Feasibility Study of ITER In-Vessel Coils Bracket Manufacture and Integration

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1. Introduction

Feasibility study of ITER In-vessel coils bracket manufacture and integration had been developed in Institute of Plasma Physics, Chinese Academy of Sciences. The ITER In-Vessel Coil system is comprised of Edge-Localized Mode (ELM) and Vertical Stabilization (VS) coils. The ELM coils are used to mitigate the Edge Localized Modes and the VS coils are used to provide Vertical Stabilization of the plasma. Designed bracket for IVC coils is a kind of building block type three or four stacked components with arcuate groove matching with round conductor (as shown in Figure 1). This paper describes structure design, manufacture and integration process of the ELM and VS bracket.

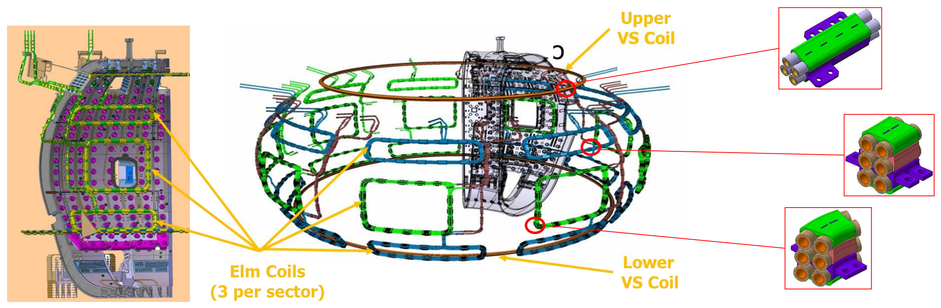

Figure 1. Overview of the IVCs and brackets

2. Structure design

Designed bracket for IVC coils is composed of four parts for the three winding layers of ELM coils (as shown in Figure 2) and three parts for the two winding layers of VS coils (as shown in Figure 3). Each bracket for ELM coil is integrated with six turns conductor by three symmetrical longitudinal outer sidewall welds. While for VS coil, each bracket is integrated with four turns conductor by two symmetrical longitudinal outer sidewall welds. Various amounts of straight comb plates are inserted through brackets internal slot and welded at top and bottom under the same compression force as for the separate modules welding.

According to welding trials and IO's proposal, ASIPP optimized the structure size of three brackets and specified tolerances for comb and defined classes of general tolerances according to ISO 2768 and ISO 13920.

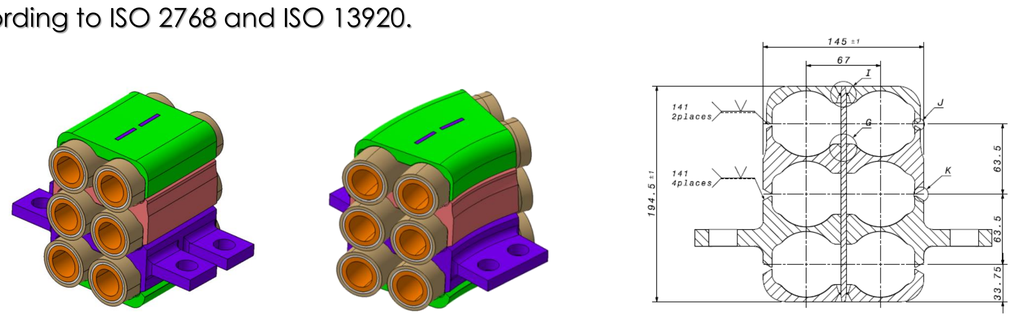

Figure 2. Two kinds of ELM brackets (left is ELM_07, middle is ELM_10) and cross section

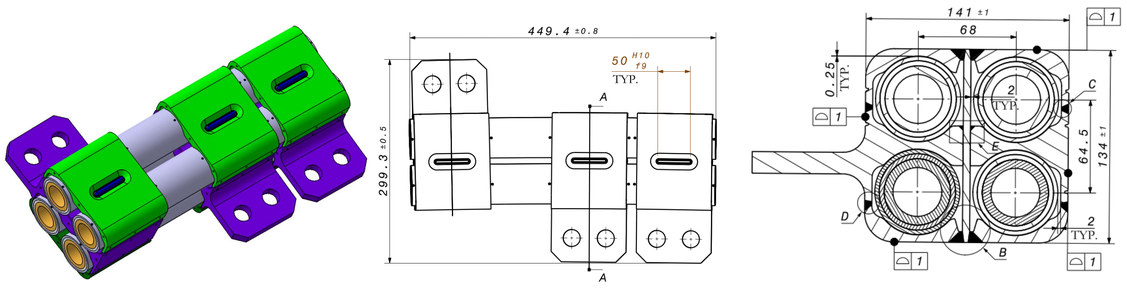

Figure 3. VS brackets and cross section

3. Bracket Manufacture Process and dimension measurement

The Inconel 625 forged according to ASTM B-564 was authorized by IO in place of Inconel 625 according ASTM B443 as required. The manufacturing process of ELM_07 will be introduced as an example for manufacturing process of the three brackets is similar. As shown in figure 4, parts ①(Upper clamp), ③(Upper housing), ④(Low housing) and ⑤(Low clamp) shall be manufactured in the same process as follows: raw material inspection, material identification, planer, WEDM, CNC, cleaning and dimension measurement. Machine process of part ② (Comb) includes raw material inspection, material identification, planer, CNC, cleaning and dimension measurement.

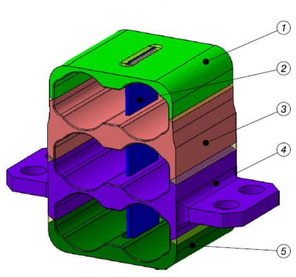

Figure 4. ELM_07 and part No.

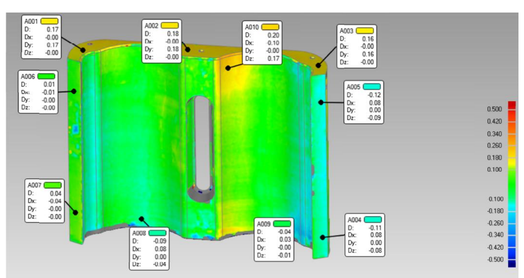

Figure 5. Dimension result by FARO arm

After the machining the dimension measurement for bracket components was carried out by the Faro arm. The dimension of ELM_07, ELM_10 and VS_02 components can meet the design tolerance except the arc face profile deviation of upper housing for ELM_10. (0.538mm).

4. Bracket Integration

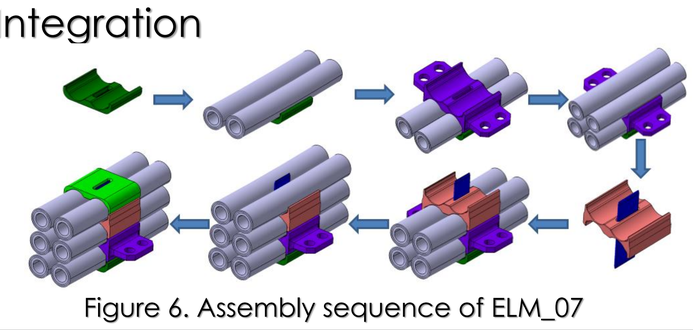

Figure 6. Assembly sequence of ELM_07

Bracket assembly sequence is from bottom to top as shown in Figure 7. Step 1: Install the lower clamp on the assembly platform. Step 2: Install the 1st layer conductors and filling material on the lower clamp according to the measurement of grooves and conductors. Step 3: Install the lower housing and filling material according to the measurement of grooves and conductors. Step 4: Install the 2nd layer conductors and filling material on the lower housing according to the measurement of grooves and conductors. Step 5: Weld upper housing and comb together. Step 6: Install the upper housing & comb and filling material according to the measurement of grooves and conductors. Step 7: Install the 3rd layer conductors and filling material on the upper housing according to the measurement of grooves and conductors. Step 8: Install the upper clamp and filling material according to the measurement of grooves and conductors. Step 9: Compress first at 420 N/mm. Step 10: Several compression until obtain 1.7±0.1 mm of gap (Load Max = 850 N/mm or Diameter Deformation Max = 0.1 mm) and used different copper foil thickness if needed. Step 11: Check the gap before comb welds. Step 12: Weld the combs. Step 13: Release the compress load and check the gap (Apply load if the gaps are higher than 2.2 mm). Step 14: Weld the sidewall.

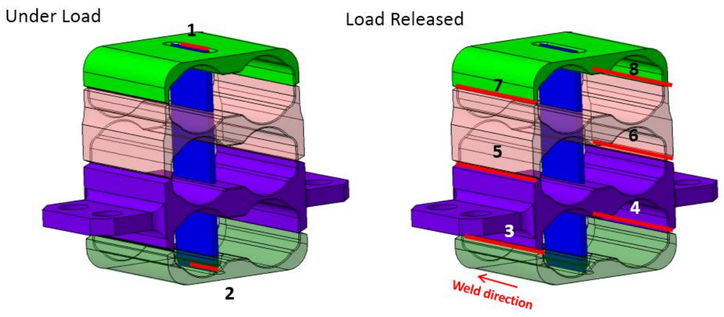

Figure 7. Weld sequence of ELM_07 and comb weld sequence

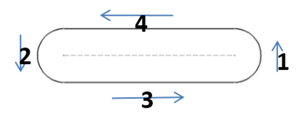

Figure 8. Weld sequence of comb weld

MTIG is used for bracket weld. The sidewall weld includes a layer of backing weld, one layer of filling weld and a layer of cosmetic welding. Weld sequence of ELM_07 is from 1 to 12 as shown in Figure 7. Figure 8 gives the weld sequence of one comb weld. The weld parameter is shown in Table 1.

Table 1 weld parameter

Backing welding	Filled welding	Cosmetic welding	Shielding gas	Backing gas
I=80-85A	115A	115A	10-15L/min	10-15L/min

Figure 9. ELM_07, ELM_10 and VS_02 bracket after integration

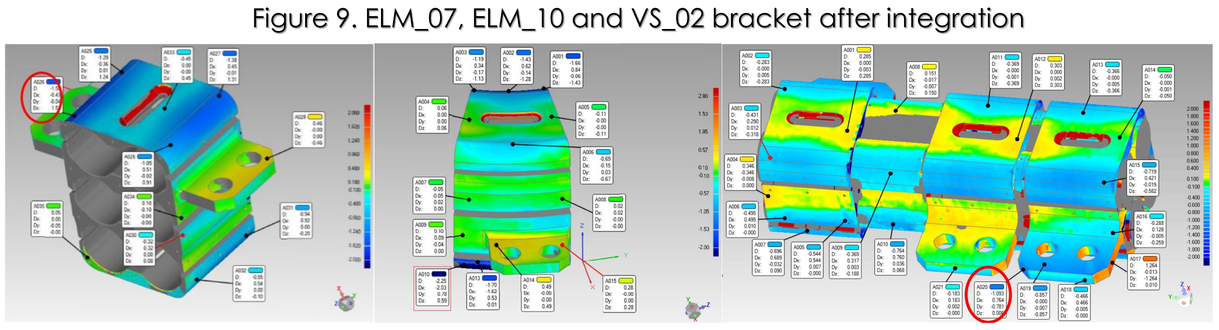

Figure 10. ELM_07, ELM_10 and VS_02 bracket after integration

FARO arm was used to measure the reference point in the bracket and conductor during assembly. The measured result before and after compression, before and after welding will be compared in pairs to get the deformation between different states. For the measurement result, we get bracket and conductor dimension change value in Z axis. The conductor shrinkage after bracket integration is less than 0.65mm. And the side wall shrinkage is less than 1mm for three weld pass. And the side wall shrinkage is 1-1.3mm for four weld pass.

5.NDE of bracket weld and weld repair

PAUT or RT is performed in the ELM and VS welds inspection. The NDE result of three bracket shows that all comb welds are qualified. But the quality of sidewall weld is unstable. ASIPP carried out the R&D of weld repair. The defect of Weld 8# is concave. The defect area is machined by CNC. The weld parameter of repair is same as before. The RT result after weld repair shows that the weld quality can meet the requirement of ISO 5817.

Figure 11. Weld 8# repair of ELM_10

6. Conclusion

This paper described structure design and optimization, manufacture process and integration of IVCs bracket. Three representative brackets integration were finished. The profile of three bracket can meet design tolerance. For weld quality instability, weld repair was carried out successfully. It shows that ITER In-Vessel Coils Bracket Manufacture and Integration is feasible in engineering.

Author: Aihua Xu, E-mail: xuah@ipp.ac.cn. Title: *"Feasibility Study of ITER In-Vessel Coils Bracket Manufacture and Integration"*