Detection of Segregations in Aero Engine Turbine Discs with the Thermoelectric SQUID Method

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Aero engine turbine discs are most critical parts. Material inhomogeneities can cause disc fractures during the flight with fatal air disasters. Non-destructive testing (NDT) of the discs in various machining steps is necessary and performed as well as possible. Conventional NDT methods, however, like eddy current testing and ultrasonic testing have unacceptable limits. For example, subsurface segregations often cannot be detected directly but only indirectly in such cases when cracks already have developed from them.

Another example for the need to detect material inhomogeneities is texture in rolled metal sheets. To be more specific, niobium sheets are to be tested for texture variations and other inhomogeneities. From these sheets cavities are made which are liquid helium cooled and used as superconducting radio frequency resonators. Material inhomogeneities will cause quenching, that means a lost of superconducting state, before the intended accelerator energy has been reached. Careful testing is necessary before use in these expensive experiments.

The Thermoelectric SQUID Method has proven well suited for both of these tasks. Use is made of the thermoelectric Seebeck effect which is used in thermocouples to measure temperatures. Due to this effect an electrical voltage is generated across a metal inclusion 1 within a host material 2 if both connecting surfaces are on different temperatures. If the host material forms a closed loop, electrical currents will flow and an associated magnetic field distribution will occur. Therefore, when impressing a thermal gradient onto a metallic sample and measuring a magnetic signature as a consequence, one can conclude that there is a material inhomogeneity inside the sample. The magnetic field strengths, however, are very small and most sensitive magnetometers have to be used. Only an appropriate SQUID-based measurement system can be successful. We used the magnetic measuring system HMT [1].

DaimlerChrysler Aerospace MTU München GmbH had placed aero engine turbine discs at our disposal. These discs are made from INCONEL® 718. MTU had tested these unused parts by segregation etching and had found segregations extending to the surface. MTU had scrapped these parts because of material flaws.

Test results with the Thermoelectric SQUID Method are described in figures 1 and 2, each with a photograph in the lower right corner, an inset showing the test arrangement in the upper right corner and a measurement plot on the left. The plot gives the amplitude of the magnetic field in arbitrary units as measured by the fixed HMT versus the rotation angle of the disc placed just below the magnetometer on a turntable. Two periods are plotted. The HMT is set to a radius according to the inset in the upper right corner.

A pair of two adjacent segregations had been found by MTU and was marked at 310°, a third segregation was marked at 90°. Both locations are rediscovered in the magnetic field plot, see figure 1. A further significant extremum, namely at 197° can be seen. This is considerably enhanced when testing the disc from the reverse side, see figure 2. At this angle no segregation had been detected before, but the existence of this signal can only be explained by a further segregation inside the material that could not have been detected before by segreagtion etching. Segregation etching can only detect such segregations which extend to the surface.

Figures 3 and 4 show test results on niobium sheets with 26,5 mm x 26,5 mm x 2,7 mm in size. They are from the Deutsches Elektronen-Synchrotron (DESY). The right-hand sides of figures 3 and 4 show the magnetic field distribution on top of the sheet without and with temperature gradient which in this case has been realized by blowing with hot air. The left-hand sides show the magnetic field distribution in a C-scan plot. Figure 3 as a test result of sheet # 1 from manufacturer # 1 shows the pronounced magnetic field variation, from our understanding caused by pronounced material inhomogeneities. Figure 4 shows results from sheet # 2 from manufacturer # 2, which even with realized temperature gradient does not cause any significant magnetic field variation. This is a very homogeneous material.

It has been shown that the Thermoelectric SQUID Method can detect material inhomogeneities even if subsurface. The method can be used to detect subsurface segregations in aero engine turbine discs and therefore can help to increase air safety considerably.

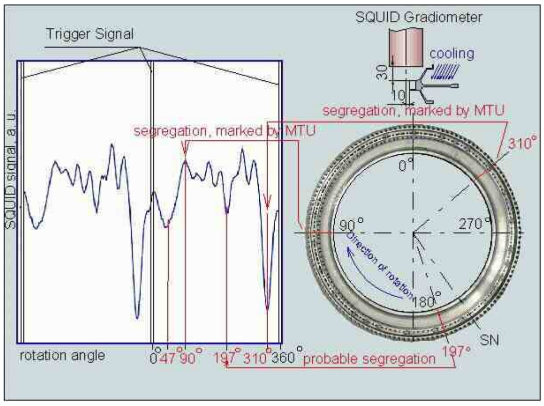

Figure 1: Disc with segregations: photograph, measurement arrangement, and magnetic field. Test from first side.

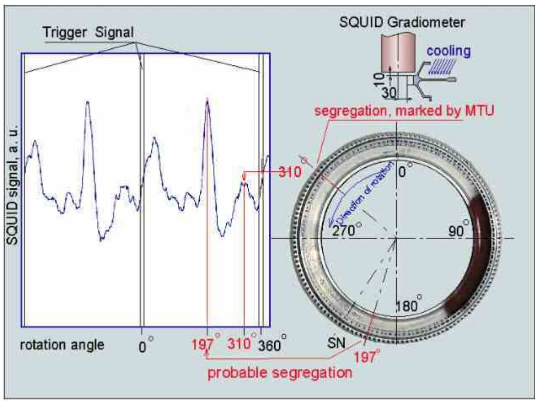

Figure 2: Disc with segregations: photograph, measurement arrangement, and magnetic field. Test from reverse side.

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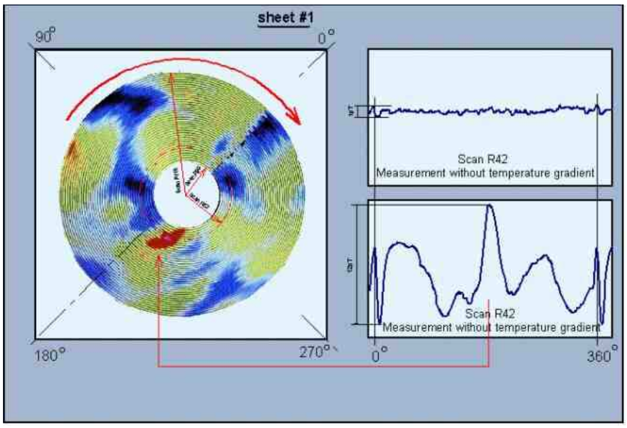

Figure 3: Niobium sheet # 1: right-hand side: single scans at radius R = 42 mm without and with temperature gradient. Left-hand side: magnetic field distribution with realized temperature gradient

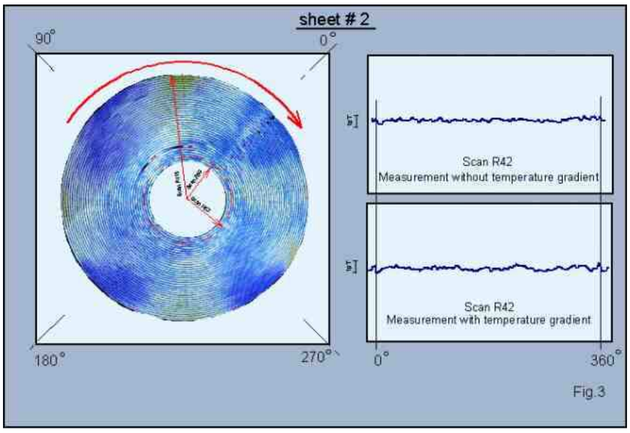

Figure 4: Niobium sheet # 2: right-hand side: single scans at radius R = 42 mm without and with temperature gradient. Left-hand side: magnetic field distribution with realized temperature gradient.

REFERENCES

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