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Effects of surface condition on Barkhausen emissions from steel

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Effects of surface condition on Barkhausen emissions from steel

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Temperature changes during mechanical processing such as grinding of steel parts can cause phase changes in the microstructure. Thermal shock during the process can give rise to localized surface residual stress. The net result can be reduced wear resistance and fatigue life leading to early failure during service. Effective methods for the detection of such damage are necessary. Barkhausen emissions, which arise from discontinuous motion of domain walls, are sensitive to microstructural changes that affect domain dynamics. Detected Barkhausen signals are predominantly from a surface layer about 200 μm thick, those from deeper being attenuated due to eddy currents. An analysis of the detected signals can provide an indication of the surface condition of the material. Barkhausen signals from parts ground under controlled conditions were found to be dependent on the grinding process conditions. The signal changes were consistent with residual stress measured by x-ray diffraction and with hardness measurements that are indicative of changes in microstructure. © 1996 American Institute of Physics.

I. INTRODUCTION

Surface microstructure plays an important role in determining the mechanical properties of materials. Improper manufacturing process conditions for structural components can adversely affect the microstructure and residual stresses in the material and lead to early fatigue failure.

Barkhausen emissions in steels arise from discontinuous changes in the magnetization and are predominantly the result of spontaneous motion of domain walls in the presence of a changing magnetic field. The Barkhausen emissions, typically detected as voltage pulses in a field coil, appear as an a burst of pulses localized in time regions where the magnetization in the material changes polarity as seen in Fig. 1. The signal is influenced by stress, which changes the differential permeability of the material and hence the height of the detected signal, and by microstructure, which determines the defect density in the material and hence the overall shape of the emissions. The sensitivity of this technique can also be adjusted to different depths in the material since the higher frequency components of the emissions from deeper inside the material are selectively attenuated due to eddy currents before being detected at the surface.

Grinding involves the removal of material from the surface of a part for the purpose of attaining dimensional tolerances and surface conditioning. A significant portion of the energy used in removing the material results in localized heating. An abnormal rise in temperature during the process can result in detrimental metallurgical phases in the surface microstructure, and the thermal and mechanical shock from the process can introduce localized surface stress.

Damage from improper grinding procedures can arise from several conditions including reduced coolant flow, and is broadly classified by the rise in temperature. Retempering damage occurs when the temperature of the part rises high enough to relieve some of the compressive surface stress, previously introduced by induction hardening for example, leaving regions less resistant to wear. At significantly higher temperatures, rehardening damage occurs which results in a phase change from ferrite to austenite. On quenching by the cooling fluid this produces regions of martensite, a hard and brittle phase, which is prone to cracking. Effective methods are necessary for the detection of such metallurgical changes in the material.

II. EXPERIMENTAL DETAILS

Automobile wheel bearing components were ground to required dimensional specifications under progressively reduced coolant flow rate (normal flow rate, half, quarter and no coolant) in order to induce different degrees of grinding damage in the surface. Barkhausen measurements were conducted on these components using the Magneprobe. Other measurements using x-ray diffraction, for the determination of the absolute stress level, and Vickers surface microhardness, for the estimation of surface microstructure, were conducted on similarly ground components, and correlated with the Barkhausen measurements. Barkhausen signal was detected from regions where most damage was expected using a customized magnetic sensor. Discrimination frequencies for depth were set for maximum sensitivity to physical changes in a region approximately 20 μm thick.
III. RESULTS AND DISCUSSION

The change in the peak amplitude of the smoothed signal envelope and the width of the peak, determined simply as the ratio of the envelope area to the peak height, for specimens that had undergone progressively greater surface damage are shown in Figs. 2 and 3. The peak amplitude is an indicator of the local residual stress, since tensile stress in materials with positive differential magnetostriction $\frac{dx}{dM}$ increases the maximum differential permeability and hence the amplitudes of the Barkhausen signal. The peak width on the other hand is an indicator of the distribution and strength of sites pinning the domains walls. The observed decrease in the peak widths is an indication of the altered microstructure. These trends were verified by x-ray measurements of the surface residual stress and the surface hardness for similarly treated specimens.

IV. CONCLUSION

The Barkhausen technique has been shown to be a viable method for assessing residual stress and microstructural phase changes in steel components and the detection of unfavorable surface conditions. Residual stress, measured by x-ray diffraction, and changes in microstructure, estimated by hardness measurements, verified the measured changes in Barkhausen signals.


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