Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 29-30, 2014

Manufacture of a Dual-Cooled Fuel Assembly Mockup for Mechanical Characterization Tests

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1. Introduction

Until now, some components such as a top end piece (TEP), a bottom end piece (BEP), guide tubes (GTs), an instrumentation tube (IT), spacer grids (SGs) and fuel rods (FRs) for a dual-cooled (DUO) fuel have been designed and manufactured. These parts will be used to execute mechanical integrity tests of each component as well as a DUO fuel assembly. All components were made of stainless steel 304 for research. A DUO fuel assembly mockup was assembled by mechanical fastening and laser welding methods with them. The conceptual feasibility of each component was checked through it. In this paper, manufactured items for a DUO fuel and a DUO fuel assembly are briefly described.

2. Components for a DUO fuel

2.1 Top end piece and bottom end piece

In a DUO fuel assembly, the array of fuel rods was changed from 16×16 for a conventional PWR fuel assembly to 12×12 due to the increasing outer diameter of the fuels. The pattern of the slots and holes of the conventional TEP and BEP should be modified to provide a coolant flow inside the internal flow passage of a DUO fuel rod as well as the external flow passage, respectively. A manufactured flow plate of TEP and a BEP for a DUO fuel are shown in Fig. 1. The pressure drop of a newly designed TEP and BEP was predicted to be a 18 % and 14 % decrease over conventional ones using ANSYS/CFX, respectively [1,2]. The TEP/BEP should satisfy the stress intensity limits according to the conditions A and B of ASME, Section III, Division 1-Subsecion NB. The strength compatibility was evaluated by comparing with the Tresca stress limit in the case of an axial load [3].

Fig. 1 A flow plate of TEP and a BEP.

2.2 Guide tube and instrumentation tube

Because the possibility of replacing the reactor internals has to be minimized when DUO fuels are loaded into an OPR-1000, the dimension and position of a GT and an IT for a DUO fuel assembly should be same as those of conventional one. In this case, the gap between a guide tube and a fuel rod could be much bigger than that between fuel rods [4]. This causes the coolant to likely flow around the guide tube rather than around the fuel rods. To decrease the flow area around the guide tubes, another tube of a larger diameter was designed and manufactured outside the conventional ones shown in Fig. 2. a dual tube would enhance the mechanical integrity such as bending and buckling stiffness by about 186.8 % and 228.5 % which were predicted by the FEM, respectively.

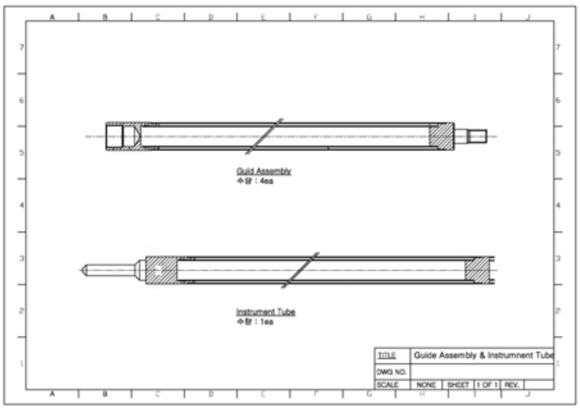

Fig. 2 A dual GT and IT.

2.3 Spacer grid

Several types of SG springs had been invented for DUO fuels considering narrow gaps between fuel rods and spacer grid plates. It is not difficult to imagine the narrow gap due to an increase of fuel rod's outer diameter. To utilize the limited spacer in a fuel bundle, differently from the conventional PWR fuel design, SG springs and dimples can be formed near the cross points of the SG plates, which we call center-moved supports [5] or in the narrow center of SG plates, center-supported supports. We manufactured a SG with a kind of center-supported support, a modified H type for DUO fuels [6]. It resolved the weak points of the center-moved supports such that the fuels could be moved in arbitrary directions because the fuels would be supported by supports in the diagonal direction and the stiffness of supports might be too soft or too stiff. The spring stiffness obtained using a strap-based analysis and assembly-based analysis was 100 N/mm and 74.4 N/mm, respectively. Verification tests are planned for a strap-base and an assembly-base.

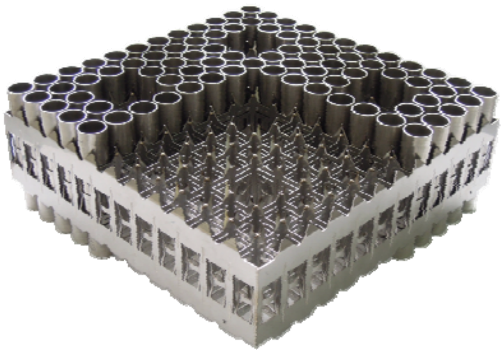

Fig. 3 A SG with modified H type springs and fuel rod mockups.

2.4 Fuel rod

A DUO fuel rod consists of donut-shaped pellets, a plenum spring, an inner/outer cladding tube and a top/bottom end plug. Donut-shaped pellets were replaced by Pb and SUS304 tubes to execute out-pile tests using FAMeCT (Fuel Assembly Mechanical Characterization Tester) in KAERI. The length and quantity of Pb and SUS304 tubes were decided for a DUO fuel rod mockup to get almost the same mass as a real one. Inner/outer tubes were manufactured by a pullout process of SUS316L. End plugs were fastened by laser welding at 4 positions. The domestic patent of welding process was obtained and an application for an international patent is pending. Components of a DUO fuel rod are shown in Fig. 4.

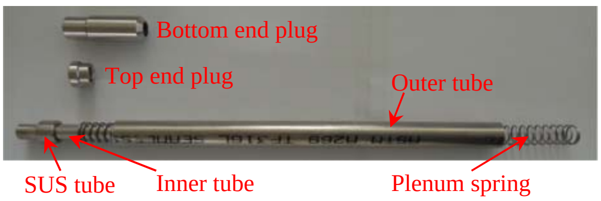

Fig. 4 Components of a DUO fuel rod.

4. A DUO fuel assembly mockup

4 GTs and 1 IT were fixed with 11 SGs by using laser 8 welding points shown in Fig. 5. After then a BEP was assembled by mechanical fastening method. 124 fuel rods were inserted. Finally, a TEP was fastened by tightening external screws of the guide posts with the guide tubes' internal screws. Total mass of a DUO fuel assembly is about 691 kg.

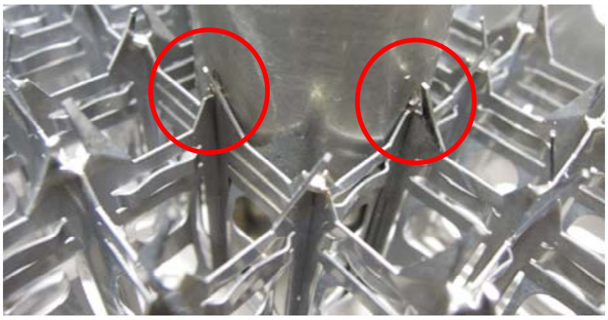

Fig. 5 Laser welding positions between SGs and a GT.

4. Conclusion

Although the research of a DUO fuel has been done by USA, they have just focused on pellets, not mechanical parts such as TEP/BEP, GTs, and SGs. We designed and manufactured them and assembled a DUO fuel assembly. The realizable possibility of a DUO fuel assembly was checked. Mechanical characterization tests will be performed to measure the DUO fuel's mechanical properties such as bending rigidity, modal characteristics, impact durability, etc.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MISP) (No. 2012M2A8A5025825)

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