Development of a Fabrication Procedure Considering Non-Destructive Testing for HCCP TBM Shield Fabrication

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***Keywords :** HCCP TBM, HCCP TBM Shield, fabrication procedure

1. Introduction

Korea has been developing a helium-cooled ceramic reflector (HCCR) breeding blanket for the Korean nuclear fusion demonstration reactor and fusion reactor development [1]. As part of this effort, Korea is collaborating with Europe to develop an HCCP Test Blanket Module (TBM) for installation and testing at ITER. Reduced-activity ferrite/martensitic (RAFM) steels are among the candidates for fusion reactor structural materials, and countries conducting fusion reactor research have developed several types of RAFM steels, including EUROFER [2] and F82H [3]. In Korea, a RAFM steel grade called Advanced Reduced Activation Alloy (ARAA) has been developed for fusion reactor components, including ITER's HCCP TBM [4-7]. The HCCP TBM is divided into a TBM box and a TBM shield structure.

The HCCP TBM box is made of RAFM steel, specifically EUROFER-97, while the HCCP TBM shield is made of SS316L(N)-IG. The production of HCCP TBMs for ITER is shared between Korea and Europe. Korea is responsible for manufacturing the TBM box's internal elements (Breeder Units) and TBM shields, while Europe is responsible for the TBM box envelope and TBM manifold structure. The final assembly will be carried out by Europe. The structure and geometry of the HCCP TBM are shown in Fig. 1.

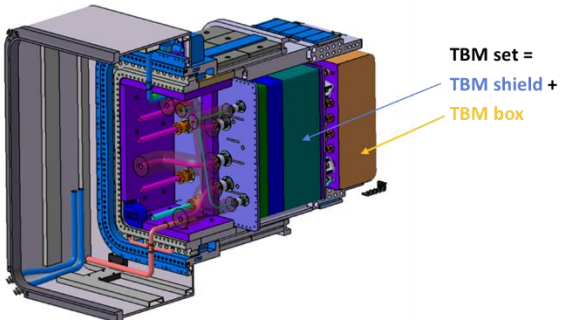

Fig. 1. HCCP TBM geometry diagram

2. HCCP TBM Shield Manufacturing Procedures and Methods

The design of the HCCP TBM was carried out by Europe, and Korea and Europe agreed to co-produce it based on this design. The HCCP TBM set consists of a TBM box and a TBM shield. Korea is responsible for producing the breeder unit and the TBM shield, which are internal elements of the TBM box, while Europe handles the TBM box body, the TBM manifold structure, and the integrated assembly of the TBM set. To manufacture the HCCP TBM, the performance of the TBM must be validated through design and structural analysis, and a manufacturability review is required to verify fabrication procedures and methods. Existing HCCP shield designs feature multiple reinforcement plates, which are challenging to weld and fabricate.

This study reviewed the characteristics of the HCPB TBM shield, WCLL TBM shield, and HCCR TBM shield developed in Europe and Korea, leading to a simplified welding process and easier fabrication procedures for the HCCP TBM shield. The schematic of the HCCP TBM shield fabrication is shown in Fig. 2. The HCCP TBM shield structure includes a pipe and casing arrangement with five shield blocks and three additional blocks at the front, bending, and rear. The pipes and casing include water inlet/piping, helium inlet/piping, purge gas inlet/piping, and NAS I&C piping, connecting to the TBM manifold. The improved HCCP TBM shield design incorporates geometric design and fabrication procedures. The schematic of the HCCP TBM shield assembly procedure is shown in Fig. 3. The HCCP TBM shield can be manufactured using TIG welding, allowing for visual and non-destructive inspection of the welded areas.

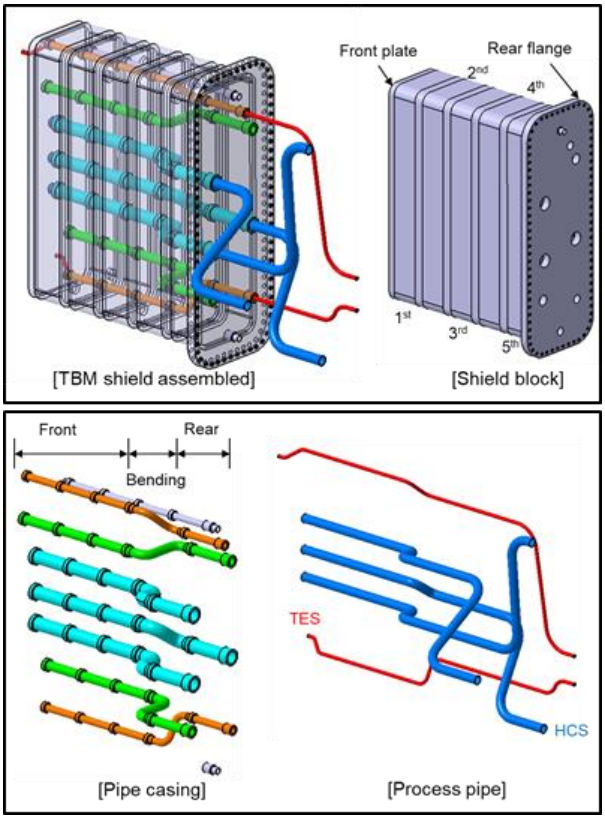

Fig. 2. Schematic of HCCP TBM Shield fabrication

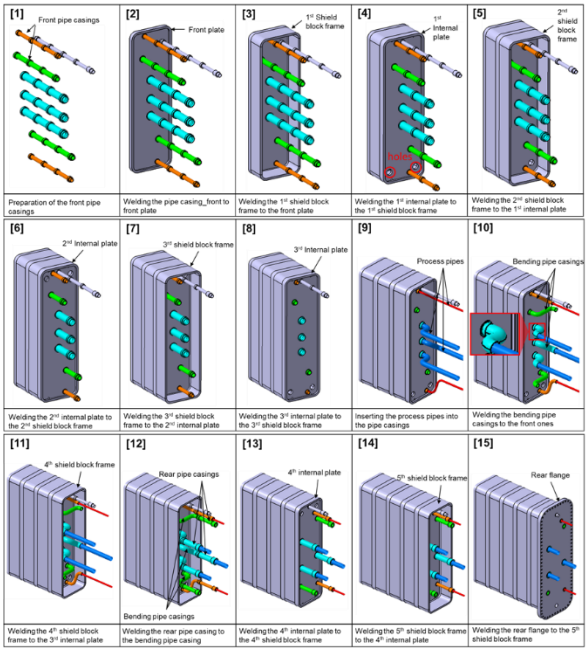

Fig. 3. Schematic of HCCP TBM Shield assembly procedure

3. Conclusions

The existing European designs, including the HCPB TBM shield and the WCLL TBM shield, as well as the Korean-designed HCCR TBM shield, are expected to face challenges in welding and inspection due to the presence of multiple reinforcement plates. To address these issues, the HCCP TBM shield has been designed to simplify the welding process and facilitate the manufacturing procedures. The improved design is expected to ease the manufacturing process, with the shield anticipated to be produced using TIG welding. This approach allows for visual inspection of the welds and simple non-destructive testing.

Acknowledgments

This work was supported by the R&D Program through the Korea institute of Fusion Energy (KFE) funded by the Ministry of Science and ICT of the Republic of Korea (KFE-IN2403)

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