Validation of Vacuum Vessel Thermal Shield deformation via Finite Elements and Morphing Techniques based analysis

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Scope of work

The **Vacuum Vessel Thermal Shield (VVTS)** is the barrier that reduces by two orders of magnitude heat loads transferred by thermal radiation and conduction from warm components to magnets and other systems inside the cryostat that operate at 4.5K.

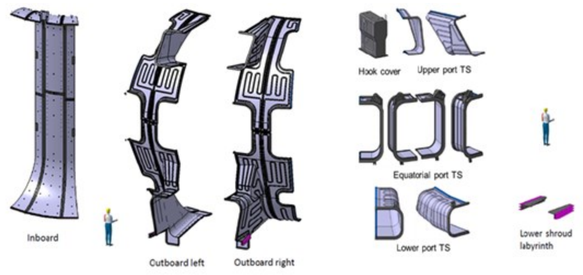
In order to maintain its function during operation, the **clearance between VVTS, Toroidal Field Coils (TFC) and Vacuum Vessel (VV),** shall be guaranteed. Hence, it is of paramount importance to monitor the gap during the machine assembly phase, when changes in the constraints of the flexible structure may affect the as-built geometries.

In particular, after the assembly of the TF coils on the sector module in the SSAT, **accessibility to the VVTS becomes limited** to the area of the sector edge. From this stage on, as-built data of the accessible surfaces may not be representative of the full deformed shape.
In order to validate the actual measurement strategy, an analysis based on Finite Elements and Morphing Techniques has been carried out.

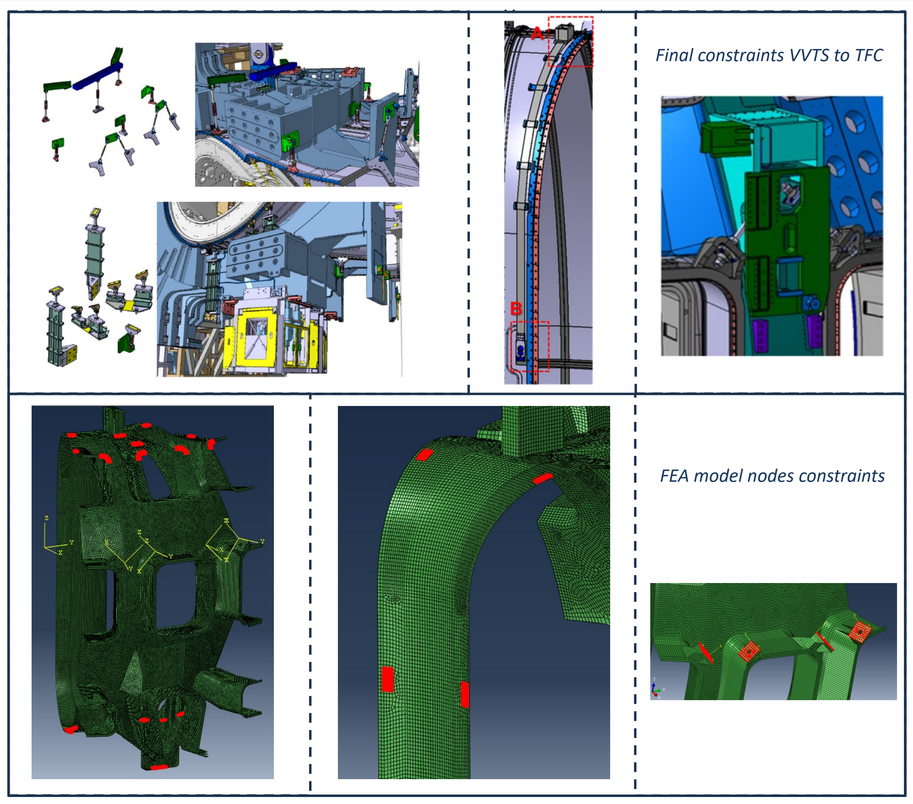
Aim of the work:

- Define and qualify a workflow based on morphing to extrapolate the "integral" deformed shape of the VVTS in different supporting configuration by measuring a discrete (few) number of points
- Define the minimum number of measurements required for making the extrapolated "integral" deformed shape representative within a certain level of uncertainty

The work is in the scope of the integration between F4E and IO



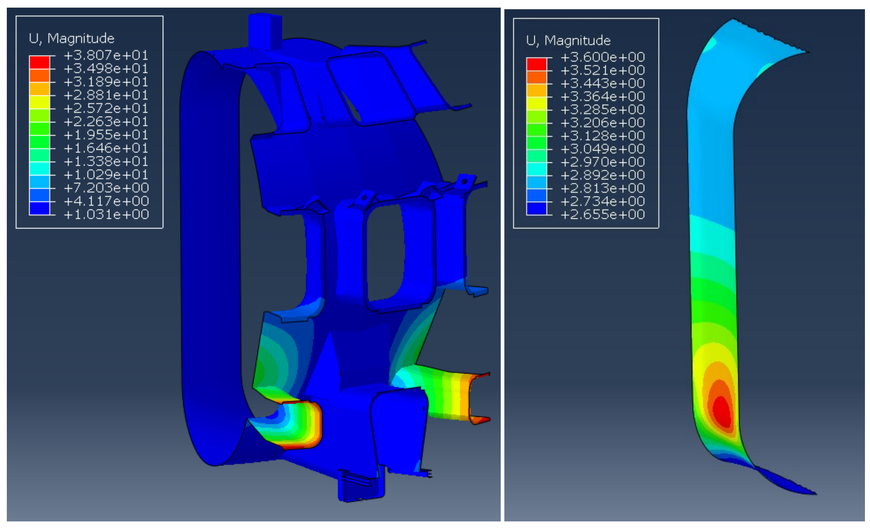
Morphing benchmark

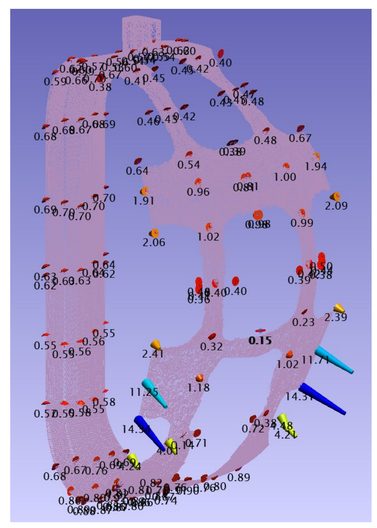


Finite Element Analysis

A Finite Element Model has been deployed simulating the **VVTS under gravity in the final support configuration** of the assembly, in which it will be connected to the TFCs.

Expected deformation are **is less than 1mm** in most of the areas (excluding ports).
Deformation is **uniform**, without waviness in the shape induced by the constraints.





Morphing

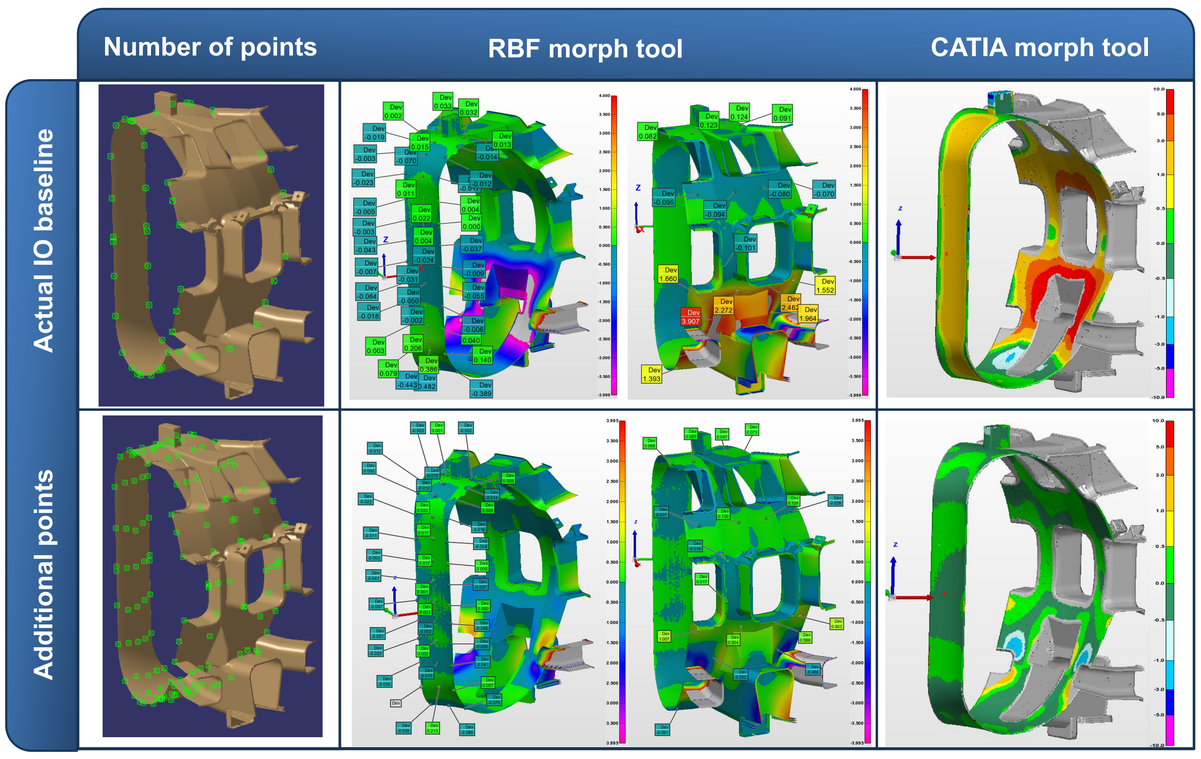
Morphing tools (CATIA and RBF) are used to reproduce the FEA deformations using only the coordinates of **discrete sets of points**, simulating actual measurements during assembly.
The Deformed VVTS from FEA has been used as reference shape to assess the quality of the morphing tools.

IO baseline of points:

- RBF morph: deviation from the Deformed VVTS on the **inboard** and top and bottom (most critical areas) is **around 0.2mm**. On the **outboard** deviation is **around 3-4 mm**, accurate enough for this region, being the gap requirement much larger.
- CATIA morph: criticalities due to **3mm deviation on the inboard** (mostly in the central area).

Additional points:

- RBF morph: able to tackle the deformed shape even on outboard side.
- CATIA morph: performing well in all areas.



Highlights

Following the results of the analysis, the following conclusions can be driven:

- **Review the applicable Morphing techniques:** RBF morph tool performs well in tackling the deformed shape of the VVTS, already with the actual set of fiducials foreseen to be measured. In the outboard area, where deviations to target are higher, results are still acceptable given the allowed clearance.
- **Review and evaluation of additional fiducial points to be measured:** the actual set of fiducials foreseen to be measured is acceptable to tackle the deformed shape with the RBF morph tool. With the CATIA morphing tool, additional points to be measured are needed, especially in the inboard area.

Acknowledgement

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References

[1] Assembly Procedure for the VVTS in Assembly Hall (X7WLUX v1.1)
[2] RBF Morph: a fast meshless morpher for Fluent