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Monitoring of Hard Milled Surfaces via Barkhausen Noise Technique

M. Neslušan[a,*], T. Hrabovský[a], M. Čilliková[a], A. Mičietová[a]

[a]University of Žilina, Faculty of Mechanical Engineering, Univerzitna 1, 010 03 Žilina, Slovak Republic

Abstract

This paper deals with the non-destructive evaluation of surface made of hardened roll bearing steel after hard milling via Barkhausen noise technique. The paper discusses magnetic anisotropy linked with the structure transformations with regard to variable flank wear of cutting tool. Effective value of Barkhausen noise (BN) and Peak Position derived from the raw BN signal as well as BN envelopes are compared with metallographic observations and theoretical background about magnetic domains reconfiguration when the near surface undergoes severe plastic deformation at elevated temperatures.

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Keywords: Barkhausen noise, hard milling, surface integrity

1. Introduction

Cyclic magnetization in a ferromagnetic structure produces magnetic pulsation as a result of nucleation and reconfiguration of magnetic domains and corresponding motion of Bloch Walls (BW). This motion is usually pinned by precipitates and other lattice defects and result in their discontinuous irreversible motion. Pulsating magnetization is a product of discontinuous BW jumps. This phenomenon is named as Barkhausen noise [1, 2]. Micromagnetic investigation of machined surface based on Barkhausen noise (BN) has found a high industrial relevance. BN techniques are mainly applied for monitoring surface integrity of parts loaded near their physical limits. Surface integrity expressed in terms of residual stresses, microhardness or structure transformation is correlated with BN

* Corresponding author. Tel.: ++421-41-513 2785; fax: 00421-41-565 29 40.
E-mail address: miroslav.neslusan@fstroj.utc.sk

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values obtained from surface. This technique is mostly adopted for inspection of ground surface due to strong correlation between the heat generated in the grinding wheel – workpiece contact, associated surface burn and the corresponding magnetoelastic responses, expressed in BN values. Grinding operations can suffer from mainly temper burn when thermal softening of the near surface occurs [3]. Over tempering of the near surface result in decrease of dislocation density (and the corresponding hardness decrease) as well as carbides coarsening induced by elevated temperatures. Furthermore, shift of stresses to the tensile stresses [4] also contributes to the higher magnitude of BN. Being so, surface overtempering can be revealed by the use of the BN technique [5]. Nowadays, it can be found that hard machining (mainly turning and milling) can substitute grinding cycles especially when high removal rates are needed or components of complicated geometry are produced. Development in machine tools (especially CBN and ceramics) as well as in process technology focused on cutting of hardened steel lead to a high raised industrial relevance of hard machining [6]. On the other hand, hard turning operations exhibit specific disadvantages such as formation of white layers induced in the early stages of tool wear or unexpected catastrophic tool failures. It should be also reported that nondestructive monitoring of hard turned or hard milled surfaces based on BN technique has not found industrial relevance yet due to complicated relations between BN and surface integrity. Surface state after hard machining is a function mainly of flank wear VB and cutting speed. Application of a tool of high VB produces relative thick white layer (WL) as well as the corresponding heat affected zone (HAZ) [7]. On the other hand, grinding cycles produces usually WL free surfaces. Thickness of HAZ after hard milling is about 1 order lower than that induced by grinding cycle. HAZ increases magnitude of BN compared to bulk whereas WL in the near-surface region emits poor BN due to existence of higher volume of retained austenite, compressive stresses and very fine grain [8]. Being so, relation BN versus VB is not always monotonous thus making application of BN for hard turned or milled surface a debatable issue. Conventional attempts to correlated BN signal and the corresponding BN features with microstructure or stress state can fail. The main problem is linked with the contra indicatory effect of the different surface constituents contributing to BN emission received on the free surface. While HAZ in deeper regions enhances BN emission, the near surface layer containing WL gives quite poor BN. Moreover, complicated stress state cannot be easily linked with magnetoelastic responses. This study is mainly focused on evaluation of surface integrity after hard milling with inserts of variable VB. Specific aspects of such surfaces as very high BN responses and strong magnetic anisotropy are discussed. Except conventional BN values (representing the effective value of the raw BN signal) additional BN features are extracted such as BN envelopes and the corresponding Peak Position. BN measurement is confronted with metallographic observation and appearance of hysteresis loops. Hysteresis loops, especially their shape is studied due to specific mechanism in which domain and the corresponding BW are switched.

2. Experimental conditions

Experiments were conducted on samples made of bearing steel 100Cr6 of hardness 62 HRC. 10 pieces of dimension 60x43x25 mm were prepared for long term test. Cutting process was monitored as a long term test where such aspects as flank wear VB, structure alterations and corresponding surface integrity expressed in magnetoelastic responses (BN) of the hard milled surface were investigated. Cutting and other conditions: milling machine - FA4 AV, dry cutting, cutting tool made of cemented carbides R300-1240E-PM, R300-050Q22 - 12M 262489 of diameter Ø 50mm with 2 inserts of variable flank wear VB (in the range 0,05 to 0,8 mm), ap = 0,25 mm, vf = 112 mm.min-1, n = 500 min-1. Flank wear was measured for both cutting inserts and VB values indicated in the paper represent their average value. BN measurement was performed by the use of RollScan 300 and software package MicroScan in the frequency range of 10 to 1000 kHz (mag. frequency 125 Hz, mag. voltage 10 and 16 V). Each BN value was determined by averaging of 10 consecutive BN bursts (5 magnetizing cycles). Due to strong surface anisotropy, each surface was measured in two directions - tangential and axial as Fig. 1 illustrates. BN values indicated in the paper represent the effective (rms) value of BN signal. To reveal the microstructure transformations induced by milling 10 mm long pieces were sectioned from the samples and routinely prepared for metallographic observations (etched by 5% Nital for 10s).