Modeling and Experimental Study of Cu/Al Clad Sheet by Twin-Roll Casting

Zhiping Mao[1,2,*], Jingpei Xie[1,2], Aiqin Wang[1] , Pei Liu[1], Douqin Ma[1,2]
1. School of Material Science and Engineering, Henan University of Science and Technology, Luoyang, China
2. Collaborative Innovation Center of Nonferrous Metals, Henan University of Science and Technology, Luoyang, China, 471003
*Corresponding address: e-mail: zpmao@haust.edu.cn

Abstract: A mathematical model of Cu/Al clad sheet by twin-roll casting was developed to study the influences of casting parameters on temperature field of cast-rolling process. The effect of the casting speed, casting temperature of melt, and roll gap on the flow and temperature field was predicted. Meanwhile, the microstructure of Cu/Al clad sheet interface was studied.

Keywords: Mathematical model, Cu/Al clad sheet, Twin-roll casting.

1 Introduction

The Cu/Al clad sheet can use aluminium to instead of most copper, which not only reduce the total material cost, but also has good electrical and thermal conductivity. It is more wildly applied to the fields of building, electric-power, chemical and so on [1-3]. Many kinds of developed techniques can fabricate the clad sheets, such as rolling bonding [4], explosive cladding [5], cast cladding [6] and friction-stir welding [7]. Among these composite techniques, twin-roll casting (TRC) has many advantages such as shorter production routines, lower capital investment, low production cost, etc. [8]. It can be modified for the TRC process to produce many clad metals. The interface of metal layered composite materials is particularly critical to their performance [9]. Mechanical properties of the clad sheet depend on the quality of interface layer, which is influenced by temperature at the interface and compressive stresses from the roll force [10].

For the complex situation of TRC, mathematical and numerical simulation methods are widely used to describe the distribution of temperature and flow inside the TRC area. Plenty of researchers use simulation software to study the relationships between the main process parameters and field of temperature and flow in the TRC process [11,12]. However, further research is needed on the influence of key process parameters on the heat flux field of horizontal cast-rolling of copper aluminum composite plates. In this paper, a mathematical model of Cu/Al clad sheet by twin-roll casting was developed to study the influences of casting parameters on temperature field of cast-rolling process. The effect of the casting speed, casting temperature of melt, and roll gap on the flow and temperature field was predicted. The Cu/Al clad sheets with different thicknesses were produced by horizontal twin roll caster. Simultaneously analyzed the influence of different TRC process parameters on the interface layer structure of copper aluminum composite plates.

2 Experimental procedure

The description of the TRC composite process is as follows: after melting, the liquid aluminium is fed to the region between the rotating rolls. Copper sheet was inserted in between the melt stream and the roll, then heat transfer from the molten metal to the clad/roll interface and solidification of the melt takes place resulting in a Cu/Al clad sheet.

3 Result and discussion

3.1 Optimization and Impact of Heat transfer coefficient of copper and roller (HTC_1)

During the casting and rolling process, HTC_1 is mainly related to the contact state of copper/roller. The variation of outlet temperature in the casting and rolling zone under different HTC_1 conditions was studied. The results indicate that when the HTC1 value is set to 10000 $wm^{-2}k^{-1}$, the error between the simulation results of the outlet temperature and the experimental results is the smallest.

3.2 The influence of casting speed

The effect of casting and rolling speed on the interface melt length and centerline melt pool depth indicated that with the increase of casting and rolling speed, the depth of interface molten state and the depth of molten pool at the centerline increase. The casting and rolling speed is fast, and the heat transfer time from aluminum to copper strip and from copper strip to roller is short.

3.3 The influence of casting temperature

Figure 1 shows the effect of casting temperature on the interface melt length and centerline melt pool depth. The results indicate that as the casting temperature increases, the amount of heat entering the casting and rolling zone from the inlet increases rapidly, but the heat transfer rate between copper/aluminum and aluminum/roller remains unchanged, resulting in an increase in the depth of the interface molten state and the depth of the centerline molten pool.

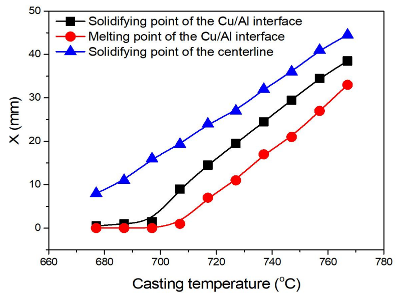

Fig. 1 The relationship between casting temperature and sump depths of the Cu/Al interface and centerline.

4 The microstructure of Cu/Al clad sheet interface

Using transmission electron microscopy to perform diffraction spot analysis on the interface characteristic area and determine the phase of the interface, as shown in Figures 2. The area with darker contrast is the copper matrix, exhibiting twinning characteristics, while the area with brighter contrast is the aluminum matrix, whose grain size is much larger than that of the interfacial compound. Through the analysis of diffraction spots in the characteristic region, it can be concluded that the compound layer near aluminum is Al_2Cu, while the layer near copper is Al_4Cu_9. The composition distribution of the interface layer is uniform, and the grain size is mostly within 500 nm, exhibiting certain equiaxed crystal characteristics.

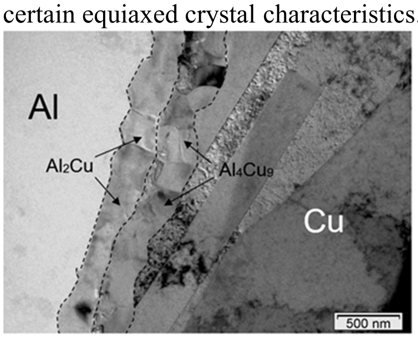

Fig. 2 BF TEM image of the interface for the as-cast clad sheet

4 Conclusion

In this paper, a thermal flow coupling model for the horizontal casting and rolling process of copper aluminum composite plates was constructed. The influence of casting and rolling parameters on the temperature field of the casting and rolling zone was studied. The microstructure of Cu/Al clad sheet interface was revealed. Two intermetallic compound layers (Al_2Cu and Al_4Cu_9) with the total thickness of around 500 nm were formed at the interface.

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