Effects of surface condition on Barkhausen emissions from steel

Anthony P. Parakka
Iowa State University

David C. Jiles
Iowa State University, dcjiles@iastate.edu

H. Gupta
University of Connecticut

S. Jalics
Delphi Chassis

Follow this and additional works at: http://lib.dr.iastate.edu/cnde_pubs
Part of the Electromagnetics and Photonics Commons, and the Engineering Physics Commons

The complete bibliographic information for this item can be found at http://lib.dr.iastate.edu/cnde_pubs/26. For information on how to cite this item, please visit http://lib.dr.iastate.edu/howtocite.html.
Effects of surface condition on Barkhausen emissions from steel

Abstract
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.

Keywords
Barkhausen effects, Surface dynamics, Materials analysis, Domain walls, Eddies

Disciplines
Electromagnetics and Photonics | Engineering Physics

Comments
The following article appeared in Journal of Applied Physics 79 (1996): 6045 and may be found at http://dx.doi.org/10.1063/1.362085.

Rights
Copyright 1996 American Institute of Physics. This article may be downloaded for personal use only. Any other use requires prior permission of the author and the American Institute of Physics.
Effects of surface condition on Barkhausen emissions from steel
A. P. Parakka, D. C. Jiles, H. Gupta, and S. Jalics

Citation: Journal of Applied Physics 79, 6045 (1996); doi: 10.1063/1.362085
View online: http://dx.doi.org/10.1063/1.362085
View Table of Contents: http://scitation.aip.org/content/aip/journal/jap/79/8?ver=pdfcov
Published by the AIP Publishing

Articles you may be interested in
Reduction of field emission current from stainless steel and copper surface
AIP Conf. Proc. 570, 1009 (2001); 10.1063/1.1384244

The effect of microstructural changes on magnetic Barkhausen noise and magnetomechanical acoustic emission in Mn–Mo–Ni pressure vessel steel
J. Appl. Phys. 87, 5242 (2000); 10.1063/1.373308

Barkhausen effect in steels and its dependence on surface condition
J. Appl. Phys. 81, 5085 (1997); 10.1063/1.364516

Monitoring neutron embrittlement in nuclear pressure vessel steels using micromagnetic Barkhausen emissions
J. Appl. Phys. 75, 6981 (1994); 10.1063/1.356748

Effects of surface condition on the infrared absorptivity of 304 stainless steel
J. Appl. Phys. 50, 1071 (1979); 10.1063/1.326083
Effects of surface condition on Barkhausen emissions from steel

A. P. Parakkai and D. C. Jiles

Center for NDE, Iowa State University, Ames, Iowa 50011

H. Gupta

Center for Grinding Research and Development, University of Connecticut, Storrs, Connecticut 06269

S. Jalics

Delphi Chassis, Sandusky, Ohio 44780

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. [S0021-8979(96)76008-0]

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 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 size 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 tolerance 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.

FIG. 1. Magnetizing signal and Barkhausen emissions as a function of time.
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 $d\lambda/dM$ 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.

2 D. C. Jiles, NDT Int. 21, 311 (1988).

Published without author corrections