MATEC Web of Conferences **142**, 03004 (2018) https://doi.org/10.1051/matecconf/201814203004
ICMAE2017

Effects of Ar and He on Microstructures and Properties of Laser Welded 800MPa TRIP Steel

Wen-Quan Wang[1, *], *Shu-Cheng* Dong[1], *Fan* Jiang [1], and *Ming* Cao [1]

[1]School of Material Science and Engineering, Jilin University, Changchun, PR China

Abstract. Fiber laser welding of cold rolled TRIP steel (transformation Induced Plasticity steel) sheet with tensile strength of 820MPa and thickness of 1.4mm was carried out using shielding gases Ar and He, respectively. For the same laser power and welding speed, the effects of different shielding gases on penetration and bead section morphologies were investigated. The microstructures and properties of the TRIP steel joints were also studied. The investigation showed that higher penetration and lower porosity could be obtained under shielding gas He using the same laser power and welding speed. The microstructures of the TRIP joint mainly included martensite and retained austenite. But the joint microhardness and tensile strength were higher under the shielding gas He. The tensile strength of the welded joint perpendicular to the weld line was equal to that of the base metal. But the tensile strength of the joint parallel with the weld line was higher than that of the base metal. The plasticity and formability of the welded joint were impaired due to the formation of martensite in the weld metal.

1 Introduction

Weight reduction of automobiles is one of the effective measures for decreasing gas consumption and minimizing environmental pollution on the premise that safety provisions are guaranteed. It was estimated that 10% of weight reduction generally may bring about 5% less of gas consumption [1]. Therefore, these years light metal materials such as Al alloys and Mg alloys have been increasingly used in automobile industry. But the high cost of manufacturing all light metal car body has greatly limited the usage expansion. During the past years, ultra-high strength steels (UHSS) such as transformation induced plasticity (TRIP) steels and dual phase (DP) steels were increasingly applied in automobile industry due to their good combination of high strength and formability. The excellent mechanical properties of TRIP steel mainly contribute to the ferrite matrix, for ductility, bainite, for strength, and retained austenite, for uniform elongation produced by martensite transformation from austenite when subjected to external tensile stress. For the sake of the superior properties of TRIP steel, thinner steel sheets can be adopted for the same strength

[*] Corresponding author: wwq@jlu.edu.cn

requirement to reduce the vehicle weight but improve the vehicle performance at the same time [2-5].

Recently, laser cutting and welding technology has been increasingly used in automobile and its components supplier industries [6-8]. Laser beam welding (LBW) is considered as an optimal joining alternative for its high quality, high productivity and low thermal deformation. In this paper, microstructural characteristics and mechanical properties of fiber laser welded TRIP steel sheet with tensile strength of 820MPa were investigated to provide some fundamental knowledge about laser welding TRIP steels for the engineers in automobile industry.

2 Experiment

In this work cold rolled TRIP steel sheet with tensile strength of 820MPa and thickness of 1.4mm was used as base metal. Its chemical compositions and microstructures were shown in Table 1 and Fig.1. The study showed the multi-phase microstructures of the base metal including ferrite matrix plus bainite and a little retained austenite. This was attributed to the heat treatment history of the base metal. Generally, transformation induced plasticity steel was produced by intercritical annealing followed by austempering at the bainite transformation temperature range.

Table 1. The chemical compositions of base metal (wt. %)

C	Mn	Si	S	P	Fe
0.09	1.7	1.0	0.005	0.06	balance

Laser beam welding was carried out with fiber laser system (IPG YLS 4000) under different shielding gases Ar and He, respectively. The focus distance was 180mm and beam size was 0.4mm in diameter. The micro Vickers hardness was measured near fusion zone with a load holding time of 12sec and a load of 3.0N. The specimens for metallographic analysis were prepared following the steps of cutting, grinding, polishing and etching. The microstructures of the weld zone were investigated with scanning electron microscopy (SEM). The phase’s identification was determined by X-ray diffraction (XRD). Tensile tests were conducted under load perpendicular to the weld line and load parallel with the weld line at a crosshead moving speed of 4.5mm/min.

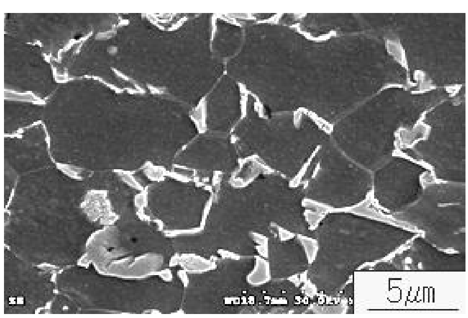


Fig. 1. Microstructures of the base metal

3 Results and discussions

3.1 Effects of shielding gases Ar and He on laser welding of TRIP steel

Fig.2 revealed that the relationship between laser power and welding speed for full penetration under different shielding gases Ar and He. Obviously, with the rise of laser power, the welding speed increased for full penetration. But for the same laser power, higher welding speed can be used under shielding gas He compared with shielding gas Ar for full penetration. This should be attributed to the higher ionization energy of He, which may lead to the increase of laser beam energy density

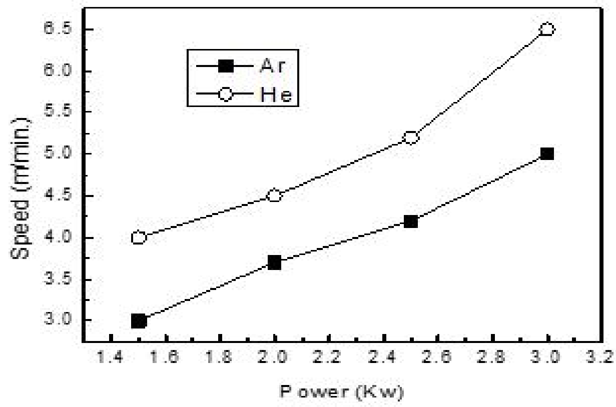


Fig. 2. Relationship of laser power and welding speed for full penetration under Ar and He

In order to understand the effects of shielding gases on bead morphologies, the macrostructure of beads at different welding speed was observed. Fig.3 presented that bead and bead cross-section morphologies at the same welding speed of 4m/min. under shielding gases Ar and He, respectively. The experiments indicated that sound beads could be obtained using proper welding parameters under shielding gases of either Ar or He, as shown in Fig3(a). No obvious difference for bead surface was detected under different shielding gases. But the porosity rate was higher for the TRIP joint under shielding gas Ar than that under He. For fiber laser welding of TRIP steel, the weld bead cross-section of full penetration joint presented drum shape with wide upper and bottom part but narrow middle part. For the same welding speed and laser power, the cross-section of bead under shielding gas He had bigger size compared with that under shielding gas Ar, as shown in Fig.3 (b) and Fig.3 (c). This was associated with high energy density of laser beam in shielding as He. The study also showed that the weld bead cross-section for partial penetration would become trapezoid shape with narrow upper part and wide bottom part with the increase of welding speed or decrease of the laser power, as shown in Fig.4 (b). The further investigation demonstrated that the scope of fusion zone (FZ) and heat affected zone (HAZ) of the TRIP joint would shrink at the same time (Fig.4 (a)).

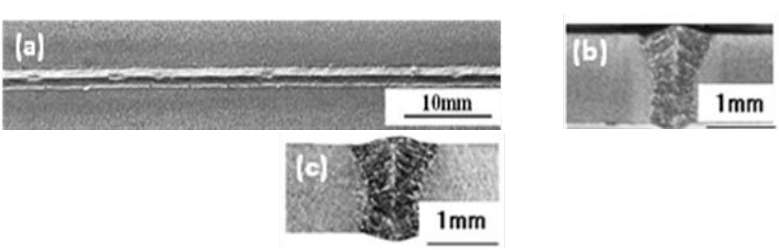
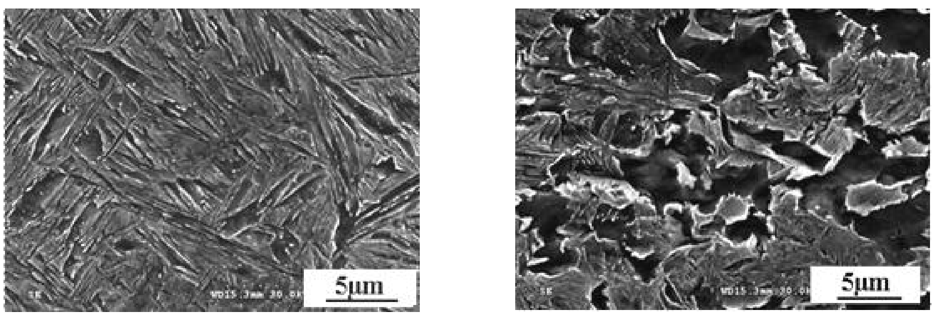


Fig. 3. Morphologies of weld bead and bead cross-section under welding speed of 4.0m/min., shielding gases Ar and He (a) weld bead surface, (b) bead cross-section under Ar, (c) bead cross-section under He

(a) Diagram of bead cross-section (b) 6.0m/min

Fig. 4. Morphologies of bead cross-section at different welding speed

Fig.5 showed the microstructures of different positions at the welded joint at welding speed of 4/min. At the position of weld metal and HAZ near weld metal, the amount of martensite increased rapidly because of high cooling speed, which could contribute to the austenite transformation to martensite, as shown in Fig.5 (a). At the position of HAZ center (Fig.5 (b)), the microstructures included ferrite matrix distributed with bainite and retained austenite. A little martensite could also be detected due to the high heating and cooling speed.



(a) Microstructure of weld metal (b) Microstructure of HAZ center

Fig. 5. Microstructures of different welded joint positions (4m/min)

3.2 Mechanical properties of laser welded TRIP steel joint.

For ultra-high strength steel (UHSS) sheets applied in automobile industry, the hardness of materials is one of critical factors which determine the formability during the process of pressing or stamping. Fig. 6 showed the hardness distribution of welded joint prepared under different shielding gases Ar and He, respectively.

The weld metal and HAZ had maximum hardness, which decreased rapidly approaching the base metal. This hardness distribution could be attributed to the microstructural constitution of various positions at the weld zone. As discussed above, the amount of martensite gradually decreased from the central welding line to the base metal at weld zone. Therefore, the maximum hardness occurred at the fusion zone or HAZ near the fusion zone. In addition, Fig.6 revealed that the maximum hardness at the fusion zone was higher under the condition shielding gas He. This was attributed to the lower porosity rate under shielding gas He. Further, Fig. 6 also indicated that the fusion zone was wider for the same power and welding speed under shielding gas He.

Fig. 7 illustrated the tensile test results under a load parallel with the weld line of TRIP joint prepared under shielding gases Ar and He, respectively. The test showed that both the yield strength and tensile strength of the specimens were a little higher than those of the base metal. The fracture always occurred along the plane vertical to the tensile direction and the fracture surface was like drum shape, with a narrow upper and lower part but a wider middle part, as shown in Fig.8. This meant that the weld metal had different elongation from that of the base metal. In other words, the weld metal has lower elongation than that of the base metal. Further study revealed that the tensile strength of the joint prepared under shielding gas He was higher than that of the joint prepared under Ar. But the yield strength of two kinds of joints had little difference. The analysis to the fracture of the joint indicated that could be explained by higher hardness and lower porosity of the joint prepared under He.

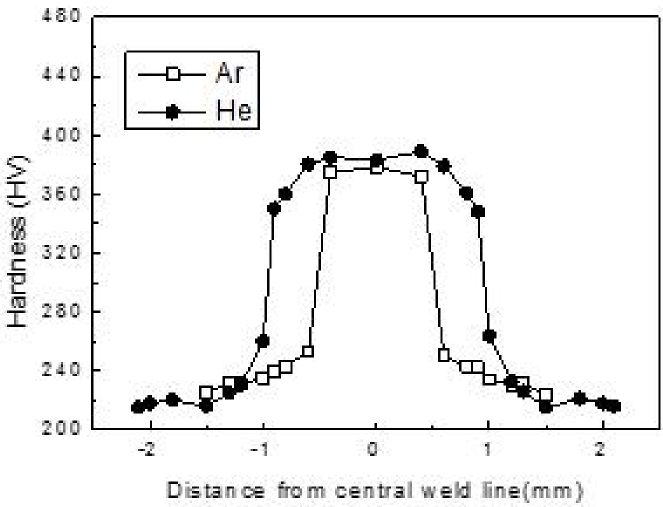


Fig. 6. Hardness distribution at weld zone

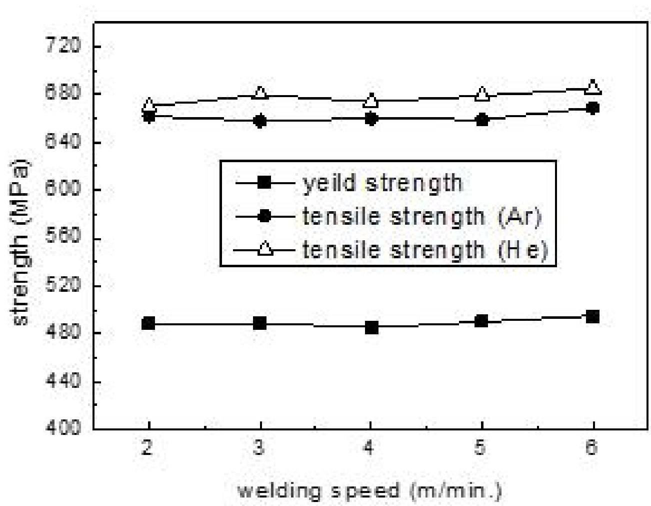


Fig.7. Tensile test of laser welded TRIP joints

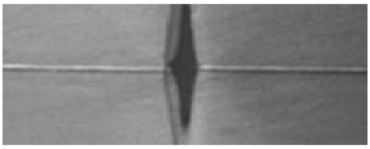


Fig. 8. Laser welded TRIP joint specimen after tensile test

4 Conclusions

(1) Shielding gases He and Ar have different effects on laser welding of TRIP steel sheet. For the same laser power, higher welding speed could be obtained under shielding gas He than that under shielding gas Ar in the case of full penetration. The joint prepared under shielding gas He had lower porosity than that prepared under Ar.

(2) The weld metal of joint mainly consisted of martensite due to high cooling speed. HAZ consisted of martensite, ferrite, bainite and retained austenite. Therefore, the weld metal or heat affected zone near the weld metal had maximum hardness for the whole welded joint.

(3) Both the yield strength and the tensile strength of the welded joint tested parallel with the weld line were a little higher than those of the base metal. The tensile strength of the TRIP joint prepared under shielding gas He was higher than that of the joint prepared under shielding gas Ar. Laser welding decreased the plasticity of TRIP steel joint due to the formation of hard phases.

References

1. H.X. Yin, A. Zhao, X. Li, Int. J. Min. Met. Mater, **22**, 262 (2015)
2. A. Grajcar, M. Różański, S. Stano, A. Kowalski, J. Mater. Eng. Perform, **23**, 3400 (2014)
3. O. Kwon, K.Y. Lee, G.S. Kim, et al, Mater. Sci. Forum, **638-642**, 136 (2010)
4. X.Y. Hou, Y.Q. Wang, R.C. Xu, et al, S. J. R, **4**, 156-161. (2014)
5. C. Seang, A.K. David, E. Ragneau, Physcs. Proc, **41**, 448-459 (2013)
6. L. Romoli, C.A. Rashed, Int. J. Adv. Manuf. Tech, **81**, 563 (2015)
7. X.L. Gao, L.J. Zhang, J. Liu, et al, Mat. Sci. Eng. A-Struct, **559**, 14 (2013)
8. H. He, S. Lin, C. Yang, et al, J. Mater. Eng. Perform, **22**, 3315 (2013)