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EVALUATION OF UIT ON TITANIUM ALLOY RESIDUAL STRESS ELIMINATING BY ULTRASONIC RESIDUAL STRESS MEASUREMENT SYSTEM

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Abstract. Residual stress of titanium alloy welded structure is in a high tensile stress state, it reduces the reliability and mechanical property of the components. Ultrasonic impact treatment technique is developed to relieve residual stress. In this paper, ultrasonic impact treatment is employed to eliminate titanium alloy welding residual stress. A titanium alloy TA-15 butt weld joint is taken as a sample. Longitudinal weld residual stress distribution along the weld bead before and post ultrasonic impact treatment are evaluated by self-developed ultrasonic residual stress measurement system base on acoustoelaticity of critically refracted longitudinal wave. The residual stress distribution of weld joint after ultrasonic impact treatment was analyzed. High tensile stress near the weld bead change into a lower tensile state, the effect of ultrasonic impact treatment is obviously. Combining the characteristics of ultrasonic residual stress measurement system, the use of ultrasonic residual stress measurement system on real-time monitoring the welding residual stress elimination by Ultrasonic impact treatment method is proposed in production.

1. INTRODUCTION

Titanium alloy has advantages in high yield stress with less density, excellent mechanical property, corrosion resistance, good cryogenic property. They are mainly used in aero engine, structure of rocket and missile, and other fields.

Welding is a very important process in manufacturing titanium alloy components. With high yield stress, the welding residual stress in titanium alloy is very high. It reduces the reliability and mechanical property of the components. So, residual stress in components should be eliminated to a low level, or compression stress.

Ultrasonic impact treatment (UIT) is a common post weld treatment. It's effective on local stress intensification and eliminating residual stress. It can reduce the factor of stress concentration by improving the shape of weld joint. Change metal surface stress distribution into a compression stress state. Enhance metal surface strength and the fatigue resistance of the joint [1]. Ultrasonic impact treatment (UIT) using high speed instant impact energy to heat up the joint surface temperature to about 600 °C in one moment, and cool immediately. The high frequency energy enters the weld bead, metallurgical structure in surface area changes [2]. Its characteristic is as follows [3]:

(1) High tension stress in the weld bead is changed into a compression stress state. And the fatigue endurance of the joint is enhanced greatly.

(2) Grain in metal surface is refined. Plastically deforming layer is created. So the surface strength and hardness are heightened.

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Fig. 1. HY2050 ultrasonic impact treatment equipment.

(3) Improve the shape of the weld toe. Reduce the stress concentration factor of the joint.
(4) Change metal surface stress distribution. Eliminate welding deformation.

Using ultrasonic impact treatment as post weld treatment of titanium alloy can enhance the performance. It is beneficially for titanium alloy components.

This paper reports ultrasonic impact treatment to eliminate residual stress of titanium alloy TA-15 abutting joint, and and duscusses the measurements of its residual stress both before and after welding by self-made ultrasonic residual stress measurement system to evaluate its effect.

2. EQUIPMENT

The HY2050 ultrasonic impact treatment equipment is used (Fig. 1), to eliminate residual stress of titanium alloy TA-15 abutting joint. Its performance parameter is as follows:

Normal frequency: 20 kHz
Maximum amplitude: 50 μm
Process speed: 20-50 m/h

Welding residual stress should be measured both before and after ultrasonic impact treatment, so self-develop ultrasonic residual stress measurement system is employed to survey its residual stress.

The state key laboratory of welding in Harbin institute of technology developed ultrasonic critically refracted longitudinal wave residual stress nondestructive measurement system based on acoustoelaticity [4-6] for two-dimensional stress field (Fig. 2).

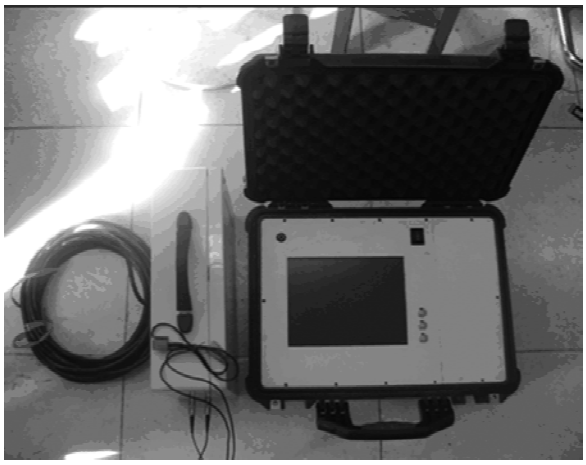

Fig. 2. Ultrasonic stress measurement setup.

This system uses longitudinal critically refracted (Lcr) waves which is sensitive to stress. This system can survey two-dimensional stress in the surface area of metal non-destructively and rapidly.

The residual stress of many weld joints with different material and welding process were measured by this system, and the results were contrasted with the data obtained by laser holography orifice method, slitting method and finite element method. They are match well. This proves that the survey result of this self-developed residual stress system is accurate in residual stress measurement. It is applied in monitoring some new welding deformation controlling methods like pre-stretching method, electromagnetism impact method, peening, and rolling method, *etc.* [7-10]. It is also applied in high-speed train carriage production, made contribution to optimizing welding procedure, obtained a good effect [11].

3. EXPERIMENT

The sample plate is a titanium alloy TA-15 butted joint. Its size is 300 mm in length, 200 mm in width, 2.8 mm in thickness. Eliminating residual stress by ultrasonic impact treatment is shown in Fig. 3. Evaluating its effect was carried out by self-developed residual stress measurement system.

Measure the butted joint residual stress with self-developed residual stress measurement system after welding first. Then fix the sample on workbench. peen it to eliminate residual stress by HY2050 UIT equipment. Impact the joint reiteratively to make sure that the high tension stress area is all impacted. When finish peen, measure the sample's residual

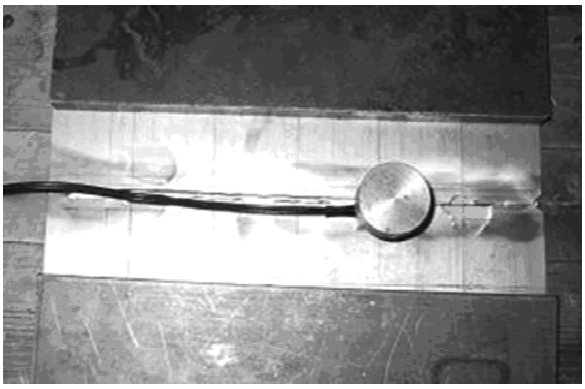

Fig. 3. Ultrasonic impact treatment and residual stress measurement.

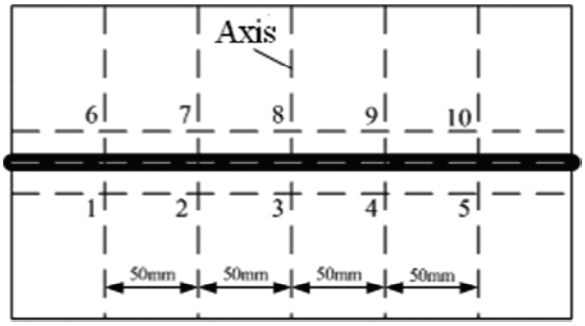

Fig. 4. Position of residual stress measurement.

stress at the same position with it before impact again.

4. RESULT

Measuring the residual stress with self-developed residual stress measurement system before and after impact were done at the same position. The survey position is shown in Fig. 4.

The longitudinal residual stress distribution along the axis which is perpendicular to the weld is measured. Set the center of weld bead as zero, spacing distance is 10 mm. The result is shown in Fig. 5.

Because of the excess weld metal, the residual stress can't be measured. So the variation of residual stress in toe zone was discussed to analyze the effect of ultrasonic impact treatment.

Residual stress distribution along axis is shown in Fig. 5. It showed that the whole residual stress became much lower obviously after ultrasonic impact treatment. But in the position near weld bead, tension stress still existed. Impacting the joint again, then measuring residual stress at the position numbered 1 to 10 shown in Fig. 5. These positions are all in high tension welding residual stress area. The result is shown in Fig. 6.

Fig. 6 shows that welding residual stress in toe area is high tension stress, residual stress in some

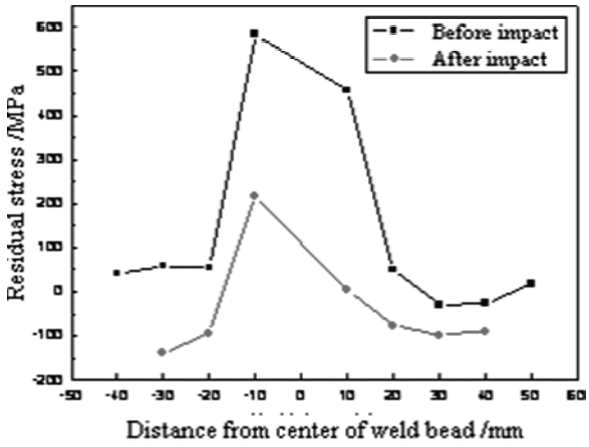

Fig. 5. Longitudinal residual stress distribution before and after ultrasonic impact on centerline.

position can reach to 70-80% yield strength. After ultrasonic impact treatment, residual stress in most of the position alter to compression stress, few positions exhibit a very low tension stress state. High tension residual stress is eliminated, whole residual stress state drops to a low level. But its distribution is not so smooth, that's due to unevenly impact.

5. CONCLUSION

(1) It's feasible to use ultrasonic impact treatment as a post weld treatment on titanium alloy TA-15 light gauge welding joint. It can decline the welding residual stress dramatically and alter tension welding residual stress into compression stress which is good for mechanical property of components.

(2) Ultrasonic impact treatment is not steady. Its effect depends on treatment time. And because of lack impact or un-impact, there may be some place still with high tension residual stress un-impacted.

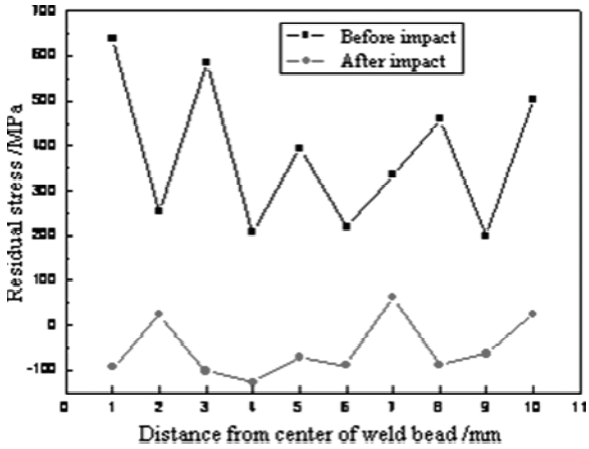

Fig. 6. Longitudinal residual stress distribution near weld bead before and after ultrasonic impact.

So it is necessary to elevate impacting effect rapidly and non-destructively after treatment to confirm the residual stress being declined to a low level evenly.

(3) Self-developed ultrasonic residual stress measurement system has its advantage in accuracy, non-destruction, rapidity and convenience. It is suitable for evaluating the effect of eliminating residual stress of titanium alloy weld joint by ultrasonic impact treatment.

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