PLM-BASED QUALITY ASSURANCE IN THE SERIES PRODUCTION OF THE SUPERCONDUCTING CAVITIES FOR THE EUROPEAN XFEL

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Abstract

This paper describes the quality assurance (QA) procedures which are implemented for the series production of the superconducting cavities for the European XFEL. The cavities are produced by two manufacturers. To ensure they satisfy their performance requirements, the cavities have to pass more than 50 quality inspections, which are combined into three acceptance levels. Part of the inspections are done by the manufacturers, the remaining tests are conducted in a test facility at DESY. The QA procedures are implemented using DESYs Product Lifecycle Management (PLM) system, aka DESY EDMS. The DESY EDMS tracks all the individual cavities, records their entire production history, and associates all certificates and inspection results with the appropriate parts. The two manufacturers are integrated in the solution and can automatically and promptly upload inspections results to the DESY EDMS. The solution enables DESY to monitor the production progress and to ensure production quality.

INTRODUCTION

Superconducting cavities are mission-critical components which are facing outstanding performance requirements, and which have to be documented in compliance with legal regulations [1]. The XFEL has established procedures and tools for reliably gathering, recording, processing and archiving the complete mandatory fabrication information [2].

BACKGROUND: TRACKING & TRACING

Quality assurance during fabrication is based on the concepts of tracking and tracing: Tracking records the outcome of every relevant process step during production ad requires that these records are kept with the contractor throughout the component's lifetime. It is the major mechanism for guaranteeing safety and quality.

Tracing establishes links between tracking records and further supporting documentation, such as e.g. manufacturing process instructions, technical drawings, or records of decisions taken. Tracing provides the ability to reproduce information and decisions at any later time and ensures compliance with legal documentation requirements.

QUALITY ASSURANCE REQUIREMENTS

Figure 1 sketches the cavity production scenario with the roles of the suppliers and the contractor DESY [3]. Cavity fabrication has been contracted to two suppliers. DESY provides the material, inspects cavity production at certain "quality gates" in the process and needs to give a go-ahead for a cavity to enter the next production stage.

The go-ahead can be given only based on the tracking information. Tracking information can be captured only by the manufacturer.

Based on this scenario, the following major requirements are identified:

1. Manufacturers have to be able to easily record tracking information in an orderly way.
2. Manufacturers have to be able to forward the tracking records to the DESY easily and promptly.
3. Mechanisms and tools have to be provided to the fabrication manager for easily and reliably inspecting and signing-off the tracking information, in order to endorse the production go-ahead
4. Tracking records have to be stored in a transaction-safe way: They have to be linked with their source information and with other depending documents, they have to be permanently available throughout the accelerator lifetime, and they must not be modified under any circumstances.

SOLUTION ARCHITECTURE

Figure 2 illustrates the solution architecture and how it respects the requirements: The manufacturer captures tracking records in standardized templates (Req.1) and submits then to the contractor DESY through web-

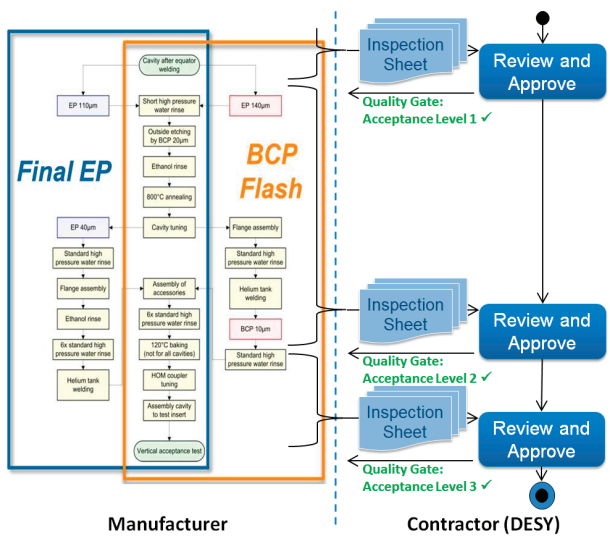

Figure 1: Cavity treatment from the manufacturer's and DESY's contractor perspective.

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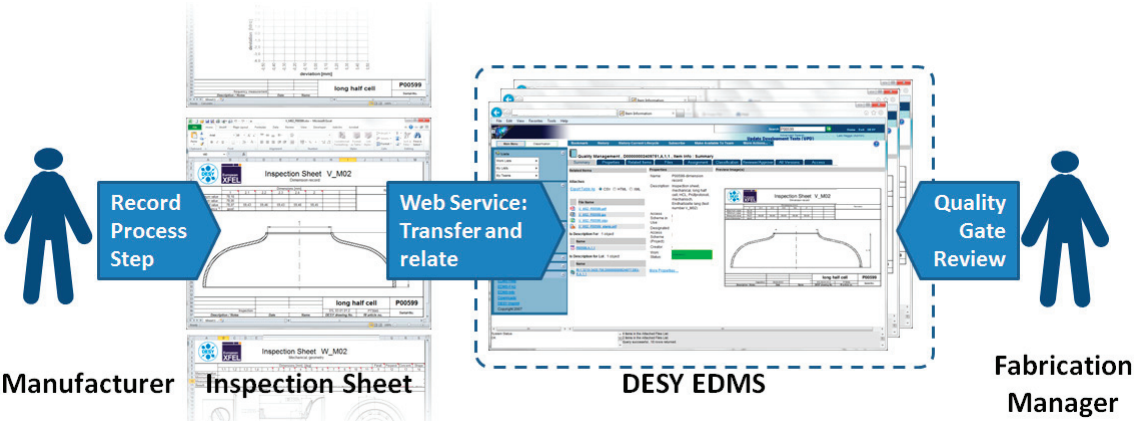

Figure 2: Quality assurance solution architecture.

services (Req.2). DESY receives the records in its PLM system, the DESY EDMS [4], where they are automatically processed and inserted in the inventory documentation, along with all their necessary links (Req.4). DESY's fabrication supervisor inspects the documents and approves the production go-ahead (Req.3) using PLM-workflows and reports.

The following sections briefly introduce the major solution elements.

TEMPLATE-BASED INSPECTIONS

Process steps are tracked by final inspections. For every process step, quality criteria are defined and are part of the tendering contracts. Figure 3 shows an excerpt from the list of mandatory inspections which have to be performed for every individual cavity.

Each inspection is detailed in a template which contains test instructions and a form for recording the test conditions and results. The templates are created based on spreadsheet, as they are well-known and easy to handle for all participants, and can be easily automatically evaluated and further processed. Figure 4 shows an example template for a mechanical inspection of a long end group: The template shows measures to be taken, lists their acceptable tolerances, and contains fields for entering the result of measurement. More than 50 inspection sheets have been defined for each manufacturer, which take into account their different fabrication processes.

S01		3D measurement	DB
S02		3D measurement	EGL
S03		3D measurement	EGS
L01		leak check between space I and III	EGL
L02		leak check between space I and III	EGS
Finished cavity			
HCP		half cell position, expected (foreseeable) length after tuning	CAV
V01		Optical inspection of the equator welding seams	CAV
M01		Mechanical, geometry	CAV
		RF-Measurement - frequencies of the	

Figure 3: Inspections for cavity production process steps: Columns show inspection name and description and name of checked part (e.g. EGS = end group short).

MANUFACTURING AND INVENTORY DOCUMENTATION

Manufacturing and inventory documentation are recorded in DESY's PLM system, the DESY EDMS, which for this purpose has been extended with a dedicated solution for parts tracking during fabrication and maintenance [3].

Key concept is the "fabrication part", which represents the planned deliverable of a production step, the type of part that will be created in that step. In the EDMS, fabrication parts link to the manufacturing documentation of that part, such as e. g. process instructions and assembly drawings.

"Physical parts" represent the individual real-world items which have been produced using the manufacturing documentation. The EDMS treats them as instances of their fabrication part and links them with their specific inventory documentation, such as inspection sheets and material certificates.

Parts can be used in subsequent process steps, for example half cells and stiffening rings can be welded into dumb-bells. The EDMS relates parts by usage relations, this way obtaining a hierarchy which represents the

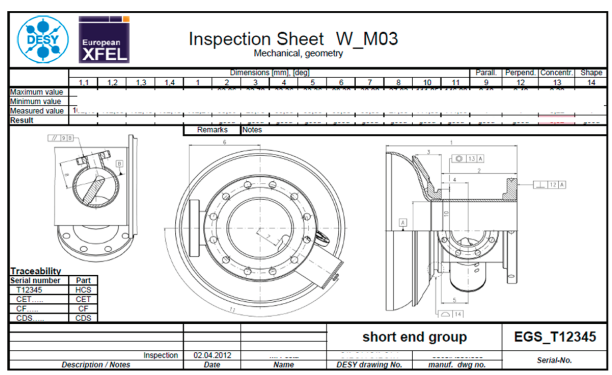

Figure 4: Example for a template-based in-process inspection (mechanical inspection of cavity end group).

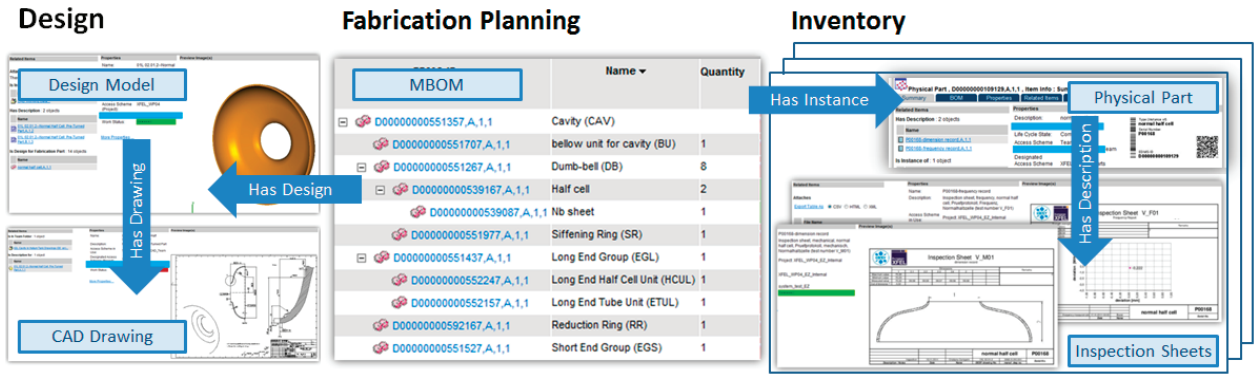

Figure 6: Traceability in the cavity documentation.

evolution of component during its fabrication process. The hierarchy of fabrication parts is called MBOM, manufacturing bill of material, and defines how components should be created during manufacturing. The hierarchy of physical parts is call physical structure and represents how components have been assembled during manufacturing.

By linking physical parts with inspection sheets, the EDMS implements parts tracking during fabrication. By establishing relations to additional documents and by building usage hierarchies, the EDMS implements traceability. As an example for traceability, Figure 6 shows how EDMS users can navigate from individual half-cells to their fabrication and design documentation, and understand their usage. Figure 5 shows an example record of an individual Nb sheet and the tracking (and tracing) information which is directly accessible from this record.

APPROVAL PROCESSES

At the three quality gates, all the tracking documentation which has been created up to that process step has to be checked and approved by the fabrication manager before fabrication can continue. Dedicated workflows und functionality have been implemented in the EDMS which collect the available documentation, route them to the fabrication management team for review and approval, pre-check if the documentation is complete or deviates from the specified structure, and inform the manufacturers to continue the production as soon as the documentation has been signed-off. All these actions and their dates are recorded in the part history for potential later analysis.

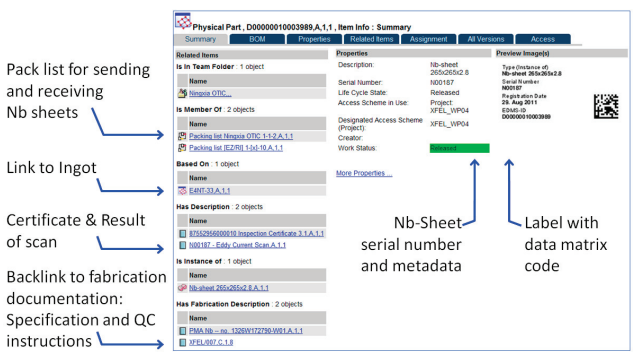

Figure 5: Example record of an individual Nb sheet and its related information in the DESY EDMS.

MANUFACTURER INTEGRATION

Manufacturers access documents and process information in DESY EDMS and transmit inspection sheets electronically to the system. Dedicated web services receive and post-process the data according to the type of sheet. Post-processing includes e. g. creating records in the EDMS, relating the sheet with the appropriate physical part, and interpreting the data in the sheet to e. g. establish usage relations or collect parts of the same delivery into lots.

The web services are called directly from the manufacturer's production planning systems. Alternatively, documents can be provided interactively through simple web forms.

CONCLUSION

The series production of the superconducting cavities is supported by a powerful PLM-based parts tracking solution which ensures that performance and legal documentation requirements are met. The solution enables DESY to monitor the production progress and to ensure production quality. With the help of electronic workflow and direct integration of manufacturers it can handle the high process rates of the full series production.

REFERENCES

[1] W. Singer et al., "Preparation Phase for 1.3 GHz Cavity Production of the European XFEL", IPAC'10, Kyoto, THOARA02, p. 3633 (2010); http://www.JACoW.org

[2] J. Dammann et al., "Parts Management during Fabrication at the European XFEL", WEPPC005, these proceedings

[3] J. Dammann et al., "Towards PLM-Based Quality Assurance in the Fabrication of the Superconducting Cavities of the European XFEL", IPAC'11, San Sebastián, September 2011, WEPEC006, p. 2899 (2011)

[4] J. Bürger et al., "DESY EDMS: Information Management for World-Wide Collaborations", PAC'09, Vancouver, May 2009, WE6RFP045, p. 2896 (2009)

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