TESTING OF NIOBIUM MATERIAL FOR THE EUROPEAN XFEL PRE-SERIES PRODUCTION

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Abstract

For the European XFEL cavity pre-series production a rather large quantity of niobium sheets from partially new niobium vendors has been delivered according to the XFEL Cavity Specification. It is of high importance that the material monitoring of this niobium has to be done within the production process to ensure a high performance of the cavities. The quality assurance program includes electrical resistance measurements, structural and chemical material analysis. For the surface investigations two new eddy current scanning devices have been fabricated on the basis of our specifications and experience. The scanning process and evaluation of test results can now be done in a few minutes per sheet. We describe the material test methods and the scanning machine. Measured results of the pre-series niobium are compared to older material test results.

INTRODUCTION

Since the decision was made that DESY will provide semi-finished products for the European XFEL cavity production, DESY has to take over the quality control (QC) of this material and also to monitor the quality management measures of the niobium vendors. The XFEL pre-series cavity production was a good opportunity to test and verify the QC process. In the following we give a short insight into the procedures by means of some examples.

NEW EDDY CURRENT SCANNING SYSTEMS

The high amount of niobium blanks needed for more than 600 XFEL cavities demanded to build new Eddy Current Scanning devices. The old apparatus, custom built in the mid-nineties and prototype like, provided a lot of experiences that have been considered in new devices. Some features like a vacuum clamping table or a turntable could be adopted. The new setup has to be faster in measurement and evaluation, easy to handle and serviceable in an industrial environment.

Improvements

Two new devices have been fabricated at the company ROHMANN GmbH in Frankenthal/Germany based on our experience. A detailed technical description of our prior Eddy Current Scanning device was already given in [1] and [2]. In this paper only the improvements of the new device are listed:

- Elimination of the air cushion between probe and blank. Before each scan a topographic profile is recorded by distance sensors which will be traced by the probe during scanning.
- Reduced scanning-time. Duration decreased from 17 min. to 8 min.
- Evaluation is now fast and easy and can be done directly after the scan.
- Optimized flaw detection with new commercial software.
- Industrial design: All moving parts are completely enclosed.
- Guaranteed spare parts supply.
- Improved vacuum clamping table.
- Lift-off effect is less pronounced.

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Figure 1 shows the new eddy current devices at our new QC-Lab at DESY.

Figure 1: Eddy current devices at DESY.

Directly after the scan is taken the data including information of phasing and amplitude of the signal can be analysed. A great advantage represents the decoupling of the control and evaluation software. Hence it is possible to evaluate data while a new scan is running.

Comparison of Scan Results

The following figures show scans taken from our calibration test sheet with artificially prepared tantalum inclusions and from an old sheet with iron inclusions accidentally rolled in during sheet fabrication. Figure 2 shows a scan recorded with the new device. Less disturbing signals caused by distance variations between probe and blank can be seen compare to old device. The lift-off effect is negligible. This leads to more clearly visible defects. Figure 3 shows the scan from the same blank taken with the old setup. Here some grinding locations are visible which may cover real defects. Figure 4 and 5 shows signals from iron inclusions taken with the new respectively with the old setup. More inclusions are detectable with the new system.

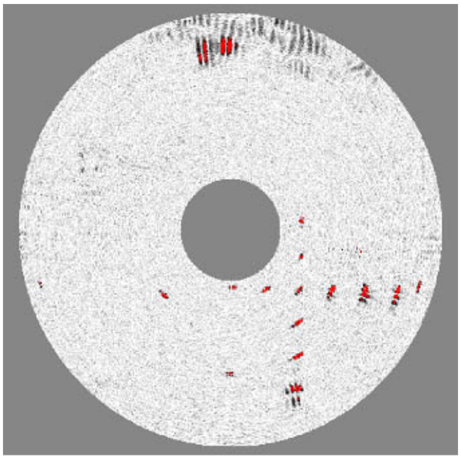

Figure 2: Scan image of a test sheet, new device

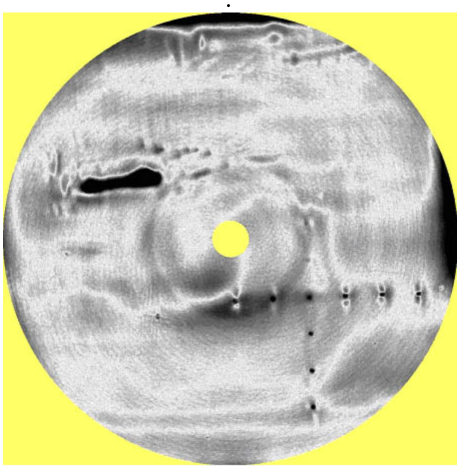

Figure 3: Scan image of a test sheet, old device.

INCOMING CONTROL

The niobium sheets have to be delivered by vendors together with the inspection certificates of the material supplier that confirm the fulfilment of the requirements of pressure equipment directive PED 97/23/EC.

A certain amount of Nb-sheets has been tested independently at DESY. The quality control of the sheets includes additionally to eddy current scanning measurements of electrical resistance from the room temperature to cryogenic temperatures (RRR) [3], mechanical (Vickers hardness measurement, tensile test), microstructure inspection and a chemical analysis of the interstitial impurities. The samples for measurement have been taken on following way:

The Hardness (HV) was measured on all delivered sheets. The residual resistance ratio (RRR), grain size and the gas content measured was on two samples, taken from the sheet with min. HV and max. HV. In order not to destroy the material, these samples have been taken from

Figure 4: Scan image of a sheet with iron inclusions, new device.

Figure 5: Scan image of a sheet with iron inclusions, old device.

corners of the sheets. Samples for tensile tests have been taken from the rest of the final sheet material. Typical data from these measurements can be seen in table 1.

Table 1: Incoming Quality Control Data of Nb Material

Example of QC:	Sheet PL 287
Hardness HV 10	45.8 – 42.4
RRR:	345 – 365
Tensile strength, N/mm^2	Longitudinal: 148 – 161 Transversal: 159 – 168
Elongation, %	Longitudinal: 43.9 – 53.3 Transversal: 28.6 – 50.5
Contents of interstitial components [ug/g]	H,O,N,C: 1, <5, <5, 7
Microstructure inspection	Grain size to ASTM E 112: 5.0 – 7.0, 100% recrystal.
Surface roughness]um]	Ra: 0.8 – 1.8, Rz: 5.8 – 9.6 Rmax: 5.8 – 14.2

Advanced Non-Destructive Testing of Defects Found with Eddy Current Scanning

Eddy currant scanning of niobium sheets allows detection of rather small defects (above 0.1 mm) of different nature. The structure of the eddy current signal allows the rough estimation of the defect type. Nevertheless special analysis of the defects is necessary in order to give detailed feed back to material producers. Some defects found with the eddy current scanning system have been further investigated concerning surface topography and presence of foreign material inclusions using available devices in the laboratory. Since the last sheet production campaign it became noticeable that assumed defects occurs more often as tiny holes and pits on the sheet surface. A KEYENCE digital microscope was used to provide information about the depth profile of defects [see example in Fig.6]. In addition a non destructive x-ray fluorescence element analysis with a FISCHERSCOPE X-RAY [example in Fig.7] was done on the found defects.

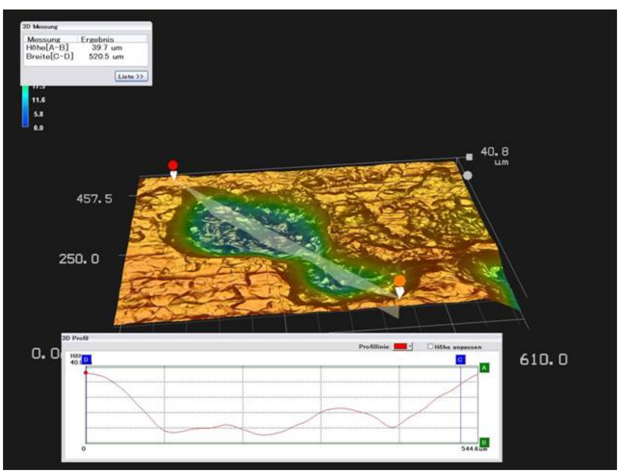

Figure 6: Optical 3D image and profile of the defect area of a niobium sheet (protrusion of ca. 16 µm).

Figure 7: Example of nondestructive x-ray fluorescence element analysis done with a FISCHERSCOPE XDAL.

SUMMARY

Approximately 400 Niobium sheets have been provided up to now from one niobium vendor for the XFEL pre-series fabrication. With this amount we were able to break in the quality control process with the two new eddy current scanning systems in combination with the other inspection tests. Since we use two scanning systems in parallel, the scanning process is now four times faster than before. A big advantage is the “ad hoc” evaluation and the contemporary advanced investigation which gives the possibility to exert influence on the sheet production process at the manufacturing companies almost in real-time. The new eddy current systems built in an industrial manner have the ability to handle the several thousands of niobium sheets needed for the European XFEL cavity production.

REFERENCES

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[3] W. Singer, A.Ermakov, X. Singer, “RRR-Measurement Techniques on High Purity Niobium”, TTC-Report 2010.