TESTING OF NB SHEETS ON A SQUID NDE SYSTEM WITH LARGE SCALE X/Y TABLE FOR USE IN INDUSTRIAL ENVIROMENT

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Abstract

The reachable field strength in superconducting resonators used in particle accellerators is limited by surface defects or inclusions of unwanted elements. Inclusions of some 100µm in diameter can significantly reduce the reachable field strength. Since the manufacturing of Nb resonators is very expensive, the Nb sheets must be checked prior to production of the tubes on such defects.

We have constructed a system for non-destructive inspection of niobium sheets, based on eddy current measurements. To receive the neccessary detection sensitivity, a SQUID sensor for measuring the local eddy current desity is used. The system works in a non-shielded enviroment. Within test sheets supplied from DESY tantalum inclusions with diameters of approximately 100µm could be confidentially detected.

With a sheet size of about 300x300mm² and a line width of 1mm a scan of one sheet lasts about 15min, because of the SQUID's low noise the sheets can be scanned with up to 100mm/s scanning speed.

Because of the high sensitivity of the SQUID detector it is not only possible to detect very small defects within sheets but also to gather a detailed image of the found defects, so it is easier to categorize the results than with an inspection of lower resolution and sensitivity.

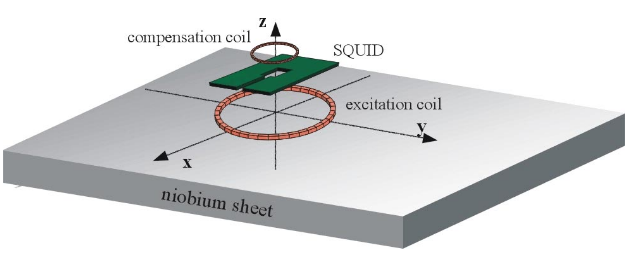

Figure 1: Principle of eddy current measurements with a SQUID.

The software written for the project allows it to group different measurements on the same sample and catalogizes the measured results.

During the project, different measurement equipments were built up, some with stationary SQUID systems, other with stationary sample holder. In all cases it was possible to operate the SQUID, even if a setup with stationary SQUID are often easer to work with, since gradients in the local field in such a case are no problem for the dynamic range of the magnetic field sensor.

DESCRIPTION OF THE MEASUREMENT SYSTEM

When using a SQUID as magnetic field detector, a measurement system has a much higher sensitivity to changes of the magnetic field than with any other type of sensor. Especially low TC SQUID sensors reach sensitivities close to the theoretical limit of a single flux quantum per sensor area (which, in case of the SQUIDs used is approximately 0,1mm²).

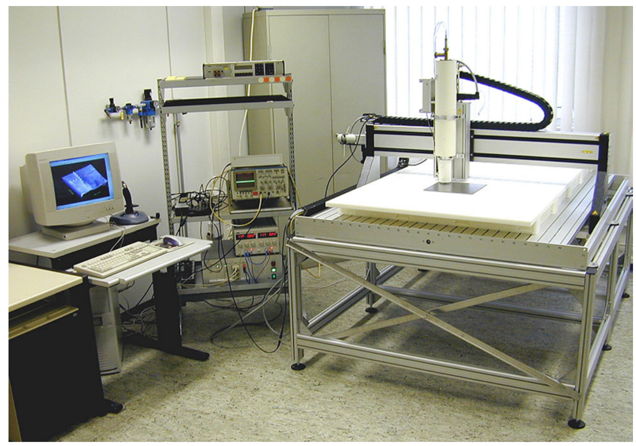

Figure 2: SQUID measurement system at W.C. Heraeus, Hanau.

Our measurement system is based on an xyz table with 1m x 1,25m travel area in order to scan Nb sheets with more than 1m² of area. The measurement is controlled by an ordinary PC, which does data acquisition, mapping of the values on a grid and control of the three servo motors which drive the table. Measurement speeds of up to 100 mm/s are possible, and with distances of some 5 mm between the scan lines, a 30x30 cm² sized sheet of Nb can be scanned within less than five minutes.

At the IAP of the University of Giessen, a different system with fixed dewar and stationary SQUID is used, where the sample is moved by a two axis unit.

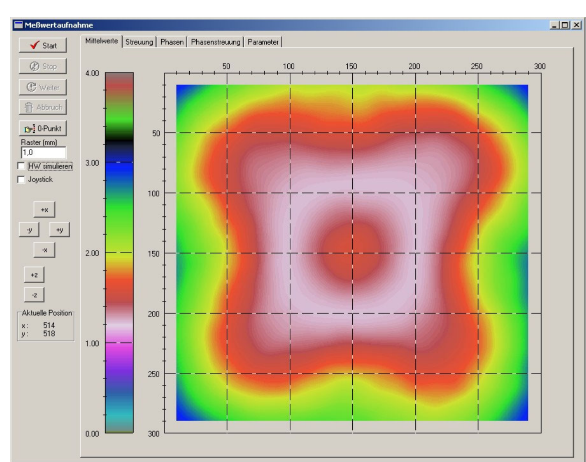

Figure 3: Sample screenshot of the data acquisition software with a simulated surface respond.

The Nb sheets are fixed by a vacuum sample holder in order to keep them as flat as possible, additionally the distance between sensor system and the surface is measured and the measurement signal is corrected for the difference occurring due to a lift-of between sample and exitation coil.

The SQUID sensor is electronically controlled by a 4 MHz flux modulation and control loop, in order to keep the magnetic flux through the SQUID constant A compensation current is controlled by the flux measurement. The amount of compensation current necessary to keep the SQUID's flux constant is then taken as measurement value from the control loop. This signal is then processed by a lock-in amplifier to eliminate noise with a spectral density apart from the excitation frequency. Different filters are implemented into the lock-in amplifier to improve the S/N ratio.

Due to the relative complex design of the SQUID electronics, the usable frequency spectrum is limited to around 0-100 kHz. For Measurements on Nb sheets, frequencies from 20 to 90 kHz have been used. In difference to the BAM system used at DESY, only a single frequency is used. One reason for this lies in the very high sensitivity of the SQUID system: Even with 90 KHz (skin depth of eddy current in Nb: 0.16 mm), scratches and paintings on the back of the sheets (thickness: 2.8 mm) are detected! This means, that not only defects within the skin depth are detected, but up to a multiple of it remain visible. When scanning with different frequencies, a detection of the depth of inclusions is only possible for a significant difference in signal response over the used channels. This means, that for a two channel analysis with a SQUID detector the frequencies used have to differ by approximately a factor of 100 (the skin depth, which determines the current distribution in the sample scales with the square root of the frequency used).

Since the management of the measured data is a second aspect towards an effective quality control, the data acquisition software developed for the measurement system implements a data management based on a relational database system. The data is placed in a hierarchical order, so that different measurements on one single sample are possible and can be related to each other.

One aim is the possible presentation of different testing results together with remarks of the tester.

TESTING RESULTS ON NB SHEETS

The following images show testing results on Nb sheets both from the SQUID measurement system and the BAM test equipment at DESY.

While some of the test results (as with sheet 41) are nearly identical, some details are seen with the BAM equipment are not visible with the SQUID measurement system and vice versa. Very astonishing is the difference in measurement expense: BAM uses two different excitation frequencies on a total of four input channels, the table itself scans with four times the track density and the sensor head used for moving the coils over the sample are special constructions lifted by pressurized air in order not to touch the surface of the sample.

The images are placed side-by-side, so a comparision of conventionally taken images and the SQUID measurements can easily be made.

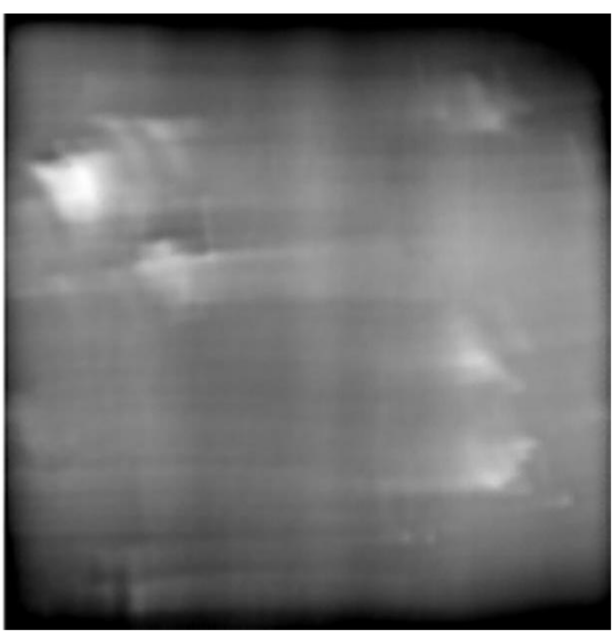

Figure 4: Scan of sheet 41 with SQUID sensor system. Scanning resolution was set to 300 scan lines, which corresponds to 1 l/mm. The frequency used was 33 kHz, which is closer to DESY's measurement channel 1 (170 kHz).

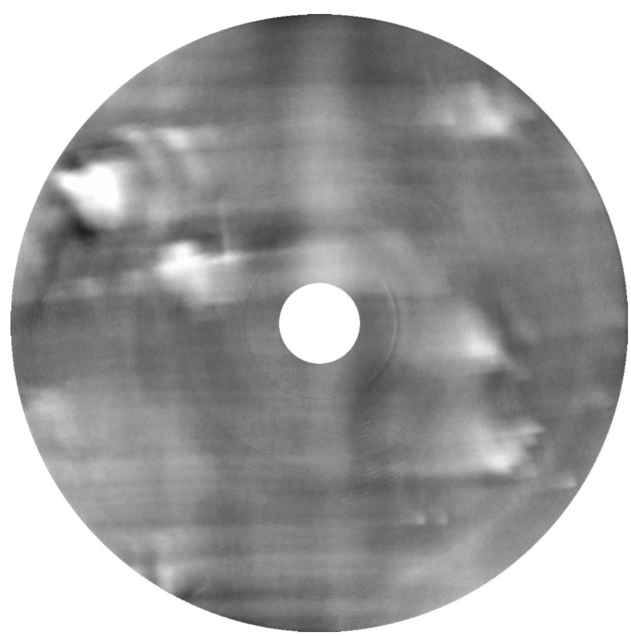

Figure 5: Scan of sheet 41 with conventional sensor system. DESYs default setup was used, with 4.16 l/mm track density. The y-val. of channel 2 (at 1 MHz) is shown, which (in this example) delivers the most similar image).

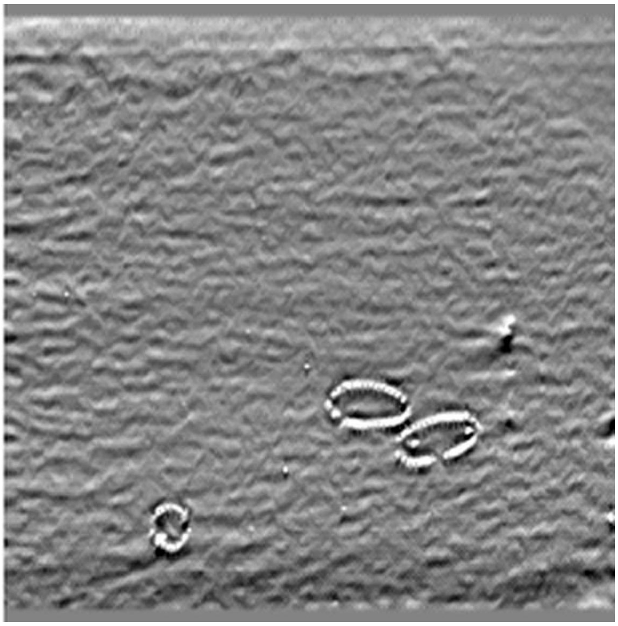

Figure 6: Scan of sheet 9 with SQUID sensor system. The three ellipses shown are pen markings for scratches (within the ellipses) on the BACK of the sheet. Some more dots and one large signal source (center left) are visible.

Figure 8: Scan of sheet 9 with conventional sensor system. The y-val. of channel 1 (at 170 kHz) is shown. None of the scratches is visible, as the back of the sheet is far beyond the skin depth (0.12 mm) of the frequency used.

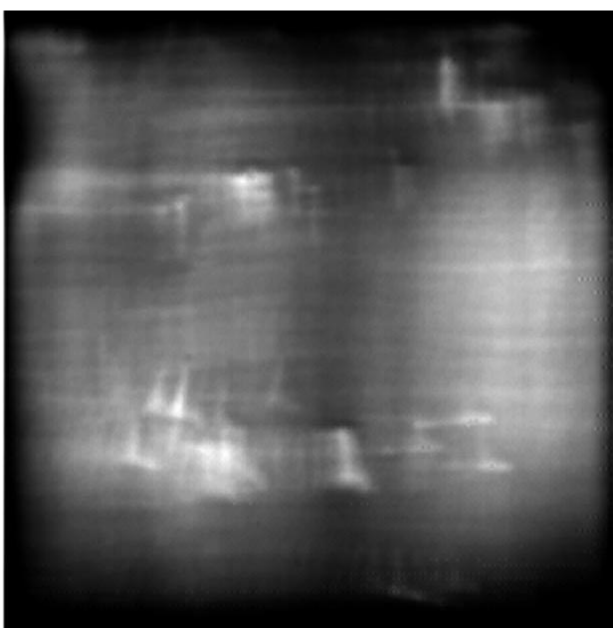

Figure 7: SQUID-scan of sheet 45. Detailed reproduction without artifacts caused by lift-off. No circular artifacts from the scanning process.

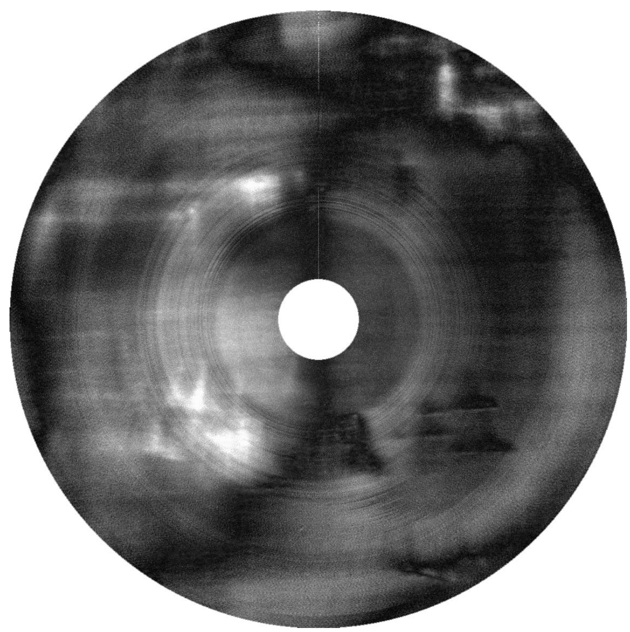

Figure 9: Eddy current scan of sheet 45 (amplitude of channel 1). The dark shapes are partially artifacts caused by lift-off and the signal is close to noise level.

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