Various Approaches to Obtain an Eddy Current Signal in Case of Overheating

Konstantin HÄRTEL [1], Antje ZÖSCH [1], Martin Wolfgang SEIDEL [1], Christopher SEIDEL [1]
[1] imq-Ingenieurbetrieb für Materialprüfung, Qualitätssicherung und Schweißtechnik GmbH, Crimmitschau, Germany

Contact e-mail: k.haertel@imq-gmbh.com

Abstract. In recent years eddy current testing has proven a safe method for the detection of overheating indicators. Localized tempered zones and rehardening zones that may arise during the finishing of hardened surfaces are reliably detected. Test samples with failures featuring the same properties as real grinding burn can be produced and used for setting and verifying responsivity of the eddy current method.

In the presented study the physical effects generating eddy current signals are investigated. Differences between signals obtained using absolute probes and differential probes are discussed. The influence of process parameters especially of measuring frequency on measuring process are analysed and possibilities and limitations of the testing method shown. Probability of detection for various defect geometries is examined. Results have been verified using reference methods such as metallography and measurement of hardness.

1. Introduction

Grinding burn is a local overheating caused during machining of hardened surfaces by grinding. The applied heat causes structural changes in the material near to the surface (see Fig. 1). This is expressed by changes in the internal stress, as annealing zones or as rehardening zones caused by intense heat input. As a result of these effects the aggrieved component will have a shorter lifetime or will be destroyed in field.[1]

In the past plenty of organizations used nital etching to ensure that components with grinding burn were not applied. However, in the recent past the eddy current testing has as well developed to become a fast and reliable testing method.

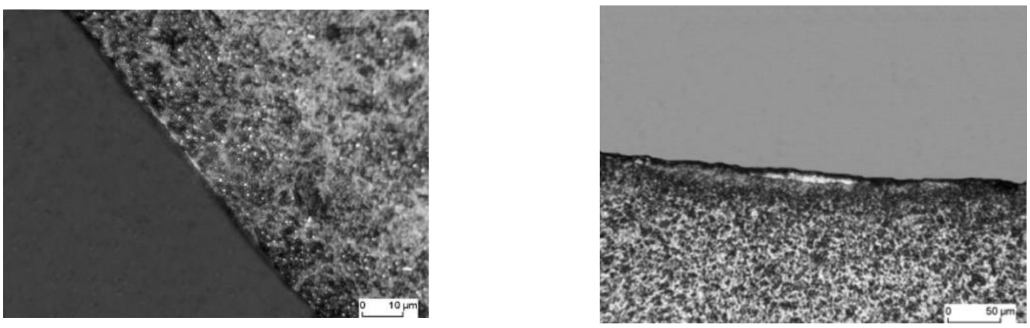

Fig. 1. Microsections of bearings; left image: annealing zone; right image: annealing and rehardening zone

License: http://creativecommons.org/licenses/by-nd/3.0/

2. Non-destructive detection of overheating

2.1. Artificial defects

To ensure reliability and repeatability of eddy current testing, it is necessary to use artificial defects of the damage symptoms. This is also claimed by the international standard DIN EN ISO 15549 „non-destructive testing – eddy current testing - general principles".

A so called reference block is supposed to feature the same manufacturing conditions, the same material and a defect with known properties. The repeatable manufacturing of natural grinding burn is nearly impossible, due to the plurality of multiplicative influences on the grinding process. Therefore imq has developed a technology to generate grinding burn areas in customer components by laser treatment (Fig 2). The laser-generated overheating causes nearly the same changes of internal stresses, hardness and structure as natural grinding burn and can be produced in a repeatable way.[2]


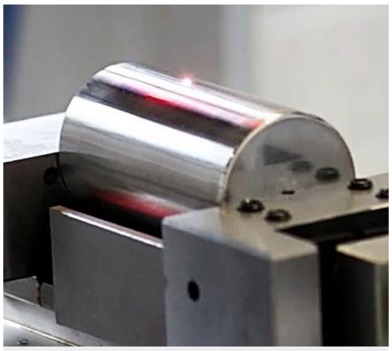

Fig. 2. Laser generated defects; left image: crankshaft with artificial defects; right image: bearing while laser treatment

2.2. Signal formation

For eddy current testing of grinding burn mostly absolute and differential probes are used. The absolute probe detects changes in the structure of the material in terms of a variation of the magnetic properties in the area. In addition to testing frequency, the probe diameter is significant for signal formation in relation to defect size.

The differential probe consists of two or more coils. The coils detect changes in the magnetic properties like absolute probes, but they are compared with each other. In addition to testing frequency and the probe diameter in relation to defect size, the distance between the coils is significant for signal formation.

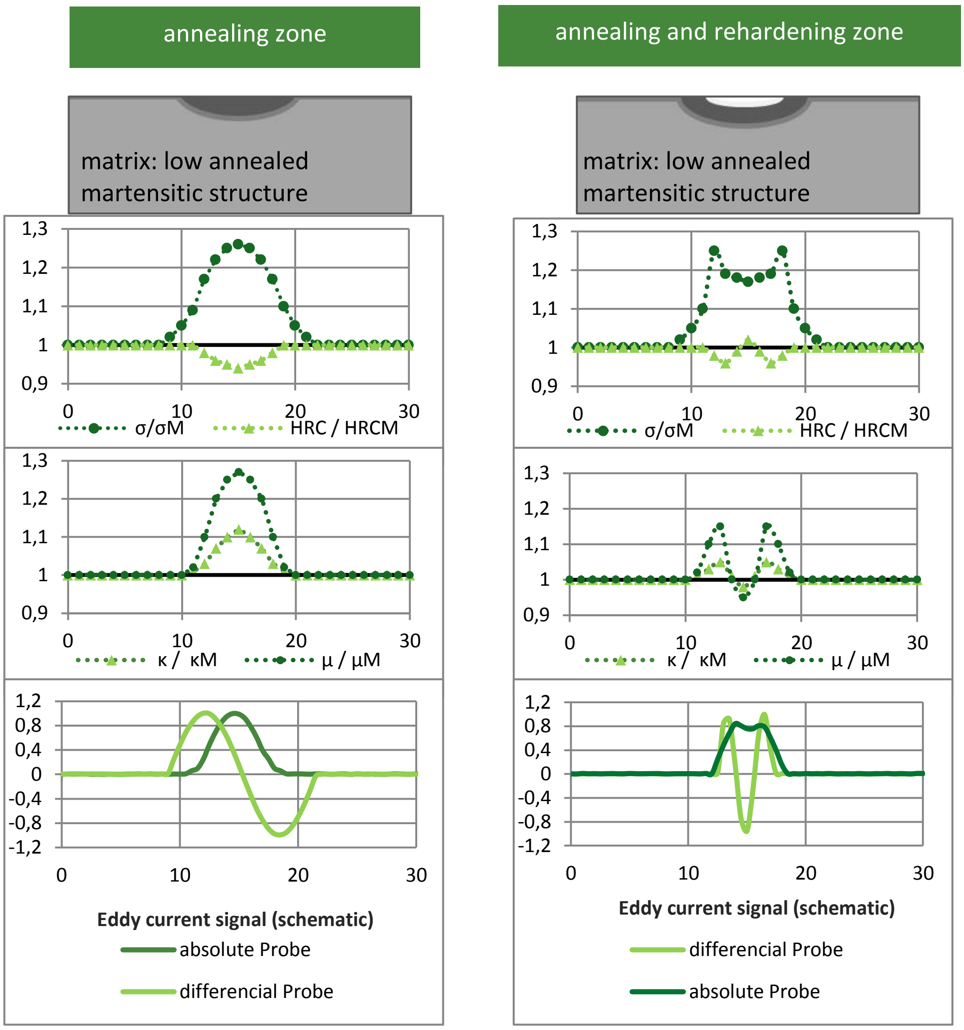

Fig. 3. Several changes in component and magnatic properties and the influence on eddy current signal

In the figure above (Fig. 3) several changes in component (internal stress σ, rockwell hardness HRC) and magnetic (magnetic permeability μ, electrical conductivity κ) properties relative to the basic matrix of a bearing component are shown. In the last figure the resulting eddy current signal of the absolute and the differential probe is drawn.[3]

It becomes apparent that structural changes in the component (like grinding burn) directly cause changes in the magnetic properties. This schematic figure can be transformed to practical testing applications – figures below (Fig. 4).

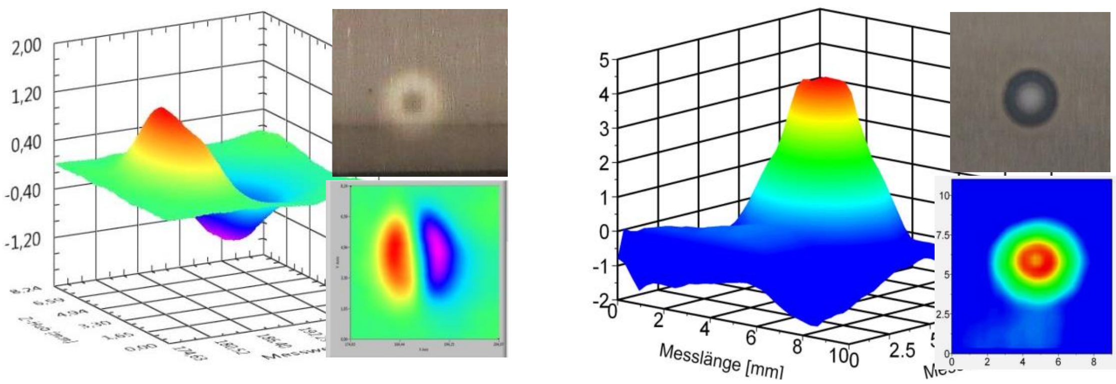

Fig. 4. Eddy current scan of artifical defects; left image: annealing zone by differential probe; right image: annealing zone an rehardening zone by absolute probe

2.3. Penetration depth

The penetration depth is directly guided by testing frequency. The figure 5 below shows the theoretically calculated penetration depth vs. different frequencies. The relative permeability of steel reaches from 40 to 7000. Therefore, different values for relative permeability, starting by 50 to 1000, were adopted.[4]

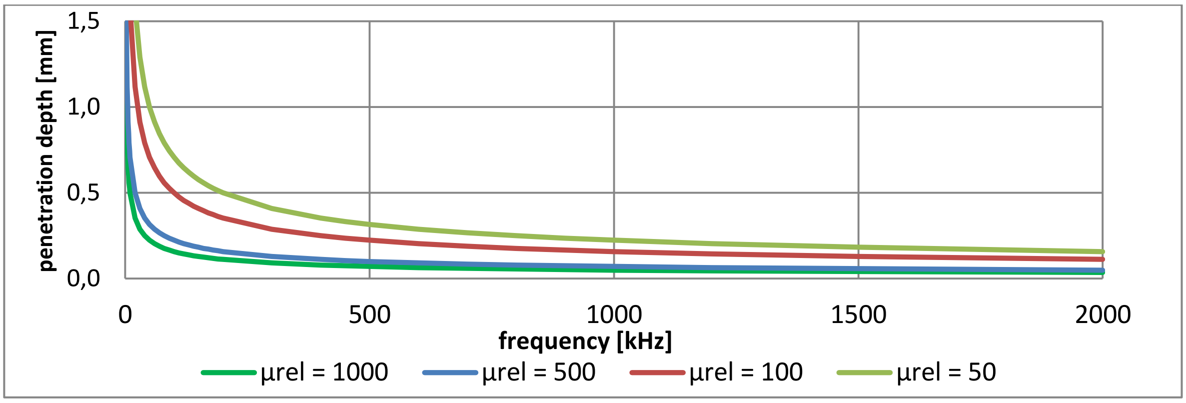

Fig. 5. Penetration depth according to frequency for different values of relative permeability

The eddy current testing of grinding burn uses preferential high frequency in kHz to MHz range. For that reason the testing method is very surface sensitive and the depth of defect is underpart. The figure 6 illustrates the penetration behavior of eddy current in field. A significant variation of amplitude is only visible in the first three artificial defects; afterwards the amplitudes are almost on similar level.

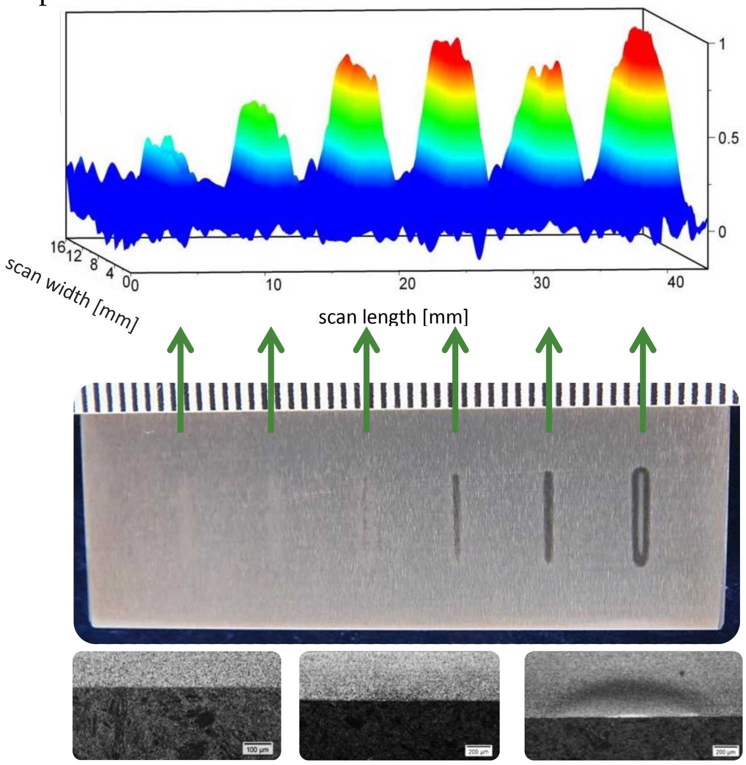

Fig. 6. Dependence of eddy current signal on grinding burn level;
top: eddy current scan (3 MHz) of a reference block with synthetic grinding burn different depths;
middle: reference block with synthetic grinding burn – depth (left to right): without visual structure changes, 20 µm, 60 µm, 100 µm, 160 µm and 270 µm (with rehardening zone);
bottom: selected micro sections (left to right) – without structure changes, 60 µm, 270 µm

3. Summary

- The eddy current testing remains a suitable method for the detection of grinding burn. Especially for rotationally symmetric components it is a fast way for quality assurance.
- Repeatable produced reference blocks guarantee safe and significant eddy current testing results.
- The correlations between magnetic and component properties support the capabilities of eddy current testing.
- For detection of grinding burn the lateral dimension is more essential than the depth, due to high frequency mode of operation causes low penetration depth.

References

[1] ISO 14 104 "Gears – Surface temper etch inspection after grinding, chemical method"

[2] DIN EN ISO 15549 "non-destructive testing – eddy current testing - general principles"

[3] Seidel, M: Gefüge- und Eigenschaftsprüfung von Wälzlagerteilen mittels elektromagnetischer Methoden Dissertation B Technische Hochschule Zwickau 1991

[4] H. Stroppe, K. Schiebold, B. Hentling: Wirbelstrom Materialprüfung. Castel-Verlag 2012