First Detection of an Overheating Zone by the Thermoelectric SQUID Method

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1. Introduction

In preliminary discussions with Volvo Aero Corporation, a manufacturer of rotating parts for aero engines, the problem of possible overheating during the drilling of a hole due to a broken tool or chip packing was a subject. Such an overheated zone is typically circumferencial. The overheating can lead to a change of material microstructure and a degradation of mechanical properties. Therefore such overheating zone is not acceptable and has to be inspected for by non-destructive testing. VOLVO had prepared an artificial sample with overheating zone in order to have it tested by various inspection methods. To simplify the geometry restrictions the sample was splitted longitudinally along the hole. The sample was sent to F.I.T. Messtechnik GmbH (FITM) to be inspected by the Thermoelectric SQUID Method.

2. General measurement procedure

The Thermoelectric SQUID Method makes use of the so-called Seebeck effect which is regularly used in thermocouples for temperature measurements. Hereby a voltage is measured which is generated when two surfaces between two different metal wires are on different temperature.

In the case of the Thermoelectric SQUID Method the situation is 3-dimensional and a noncontacting read out of the magnetic fields is used which are generated by thermo-currents. Therefore the principal of the test procedure is:

1. Giving a thermo gradient on the sample and
2. Measuring simultaneously the magnetic field distribution over the sample.

If the magnetic field distribution has an anomaly then it can be concluded that there is a material inhomogeneity on the surface or below the surface of the sample.

For more details of the Thermoelectric SQUID Method please see [1] ... [4].

The magnetic fields, that are to be measured by the Thermoelectric SQUID Method, normally are very small. Therefore most sensitive magnetometers are necessary. We used the HMT SQUID Gradiometer, see [5].

3. Measurement details

The bottom drawing of figure 1 shows that the sample is fixed on a mobile support. This is slided manually along a fixed guide. Three mirrors on the mobile support give trigger signals for the position of the sample during measurement: at both sample ends and at the position of the overheating zone.

Over the sample the SQUID gradiometer is placed with an adapter to realize the temperature gradient. This arrangement is shown in the upper left part and in the upper right part of figure 1. The temperature gradient is realized by blowing hot air through a nozzle onto the sample.

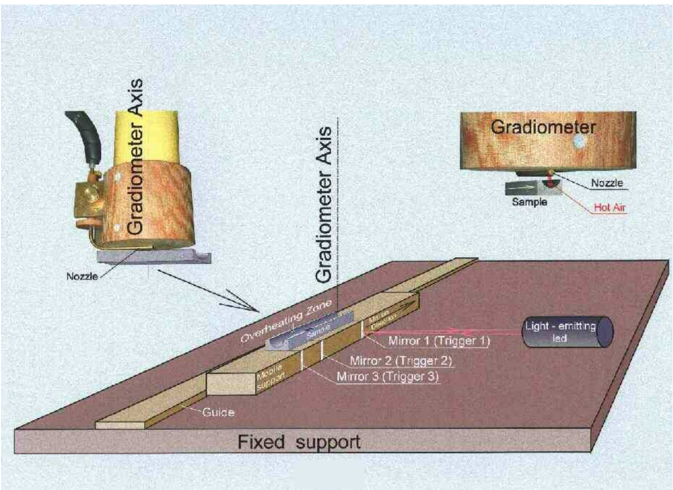

Figure 1:

4. Measurement results

Various tests were performed to optimize the test procedure. In the following the final results are described.

Figures 2 and 3 show these measurement results.

Let us first look to **Figure 2**. The drawing on the right hand side shows the position of the center of the SQUID gradiometer and the position of the nozzle, which are fixed with respect to each other during a measurement. The sample is moved in longitudinal direction below SQUID and nozzle.

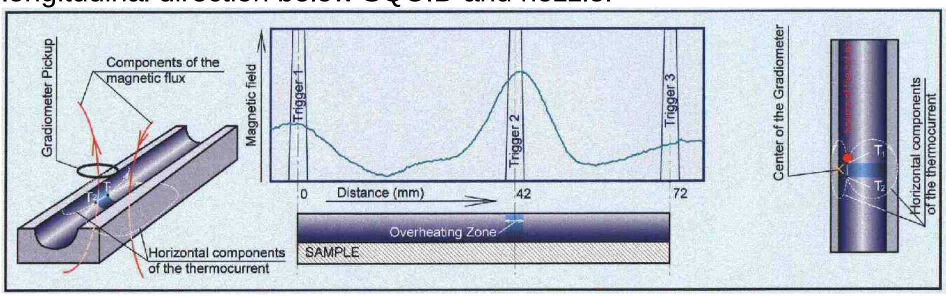

Figure 2:

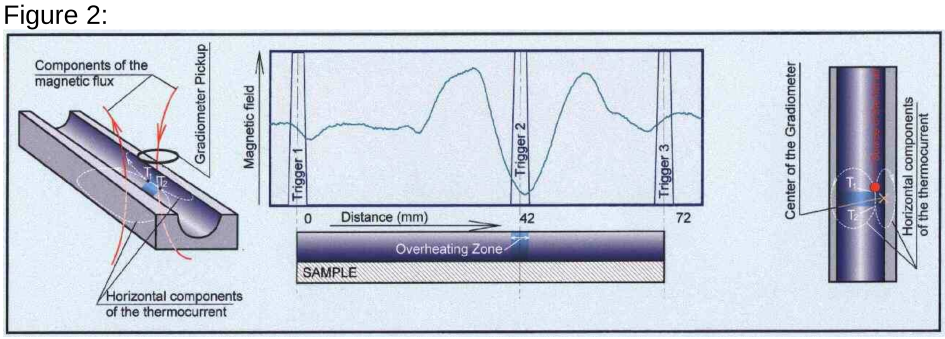

Figure 3:

During this movement the magnetic field is measured. The output of the SQUID gradiometer versus distance in longitudinal direction is shown in the plot in the middle of figure 2, together with the three trigger signals. The measurement plot shows a pronounced maximum just at the position of the overheating zone.

Our principal understanding of this signal is illustrated in the drawing on the left hand side of figure 2 which shows the situation when the SQUID gradiometeraxis is just above the overheating zone: the hot air, blown through the nozzle, creates an increased temperature T1 which is localized on one side of the overheating zone. At the opposite border of the overheating zone there is a lower temperature T2. Different Seebeck coefficients of the materials of the overheating zone and the host material lead to thermocurrents inside the sample. Their principal flow is given by white dashed lines. These currents generate a magnetic field inside and outside the sample, the principal direction of which is shown by red lines. These magnetic fields are detected during a measurement. In the special situation of figure 2 the magnetic field is positive because the SQUID gradiometer axis is above a current loop with the current flowing in counter-clock-wise direction.

When the sample is moved in longitudinal direction, the overheating zone is moved from below the SQUID gradiometer and nozzle. Then a pronounced temperature gradient only occurs in homogeneous material giving no rise for the Seebeck effect and no magnetic field.

Figure 3 is similar to figure2. The main difference is the positioning of nozzle and SQUID gradiometer axis. They are now positioned on the right hand side of the sample. The measured negative extremum in the magnetic field corresponds to our understanding that in this situation the SQUID gradiometer axis is above a current loop with the current flowing in clock-wise direction.

5. Conclusion

The overheating zone of the artificial sample has been detected with significant signal to noise ratio by the Thermoelectric SQUID Method. From our understanding in a non-artificial but practical situation the geometry of the sample will be quite different. The sample will not be splitted and access is only possible from the ends of the bore hole. For such a situation the inspection procedure has to be modified.

6. References

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