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Methodology for dimensional variation analysis of ITER integrated systems

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HIGHLIGHTS

- Tokamak dimensional management methodology, based on 3D variation analysis, is presented.
- Dimensional Variation Model implementation workflow is described.
- Methodology phases are described in detail. The application of this methodology to the tolerance analysis of ITER Vacuum Vessel is presented.
- Dimensional studies are a valuable tool for the assessment of Tokamak PCR (Project Change Requests), DR (Deviation Requests) and NCR (Non-Conformance Reports).

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ABSTRACT

The ITER machine consists of a large number of complex systems highly integrated, with critical functional requirements and reduced design clearances to minimize the impact in cost and performances. Tolerances and assembly accuracies in critical areas could have a serious impact in the final performances, compromising the machine assembly and plasma operation. The management of tolerances allocated to part manufacture and assembly processes, as well as the control of potential deviations and early mitigation of non-compliances with the technical requirements, is a critical activity on the project life cycle.

A 3D tolerance simulation analysis of ITER Tokamak machine has been developed based on 3DCS dedicated software. This integrated dimensional variation model is representative of Tokamak manufacturing functional tolerances and assembly processes, predicting accurate values for the amount of variation on critical areas.

This paper describes the detailed methodology to implement and update the Tokamak Dimensional Variation Model. The model is managed at system level. The methodology phases are illustrated by its application to the Vacuum Vessel (VV), considering the status of maturity of VV dimensional variation model.

The following topics are described in this paper:

- Model description and constraints.
- Model implementation workflow.
- Management of input and output data.
- Statistical analysis and risk assessment.

The management of the integration studies based on the Tokamak Dimensional Variation Model is also reported.

ITER is a Nuclear Facility INB-174 (Installation Nuclear de Base no. 174). This paper describes a Protection Important Activity (PIA) for safety.

1. Introduction

Management of manufacturing tolerances and assembly processes impacting ITER requirements covers all project phases

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from system design to part manufacture and Tokamak assembly/installation. Assessment of deviations impact, identification of risk issues and definition of the required mitigation logic is supported by Dimensional Variation Studies implemented and managed by the Design Integration Team within ITER Organization (IO), covering the following activities:

- Assessment of the tolerance chain between part functional tolerances/assembly processes in ITER baseline design and Manufacturing Requirements (feasibility to produce a part within required tolerances), Assembly Requirements (feasible alignment and installation) and Tokamak Functional & Interface Requirements (position of Magnets and Plasma facing components, systems alignment, critical clearances between as-built components/systems), including mitigation of risk issues.
- Early detection of potential tolerance/process deviations to mitigate its impact and optimize manufacturing issues and assembly processes. It is implemented through continuous monitoring of as-built data and the assessment of compliance with part/system requirements. It is an important activity on risk containment, allowing early implementation of corrective actions.

Studies are performed based on an integrated 3D Dimensional Variation Model representative of Tokamak functional tolerances and processes. This global model is established by using 3DCS®, a dedicated software from Dimensional Control Systems Inc.

3D Tokamak Dimensional Variation Model is an integrated statistical tool based on Monte Carlo simulations that predicts accurate values for the amount of variation in critical areas covering Magnets, Vacuum Vessel, In-Vessel Components, Thermal Shield and Cryostat [1].

The Tokamak Dimensional Variation Model will evolve from a pure statistical model (in the design phase) to an almost deterministic model (at the end of the assembly phase). The statistical model is based in the Tokamak 3D nominal geometry, whereas the deterministic model will be coincident with the as-assembled model. Tolerance studies during the construction phase are based in hybrid models, combining nominal geometries, tolerances and processes with as-built data.

2. Scope of dimensional variation studies

Dimensional Variation Studies are transverse functional analyses supporting system manufacturing and integration activities. Studies will be performed through ITER life-cycle to cover:

- Identification of risk issues based on non-compliant scenarios.
- Quantification of probability of occurrence based on Monte Carlo runs.
- Identification and assessment of mitigation strategies and customization logic, based on main contributors: part tolerances, assembly processes and compensator performance.
- Assessment of potential clashes in critical areas.
- The impact and feasibility of tolerance relaxations proposed by IO or Domestic Agencies (DA) via Deviation Requests (DR) and Non-Conformities (NC).
- The feasibility of assembly procedures.
- The reallocation and optimization of tolerances to as-built/as-assembled.

3. Model description and constrains

Tokamak Dimensional Variation Studies are based on parts geometry obtained from 3D nominal design or as-built data. Functional manufacturing tolerances are applied according the allocated values. The assembly sequence and features used to locate parts in

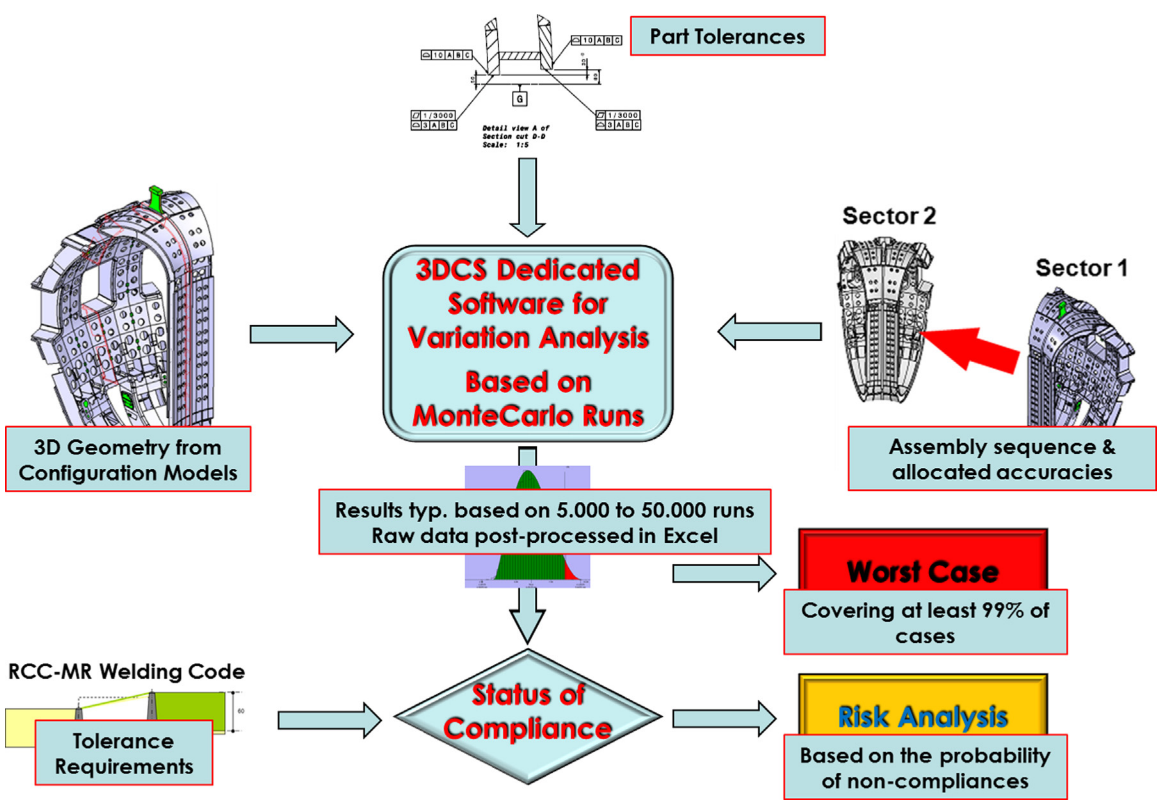

Fig. 1. Model implementation diagram.

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