# 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 14700Niobium 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.

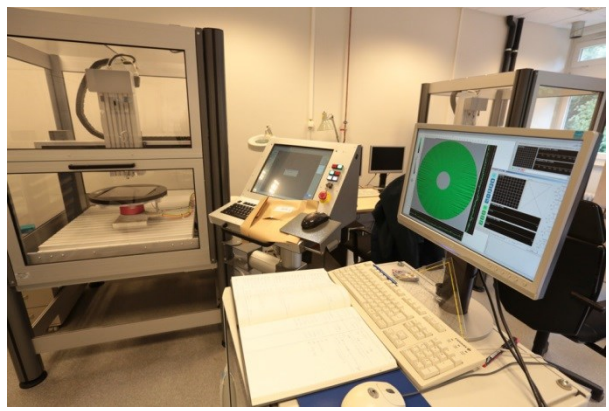

Figure 1: Eddy-Current testing devices

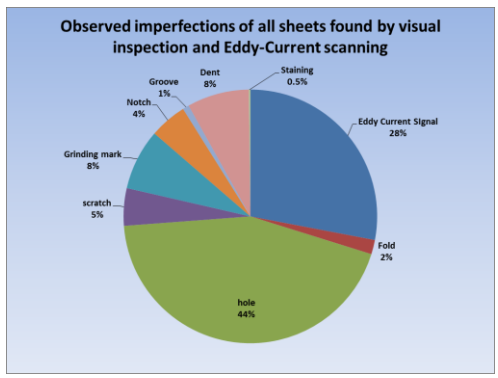


Figure 2: Observed imperfections found by Eddy-Current testing and visual inspection in total.

### *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).




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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 | 1250 | 1660 |
| (%) | 11,78 | 28,24 | 63,00 |
| Suspicious | 54 | 126 | 109 |
| (%) | 0,70 | 2,85 | 4,13 |
| Not usable | 29 | 115 | 75 |
| (%) | 0,37 | 2,58 | 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.

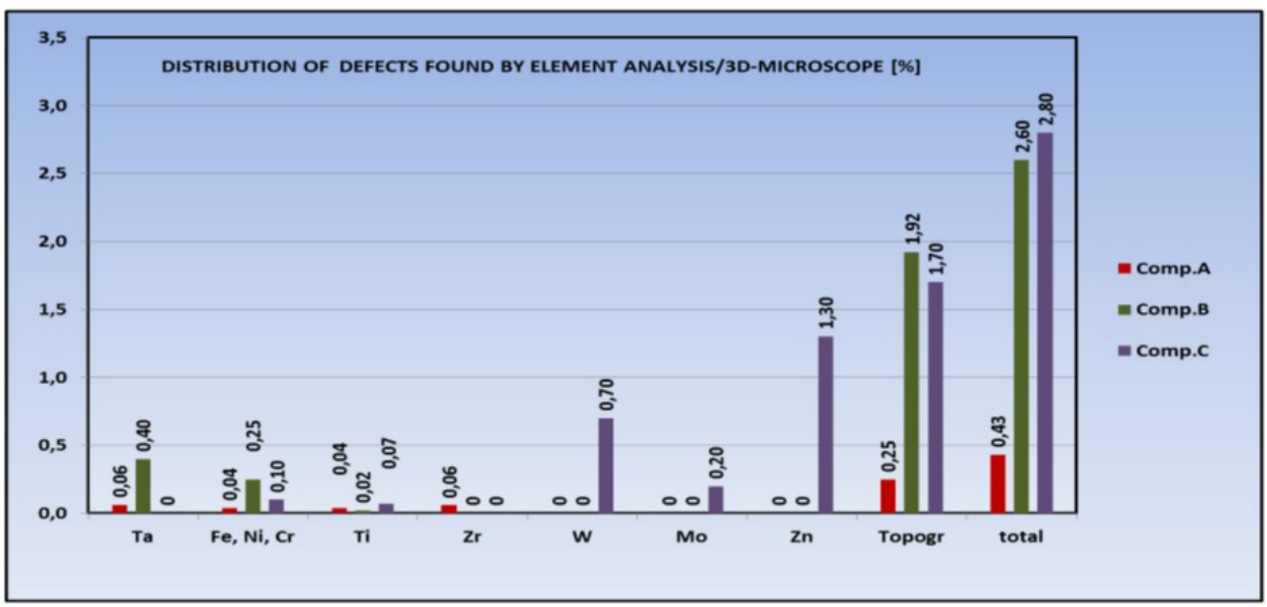


Figure 3: Distribution of defects found by element analysis/3D-microscope in %.

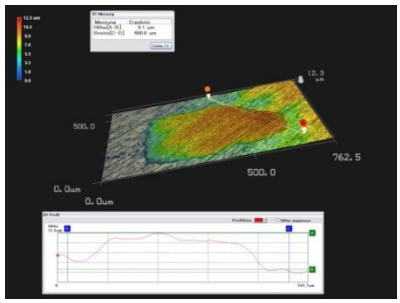

Figure 4: 3D-microscope image of a Ta inclusion.

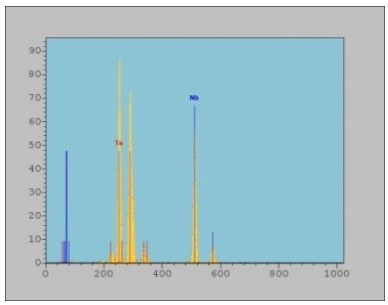


Figure 5: Example of an Element analysis showing Ta.

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.

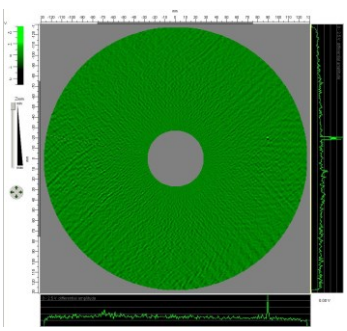

Figure 6: Eddy Current signal of a Ta inclusion found in a sheet of Company B

## 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




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