Application of High-Frequency Needle Peening Treatment on Austenite Stainless Steels

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1. Introduction

High-frequency needle peening (HFNP) is one of the promising technique in surface and subsurface treatment using ultrasonic particularly welded structure such as aerospace, automobile, heavy industry, and intensive energy generating system [1,2]. During the process, high-frequency ultrasonic oscillations (over 20 kHz frequency) are applied through needles to the surface of metallic materials then eliminate tensile stresses and introduce compressive stress as shown in Fig. 1. Also the plastic deformation is applied to surface layers leading the reduction of grain size, microstructural refinement, and geometrical modification [3]. This brings about high strength, fatigue life, corrosion and wear resistance. Similar techniques such as shot peening, laser shock peening, and cavitation peening are introduced previously [4]. But compared to those techniques, HFNP has advantages on high productivity, low cost, better mobility with light weight components, and good flexibility of working on different types of welds in various attitudes and cleanliness. Owing to the advantages of HFNP, it is expected to be used in nuclear industry such as pressure vessels, dry storage canisters, etc .

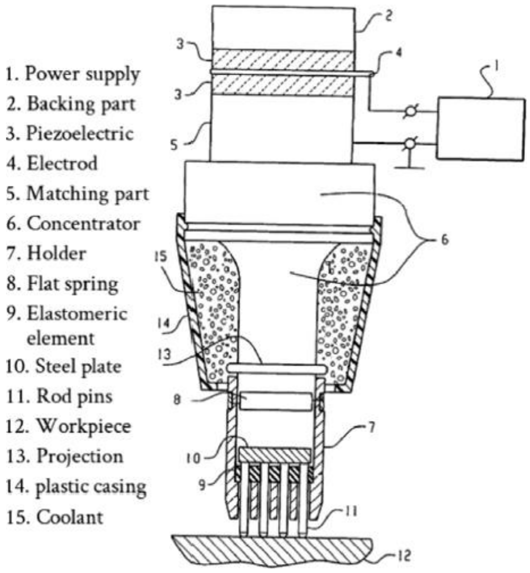

Fig. 1. Schematic drawing on a HFNP tool for surface and subsurface treatment [1].

Regardless of those advantages, its application in nuclear industry is barely reported. This is owing to the lack of comprehensive understanding on the underlying mechanism of HFNP, metallurgical effects, mechanical effects, and corrosion behavior in aggressive environments. In this study, we prepared gas tungsten arc welded (GTAW) 304L specimen and performed HFNP on both base metal and weld. Its residual stress is measured by X-ray diffraction (XRD) methods. And, for the application in nuclear engineering its physicochemical properties such as corrosion characteristics will be examined.

2. Methods and Results

2.1 Preparation of Materials

AISI 304L austenite stainless steel plate with the size of 155 × 160 × 25 mm^3 is used as shown in Fig. 2. Prepared plates were 3-pass welded by GTAW method with 220A, 13V. As a protection gas, pure Ar gas is used. Approximate heat input was 25 kJ/cm. After the welding process, the half of the surface was treated by HFNP as displayed in Fig. 3.

Fig. 2. Photographs of the welded specimen and magnified images on the surface of with and without HFNP treatment

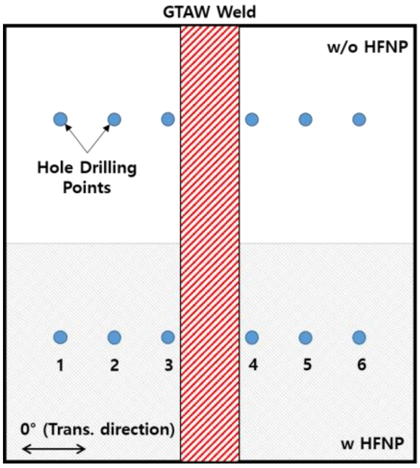

Fig. 3. Schematic diagram of GTAW 304L and the region of treated with XRD analysis points (Blue dots and numbers)

Fig. 4. Photographs of XRD residual stress measurement instrument

2.2 Residual Stresses

Xstress 3000 and G3 (Stresstech Oy, Finland) were used to analyze transverse and longitudinal residual stress formed on the surface. The specification for the tests were EN 15305 (2008) and ASTM E2860-12. Voltage and current of X-ray was 30 kV and 9 mA. Collimator was in size of 3 mm, measuring mode was modified chi. Diffraction angle was 148.9^o (Austenite, 311).

Fig. 5. Illustrates the residual stress profile of the samples. In general, tensile stress near the weld region is higher than that of base metal region. In Fig.5(a), tensile stress on transverse direction is eliminated and approximately -400 MPa of compressive stress is introduced. Likewise, in Fig. 5(b) similar trend is observable – introducing compressive stress on longitudinal direction by HFNP treatment. From the results, it can be concluded that HFNP can be successfully applicable for stainless steels.

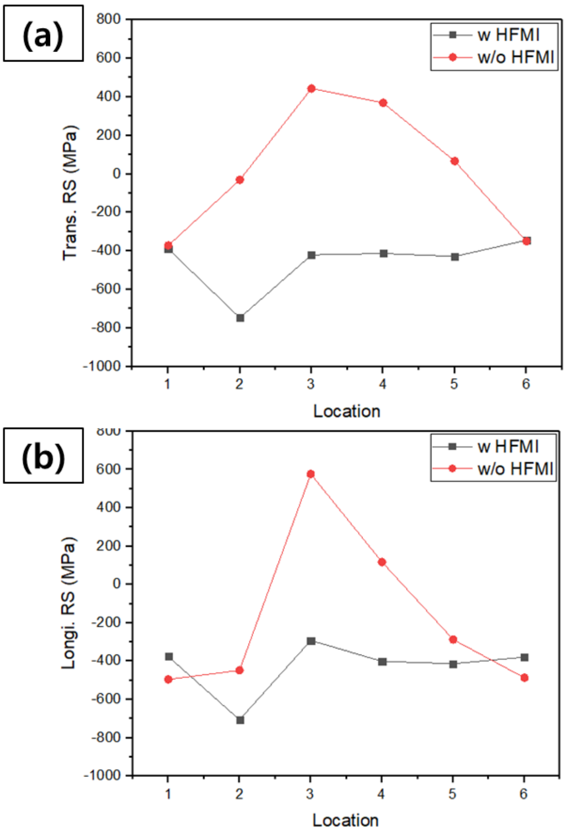

Fig. 5. Measured residual stress with and without HFNP in (a) transverse and (b) longitudinal direction

2.3 Corrosion Characteristics

For the characterization of corrosion properties, untreated and treated base metal samples are prepared. For the galvanic tests, the interface (treated/untreated) samples are also prepared. The characterization of corrosion will be carried out by electrochemical techniques.

3. Conclusions

In this study, effects of HFNP on 304L stainless steel are analyzed by XRD method. Both transverse and longitudinal residual tensile stresses are successfully eliminated and comprehensive stress is introduced. Thus, HFNP can be a good countermeasure for the degradation induced by surface and subsurface tensile stress such as stress corrosion cracking. However, it is essential to examine effects of HFNP on metallurgy, physicochemical properties, mechanical properties, and corrosion behavior. Corrosion characteristics including galvanic corrosion between untreated and treated surface will be examined.

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