Tensile Strength Measurement of the Diffusion Bonded SS316L for PCHE by Digital Image Correlation

DaeYoung Kim [a], Jong-Bae Hwang [a], Injin Sah [a], Eung-Seon Kim [a*]
[a]*VHTR Tec. Dev. Div., Korea Atomic Energy Institute, 111 Daedeok-daero 989 beon-gil, Yuseong-gu, Daejeon, 34057, Republic of Korea.*
[*]*Corresponding author: kimes@kaeri.re.kr*

1. Introduction

The noncontact measurement is an attractive method for materials used in the nuclear industry. Digital Image Correlation (DIC) can be one of the promising noncontact method to measure the displacement. DIC measures the strain to see the full field distribution on the surface optically. To see the application of nondestructive measurement, we used the diffusion bonded SS316L used in Printed Circuit Heat Exchanger (PCHE) material. PCHE is the compact heat exchanger of a stacked and a diffusion bonded under high pressure and temperature for a nuclear power plant [1]. In this work, the tensile strength of the diffusion bonded and the as-received SS 316L were measured by DIC measurement to see the quality of the results.

2. Methods and Results

In this section, Diffusion bonding and DIC measurement procedures are described. The stress-strain results of the metals are included.

2.1 PCHE

The narrow printed circuit of the metal plate make the heat exchanger smaller and lighter than a shell and tube type heat exchanger [2]. Such narrow circuit was manufactured by chemically etching method. The manufactured plates are stacked and diffusion bonded with high pressure and temperature.

2.2 SS316L Diffusion Bonding

SS316L plate (202 mm × 200 mm × 1.5(T)) were stacked and diffusion bonded under high pressure (10 MPa) and high temperature (1050 ℃) for an hour with 1.0×10^{-6} Torr. To optimized the diffusion bonding behavior, the etching was not performed.

2.3 Digital Image Correlation

An 2D image correlation system from LAVision, with a 4 MPixel digital camera, was used to record the surface of an as-received and the diffusion bonded SS316L.

DIC measurement needs the speckles on the surface of the specimen. When the speckles move by the tensile test, DIC camera capture the movement of speckles and calculated the displacement. The speckles could be generated by a spray or a stamp. The speckles by the spray was too small to measure the displacement of the specimen and the error could be occurred in this work. The stamp was applied to generate the speckles that is appropriate in our measurement system.

The speckles should be uniform diameter, high random distribution, and some densities on the specimen surface. To check the optimum speckles, 8 different stamps were used with some speckle diameter (0.1, 0.2, 0.3 mm) and density (30, 50, 70%). The reliability of the stamps was evaluated by SIGMA. SIGMA was calculated in the 2D-DIC software and evaluate the quality of speckles. The high SIGMA value represents uncertain of results. Therefore, SIGMA should be minimized.

Fig. 1 shows the SIGMA value at various stamps. The Low speckle coverage (30%) has higher SIGMA value. The optimum diameter and density was 0.2 mm and 50% respectively.

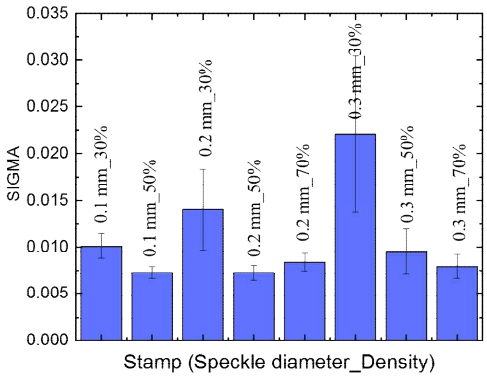

Fig. 1. SIGMA value from the 8 different stamps with 0.1, 0.2, 0.3 mm speckle diameter, 30, 50, 70% density, and 90% randomness generated by speckle generator.

2.4 Tensile Strength Measurement

The black speckles were generated to maximize the contrast on the specimen surface under the white background. The maximized contrast reduces the measurement error. The tensile tests were performed at a strain rate of 0.6 mm/min by Instron 5867 using as-received and diffusion bonded SS316L.

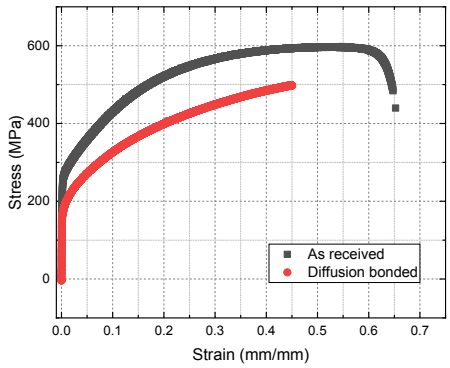

Fig. 2. Stress-Strain curve of as-received and diffusion bonded SS316L measured by digital image correlation.

Fig. 2 shows stress-strain curve of as-received and diffusion bonded SS316L measured by DIC. Ultimate tensile strengths of as-received and diffusion bonded one is 595 and 497 MPa, yield tensile strengths were 258, 170 MPa, and Strain were observed 0.64 and 0.45 respectively. Unlike the as-received SS316L, diffusion bonded has lower strain and it is broken in diffusion bonded area as shown in Fig. 3. The UTS of diffusion bonded SS316L meet the ASME code minimum value (min. 485 MPa).

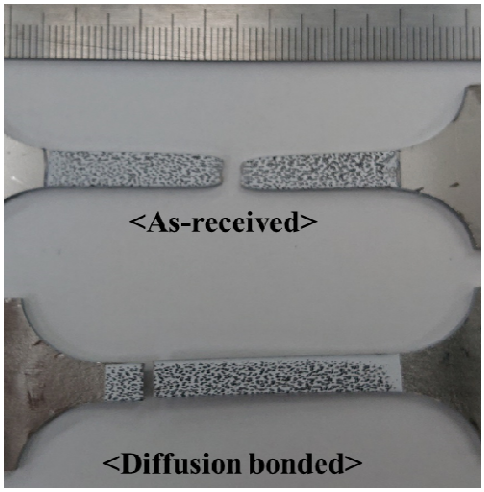

Fig. 3. The broken as-received and diffusion bonded SS316L after the tensile strength measured (Black speckles on the white background).

3. Conclusions

The tensile strength of diffusion bonded SS316L for PCHE were measured by noncontact measurement technique of DIC. The optimum speckle size and density were confirmed by SIGMA value in this DIC system. The ultimate tensile strength of diffusion bonded SS316L satisfy the ASME minimum specified tensile strength (485 MPa) under 10 MPa pressure and 1050 ℃ for an hour with 1.0×10^{-6} Torr.

REFERENCES

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[2] A. J. Jeon, T. J. Yoon, S. H. Kim, H. J. Kim and C. Y. Kang, Effect of Bonding Temperature and Bonding Pressure on Deformation and Tensile Properties of Diffusion Bonded Joint of STS304 Compact Heat Exchanger, Journal of Welding and Joining, Vol. 32, p. 385, 2014.