TOWARDS PLM-BASED QUALITY ASSURANCE IN THE FABRICATION OF THE SUPERCONDUCTING CAVITIES FOR THE EUROPEAN XFEL

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Abstract

For the series production of s.c. cavities for the European XFEL, thorough quality assurance procedures are under preparation to ensure that all cavities satisfy their performance requirements. Quality assurance is supported by the DESY Engineering Data Management System, DESY EDMS, to ensure reliable and repeatable procedures and timely responses. The paper introduces the planned QA procedures, explains the role and benefits of the EDMS, and reports initial experience.

INTRODUCTION

For the series production of s.c. cavities for the European XFEL, thorough quality assurance (QA) procedures are under preparation to ensure that all cavities satisfy their performance requirements. Each cavity needs to pass a number of quality gates at different levels of completion. At each quality gate, the so-far available manufacturing data and documentation is reviewed and approved by the XFEL cavity production team. To ensure reliable and repeatable procedures with timely responses, the QA efforts are supported by the DESY Product Lifecycle Management (PLM) System, the so-called DESY EDMS [1]. The EDMS manages fabrication data, coordinates acceptance tests, manages sign-offs and provides fabrication progress monitoring. In particular, the EDMS tracks the entire history of all individual cavities, their parts and their semi-finished products. The setup benefits from experience which has been gained at DESY in the cavity production for FLASH [2].

The paper introduces the planned quality assurance procedures (QA) and their support by the EDMS. It first gives an overview of the cavity fabrication process from a QA perspective and lists the EDMS requirements. Then, it explains the solutions for fabrication data management, process coordination, and data-exchange with the cavity manufacturers. It concludes with initial experience.

PROCESS OVERVIEW

The production process of the super conducting cavities for the European XFEL consists of two major parts, mechanical fabrication and surface treatment, with two alternative schemes for treatment. While the XFEL Work Package "S.c. cavities", WP04, is responsible for the cavity production, the series production will be contracted to industry. WP04 will closely follow the production and perform quality assurance and acceptance tests.

Figure 1 illustrates the scenario [3]: The left part shows the technical production process as it has to be followed by industry. The right side shows the same process from a quality assurance (QA) perspective: A number of quality gates are established after certain, to be agreed upon process steps. Whenever the production of a given cavity reaches a quality gate, the manufacturer has to deliver a defined set of fabrication documentation, which should then be inspected and signed off by WP04 before the production of that cavity continues. The required fabrication documentation is based on previous experience, e.g. from cavity production for FLASH, and on statutory regulations. It contains the results of numerous tests which are defined in detail in the process description.

REQUIREMENTS

Series production of cavities requires that production processes are running smooth and without delays or interruptions. For this reason, quality assurance procedures shall be supported by the DESY EDMS. The DESY EDMS has to satisfy requirements in the areas of

- Manufacturing data management
- Process support and coordination
- Change management

In particular, the EDMS shall meet the following requirements:

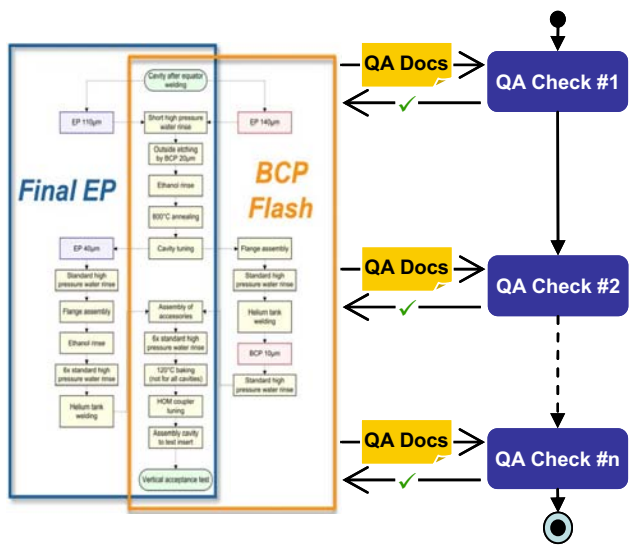

Figure 1: Cavity fabrication process from manufacturer (left) and project (right) perspective.

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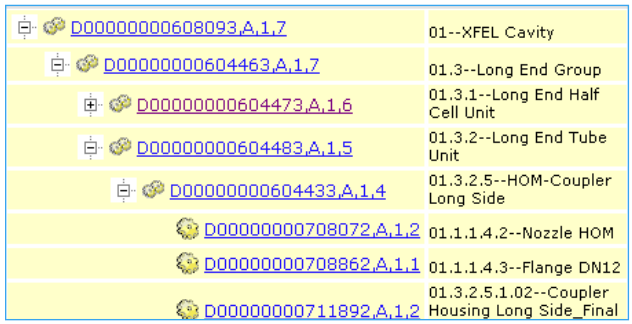

Figure 2: Cavity PBS in DESY EDMS.

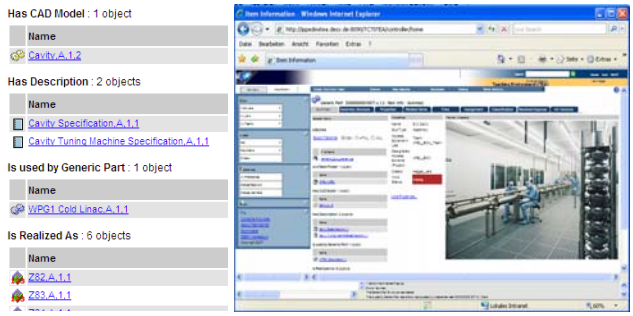

Figure 3: S.c. cavity part in DESY EDMS (mock-up data)..

- **Manufacturing Data Management**: The EDMS shall capture the complete manufacturing information of each individual cavity, including
  - Design documentation, e.g. specification, CAD data, process definition
  - In-process data, e.g. mechanical, RF and other inspections
  - Full history of each individual cavity
- **Process Support**: The EDMS shall enable WP04 to coordinate quality inspections and acceptance tests at defined quality gates. For this purpose, the EDMS shall provide
  - "Task-like" items which pre-define & follow-up all required inspections for all cavities
  - Reports of e.g. open/passed quality gates and acceptance tests, deriving level of completion
- **Change Management**: The EDMS shall help WP04 to ensure changes are made only if necessary and only after well-defined review and decision making, and in a coherent way.

MANUFACTURING DATA MANAGEMENT

In PLM, the product breakdown structure, PBS, is the leading representation of any product (i.e. component, device) that shall be manufactured. The PBS hierarchically decomposes complex products into manageable units, so-called "parts". Parts aggregate all the information which is necessary for their production, the so-called product or part definition data. Product definition data includes for example specifications, design documents, process instructions. Figure 2 shows the product breakdown structure of the XFEL cavity in the DESY EDMS. Figure 3 illustrates how associated documentation is reached from part records in the EDMS.

So-called "physical parts" represent the individual, tangible objects that have been or will be produced according to the part definition. Each manufactured cavity is represented as a physical part. As each step of the cavity assembly has to be documented, also the physical part is broken down. Note that the PBS contains only one entry for each kind of part (e.g. one dumb-bell, as it has to be defined only once), while the physical PBS contains one element for each part instance (i.e. eight physical dumb-bells, as they have to be individually inspected and traced) Figure 4 (left) illustrates the relation of parts and physical parts and shows, how spreadsheets with fabrication data are associated with physical parts. Selected data is extracted from the spreadsheets and transferred to an external database for statistical analysis.

The general scheme has been successfully established for the production of the cavities for FLASH. Based on that experience, the scheme has been extended for the series production of the XFEL cavities in two areas, manufacturer integration and fabrication structures.

Manufacturer integration: New upload tools have been developed, which enable manufacturers to directly and

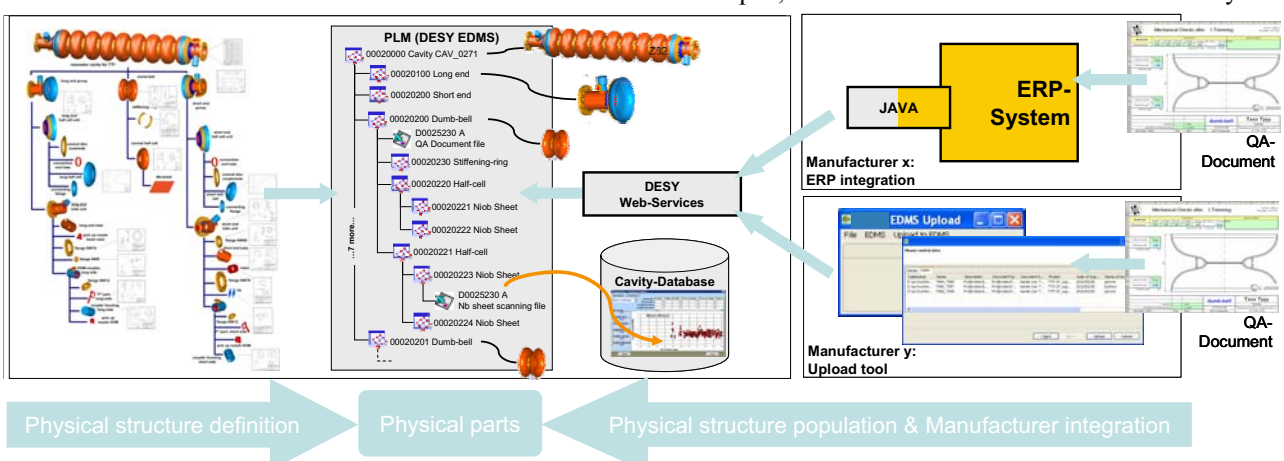

Figure 4 Relation of PBS and physical PBS: Design documents are associated with the PBS, fabrication data of individual elements is associated with the physical PBS (left). Dedicated tools enable manufacturers to automatically upload fabrication data to the EDMS and associate it with the appropriate physical parts.

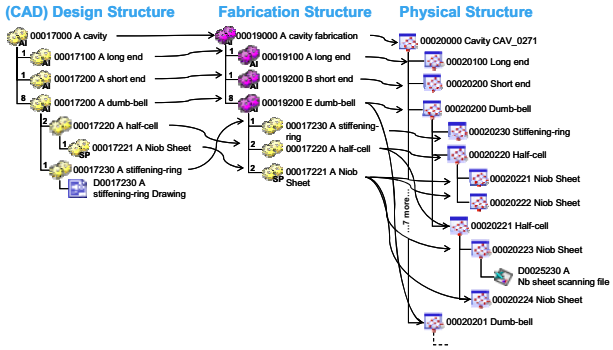

Figure 5: Design, fabrication and physical part breakdown structures of s.c. cavity in EDMS.

easily upload their fabrication data to the EDMS. Manufacturers who have established their own computerized quality assurance procedures, e.g. based on production planning or enterprise resource planning systems (PPS, ERP), can use EDMS web services to directly connect their systems with the EDMS. Manufacturers without such systems can use a bulk loading tool to automatically upload large sets of files. In both cases, the uploaded documents are automatically associated with the correct physical parts. Figure 4 (right) illustrates manufacturer integration to the EDMS.

Fabrication structure: An additional layer of indirection has been introduced to the PBS, the so-called fabrication parts. The PBS, which contains the design data, is often created directly from a CAD system. For fabrication, it may be necessary to add parts which are not represented in CAD (e.g. packaging, shipping equipment), to be able to re-organize the PBS to better suit the assembly process, and to collect specific fabrication process instructions. Using a fabrication structure also allows tracking the fabrication progress by comparing the number of fabricated physical parts with the number of elements in the fabrication structure. Figure 5 illustrates the extended scheme of design, fabrication and physical part breakdown structures in the EDMS.

The XFEL cavities have to be manufactured according to the pressurized equipment directive, which has its own requirements on documentation and traceability. It also requires that the compliance of the established solution with the directive is accepted by an inspection authority. This acceptance has been gained in a first step for the documentation and tracing of the niobium sheets.

PROCESS COORDINATION

From a QA perspective, the complex cavity production process is reduced to a sequence of quality checks which have to be done whenever the production of a cavity reaches a pre-defined quality gate. In PLM, this corresponds to a set of mandatory tasks which have to be executed on each physical cavity. The DESY EDMS offers generic "task" objects, which carry process instructions, and which refer to the needed input elements and the produced result elements. Figure 6 illustrates the mechanism for a set of quality checks on a cavity:

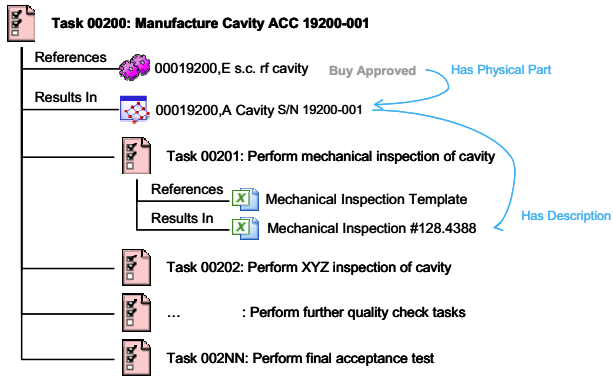

Figure 6: Example task structure for a quality check.

For each cavity, a root task is created which governs the production of that cavity. It refers to the fabrication part, which contains the part definition documents and processing instruction, and it results in the physical cavity being built and delivered. The task has sub-tasks for each quality check, which may include for example mechanical inspections, analyses of the manufacturing data, and acceptance tests. The sub-tasks refer to e.g. processing instructions and templates and result in e.g. filled and signed documents, which are linked to the physical parts they are describing.

Each task is assigned to a responsible party. Once the production of the cavity starts, the first sub-task becomes and stays active until the according quality check is completed. Then, the next task automatically becomes active, and the procedure repeats. The root task can only be completed if all its sub-tasks are complete.

The solution helps organizing the QA workflow and allows tracking and determining the work progress. It earns its value when large numbers of physical parts have to be checked in short times.

EXPERIENCE AND CONCLUSION

The DESY PLM system is successfully used for several years to manage the fabrication of FLASH cavities and has demonstrated that it fulfils all the requirements. For the series production of the XFEL cavities, it has been extended to directly integrate manufacturers, to offer some more sophisticated methods of fabrication data management, and to partially automate the coordination of large numbers of quality checks.

REFERENCES

[1] J. Bürger et al., "DESY EDMS: Information Management for World-Wide Collaborations", PAC'09, Vancouver, May 2009

[2] J. Bürger et al., "Towards Industrialization: Supporting the Manufacturing Process of Superconducting Cavities at DESY", Phys. C, 44(2006)268-271

[3] W. Singer, et.al., "Preparation Phase for 1.3 GHz Cavity Production of the European XFEL", IPAC 2010, Kyoto, Japan.