

The Barkhausen Noise Inspection Method for Detecting Grinding Damage in Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Barkhausen noise is created by the abrupt changes in the magnetization of materials under applied ac magnetizing field. These changes are known to be affected by microstructure and the presence and distribution of elastic stresses. In the case of grinding damage, both residual stress and microstructural changes occur. The most common case of grinding damage results in a loss of hardness and compressive residual stress and is referred to as retempering.

In this paper, the theory of Barkhausen noise will be reviewed with a focus on the application of non-destructively testing for grinding damage on ferromagnetic materials. The theory of grinding will be reviewed, with respect to microstructural and residual stress changes, and examples will be given to show how Barkhausen noise is used to evaluate these changes. Following this introduction is a discussion of the success of the Barkhausen noise technique when measuring grinding damage in transmission gears using a semi-automated testing apparatus. The successes include the ability to quickly and easily obtain quantitative results, to eliminate subjective "etching" techniques, to detect flaws early before a large number of damaged parts are produced, and to have a record of the results saved to hard disk. In short, it will be shown how Barkhausen noise can be used to easily detect grinding damage in surface-hardened steel components, specifically transmission gears.

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Introduction

When hardened steel components are ground, there is always the possibility for damage to the steel in the form of residual stress or microstructural changes. Methods for detecting this sort of damage have always had one or more drawbacks, such as cost, time, complexity, subjectivity, or the use of hazardous chemicals. A relatively new method, known as barkhausen noise analysis, meets the demand for measuring defects in ground steels in a very reliable, standardized and cost effective manner. Use of this technique is simple and can reduce product failures to zero percent. Semi-Automated Gear Inspection Systems have been employed by gear manufacturers to take advantage of the capabilities of barkhausen instrumentation. Combined with dimensional inspection, hardness tests and periodic metallographic analysis, the barkhausen noise analysis method can help close the loop on insuring product quality. Barkhausen noise analysis can be a strong link in the chain that ultimately leads to a long and reliable gear life.

Measurement Techniques and Instrumentation

Barkhausen noise analysis is a technique based around a relatively simple concept involving ferromagnetic materials and a magnetizing field. When a magnetizing field is placed near a ferromagnetic material, the material undergoes a net magnetization change. This change is a result of the microscopic motion of magnetic domain walls within the material. When a domain wall moves, it emits an electrical pulse that can be detected by a coil of conducting wire placed near the material. These discrete pulses are measured in a bulk manner resulting in a compilation of thousands of electrical pulses referred to as Barkhausen noise.[3,6,7,9] The amplitude of this signal is sometimes referred to as the Magneto-Elastic Parameter (MP). The amplitude is affected by anything that impedes the motion of domain walls. Some factors to consider are inclusions, precipitates, dislocations, grain boundaries, and residual stresses. In the sense of macro-metallurgy, we may sum up these factors into two categories, hardness and residual stress. In general, Barkhausen noise is increased with decreasing hardness and increasing tensile stress and

Effect of Stress

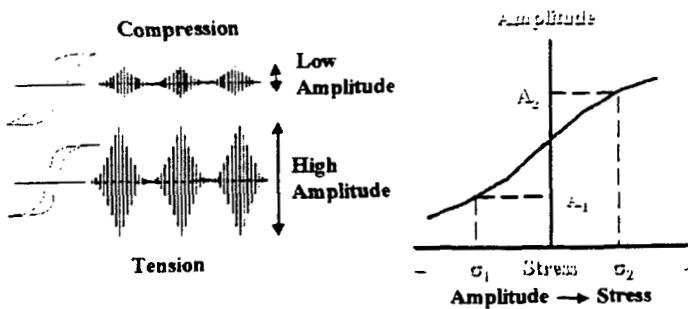


Figure 1: Barkhausen Noise Amplitude vs. Stress.

Effect of Hardness

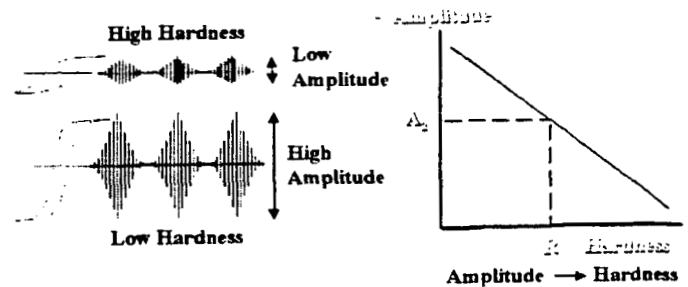


Figure 2: Barkhausen Noise Amplitude vs. Hardness.

Instrumentation

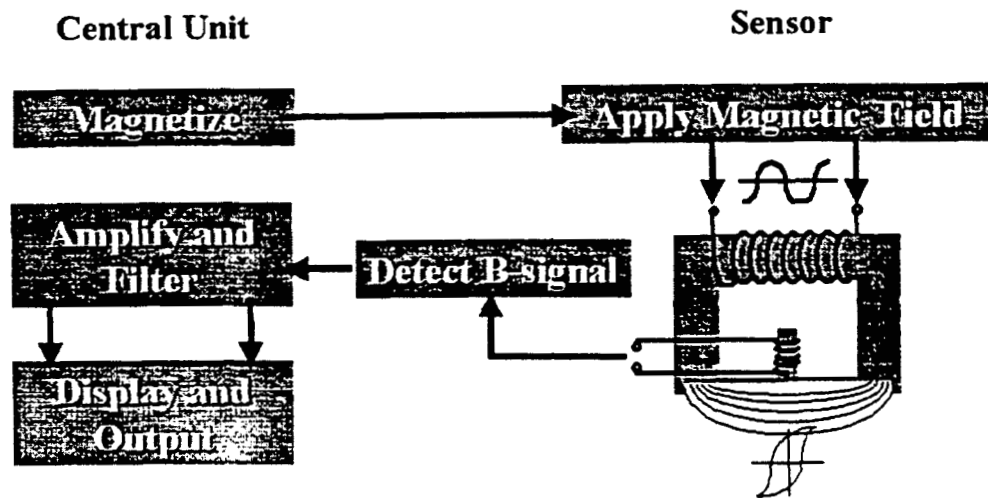


Figure 3: Instrumentation Required For Barkhausen Noise Analysis.

conversely, Barkhausen noise is decreased with increasing hardness and increasing compressive stress. This principle is illustrated in figures 1 and 2.

The instrumentation required to detect Barkhausen signals is illustrated in figure 3. A magnetizing field is created and applied to a ferromagnetic material through the use of an electromagnet. The material reacts to the magnetic field as described above and emits Barkhausen bursts, which are captured by a sensor consisting of a coil of conducting wire. The signal is then amplified and filtered. The amplitude is calculated using an RMS equation and the data is digitized for display and output to a computer.

The Nature of Material Defects Caused By Grinding

Grinding damage is the result of energy being converted to heat. This heat is concentrated in the surface layers and may cause undesirable effects if not properly managed. Some of the factors affecting the rise in temperature in the surface layer include the coolant type, coolant concentration, coolant age, coolant flow, grinding wheel type, grinding wheel speed, grinding wheel wear, feed rate and prior processing of material e.g. different heat treat batches. Wojtas, et. al.[9] explain that damage may start with the partial relaxation of desirable compressive stresses at temperatures below 500°C. As temperatures increase to near 600°C, B class thermal damage, also known as re-tempering burn, occurs. The effect will be an over-tempering causing a decrease in surface