Seminar

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Institute for Plasma Research

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Title: Preliminary study of dissimilar welding of IN-RAFM and SS316L steels using handheld laser technology

Speaker: Dr. Akhil Khajuria
Institute for Plasma Research, Gandhinagar

Date: 08th August 2025 (Friday)

Time: 03:00 PM

Venue: Seminar Hall, IPR

Abstract

The engineering design and fabrication of first wall breeding blanket components involve significant complexities and challenges, including the assembly of sub-components like the first wall itself, and other components of future nuclear fusion device. Another major engineering challenge is to join first wall i.e. RAFM steel with auxiliary systems which may be made of commercially available stainless steel (SS) 316LN. As a consequence, dissimilar weld joints between RAFMS and SS316LN steel are indispensable in the fabrication of fusion reactors. Consequently, a detailed technological investigation and development becomes mandatory on dissimilar welding of SS316LN (auxiliary components) with IN-RAFMS (i.e. first wall components of Indian TBM).

From existing literature, it is understood that laser beam welding (LBW) of RAFMS in comparison to electron beam welding (EBW) offers potential benefits in respect to occurrence of magnetic deflection, requirement of vacuum chamber with obvious high initial involvement of cost, and limitation of part size, expensive set-up and operating cost due to vacuum, release of X-rays in EBW. In addition, EBW requires complex tooling, precise fit, and secure fixtures, moderate speed due to vacuum set-up time, and longer cycle times due to vacuum pump-down/venting. As a preliminary investigation in the form of initial trails on LBW of these ferritic/martensitic and austenitic steels, SS316L is chosen as a surrogate material instead of SS316LN because of its unavialbility at present.

It is pertinent to note that dissimilar LBW of IN-RAFM steel with SS316L has not been attempted so far. Joining through LBW dissimilar materials like RAFMS and SS316L presents significant challenges due to differences in their melting points and mechanical, metallurgical, chemical, and thermal properties. As a step ahead, an exploration and research through LBW of IN-RAFMS and SS316L will help to identify and overcome these challenges, ensuring the production of high-quality, and reliable joints for future first wall components of nuclear fusion reactor. Further, the quality of welded joints becomes critical, particularly for components in high-stress environments such as fusion DEMO reactors, where certain critical components require high weld quality.

IN – RAFMS and SS316L plates of dimensions 100 mm × 50 mm × 6 mm (06 number each) were precise cut on water jet cutting machine. Handheld fiber LBW machine (Maximum power = 2 kW; Maximum

frequency = 5000 Hz; Shielding gas = 99.99% pure Argon) was used for laser welding. It is relatively a new technology that mainly uses laser beam as the energy source to impact welding joint to achieve welding purpose. To know the best fiber LBW parameters for obtaining sound welded joints of 6 mm thick plates in terms of controlled (manual) welding speed along with laser power for full penetration, bead-on-plate (BOP) trails were carried out individually on IN-RAFM and SS316L steel plates with dimensions (200 mm × 85 mm × 6 mm), and (200 mm × 103 mm × 6 mm), respectively. Further, based on the obtained BOP trail results, a total 06 nos. of LBW welded coupons were proposed to be obtained i.e., 02 trails of similar welding of IN-RAFMS with IN-RAFMS, 02 trails of similar welding of SS316L with SS316L, and 02 trails of dissimilar welding of IN-RAFMS with SS316L on 6 mm thick plates. Post weld heat treatment (PWHT) in an advanced muffle furnace at 750℃ for 2 hours followed by furnace cooling were done on similar IN-RAFMS to IN-RAFMS and dissimilar IN-RAFMS to SS316L welded coupons.

The characterization program consisted of Radiographic testing (RT), Optical microscopy, and post weld Vicker'smicrohardness at 250 g load with 10 sec dwell time. From the analysis of the obtained characterization data, it has been observed that lack of appropriate maximum fiber laser power and accordingly lack of optimized welding speed for joining 6 mm thick plates to obtain similar and dissimilar combinations of LBW joints caused porosity in all of the trails. Based on the obtained results and performed analysis of the above preliminary trails, it has been proposed to increase the fiber laser power, welding speed, and employ trailing gas with diffuser in order to obtain sound dissimilar LBW joints of ferritic/martensitic and austenitic steels.