit povrchovou vrstvu součásti a prodloužit tak její životnost a zvýšit spolehlivost. Tím se snažíme vyhovět stále rostoucím požadavkům na strojní součástí

INTRODUCTION

Current machine parts requirements project in the first place to the areas of their reliability and service life raising.. Thereby grow demands on construction as well as on production technology. One of the possibilities how to increase the service life is a quality surface layer of components improvement. And just correct working conditions of applied machining technology influence favorable of a workpiece surface layer.

Mentioned problems are possible to solve in two ways. By monitoring factors of the used technology on quality surface layer and evaluate them in relation to the components service property. By connecting this knowledge we can achieve an optimal technological conditions and processing. Problematic is a transaction compliance test on concrete types of components and materials. Tests like this are very expensive, so that is the reason why are these works collected on simulation or on transaction and checking of the tests themselves on figures [1].

Even if the problems of influence technological process on characteristics surface layer of components were handled and are handled by many workplaces, on the present it is necessary to analyze conditions characterizing the exact terms of cutting technology and monitor their influence on

* doc. Dr. Ing. Ivan Mrkvica, Department of Working and Assembly, Faculty of Mechanical Engineering, VŠB – Technical University of Ostrava, 17. listopadu 15, 708 33, Ostrava – Poruba, tel.: 00420 59 732 4451, fax: 00420 59 691 6490, e-mail: ivan.mrkvica@vsb.cz

** Ing. Vladislav Ochodek, Department of Mechanical Technology, Faculty of Mechanical Engineering, VŠB – Technical University of Ostrava, 17. listopadu 15, 708 33, Ostrava – Poruba, tel.: 00420 59 732 3513, fax: 00420 59 691 6490, e-mail: vladislav.ochodek@vsb.cz

*** Ing. Ryszard Konderla, Department of Working and Assembly, Faculty of Mechanical Engineering, VŠB – Technical University of Ostrava, 17. listopadu 15, 708 33, Ostrava – Poruba, tel.: 00420 59 732 6214, fax: 00420 59 691 6490, e-mail: ryszardkonderla@seznam.cz

characteristics surface layer, namely on its interference thermal and mechanical effects. These will take effect in a heat-up of surface layer as well as in a size of residual stress.

1 RESIDUAL STRESSES IN A SURFACE LAYER OF WORKPIECE

The residual stresses are tensions which stay in a workpiece also after remove the implicated reason. Every technological operation influences an inception and reconstruction of residual stresses in such range and depth, in which is able to evoke a plastic deformation. Generally it is possible to state, that the residual stresses after completing technologic operation are effected by features of machined material and by changes, which occur in a material during cutting process and strength effects developed by cutting, which operates in a surface layer of workpiece.

Main reasons of residual stresses rise are:

- unequal plastic deformation developed by mechanical effects,
- uneven increasing and fall of temperature, which makes e.g. a thermal gradient at heat processing, moulding, machining and environment cooling,
- uneven structural change developed by concurrence of temperature and stress as a result of technological operation (phase transformation, precipitation of new structural components, change of size grains etc.)
- chemical sources, mainly absorptions, diffuses and all chemical responses between the workpiece, tool and environment (cooling, lubricating) [1].

In the surface layer can occur residual stresses with various courses. – Figure 1. By these cutting methods, which are know for their big mechanical load by low temperatures of the surface layer, e.g. the sourcing, predominates an influence of plastic deformations above temperature and in the surface layer rises ***a compressive residual stress***. The cutting method with high temperature surface layer, e.g. finishing cut by SK (700 as far as 1100°C) and grinding (as far as 1200°C), the temperature predominates over the residual stress. The warmed surface layer has by its cooling a tendency to decrease its volume, but the lower layers, which have kept the low temperature, do not change its volume immutability and are stunting the retraction of surface layers. As a result in surface layer rises ***the tensile residual stress*** [3].

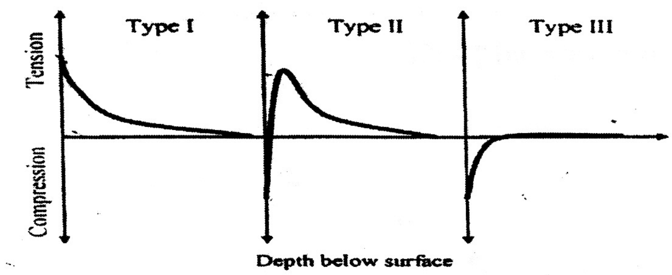

Fig. 1 Types of machining distributions [2]

2 MAGNETOELASTIC METHOD OF MEAUSURING

The method works with an use of the Barkhausen magnetic noise. It means that it is a non-destructive measurement method. The Barkhausen noise was for the first time described in the year 1919 by Prof. Hainrich Georg Barkhausen [4].

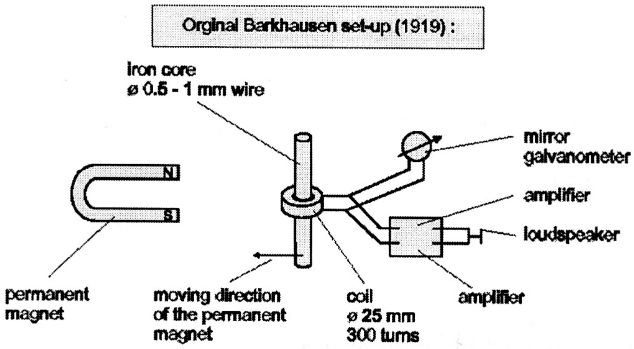

Fig. 2 Historic set up by Mr. Barkhausen [5]

Simplifiedly we can describe this method as a material response on incidence of the magnetic field. By incidence of the magnetic field on a material is happening a change of orientation Weiss´ domains. The orientation change does not happen continuously, but after some definite steps, which are in a reel circumscribed by magnetize metal, display as imputs of current. After their increase it is possible to observe the acoustically – called the Barkhausen noise. Attendance and distribution of the tension influence a way, which is used for taking direction of the domains to easy orientation on direction of magnetization. As a result at materials (as iron, majority steels, cobalt) the compressive tension lowers intensity of the Barkhausen noise, while the tensile stress increases it [6].

During common applications is the measuring depth between 0,01 mm and 1,5 mm and the scanned area is several mm^2. The Barkhausen magnetic noise is tracked at frequency (0,5 ÷ 250) kHz and it is measured in tangential magnetic field. Significant feature of this method is an absolutely non-destructive character and a high-speed response. These characteristics make possible to measure in a bigger rate of tracked places, eventually in a real-time, then other methods allow [6].

3 INFLUENCE OF THE CUTTING PARAMETERS AND CUTIING TOOL ON SURFACE LAYER HARDENING

Dependence of the hardening on the cutting speed has character of hyperbole. Influence of the cutting speed on the surface hardening follows also from shortening time incidence of the cutting force on the surface layer and expansion of the heat delivery of cutting. The cutting feed eminently influences the microhardness of the surface. By increasing the feed rises the microhardness of machining surface. The cutting depth a_p influences the hardening depth only in a narrow limit, while the hardening characteristic rise by the cutting depth increasing. By changing the positive cutting-edges of front edge it is recorded only an immaterial alteration of the hardening depth and the hardness surface. Changeover to the negative cutting-edge of front edge and their increasing evokes a strong increase of hardening depth and a less strong increasing of hardness machined surface. By observation of the influence of the cutting-clearance angle on results hardening we can see that cutting-clearance angle influences the hardening only in definite limits. Increasing of the cutting-clearance angle in interval 0°÷8° evokes a high-powered fall of the hardening depth and the surface roughness [7].

4 EXPERIMENTAL APPLICATION OF THE BARKHAUSEN NOISE

It was researched, how will change value of residual stress in surface machined sample by milling head with positive and negative geometry and with transformative angle ε. Both milling head have nine exchangeable edge tool tablet and average 125 mm. The positive head has geometry given to angles γ_p = 7° and γ_f = 0°and negative head angles γ_p = -8° and γ_f = -5° [8]. The positive head was manned exchangeable adge toll tablet with mark SPKN ER 1203EDER [8] and negative head SNH N1204 ENEN [8]. The experiment was preformed on universal milling cutter FGS 50 (v_c = 196 m·min^{-1}, f_{fr} = 224 mm·min^{-1}). Mechanided sample had proportions (44×50×198) mm (mechanided surface was 44 mm×198 mm) and material of sample was 19 552 (1.2343).

Main variable in transaction experiment was pressure angle ε. The milling head with positive geometry was adjusted in the face of workpiece so, to bring pressure angle 66,9° (matches kind catch V) and – 6° – kind catch H. The milling head with negative geometry adjusted so, that first contact SK wafer with material was in point V – it matches pressure angle 16,3° [9].

To metering residual stresses in surface layer of sample were select magnetoelastic method metering working on principle Barkahusen noise. Residual stress was measured on the sample flat in two directions – on longitude 198 mm (direction „x“) and on width 44 mm (direction „y“). From measure values removed first two and last two funds – metering was distortionless. Metering was preformed only on the machined flat a steady course tool. From left over values were calculated mean values and these were compared. Like these measured values was not in MPa, but in terms of Barkahusen noise BNa.

Tab. 1 Average values of BNa metering in direction „x“ and „y“

Sample	Average value BNa – direction „x“	Average value BNa – direction „y“
1. Negative head, catch V, ε = 66,9°	329,8	373,3
2. Positive head, catch H, ε = -6°	254,2	263,3
3. Positive head, catch V, ε = 16,3°	177,3	187,3

In Figure 3 show through variable sizes residual stresses in surfaces of samples. The biggest value BNa was measure in surface machined by milling head with negative geometry and pressure angle ε = 16,3°. Smaller residual stresses were observed in sample, which was machined by milling head with positive geometry and pressure angle ε = -6°. The machining by milling head with positive geometry and pressure angle ε = 66,9° inject to the surface of workpiece the smaller residual stresses.

From above – cited results show through, that residual stresses in surface of sample are changed depending on by used geometry of milling head and on transformative pressure angle ε. It is impossible unambiguously mark residual stress in MPa and as well as reality, whether injects stress into surface of sample are compressive or tension. Therefore was in next phase of experiment performed calibration used material. Calibration is instrumental to translation measured values BNa on values stresses in MPa.

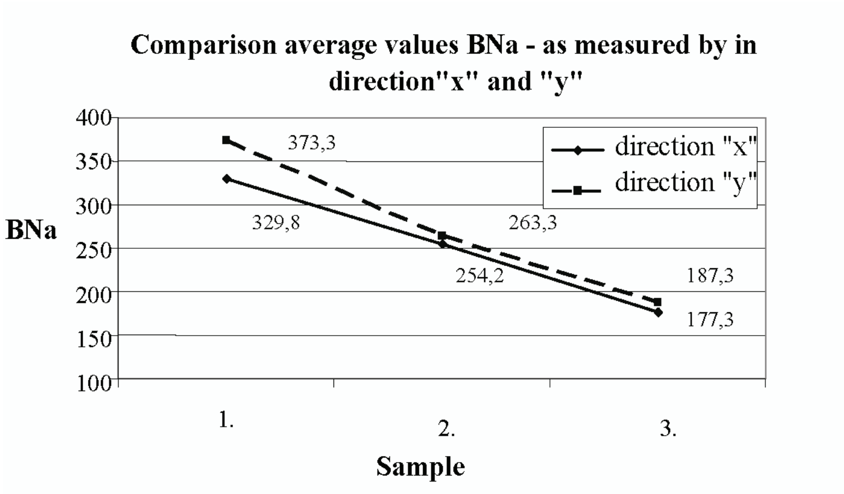

Fig. 3 Average values BNa as measured by in direction „x“ and „y“

Calibration had to performed on sample from material used in experiment, it means from material 19 552 (1.2343). This sample had from by prism with proportions (5×10×150) mm. To calibration was needed mathematical apparatus that would mean tension σ in surface string stressed sample in dependencies on deflextion sample y. Calibration proceeded so, that the sample was on one end point fixturing and on second end point was loading transformative power F. This description to us afford introduce sample like fixed beam length L and cross-section H×B by load in hid free end by lonely power – see Figure 4. In distance x from free end plumbed deflextion y and in top fibre value of Barkahusen noise BNa.

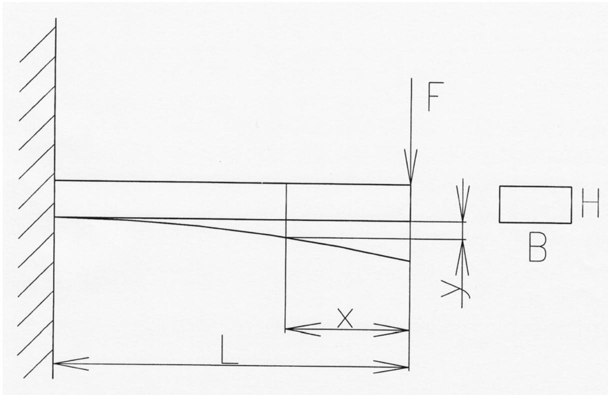

Fig. 4 Diagram of way straining calibration sample

Power F, needed to achievement requisite deflextion y, was calculated after Castiglian sentence – equation (1). Subsequently from powers F was possible to calculate tension σ at point deflextion y – equation (2).

$$F = \frac{y \cdot E \cdot B \cdot H^3}{4 \cdot L^3 - 6 \cdot L^2 \cdot x + 2 \cdot x^3} \tag{1}$$

F – power, y – deflextion of sample, E – Young modulus of elasticity, B – width of sample, H – high of sample, L – length of sample, x – distance from free end of beam, in these distance was plumbed deflextion y and tension σ.

$$\sigma = \frac{3 \cdot y \cdot E \cdot H \cdot x}{2 \cdot L^3 - 3 \cdot L^2 \cdot x + x^3} \tag{2}$$

σ – tension, y – deflextion of sample, E – Young modulus of elasticity, H – high of sample, L – length of sample, x – distance from free end of beam, in these distance was plumbed deflextion y and tension σ.

From measure values of BNa on calibration sample and from calculated values of tensions σ drew up calibrating curve, which is painted on Figure 5. According to these behaviour measured values of BNa of all three surveyed samples were transferring on founds of tensions σ in MPa.

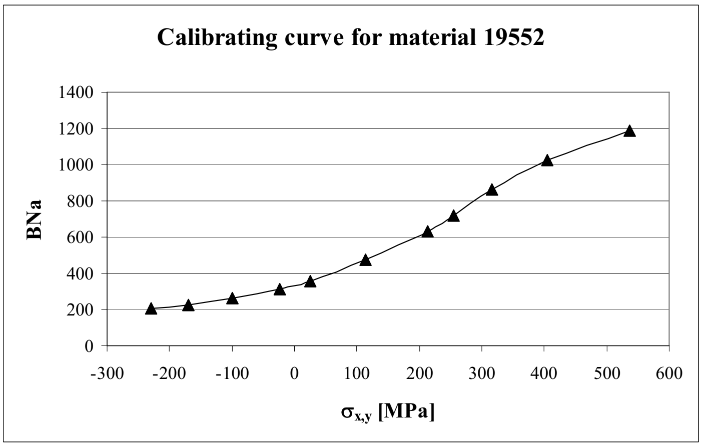

Fig. 5 Calibration curve for material 19 552 (1.2343)

Tab. 2 Average values of tension σ metering in direction „x“ and „y“

Sample	Average value σ [MPa] direction „x“	Average value σ [MPa] direction „y“
1. Negative head, catch V, ε = 66,9°	-3,1	57,0
2. Positive head, catch H, ε = -6°	-118,9	-104,1
3. Positive head, catch V, ε = 16,3°	-261,4	-242,3

In Table 2 show through, that tension in surface layer of sample (in direction „x“ and „y“) were for the most part compressive. In sample Nr. 1, it means sample machined by milling head with negative geometry and pressure angle ε = 16,3° were drowe residual stresses on interface tension and compressive values. In flat machined by tool with positive geometry and pressure angle ε = -6° were observed smaller compressive residual stresses than in flat machined by milling head with positive geometry and pressure angle ε = 66,9°.

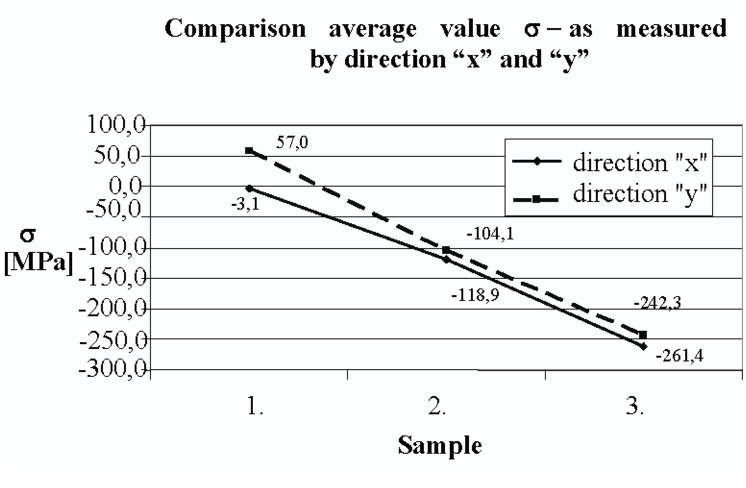

Fig. 6 Average values of stresses σ [MPa] as measured by in direction „x“ and „y“

Figure 6 shows that the biggest compressive residual stresses introduced to the surface layer of sample the milling head with positive geometry and pressure angle ε = 66,9° – these conditions answer to sample No.3, and the smallest values of residual stresses were observed in surface layer of sample Nr.1, which was machined by milling head with negative geometry and pressure angle ε = 16,3°.

5 CONCLUSION

After measuring the stress values in terms of BNa and conversion these values in accordance with the calibrating curve on stress values σ in MPa was ascertained, that the process of average values of BNa and σ is approximately the same – it has approximately the same direction. Whereas the values BNa were recorded in a bigger scatter than values σ, the results in BNa have a bigger predicated capacity than values σ. Therefore it matches to assert, that for the used material sample 15 552 (1.2343) we can use directly values of BNa, for the fast judgment of residual stresses.

Performed experiment showed, that different position setting of milling head in the face of workpiece, it is possible to greatly influence the residual stresses inject into the surface layer of workpiece. That it is possible in an appreciable measure use by increasing the lifetime and dynamic strongholds of components – into surface layer of workpiece we inject only the positive values of residual stresses.

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