Eddy Current Scanning at Fermilab

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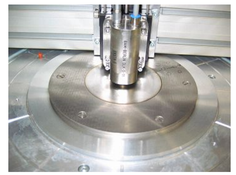
The Scanner

In the framework of SRF cavity development, Fermilab is creating the infrastructure needed for the characterization of the material used in the cavity fabrication. An important step in the characterization of "as received" niobium sheets is the eddy current scanning. Eddy current scanning is a non destructive technique originally adopted by DESY with the purpose of checking the cavity material for sub-surface defects and inclusions.
Fermilab has received and further upgraded a commercial eddy current scanner previously used for the SNS project. The upgrading process included the development a new filtering software. This scanner is now used on daily basis to scan the niobium sheets for the Fermilab third harmonic and transverse deflecting cavities.
This poster gives a status report on the scanning results obtained so far, including a discussion of the typology of signals being detected. We also report on the efforts to calibrate this scanner, a work conducted in collaboration with DESY.

Eddy Current Scanner – on loan from SNS -



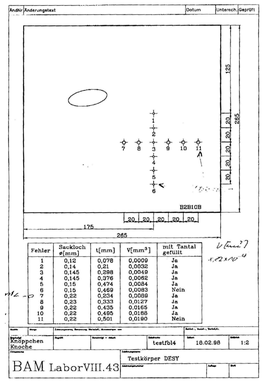
Scanning disks is part of the QC process during SRF cavities production:

-100 μm Ta defects can be detected

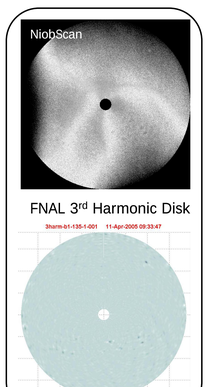
- Over 200 disks scanned

- ~30% rejection rate

Calibration



The DESY calibration disc is a ~0.1" thick, ~10" square niobium sheet supplied by the Wah-Chang company. It contains eleven implanted sub-surface defects. The figure on the left shows where the defects are located. Most defects are drilled holes of varying diameter, stuffed with Ta powder. The Ta was subsequently melted and the holes closed by superficial e-beam welding in vacuum. Holes 6 and 11 were not filled. The diameter of the holes varies between 120 and 230 mm. The drilling depths vary between 80 and 500 mm. The exact diameter and depth parameters for each hole are listed. Following the preparation of the implants the sheet was chemically polished.



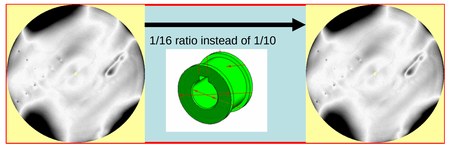
Turntable velocity
To reduce sources of mechanical vibrations, the turntable speed was reduced from 170 rpm to 105 rpm. No significant improvement.

Probe Air Pressure
The nominal setting of the air pressure of the probe is ~ 2.0 bar. This value affects the equilibrium conditions between the air bearing and the spring holding the probe modifying the total length of probe pushed out of its holder and thus modifying the distance between sample and probe. Tests were performed at pressures between 1.6 bar and 2.0 bar with similar results.

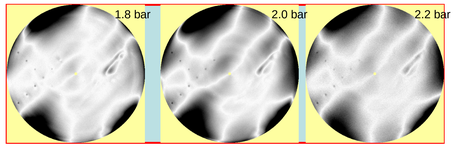
Number of Data Points
The number of points acquired during the scan is a very important parameter in terms of device sensitivity. Due to the distance of the probe from the surface and the shape of the eddy current fields generated, the size of the signal for a 100 μm defect is in the order of 1 mm. Comparison tests showed that the combination of 1600 points per track and 100 μm track spacing is optimal, producing a reasonable file dimension of ~14 Mb which needs a filtering time similar to the scanning one.

Filtering
The application of the filter allows for better detecting the defects by highlighting them above the noise level.

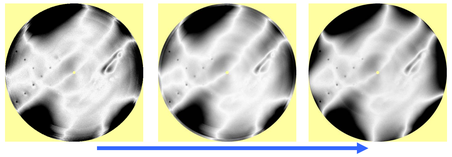
Rotating Table Speed Test

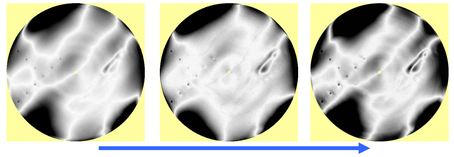


Sensing Head Pressure Test



Number of Points Acquired Test

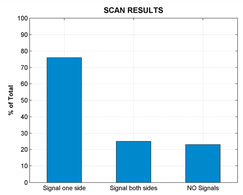


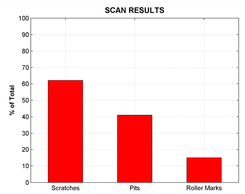


Track dist.	200 um	100 um	50 um
Points/track	4800	4800	4800
Tracks	570	1140	2280
File Mb	21 Mb	42 Mb	84 Mb
Time scan	12 mins	24 mins	48 mins

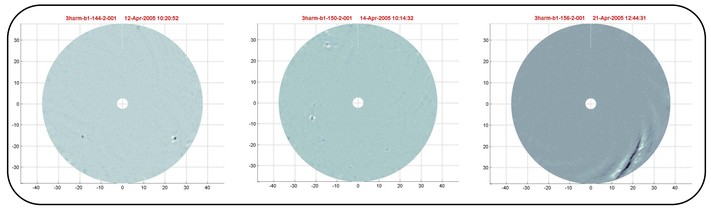
Track dist.	200 um	100 um	50 um
Points/track	1600	1600	1600
Tracks	570	1140	2280
File Mb	7.1 Mb	14.2 Mb	28.4 Mb
Time scan	12 mins	24 mins	48 mins

Results





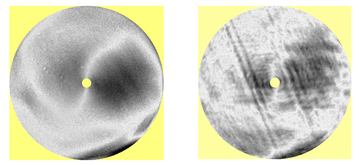
The ECS, after optimization, was employed to scan up 90 disks to be used for the production of 6 FNAL 3rd harmonic cavities. Each disk was visually inspected on both sides using a magnifying glass, afterwards it was scanned and the results filtered. The results can be summarized as follows: out of the 90 discs, 21 (23%) give no defect related signal and 22 discs (25%) give signals on both sides; 69 discs (76%) have at least one side giving a signal. 74 sides (41%) have visible pits (of which only 25% appear in the eddy current scans), 112 sides (62%) have scratches, and 27 sides (15%) have roller marks (which only appear in the eddy current scans).



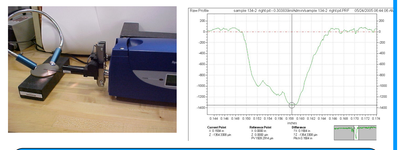
Typical defects: pits (left – center) and roller marks (right)

Additional Measurements

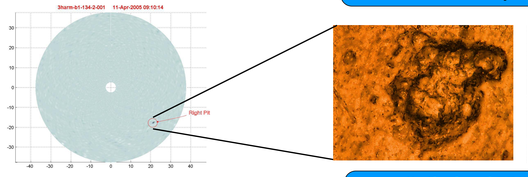
Profilometric measurements were introduced to characterize the pits present on the surface of the disks. Measurements were performed on six disks presenting several pits each, using a Taylor Hobson Talysurf Intra device equipped with a 2 μm radius diamond chisel. The measured pits dimensions varied between 0.2 and 0.5 mm in diameter and between 10 and 90 μm in depth. The rich topology of the profile suggests that these pits could be the result of imprinting of grains, previously detached from the Niobium, sticking into the cylinders during the rolling process. Additional chemical analysis of the first micron on the surface of the pits using EDX confirmed that the chemical composition of these craters is the same as the rest of the disk. BCP tests showed that these pits are not always removed during the chemical process.



ECS of the same disk before and after BCP



Measurement setup & typical profile of a pit



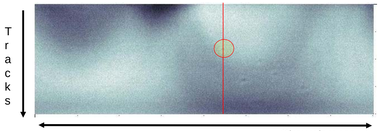
Optical and EDS pictures of a pit

Filter

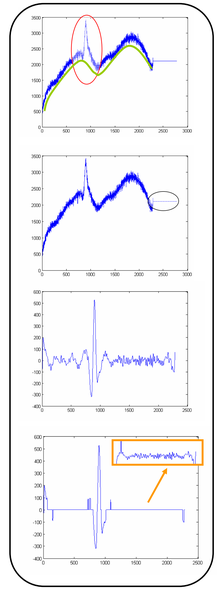
FIONDA (Filtering Images of Niobium Disks Application)

Is a software implementing an algorithm that, applied to the data resulting from a eddy current scan, allows to eliminate the masking effect due to the disk thickness variation.

The result of each scan is stored in form of picture, for easy evaluation, and in form of binary data file. Starting from the data file one can generate a matrix and manipulate single rows and columns with FIR filters. This process allows for eliminating the unwanted features and enchanting possible defects.



Polar Representation of a scanned disk



Radial Line with defect (RED) extracted from the polar representation above. In green the height variation effect

The length corresponding to the filter shift is added to the signal line

A pass band FIR filter is applied to the signal reducing significantly the height variation effect

Attenuation of the signals within the first sigma allows to highlight the defect