

STATISTIC TO EDDY-CURRENT SCANNING OF NIOBIUM SHEETS FOR THE EUROPEAN XFEL

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Abstract

The fabrication experiences of superconducting cavities for FLASH have shown that eddy-current scanning of the Nb-sheets foreseen for half-cells reduces the cavity failures. New Eddy-Current devices have been developed and build together with the industry for the production of 800 pieces 1.3 GHz superconducting niobium cavities for European XFEL. More than 14.700 Nb-sheets provided by three companies have been tested by eddy-current scanning. The sheets that demonstrated local deviations of the signal have been subsequently non-destructively examined by 3d-microscope and X-Ray element analysis. The surface defects (dents, holes, scratches) are the mainly detected flaws. In addition several types of foreign material inclusions observed. Statistic concerning eddy-current signal deviation and rejection rates for each supplier is presented.

INTRODUCTION

For the production of Superconducting RF-Cavities for the European XFEL at least about 14700 Niobium sheets has to be scanned with the Eddy-Current testing method. Found defects like material inclusions or topographical flaws which deviations do not fulfil the technical specification are investigated further with special element analysis and 3D-microscope inspections.

STATISTICS

Until end of August 2013 14752 Niobium sheets for the European XFEL were scanned with 2 company-made Eddy-Current [1] testing devices at the material testing laboratory at DESY (Fig.1). Eddy-Current testing is a part of the incoming inspection besides documentation and visual inspection [2]. Only one side of the sheet is scanned, unless a defective side is detected. Then, the other side will be scanned as well. It is possible to scan up to 300 sheets per workweek with 2 devices including analysis and documentation. If the amount 2-side-scans increases, it is evident that the rate of analysed scans drops.

Because of the huge amount of parts it is necessary to make a fast decision whether a sheet is qualified or not. Thus the operator judges by means of 4 criteria:

First side good: sheet is qualified

First side bad, second side good: sheet is qualified

First and second sides bad: sheet is not qualified

Extraordinary Eddy-Current signal on one or two side(s): sheet is not qualified

A distribution of imperfections found by Eddy-Current testing and visual inspection is shown in Figure 2.

All not qualified sheets are investigated later on with special element analysis and/or 3D-microscope evaluation. The final decision, whether a sheet is usable or not is made after this analysis. Here it can appear that a sheet is usable anyway, because of defects that still are within the technical specification.



Figure 1: Eddy-Current testing devices

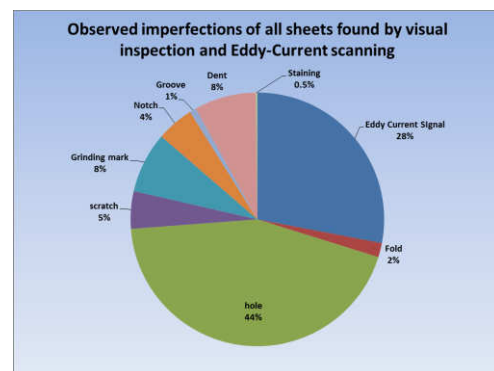


Figure 2: Observed imperfections found by Eddy-Current testing and visual inspection in total.

Detailed Statistic

A detailed Statistic of the amount of sheets which were either suspicious and needed a both-side scan or were not usable separated by different suppliers and found defects is presented in the following table (Table 1).

Table 1: Statistic to number of Scanned Nb-sheets for Different Suppliers

Company	A	B	C
Scanned (total)	7690	4427	2635
Both sides scan (%)	906 11,78	1250 28,24	1660 63,00
Suspicious (%)	54 0,70	126 2,85	109 4,13
Not usable (%)	29 0,37	115 2,58	75 2,85

1.95 % (289 out of 14752) of all scanned material was classified to be suspicious. Followed by a deeper analysis like element analysis or topographical survey of the surface we found a rate of definitely not usable sheets (rejected) of 1.48 %.

Differences between the rate of suspicious sheets and the rate of rejected sheets caused by the lack of a quantitative judgement using Eddy-Current. For instance it is possible to detect pits and holes with diameter below 0,1mm. But a statement about the hole depth cannot be given on base of Eddy - Current scanning.

Element Analysis/3D-microscope

The Element Analysis [1] showed that in an amount of sheets of all suppliers A, B and C, Fe, Ni, Cr and Ti inclusions are detected. Ta was found in sheets of company A and B. Zr was found in sheets from Company A only. Only Company C delivered material with W, Mo, Zn inclusions. As a rule the foreign material inclusions represent the palette of the material production of definite supplier Topographical deviations were found on sheets from all 3 companies. The foreign material inclusions located mostly on the surface and it can be imagine that they have been imbedded during rolling. The percentage distribution is shown in Figure 3.

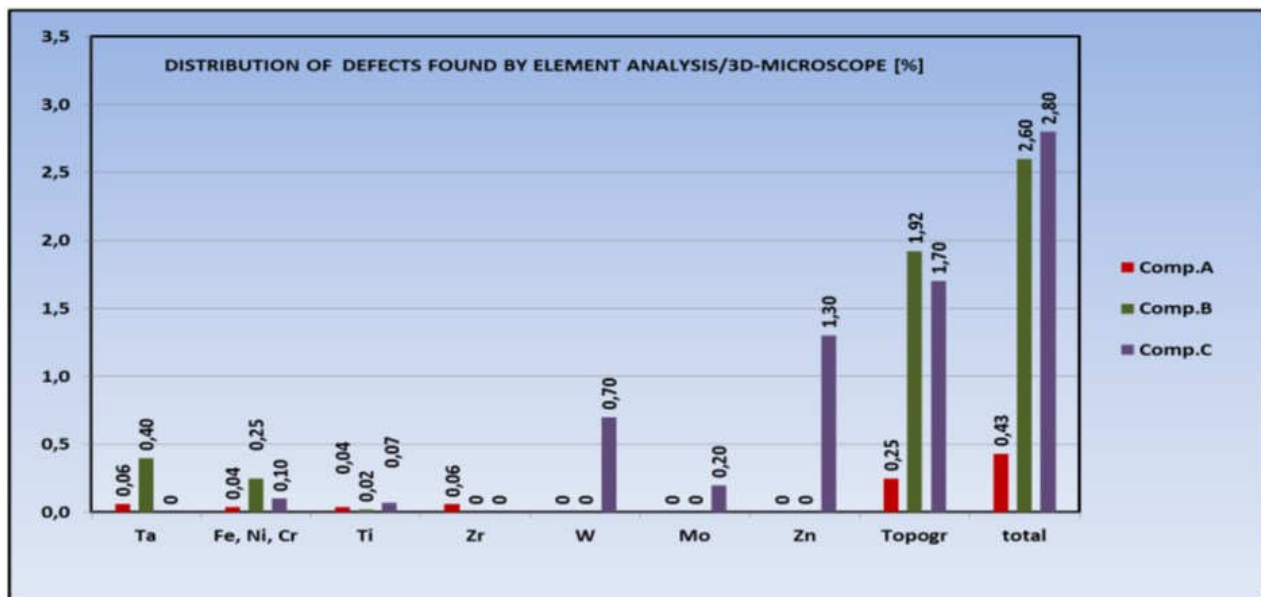


Figure 3: Distribution of defects found by element analysis/3D-microscope in %.

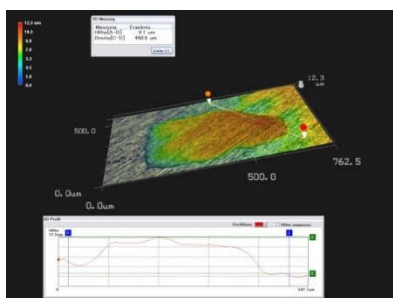


Figure 4: 3D-microscope image of a Ta inclusion.

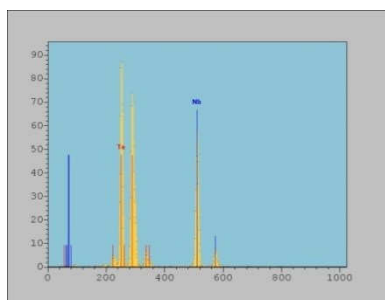


Figure 5: Example of an Element analysis showing Ta.

As an example of typical flaw detection, Figure 4 and Figure 5 shows an 3D-microscope image an Element Analysis Scan of a sheet from company B with a Ta inclusion. Figure 6 presents the corresponding Eddy-Current image of the sheet.

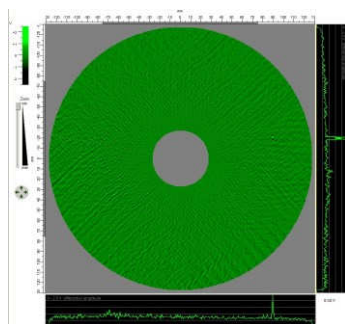


Figure 6: Eddy Current signal of a Ta inclusion found in a sheet of Company B

SUMMARY

After scanning more than 14750 Niobium sheets with Eddy-Current testing it revealed that about 1.95 % of the material showed different Eddy-Current signals. Most of these signals pointed to foreign material inclusions or topographical flaws which were outside the technical specification. 1.46 % of all sheets are rejected after completing the inspection of Nb sheets and not usable for the cavity production.

Quality distinctions between the 3 suppliers of Niobium material can clearly be seen. Company A is the manufacturer with the best quality by far, followed by Company B.

Conclusively it is obviously that material inspection such as Element Analysis and Eddy-Current scanning of 100 % of the delivered material is still the most reasonable inspection method to avoid performance reduction of RF-Cavities.

Disclaiming the Eddy-Current testing method would mean that the performance of almost every third cavity could be damaged supposing that the not usable sheet would be homogeneously distributed in the production lots.

REFERENCES

- [1] A. Brinkmann, M. Lengkeit, X.Singer, W. Singer, Testing of Niobium Material for the European XFEL Pre-series Production, DESY, LINAC2010, Sept.2010, Tsukuba, Japan
- [2] J.Iversen, A.Brinkmann, W.-D. Möller, W. Singer, X.Singer (DESY), Supply of Nb/NbTi Semi-Finished Products for Series S.C. Cavity Fabrication for the EUROPEAN XFEL - Quality Control, Logistics and Documentation. LINAC2012, Sept.2012, Tel Aviv, Israel