DAMAGE ACCUMULATION STUDY IN FATIGUE TESTING USING THE BARKHAUSEN NOISE

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Abstract. *Damage is the progressive degradation of the materials due to the action of a mechanical loading. In metals, the damage phenomenon represents the creation of superficial discontinuities (micro cracks) or volumetric discontinuities (cavities). Although the causes of this phenomenon are the same of the deformation, motion and accumulation of dislocations, the two phenomena are quite different. Due to the irreversible nature of the damage, the classical termomechanical treatments can not recover the material's initial condition and the final state of the damage is the material's rupture. The variable used to quantify the damage is the superficial density of micro defects, such as cracks, cavities, etc. Two classes of methods are used for damage evaluation. The first one consists of the direct methods, where the evaluation of the superficial density of micro defects is done using optical microscopy, measurements of porosity and X-ray diffraction techniques. The second one consists of the indirect methods, where the damage evaluation is done from the measurements of the changing occurring in the physical and mechanical properties of the material, caused by the damage level induced in it. This paper presents a study related to the use of the magnetic Barkhausen noise (MBN) analysis for damage evaluation in samples of SAE 8620 steel submitted to a high cycle fatigue. The main results obtained are discussed.*

***Keywords**. Barkhausen noise, fatigue, damage, nondestructive testing.*

1. Introduction

The use of magnetic methods for non-destructive characterisation of ferromagnetic materials has increased in the last years. They can be applied in the study of the most part of the commercially available steels used in industry. Amongst them, a recent magnetic testing method based on the Barkhausen noise analysis has acquired great importance. Barkhausen noise is generated into a ferromagnetic material during the magnetisation process and results from the interactions occurring between magnetic domains walls and structural discontinuities present in the materials microstructure (DHAR,1992). Under influence of as variable magnetic field, magnetic domains oriented in directions near to the applied magnetic field direction tends to growth, the opposite occurring with those oriented in another directions. This growth takes place by a mechanism called domain wall motion (CULLITY,1972) .

The presence of structural discontinuities and stress fields acts as pinning sites to the domain walls motion which occur in a discontinuous way and promotes discontinuous changes in the magnetic flow (SIPAHI,1994). These changes induce electrical signals in a coil placed in the material surface. The sum of all signals induced in the coil are called Barkhausen noise.

Any region into the material which presents magnetic properties different from the normal materials structure is considered as a structural discontinuity. Precipitates, inclusions, cracks, voids and grain boundaries are examples of structural discontinuities. They affect the characteristics of the Barkhausen noise generated during the magnetisation and can be evaluated by this test method after an appropriate test system calibration.

3. Experimental methodology

3.1. Material

The fatigue test specimens used in this paper were manufactured from samples of a SAE 8620 steel bar. Its geometry and dimensions were defined from recommendations of ASTM E 466 and DIN 50113, 1982 (Fig. (1)). Five test specimens, identified as test specimens 1, 2, 3, 4 and 5, were tested.

Figure 1. Test specimen of SAE 8620 steel used for damage studies.

3.2. Instrumentation

The fatigue tests were performed under controlled conditions using a rotating-bending fatigue testing machine designed and manufactured at CDTN facilities Fig. (2). The measurements of magnetic Barkhausen noise (MBN) were carried out using a Stresstest 20.04 test system Fig. (3). It consists of a test unit responsible for the test parameters control (amplitude/ frequency of the excitation magnetic field and analysis filters), signal processing tools, an electromagnetic probe for materials excitation and Barkhausen noise detection, a digital oscilloscope and a test specimen holder to fix the test specimen during the measurements. The specimen holder was designed in order to assure the same relative position between test specimen and probe during the measurements.

Figure 2. Rotating-bending fatigue testing machine used for damage studies.

Figure 3. Test system used for MBN measurements .

3.3. Measurements

In order to perform the MBN measurements, the test specimens were excited with a 10 Hz variable magnetic field and the RMS (root mean square) value of the detected MBN was recorded. The measurements were made in the central region of the test specimens, in eight different points along its circumference.

The experiment was developed in two steps. In the first one, the five test specimens were submitted to different number of cycles in the rotating-bending fatigue testing machine, without loading. MBN was measured from 0 to 2,000,000 cycles at intervals of 30,000 cycles. This procedure was adopted in order to verify the initial behavior of the MBN generated into the material due to increase of the number of cycles only. In the second step, the test specimens were submitted to a completely reversed constant-amplitude stress of 259 MPa and the MBN was measured at intervals of 30,000 cycles.

4. Results and Discussion

At the stress level of 259 MPa the failure of the test specimens has occurred after approximately 400,000 cycles. However, the rupture took place in different regions depending on the test specimen. For the test specimen 2 it has occurred in the central region, the same place where the MBN measurements were performed.

In the first step of the experiment, the test specimens were submitted to a different number of cycles but without stress applied and the results obtained showed no relevant dependence between MBN value and number of cycles, as showed for test specimen 2 showed in Fig. (4).

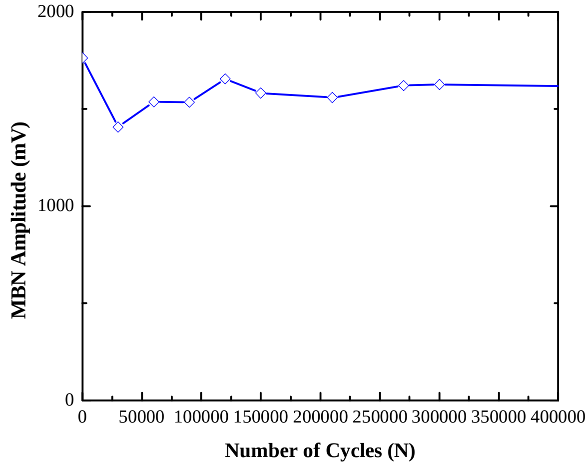

Figure 4. MBN measurements for the test specimen 2 in the initial condition.

In the second step, under a stress level of 259 MPa, the results of MBN measurements revealed a strong dependence with the number of cycles in the initial phase of the damage process. It was observed a strong increase in the Barkhausen noise amplitude with the number of cycles in the range from 0 to 60,000 cycles. After this point, a decrease in the Barkhausen noise amplitude was observed and this behavior remained the same until about 300,000 cycles. After this, a increase in the signal amplitude was observed until the material failure occurrence Fig. (5).

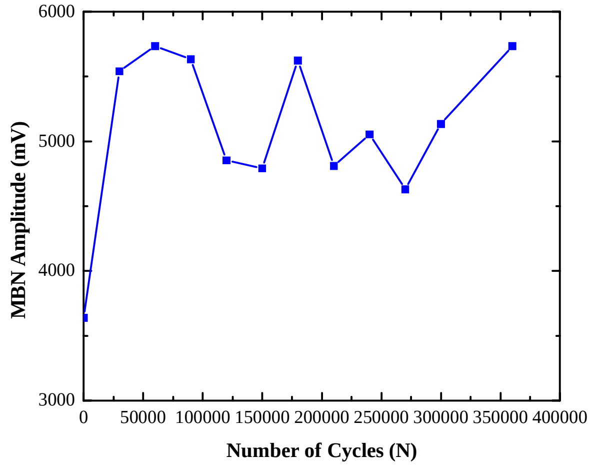

Figure 5. MBN measurements for the test specimen 2 submitted to a completely reversed constant-amplitude stress of 259 MPa.

5. Conclusions

The initial results obtained in this study show a dependence among MBN amplitude and number of cycles in the fatigue testing with a constant-amplitude stress applied to the test specimen. The trends observed in the MBN amplitude value above 60,000 cycles suggests that MBN measurements can be used to determine the damage state of the tested material. To improve the results obtained here it is necessary to perform experiments increasing the number of test specimens. The main difficult to obtain consistent results is to make sure that the failure of the material occurs in the same local where the MBN measurements are made. A possible solution for this problem is to change the geometry of the test specimens, in order to assure that the failure will occur in their central region. A decrease in the diameter of the test specimens central region can be effective to solve this.

5. References

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