Development of Weld Overlay Technology for Dissimilar Welds in Pressurizer Nozzles

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1. Introduction

As a result of Primary Water Stress Corrosion Cracking (PWSCC) in alloy 600, leaks in dissimilar metal welds of pressurizer nozzles were discovered recently in several US plants. The involved companies developed advanced repair techniques [1][2][3][4] to prevent or repair PWSCC applying weld overlay procedures to dissimilar metal welds such as those between pipes and nozzles. Within 2 or 3 years, more than half of the nuclear power plants in Korea will have been in operation for more than 20 years. From this background, a weld overlay procedure has been developed in Korea for the dissimilar metal welds of pressurizer nozzles.

2. Weld Overlay Technology

There are three types of nozzles in a pressurizer; they are safety, spray and surge nozzles. The spray and surge nozzles are located at the top and bottom of the pressurizer. The safety nozzles are located in the top head of the pressurizer, inclined by 45 degrees to the spray nozzles as shown in Fig. 1.

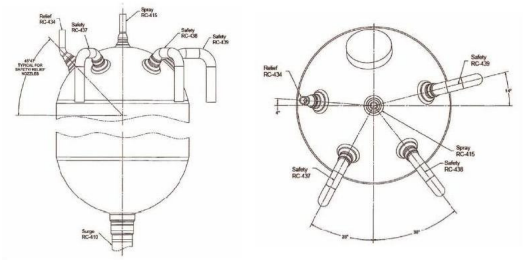


Fig. 1. Safety, Spray and Surge Nozzles in a Pressurizer

2.1 The Development of the Welding Process

The materials of dissimilar metal welds are low alloy steel, alloy 600 and stainless steel. These dissimilar materials, along with the poor weldability of alloy 52 filler metal, make the development of a single Procedure Qualification (PQ) for weld overlay somewhat difficult (Fig. 2). Because Post Weld Heat Treatment (PWHT) is difficult to apply in the field, [5] it is most important to develop a temperbead welding process.

Five different PQs were developed for the weld overlay with PQ testing performed. Based on these tests, a weld overlay system was developed.

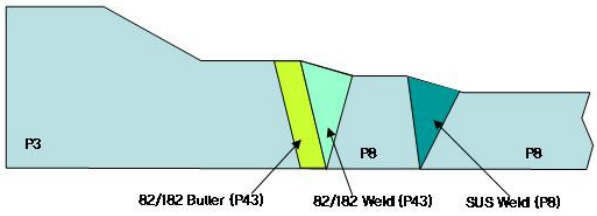
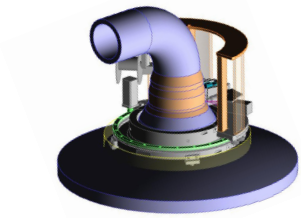


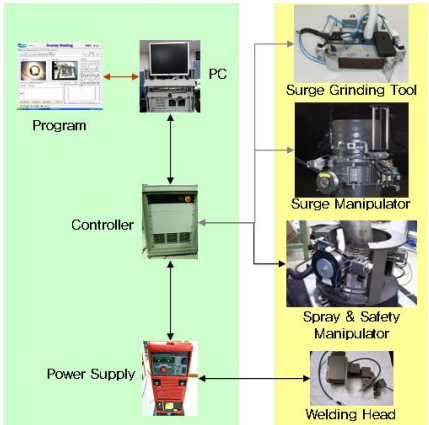
Fig. 2. Dissimilar Metal Welds

2.2 The Development of Weld Overlay System

To design the weld overlay system, the safety nozzle was chosen because of its complicated configuration and space limitations. The shape and dimensions of the safety nozzle in a pressurizer was modeled in 3D and a weld overlay system for safety nozzles was designed and manufactured as shown in Fig. 3.



(a) 3D Design



(b) Weld Overlay System for Pressurizer

Fig. 3. The Weld Overlay System

The developed weld overlay system consists of a manipulator, a control program and a GTAW power supply. The control program has two functions; the first

is real time monitoring of welding current and voltage. The second is the weld process program. The weld process program establishes the weld pass creation and sets up welding speed among other parameters. Fig. 4 shows control program.

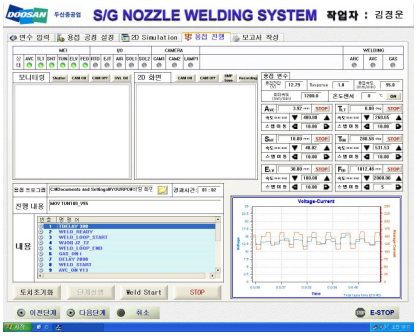
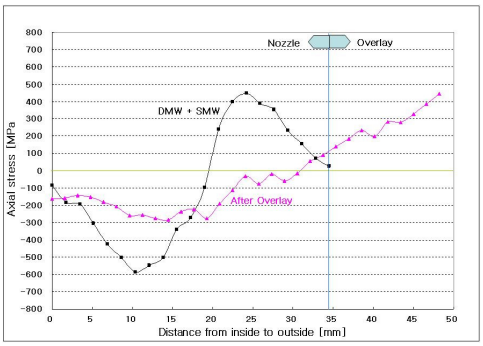


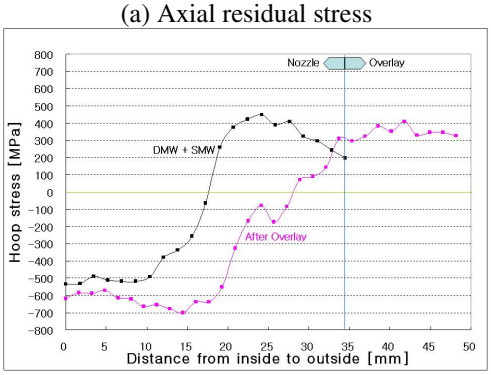
Fig. 4. The Control Program

2.3 The Analysis of Residual Stress

The purpose of a weld overlay is to change the residual stress of the inner pipe wall of dissimilar metal welds. It also reinforces structural strength through added weld thickness. More specifically, weld overlay changes the residual stress of the inner pipe wall of dissimilar metal welds from tensile stress to compressive stress. [6] To determine the amount of residual stress change, analysis of the residual stress in a safety nozzle was performed using Sysweld. Fig. 5 shows the result of residual stress after weld overlay.



(a) Axial residual stress



(b) Hoop residual stress

Fig. 5. Residual Stress Analysis Results

2.4 The Mockup Test

The mockup test was performed using the developed weld overlay system. Fig. 6 shows the safety nozzle mockup. The welding position for the mockup was 6G. The welding direction of the weld overlay was from nozzle to pipe. From the mockup test, shown in Fig 7, the ease of weld processing was confirmed and the performance of weld overlay system was evaluated.

Fig. 6. Safety Nozzle Mockup

Fig. 7. Mockup Test Setup

3. Conclusion

The overlay welding technology for alloy 600 dissimilar welds in pressurizer nozzle was developed. From the weld overlay mockup test, sound weldability was confirmed.

The next plan is to optimize the weld process and the weld overlay system.

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[5] ASME Code, Code Case N -740-2 : Full Structural Dissimilar Metal Weld Overlay for Repair or Mitigation of Classes 1, 2, and 3 Items, Section XI, Division 1

[6] Material Reliability Program: Technical Basis for Pre-emptive Weld Overlays for Alloy 82/182 Butt Welds In PWRs (MRP-169), EPRI, Palo Alto, CA: 2005.