The Microstructure and Mechanical Properties of Aluminum/Steel Composite Plates Controlled by Rheological Cast-Rolling and the Rolling

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Abstract: In this study, a new idea of prefabricated diffusion layer to improve the mechanical properties of composite plates is proposed. The results indicate that the metallurgical mechanical bonding formed by rheological cast-rolling + rolling can enhance the mechanical properties of the composite plate, and the shear strength and tensile strength under 50% reduction are as high as 105.0 MPa and 342.7 MPa, respectively. The mechanism analysis shows that cracks are formed in the diffusion layer along the normal direction during rolling, and the diffusion layer and the matrix always maintain good metallurgical bonding. The crack gaps of the diffusion layer are small when the reduction is 20%, and the soft matrix cannot enter the gaps to form secondary metallurgical bonding. The residual compressive stress is the main reason for the increase in shear strength. The aluminum matrix is recrystallized and refined when the reduction is 50%, the crack gaps of the diffusion layer increase, the fresh metal is squeezed into the gaps, the matrix re-forms metallurgical bonding. The broken intermetallic compounds and the matrix simultaneously form a mechanical lock and a metallurgical bonding, and the shear strength and tensile strength increase. The thickness of the diffusion layer increases, the unfilled crack gaps increase, the residual compressive stress of the matrix around the diffusion layer decreases, the shear strength decreases significantly, but the tensile property changes little.

Keywords: Prefabricated diffusion layer; Rheological cast-rolling; Rolling; Aluminum/steel composite plate; Shear strength; Metallurgical mechanical bonding

1 Introduction

Aluminum/steel bimetal is a typical bimetal composite material that combines aluminum alloy and steel through a certain mechanical or metallurgical method [1]. However, the preparation of high performance aluminum/steel bimetals is widely recognized as a challenge.

Semi-solid processing temperature is low, low solidification shrinkage, low slurry flow, low requirements for equipment cooling capacity [2]. This is very beneficial for controlling diffusion layer growth and stabilizing production. In this paper, the aluminum/steel composite plates with different thicknesses diffusion layers are prepared by rheological cast-rolling technology.

2 Experimental procedure

The quantitative aluminum alloy ingots were melted in the SG2-7.5-10 well crucible melting furnace. When the temperature reached 730 ℃ then refining, degassing, slag removal. Following the aluminum alloy temperature being controlled to 680 ℃, flowed through the inclined plate to prepare semi-solid slurry, the temperature of inclined plate outlet was 645 ℃ (50% solid phase temperature). Before preparing the slurry, the cleaned steel plate was placed in a mold preheated at 645 ℃. After all the slurry was poured on the surface of the steel plate, the isothermal diffusion was carried out at 645 ℃ for 30 s, 60 s, 120 s, 180 s and 300 s. Isothermal diffusion was followed by rheological cast-rolling, followed by air cooling. The process is shown in Fig.1 (a). The aluminum/steel composite plate prepared by rheological cast-rolling was cut into 60 mm×60 mm×5.5 mm small squares and then rolling (Fig.1 (a)), The reduction was 20% and 50% respectively.

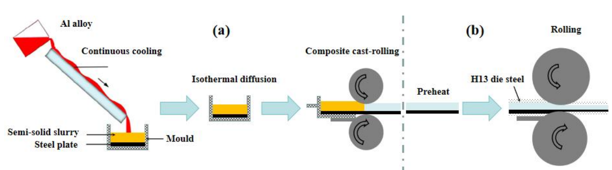

Fig.1 Schematic diagram of preparation process: (a) rheological cast-rolling; (b) rolling.

3 Result and discussion

Mechanical Properties

It can be seen that the ultimate tensile strength and uniform elongation of composite plates increased first and then decreased with the extension of isothermal diffusion time, but the change was little (Fig.2). This was mainly related to the aluminum matrix microstructure, aluminum matrix microstructure was fine and roundness at isothermal diffusion 60 s. The transverse direction ultimate tensile strength and uniform elongation of composite plates were higher than the rolling direction under different isothermal diffusion times. There may be two reasons: there were more cracks in the diffusion layer in the rolling direction than in the transverse direction, so the rolling direction ultimate tensile strength was lower than that in the transverse direction; In the rolling process, the deformation in the rolling direction was greater than that in the transverse direction, and the degree of work hardening of rolling direction was higher, so the transverse direction elongation was higher than that in the rolling direction. Fig.2(b) shows the ultimate tensile strength and uniform elongation of composite plates at 50% reduction under different isothermal diffusion times. The rolling and transverse direction ultimate tensile strength and uniform elongation reached the maximum, were 337.5 MPa, 342.7 MPa and 1.7% and 2.0%, respectively.

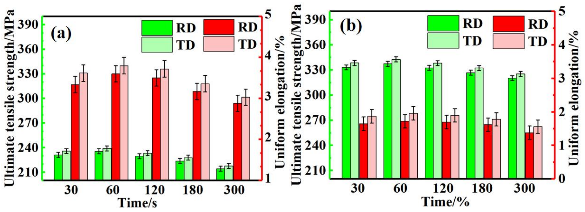

Fig.2 Tensile properties of composite plates under different parameters: (a) ultimate tensile strength and uniform elongation of composite plates at 20% reduction under different isothermal diffusion times; (b) ultimate tensile strength and uniform elongation of composite plates at 50% reduction under different isothermal diffusion times.

It can be seen that the shear strength decreased continuously with the extension of isothermal diffusion time (Fig.3). The rolling and transverse direction shear strength of composite plates decreased from 78.2 MPa and 81.8 MPa at isothermal diffusion 30 s to 52.6 MPa and 54.0 MPa at isothermal diffusion 300 s, respectively (Fig.3(a)). This shows that the thickness of the prefabricated diffusion layer had an important effect on the subsequent rolling treatment. It is found that the transverse direction shear strength was slightly higher than the rolling direction shear strength under different isothermal diffusion times, which may be related to the uneven deformation in the transverse and rolling directions. Fig.3(b) shows that the shear strength of the composite plate at 50% reduction under different isothermal diffusion times. The rolling and transverse direction shear strength decreased from 100.3 MPa and 105.0 MPa at isothermal diffusion 30 s to 73.3 MPa and 74.4 MPa at isothermal diffusion 300 s.

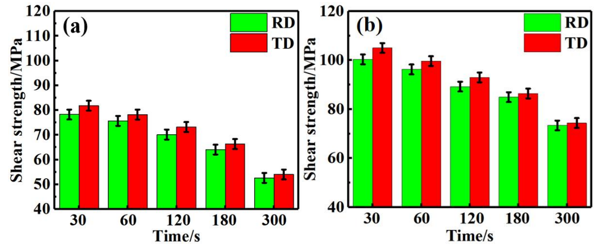

Fig.3 Shear strength of composite plates under different parameters: (a) shear strength of composite plates at 20% reduction under different isothermal diffusion times; (b) shear strength of the composite plates at 50% reduction under different isothermal diffusion times.

4 Conclusion

The prefabricated hard and brittle diffusion layer significantly improves the bonding properties of composite plates. The transverse and rolling direction shear strength reach 105.0 MPa and 100.3 MPa, respectively.

The tensile properties of the composite plate are mainly determined by the matrixes and affected by the bonding properties of the diffusion layer. The rolling and transverse direction ultimate tensile strength and uniform elongation are 337.5 MPa, 342.7 MPa and 1.7% and 2.0%, respectively.

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