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New technologies for Management of PWSCC in Dissimilar Metal Weld in NPPs

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1. Introduction

One of big issues to increase structural integrity and operating efficiency of nuclear power plants(NPPs) is now primary water stress corrosion cracking(PWSCC) occurring in dissimilar metal weld(DMW) regions, such as, inlet and outlet nozzles, and J-welds of control rod drive mechanism (CRDM) penetration and bottom-mounted instrumentation(BMI) nozzles in a reactor pressure vessel, and other nozzles in a primary system. In order to manage the PWSCC occurring in DMW, many technologies, for example, an induction heating stress improvement(IHSI) process, a mechanical stress improvement process(MSIP), overlay and inlay welding processes using conventional welding methods, water jet or laser peening processes, etc., have been developed in nuclear-advanced counties. Many of them have been being applied to some operating NPPs in the world. The most reliable, relatively new, and effective technologies are, however, thought to be a laser peening and an inlay welding process using a under-water laser welding(UWLW) method. In this talk, the laser peening process and inlay welding process using UWLW method will be introduced and their advantages will be discussed.

2. Laser peening process

Weld surfaces of metals and alloys in the most case are known to have tensile residual stress which is one of the main causes to induce PWSCC. In order to prevent and/or mitigate PWSCC in dissimilar metal welded region, one of the most effective means is to induce compressive residual stress on weld surfaces. There have been developed many methods to make the weld surfaces have compressive residual stress, such as, shot peening, surface cold rolling, hammering, water jet peening, ultrasonic peening, laser peening, overlay welding, etc.. Laser peening of them is thought to be an effective method to be applied to the DMW regions in PWR primary systems. That is why Toshiba including Westinghouse has developed and Electric Power Research Institute(EPRI) begins to develop laser peening technology for NNPs.

The basic theory for the laser peening is very simple. As shown in Fig. 1, when a laser beam is irradiated on the material surface, high pressure plasma is generated in very short time due to the high temperature generated on the surface by the laser beam. The high pressure plasma exerts shock wave in short time to deform the irradiated material surface plastically and induce work hardening, resulting in high and deep compressive surface residual stress. The compressive residual stress induced by the laser peening is very big in magnitude and also very deep from the treated surface, compared with other methods as shown in Fig. 2.

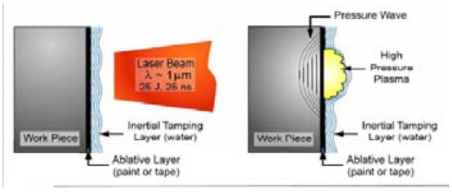
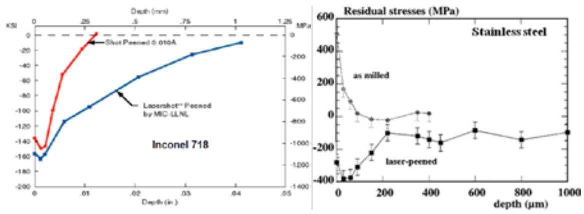


Fig. 1 schematics showing the mechanism of laser peening process



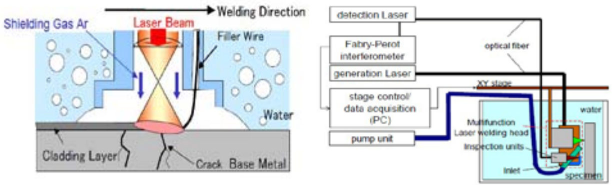
(a) (b)

Fig. 2 Compressive residual stresses induced by shot peening, surface milling, and laser peening on (a) Inconel 718 and (b) stainless steel

The laser peening technology has been developed for more than 15 years with a huge amount of R&D budget by Toshiba in Japan and has experiences to be applied to mitigate and/or prevent PWSCC in the DMW regions in BWR nuclear power plants operating in Japan. With this method, however, the damaged regions by PWSCC can not be repaired. To repair DMW regions damaged by PWSCC, a new and effective welding technology to be applied to the primary systems in NPPs has also been developed by Toshiba.

3. Under-water laser welding process

When DMW regions in the primary system in a nuclear power plant, especially for example, a reactor pressure vessel are damaged by PWSCC, it is not easy to repair the regions because of a high dose of radioactivity, very limited spaces available for repairing equipments, and primary cooling water filled in the system. Under these conditions, the best method to repair the DMW regions is known to be a under-water laser welding(UWLW) technology which has many advantages compared with other conventional welding methods, such as, welding with a very low heat input resulting in minimization of residual stress induced on the weld surfaces and of dilution between the substrate and the weld, very fine and homogenous micro-structures of welds due to rapid solidification process by an extremely high cooling rate in underwater welding, and easy automatization of the welding process which can allow the minimum dose of radioactivity to workers. Fig. 3 shows diagrams showing the concept of UWLW and a multi-laser system which can perform UWLW, laser peening and inspection of the treated region in sequence at the same time developed by Toshiba, Japan.



(a) (b)

Fig. 3 Diagrams showing (a) a conception of UMLW process and a multi-laser process system

This technique has been applied to repair a dissimilar metal weld nozzle in BWR damaged by PWSCC in Japan. Westinghouse is developing this technology with Toshiba and EPRI has also begun to develop it by making a mock-up. The under-water laser welding method can be used for temper bead welding like other conventional TIG welding processes. So, this technique is sure to be able to be used to repair the clad-damaged region on a reactor vessel inside-wall using a temper bead welding. At present, however, there is no code for applying this welding method to internals and clad wall in reactor vessels. Westinghouse is heard to be applying a code for this technique to USNRC and expected to get permission from USNRC probably next year.

In Korea, major maintenance companies now begin to have interest in these new and advanced technologies, and try to do researches to develop them to manage PWSCC expecting to occur in operating nuclear power plants in Korea, soon.

4. Summary

Nuclear technology in Korea has been being developed very rapidly and thus now Korea is one of the countries to export nuclear power plants designed and fabricated by her own technology. However, the maintenance technologies, such as, proactive measures for key components expecting to be aged to fail during operation and repairing technologies for them are relied on some foreign companies having many experiences and advanced technologies in those fields. In order to increase and continue exporting Korean-made NPPs, the managing technologies for the major components which are expecting to prone to fail during operation should be developed by her own R&D programs. In this sense, the new and advanced technologies are introduced in this paper

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