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6th New Methods of Damage and Failure Analysis of Structural Parts [MDFA]

Concept of Damage Monitoring after Grinding for Components of Variable Hardness

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Abstract

This paper deals with nondestructive magnetic evaluation of ground surfaces of chosen material hardness. The properties of prepared surfaces are studied with respect to the progressively worn grinding wheel. The nondestructive testing is based on the Barkhausen noise (BN) technique and obtained BN signals are supplemented by metallographic observations. The results show that the nature of thermal injury of the surfaces prepared by strongly worn grinding wheel significantly depends on the hardness of material. The typical thermal softening induced by grinding cycle is found on the surfaces of hardness 62 HRC whereas samples of lower hardness exhibit rehardening effect associated with the formation of white layer. These material changes are strongly correlated with the BN properties.

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Keywords: bearing steel; heat treatment; grinding; Barkhausen noise

Nomenclature

BN	Barkhausen noise	HRC	Rockwell C hardness
BW	Bloch wall	PP	Peak Position
WL	white layer		

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1. Introduction

Roll bearings are routinely heat treated in a variety of manners. Except induction or case-hardening, conventional heat treatment is carried out to impart the high hardness and the corresponding high resistance against friction and contact wear. Annealing process is always performed after hardening to reduce the high internal stresses induced during rapid cooling. Additional heat treatment is sometimes required to enhance the toughness of hardened parts. These parts are exposed to the elevated temperatures for a certain period within hardness of parts decreases as a result of carbides coarsening, decrease of dislocation density and stress relaxation. Hardness of such parts can vary in the range 38 to 62 HRC.

Grinding operations are usually involved in production of bearings to achieve the required surface roughness, shape and dimension accuracy. Nowadays, alterations of surface structure, hardness or stress state are also monitored due to its substantial influence on functionality of parts in operation.

Non-destructive monitoring of critical surfaces has to be carried out to reveal the parts containing the unacceptable surface integrity. Magnetic method based on BN is very often employed for such purpose, especially ground surfaces due to the high sensitivity of BN emission to the thermally induced surface overtempering, Moorthy (2001) and Čiliková (2013). As widely discussed by Moorthy (2001), Karpuchewski (2002), Kameda and Ranjan (1987), Buttle (1991), Gatelier-Rothea (1998) and Ranjan (1987) BN originates from irreversible BW motion during cyclic magnetization due to existence of pinning sites such as grain boundaries, dislocations, precipitates, other phases. Ground parts can suffer from thermally induced burn as a result of excessive heat generation in the wheel – workpiece contact. Being so, Moorthy (2001), BN emission increases in magnitude due to decreased pinning strength of thermally softened layer produced by improper grinding as a result of carbides coarsening and decrease of dislocation density (stress state is also altered). Thermally softened layer contributing to the more enhanced BN signal received on the frees surface layer can be easily contrasted and recognized when compared with untouched deeper regions in an optical image due to reduced resistance against etching Čiliková (2013).

Concept for monitoring of surface damage after grinding is based on the contrast between BN emission of untouched structure and altered BN response (its root mean square value) of the surface undergoing the elevated temperatures, Čiliková (2013), Moorthy (1998) and Čiliková (2014). On the other hand, such concept can fail when the hardness of a component decreases. Then the overtempering effect induced by grinding is shadowed by the previous heat treatment regime since the both processes represent nearly the same thermal load of the surface. BN emission and its evolution depend on the annealing temperature and the temperature in wheel – workpiece contact. The higher annealing temperature is, the less pronounced contribution of the surface overtempering induced by grinding itself would be expected which in turn corresponds to the less remarkable contrast between the deeper untouched and the near surface thermally softened layer. Critical components are usually heat treated to impart quite high surface or/and core hardness. Ground surfaces of such components can be easily monitored when BN technique is employed.

Nowadays, industry customers require employment of BN or other non-destructive techniques to reveal the unfavourable surface state on components of variable hardness. Being so, manufacturers tend to modify the techniques already available in their production for additional applications, surfaces and components made of the variable hardness. These modifications rely on the deep understanding of between the surface properties and the measured BN signal. The properly suggested concept, which implementation would bring the substantial benefits, can be based only on the true interpretation of received signals and their correlation with surface integrity expressed in terms of stress state and microstructure.

This paper represents the initial study in which the evolution of BN and the BN features versus progressive grinding wheel wear for components of variable hardness is investigated. This paper discusses the specific aspects of the surfaces machined on the bearing steel heat treated on selected hardness. Surface characterization is determined by BN technique as well as the conventional ones such as metallographic observation.