Development of Technology for Remote Fabrication of Pressurized Capsule in a Pressurized Chamber using LASER (An Effort Towards Re-Irradiation Program)

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1.0 Introduction

Fast Breeder Test Reactor (FBTR) at IGCAR, Kalpakkam serves as a test bed to carry out irradiation of newly developed fuels and structural materials. Re-irradiation program is required to re-irradiate the selected samples (irradiated fuel pins / structural specimens) after post irradiation examination. Remotely controlled welding work will be required to be carried out, inside the highly radioactive hot cell. The laser has been considered for the remotely controlled welding work since the optical fiber transmission system of laser can be easily adopted in the shielded facility, but there is also a technical challenge of securing higher welding quality in the laser welding work to remotely fabricate / encapsulate the specimens such as pressurized capsules. For this purpose, a high pressure chamber has been designed and fabricated with the attachment of anti- reflective (AR) coated window. Both the end of the chamber is closed with flanges. The AR coated window is attached with the top flange to transfer the laser energy to the capsule. Necessary connections were provided in the chamber with butterfly valve and pressure gauge to evacuate and pressurize the chamber to required pressure. Remote fabrication of pressurized capsules in pressurized chamber using laser has been carried out and the capsules have been fabricated up to the pressure of 100 bar at room temperature (RT). To verify the integrity of the capsules, these capsules were encapsulated in separate quartz tubes under vacuum. Thereafter, they (pressure: 80/90/100 bar, at RT) were exposed at different temperatures ranging from 300 °C to 850°C in an electrical furnace. Weights of the capsules were measured before and after exposure to test temperatures. No change in weight has been observed, which ensures leak tightness of the weld joints, which are remotely carried out. Development of technology for remote fabrication of pressurized capsule in a pressurized chamber using LASER which can be used for Re-Irradiation program is presented in this paper.

2.0 Design and development of a high pressure chamber

A high pressure chamber (Fig. 1) has been designed and fabricated with the attachment of anti-reflective (AR) coated window. The AR coated window is fitted using top flange in the high pressure chamber to transfer the laser energy to the capsule. Necessary connections were provided in the chamber with butterfly valve and pressure gauge to evacuate and pressurize the chamber to the required pressure. AR coated windows are used to separate the outside environment from the high pressure chamber. The infrared ray transmitting materials have a high index of refraction. Anti-reflective coating is normally applied to windows to minimize the losses due to the reflection. The AR coated window / optics must withstand the pressure loading. It is important that the optics under pressure be sufficiently thick to withstand the pressure loading without breaking [1, 2] and at the same time, it is necessary to minimize the thickness for optical considerations, since increase in thickness reduces the optical transmission.

3.0 Pressurized capsule

The pressurized capsules have been fabricated using SS 316L material. The dimensions of the pressurized capsule are: 70 mm overall length (50 mm length of gas filling portion), 6.5 mm outer diameter of the tube and 0.5 mm wall thickness. As in the conventional welding (GTAW) process both the ends of the tube are closed by the end plugs. However, in case of laser welding technique (Fig. 2), the top end of the plug of the pressurized capsule has a hole of diameter: 0.2 mm through which the evacuation and filling of gas can be carried out. Once the required pressure is achieved, the hole is spot welded and closed using laser beam passed into the pressurized chamber through the AR coated window (also called seal weld). After taking out the pressurized capsule from the chamber, a disk of SS 316L is welded over the end plug to provide the additional sealing. Exact pressure of the gas filled in the pressurized capsule is determined by indirect method. The weight of the pressurized capsule is measured before and after pressurization, and the weight of the gas filled is calculated. To check the integrity of the pressurized capsule, the pressurized capsule is encapsulated in quartz tube under vacuum and is exposed to various temperatures in the electrical furnace. Further, the capsule is checked for defects (if any) visually using magnifying glass and further change in mass is measured to verify the leak tightness of the capsule.

4.0 Experimental work

A total of seven numbers of pressurized capsules (Fig. 3) were fabricated with different pressures (80/90/100 bar, at RT) and out of them, three numbers (Sample-1, Sample-2 and Sample-3) were selected for the furnace tests. Sample-1 was at the pressure of 80 bar (at RT), Sample-2 was at the pressure of 90 bar (at RT) and Sample-3 was at the pressure of 100 bar (at RT). All the three pressurized capsules (Samples) were encapsulated separately in quartz tubes under vacuum and were exposed at different temperatures starting from 300 °C upto 850 °C in an electric furnace. Sample-1 was exposed at 300, 400, 500, 550, 600, 650, 700 and 720 °C for the duration of around 6 hours at each of the temperature. Similarly, Sample-2 was exposed at 400, 500, 550, 600, 650, 700, 750, 800 & 850 °C and Sample-3 was exposed at 400, 500, 600, 650, 700, 750 & 800 °C for the duration of around 6 hours at each of the temperature. After exposure to each of the temperature in the furnace, the sample encapsulated in quartz tube was taken out from the furnace and observed (visually) for change in volume (if any) and in case of no considerable change, it was kept back in the furnace for further exposure at higher temperature. Sample-1 was exposed upto the temperature of 720 °C, Sample-2 upto 850 °C & Sample-3 upto 800 °C and thereafter, quartz tubes were broken open and detailed inspection was carried out.

5.0 Result and discussion

During inspection of pressurized capsules (Sample-1, 2 & 3), weight was measured and it was found that there is no change in weight between before and after furnace test. Dye penetrant test (DPT) was also carried out on the samples after exposure of high temperature in furnace and no observable defect was noticed. These tests confirm the integrity of the weld joints in the pressurized capsules. Sample-1 was exposed in the furnace upto the temperature of 720 °C and no considerable change in volume was observed. Further, it is planned to expose it to higher temperature in the furnace. Sample-2 was exposed in the furnace upto the temperature of 850 °C and thereafter considerable change in volume (Fig. 4) was observed. Therefore, further exposer to higher temperature was stopped. In Sample-3 also, considerable change in volume was observed after the exposure of 800 °C, therefore, further exposer to higher temperature was stopped.

Pressurized capsules made of SS 316L have been successfully developed in a pressure chamber using LASER upto the filling pressure of 100 bar (at RT) which can withstand exposure temperature up to 800°C without rupture. Further work is required to develop the pressurized capsules inside the hot cell of Radiometallurgy Laboratory of IGCAR using the similar technique from the clad tube of irradiated fuel pins for re-irradiation.

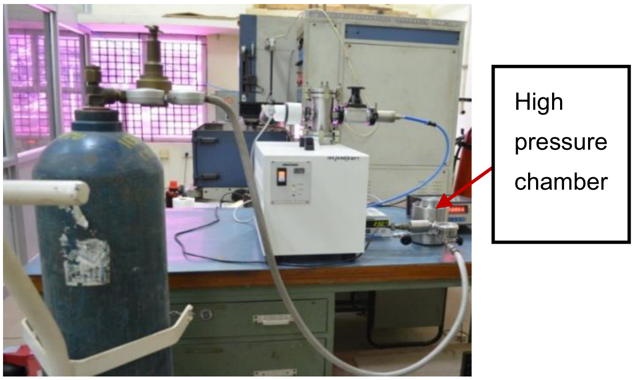

Figure 1 Pressurization set-up

Figure 2 Laser welding set-up

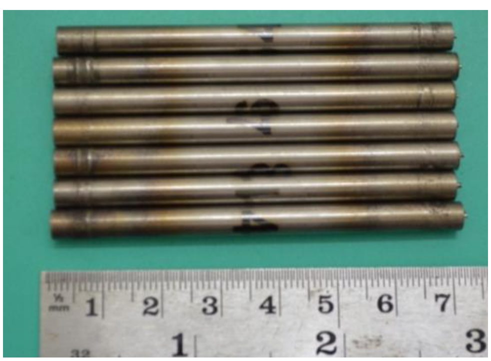

Figure 3 Pressurized capsules (after LASER welding)

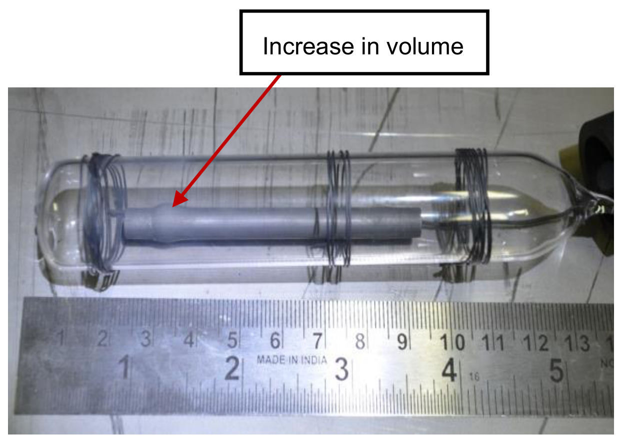

Figure 4 : Increase in volume noticed in one of the pressurized capsule (After furnace test)

References

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