§28. Optimized Thermo-mechanical Design of High Intensity Neutron Source Test Cell for Material Irradiation

Shimizu, A., Yokomine, T., Ebara, S., Yoshida, N., Watanabe, Y., Irisa, H. (Kyushu Univ.),
Nakamura, H. (JAEA),
Hasegawa, A. (Tohoku Univ.),
Noda, N., Muroga, T., Sagara, A.

Engineering Validation and Engineering Design Activities for the International Fusion Materials Irradiation Facility (IFMIF-EVEDA) is one of the broader approach activities. IFMIF-EVEDA includes three themes: prototype accelerator, lithium target and test cells. The activities, planned over a period of six years, are shared between the Team Project located at Rokkasho (Japan) and the System Groups distributed between Europe and Japan.

In the test cell region, by means of detailed neutron calculations, three zones of relatively uniform radiation levels were defined. A zone in which it is possible to obtain dpa (displacement per atom) rates of the order of 20–50 per full power year (fpy) within a volume of around half a litre is called as High Flux Test Module (HFTM). The detailed engineering file of the HFTM requires the validation of a few key technological points, taking benefit of the experience acquired at EU and Japan. The reference solution for the assemblies is a vertical set-up (EU); an alternative horizontal solution (Japan), which could become very useful for very high temperature tests, is also part of this work. Main objective under EVEDA phase is to provide the full detailed design file of the HFTM, after completion of technological validation (brazing, welding…), thermo-mechanical and hydraulic validation, post irradiation examination of the critical elements of the test rigs (heating devices, sensors, etc.). A full-size HFTM for the vertical set-up will be designed, fabricated and intensively tested. This task involves the use of heavy experimental structures (nuclear irradiation reactor(s), helium loop, etc.). A full-size HFTM for the horizontal set-up will be designed, and a heater-integrated (H-I) plate and capsule will be fabricated and intensively tested in Kyushu University.

This study's objective is to provide the conceptual design file and fabrication of a model of the High Flux Test Module (HFTM) with horizontally-elongated capsule which will be controlled at the temperature range of 250-1000°C by using gas loop.

Our HFTM has cast-like capsules in it to reduce the gap problem and can monitor the temperature of test pieces during irradiation by measuring the dummy test piece. Because the gap in the capsule is fulfilled helium gas of which pressure is equivalent to the flowing coolant pressure, our HTMF can be used up to 1000 degree C and can become alternatives of EU's HFTM for mid-temperature level using NaK to fill the gap.

The essential point to design the capsule is;

- Electrical output corresponds to nuclear heating profile
- Prolong and high temperature use
- NOT be thermal barrier in respect to coolant
- Thin (less than 1mm) and high power density without large terminal.

Conventional line-heater which is used in EU's HFTM has empirically doubt in respect to the strength and the un-uniformity of heating especially at corner. On the other hands, the plate heater has problem that insufficiently contact occurs at high temperature level. Therefore, heater –integrated (H-I) capsule is proposed and developed in this study.

The conceptual design of H-I capsule is shown in Fig. 1. The performance of H-I capsule is numerically predicted. (Fig. 2.) Following conceptual design and comprehensive numerical estimation including thermo-mechanical calculation, finally, prototype of H-I capsule can be fabricated as is shown in Fig. 3. In IFMIF-EVEDA stage, the H-I capsule is tested in respect to power distribution corresponding to nuclear heating profile, ruggedness of long-use in high temperature level and so on.

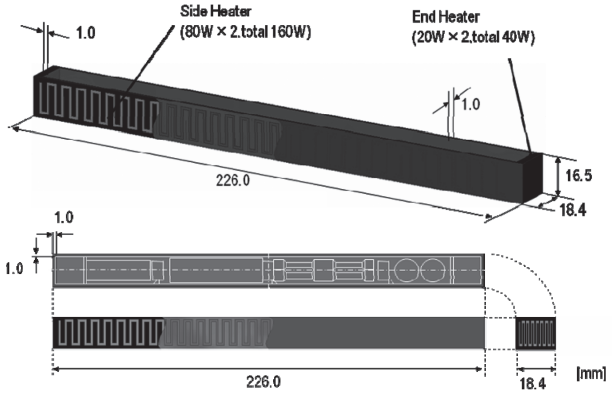

Fig.1 Conceptual design of heater-integrated capsule

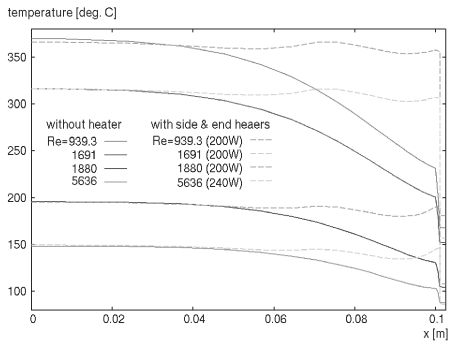

Fig.2 Uniform profile of temperature due to H-I capsule

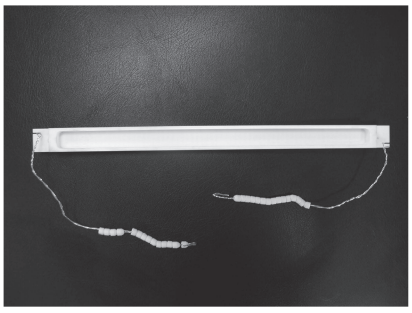

Fig.3 Heater-Integrated capsule for HFTM