The Qualification of Welding Procedure on DCF Test Rig Fabrication

Chang-Young Joung [a*], Sung-Ho Ahn [a], Jin-Tae Hong [a], Chul-Yong Lee [a] and Hwang-Young Jeong [a]

[a] ***Korea Atomic Energy Research Institute, P.O. Box 105, Yuseong, Daejeon, Korea, 305-600***
Tel: 82-42-868-2519, Fax: 82-42-868-8364, E-mail: joung@kaeri.re.kr

1. Introduction

Dual cooled fuel (DCF) is reactor fuel with a geometry allowing cooling water on the inner and outer surfaces of an annular fuel rod. Its concept was proposed for use in gas-cooled reactors during the 1960's and has recently been considered for utilization in PWRs [1]. The main advantage of DCF is an increased heat transfer surface and a reduced fuel temperature, which result in less fission gas release, as well as an increased departure from nucleate boiling (DNB) and margins against fuel melting compared to standard type fuel [2]. Another beneficial consequence is lower stored energy and lower peak cladding temperatures during a loss of coolant accident (LOCA). Welding of the test pieces is needed for a approval of welding procedure specifications and has to be carried out as a preliminary step [3]. If standard requirements are fulfilled, the welding procedure specifications become a document providing in detail the required variables for a specific application to assure repeatability. Qualification of the welding procedures serves to demonstrate that production operations fully comply with the agreed welding procedure, including preliminary and subsequent treatment. Before a particular welding procedure is used in a production operation, the manufacturer should determine and document the suitability of the welding procedure specification (WPS) to produce a weld of the required quality.

This paper will give an overview of the work done with the qualification of the welding procedure to weld a DCF rod and an insulated test channel assembly in a DCF test rig fabrication.

2. Methods and results

2.1 Weld points

To issue the WPS for all critical weld points of the DCF test rig, the qualifications of the weld procedures were carried out according to the requirements of NS-EN ISO 15609-1 (Seal weld test), NS-EN ISO 15609-3 (Insulated channel weld test) and NS-EN ISO 15614-11 (DCF rod weld test). The EB round weld was performed in different weld points of the insulated test channel and DCF test rod. In addition, the TIG seal spot weld was fulfilled in the weld point of the insulated test channel. A drawing of the insulated channel test weld specimen for the welding procedure specifications is shown in Fig. 1. In this test, an insulated test channel is used to insulate the temperature of the circulating water during the irradiation test in the test rig.

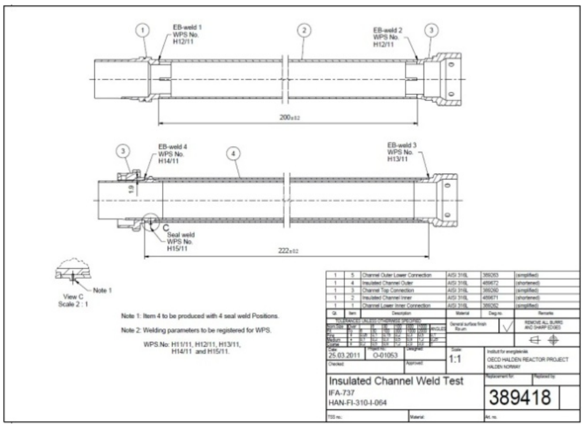

Fig. 1. The drawing of the insulated channel weld test specimen for WPS.

2.2 Weld methods

The qualification of the insulated channel and test rod for a round weld is used by an EB welder, which is a Hamilton Standard (25Kw). The base material of the insulated test channel is AISI 316L, and that of the test rod is Zr-4. All weld tests were performed in a high vacuum ($1x10^{-4}$ mbar) atmosphere. The establishment process of the electrode in the TIG seal spot welding to fill up gas to an insulated test channel specimen welded by a seal spot weld is shown in fig 2.

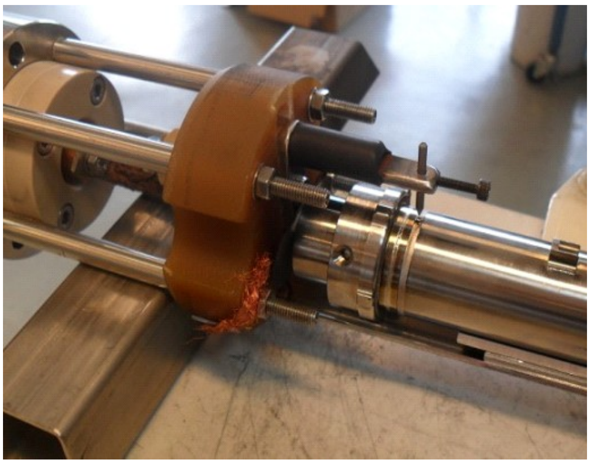

Fig. 2. The establishment process of the electrode in TIG seal spot welds to fill up gas to an insulated test channel.

A seal spot weld test is used by a TIG welder, a Millar Syncowave 300P. The base material is AISI 316L, and the hole, which is made at a dia. of 0.6mm to fill in the inert gas, is welded by a seal spot welder. The chamber in the insulated channel was filled with 95% Ar and 5% He gas of 50bar. The welding current of the TIG is 120A and the welding time is 0.4 sec.

2.3 Weld inspection

Non-destructive visual tests were carried out on all test specimens. No weld defects in these welding specimens were detected. The root and face of the welded joints had a regular shape. The He leak test for the insulation channel and DCF rod welded to be filled with mixed gas (He 5%/Ar 95%) was performed using an Alcatel ASM 142 (helium detector). In addition, a destructive metallographic test was performed to detect weld defects in the test specimens. To see the microstructure, the microstructure specimen was prepared and etched on one side in accordance with EN 1321, to clearly reveal the fusion line, HAZ, and buildup of runs for the EB or TIG weld. No weld defects were detected in these welding specimens. The microstructure of the insulated channel weld test specimen welded by a TIG seal spot welder is shown in Fig. 3. The heat affected zone (HAZ) for a weld joint looks like an ellipsoid, which is 4.1mm in width and 1.08mm in height. We confirmed that the entire welding process will be performed in compliance with the specified instructions and requirements given in this procedure.

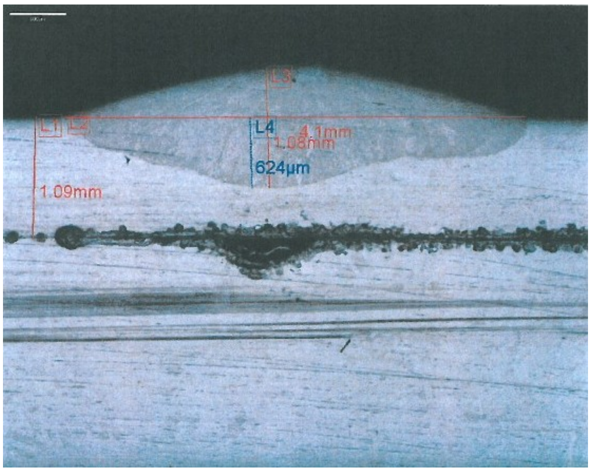

Fig. 3 The microstructure of the insulated channel weld test specimen welded by a TIG seal spot welder.

3. Conclusions

All critical welds are specified with the depth and given distance from a fixed point. It was confirmed that in all cases the mechanical properties of the welded joint are higher than those of the base material, and thus these results obtained from the weld tests were accepted as WPS for the weld points of a fuel rod and insulated channel. In the DCF test rig fabrication, a WPS for the weld methods was used for real product welds.

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