A Review of Research on DP780 Welded Joint Microstructure and Mechanical Properties

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Abstract. Dual phase (DP) high strength steel have excellent performance of stamping and forming, and has been widely applied in the field of automobile and aerospace. Among them, high strength and good ductility makes DP780 become the ideal material for the auto body, but in the welding process, high strength steels will produce brittle hard weld microstructure, which affects the mechanical properties of the welded joints. Through the domestic and international review about present situation and the measures in DP780 welded joint, the results show that most of the research is to improve the welded joint of DP780 by changing the inclusion density and the heat treatment method, distributing the solder joint reasonably or adding preheating current to change the mechanical properties.

Introduction

The low strength and high thickness of alloy steel were used in traditional automobiles, which resulted in the heavy body and reduced the automobile speed. With the development of society, the lightweight and service safety requirements of people about the automobile body were improved continuously. Duplex steels have better plasticity and toughness than ordinary low-alloy high-strength steels [1]. It can made the lower yield strength ratio cooperated with the better strength plasticity, reduced the quality of the car body, reduced fuel consumption, improved the crashworthiness and protected the environment [2]. So, dual phase (DP) steels have been widely used in the body structure. The paper intends to explore the research status of the microstructure and mechanical properties of DP780. To use the steel with higher strength replace the traditional steel, and meet the demand of people for lightweight and safety.

The combination of soft ferrite and hard martensite in the DP780 steel structure can cooperated with each other, which can guarantee the excellent comprehensive performance of the automobile shell. The soft ferrite provided plasticity, and the hard martensite determined the strength. However, the strength of automobile duplex steels were higher, the DP780 high strength steel were more prone to local necking and fracture failure in the process of bending [3]. According to the literature, the decrease of the overall stiffness of vehicles, the failure of parts and the fatigue damage of welding joints and solder joints during welding was the main reason [4]. Therefore, it have a great significance to study DP780 the welded joint, in order to meet the safety and reliability of the car.

Research Status of DP780 Welding Joint Microstructure

P.F. Huang et al. [5] researched the microstructure and tensile shear strength of DP780 lap joints, which used metal active gas (MAG) welding with different heat input. When at lower heat input, inclusion aggregation appears in the fusion zone of welded joint, which reduced the effective bearing area of joint mechanics and made it become the weak areas. The post welding tempered martensite of DP780 were precipitated cementite particles, which are usually embedded in continuous ferrite matrix. While S.C. Li et al. [6] researched the behavior of microstructure and incision position fatigue crack growth of DP780 of post-weld. As shown in Fig. 1 b, only a part of martensite can be

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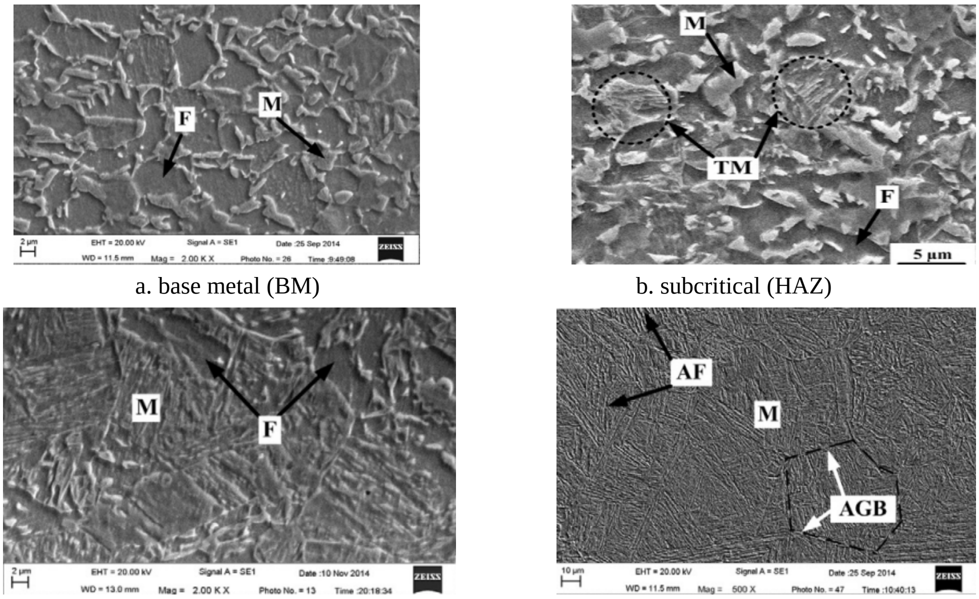
decomposed into tempered martensite (TM). In the process of cooling, the acicular ferrite (AF) grain boundary were less, and the austenitic grain boundary (AGB) were shown early (Fig. 1 d), which leaded the fusion zone (FZ) chemical inhomogeneity and hardness. While the local microstructure and microhardness of the welding material change, it affected the fatigue crack growth behavior and failure mechanism of the whole. Fig. 1 shows the microstructure of DP780 welded joints.



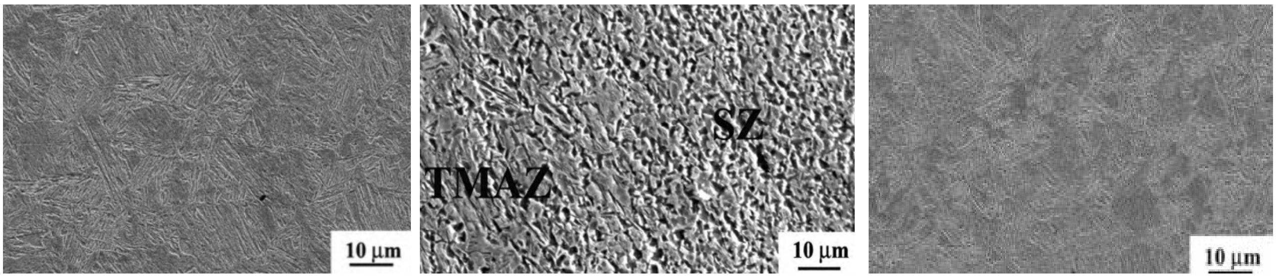
a. base metal (BM) b. subcritical (HAZ)

c. upper critical (HAZ) d. fusion zone FZ

(M: Martensite, F: Ferrite, TM: Tempered martensite, AF: Acicular ferrite, AGB: Austenite grain boundary)

Fig.1 Micrographs showing the microstructure evolution of DP780 weld joint

Fig. 2 showns the microstructure of stir zone（SZ）under different stirring speeds during friction stir spot welding [7], and TMAZ represents the thermo-mechanical influence zone during mixing. At a higher rotation rate than 1000r/min, complete martensite structure was observed in the whole SZ (Fig. 2a). While at a lower rotation speed than 500r/min, SZ was composed of fine biphasic structure of ferrite and martensite (Fig. 2b). The maximum failure load was 18.2kN obtained at an average rotation speed of 1000r/min (Fig. 2c), and fracture occurred at this rotation speed.



a 1500 r/min b 500 r/min c 1000 r/min

Fig.2 Microstructures of SZs

Mechanical properties of DP780 welded joints

Influence of Welding Method on Mechanical Properties of Welded Joints. In the welding process of DP780 steel, under the action of welding heat cycle the mechanical properties of the joint were changed greatly, because of the change of the base metal microstructure and the welding conditions [8]. X.Y. Sun et al. [9] in the resistance spot welding process, established the axial symmetric finite element model of DP780 steel. It was found that the strength of welding joint in the shear direction was much stronger than that in the tensile direction. Therefore, the solder joint is generally arranged in the shear position of the automobile body, in order to improve the mechanical properties of the welded joints and the crashworthiness. S.L. Gao et al. [10] conducted laser welding on DP780 steel. The mechanism of transformation from austenite to martensite was found. The heat affected zone was the largest deformation, and the elongation of DP780 heat affected zone decreased with the decreasing of heat input. L. Yang et al. [11] studied the mechanical properties of laser welded DP780 steel joints under strain rate. Researched the fracture behavior of base metal (BM) and welded joints (WJ). Each group was tested three samples in the range of strain rate (0.0001-1142s^{-1}), and the engineering stress-strain curve under strain rate was shown in Fig. 3. There were significant differences between the quasi-static curve and the dynamic curve. The tensile failure location of DP780 welded joint was sensitive to strain rate. Within the whole strain rate range, with the increase of strain rate, the distance between the failure location and the center line of the weld decreases. The fracture mainly presents as cup-shaped dimple fracture. This typical ductile failure characteristic did not change with the increase of strain rate.

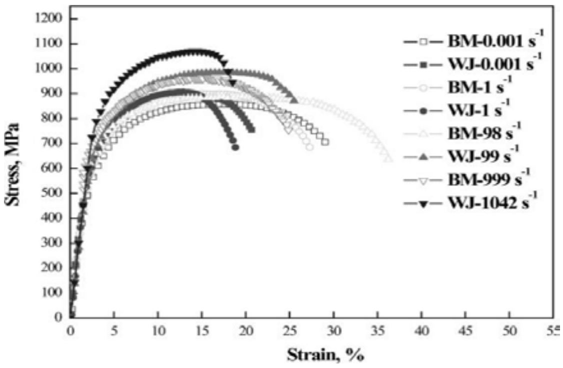


Fig.3 Engineering stress–strain curves of the DP780 BM and WJ at representative

Influence of Annealing Method on Mechanical Properties of Welded Joints. A. Ghaheri et al. [12-13] studied the mechanical properties of DP steel at different annealing temperatures. Annealed directly and continuously at 800℃, 770℃, 750℃ and 725℃, it concluded that the optimum mechanical properties critical temperature of DP steel is 725℃. Z.P. Xiong et al. [14] conducted the microstructure annealing of cold rolled ferrite pearlite structure. Then quenched it in water to obtain ferrite-martensite DP steel structure, and annealed short-term at a low temperature. Finally, the DP steel with excellent ductility was produced by water quenching. H. Ashrafi et al. [15] found that the Avrami exponent was 0.56, so the annealing temperature could affect the transformation process of ferrite. Furthermore, DP steel with good properties were obtained. J.F. Hu et al. [16] found that with the increase of annealing temperature, under the various of rapid cooling conditions, the yield strength and tensile strength curve showed a tendency of rising first and then decreasing. So the two conditions of annealing temperature and cooling rate cooperated with each other, to improve the mechanical properties of welded joints of high strength steel.

Conclusion

Compared with ordinary steel, DP780 steel have high weight loss potential and good mechanical properties. However, different fracture modes will occur in the high strength steel forming process, and brittle and hard microstructure will also occur in welding process. So when choosing welding methods and changing welding conditions, try to avoid excessive density inclusions or concentration of inclusions. In addition, different annealing methods can also be used. The mechanical properties of welded joints can be improved by controlling the annealing temperature or cooling rate.

Welding joints were prone to failure and fracture in the fusion zone, and the distribution of the solder joint will also affected the high strength steel mechanical properties during welding. Therefore, it is necessary to consider the welding situation of each welded joint area and the reasonable distribution of solder joints.

The shear strength of welded joints can be strengthened by adding preheating current, or increasing tempering current before welding. However, intergranular fracture of surface crack, risk of edge fracture and transgranular fracture of internal crack will occur in the welded joint. These problems could also be solved by adding preheating current.

In order to improve the microstructure and mechanical properties of DP780 steel, most of the current researches focused on the numerical simulation of welding. However, there are few studies on material improvement of DP780.

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