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Interfacial microstructure and mechanical properties of Cu/Al clad sheet fabricated by asymmetrical roll bonding and annealing

Xiaobing Li, Guoyin Zu*, Mingming Ding, Yongliang Mu, Ping Wang

School of Materials and Metallurgy, Northeastern University, Shenyang 110004, PR China

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ABSTRACT

The interfacial microstructure and mechanical properties of Cu/Al clad sheet fabricated by asymmetrical roll bonding and annealing were studied by scanning electron microscope equipped with energy dispersive X-ray detector, micro-hardness, tension and peeling test. The stress state of deformation zone was analyzed qualitatively to express the advantage of asymmetrical roll bonding. The results show that the asymmetrical roll bonding with larger mismatch speed ratio causes severe shear plastic deformation of component metals, and provides a good interface for atoms diffusion during annealing. The interfacial microstructure is improved and interfacial layer thickness increases. The roll bonding with larger speed ratio improves the ultimate tensile strength, elongation and peeling force of clad sheet, and reduces the micro-hardness of interfacial zone.

1. Introduction

Copper/aluminum (Cu/Al) clad sheet has drawn a growing interesting for cost reduction, especially, combining the advantages of high specific conductivity and good resistance to corrosion. The sheet possesses high formability, electrical and thermal conductivity, making it a chosen material for specific application in automobile and electronics industry. However, producing Cu/Al clad sheet is a great challenge due to the different chemical and physical characteristics of component metals. The formation of brittle Cu_xAl_y intermetallic compound at elevated temperature destroys seriously the interfacial bonding [1,2].

Several processes have been used to fabricate bimetal clad sheet, including explosive welding, diffusion welding, roll bonding, friction stir welding, and laser bonding [3,4]. However, the cold roll bonding (CRB) is more efficient and economical than other types of processes [5]. Bonding is achieved when surface deformation breaks up the contamination layers and roll pressure causes the extrusion of material through any cracks present in fractured surface [6].

Many studies about asymmetrical roll technique indicate that the cross shear deformation zone, caused by the displacement of neutral plane of upper and lower roll, provides a severe deformation for materials and lowers the power consumption. In addition, asymmetrical roll technique improves the interfacial bonding of clad sheet [7–10]. Consequently, asymmetrical roll bonding is desirable to bond dissimilar component metals, especially for which are difficult to deform.

There have been some researches about the cold roll bonding process. Bay has studied the roll bonding for long time and established a systematic theory of metal bonding [3,11]. Manesh has investigated the effect of process parameters of warm and cold roll bonding, bonding mechanism and mechanical properties of clad sheet [1,12]. Jamaati and Toroghinejad have taken some works to research the cold roll bonding of bimetals and achieved some key parameters [6,13–16]. Acoff has studied the sandwich sheet by roll bonding and annealing, and produced the Ti–Al intermetallic compound bulk material [17,18]. Tsuji has developed the accumulative roll-bonding (ARB) process, and investigated the interface of roll bonded bulk materials [19,20]. The asymmetrical roll bonding model with different diameters rolls has been analyzed by Hwang and Tzou using mathematical and mechanical approaches [8,21]. Pan has prepared some clad sheets using cross shear roll bonding, and concluded that large mismatch ratio of rolls speed improves the peeled strength [22]. However, the mechanism of improvement of interfacial bonding as well as the metal flow in deformation zone by asymmetrical roll bonding has not been apparent.

In this paper, the stress states in deformation zone under same work rolls with different rotational speeds were analyzed to investigate the asymmetrical roll bonding process. The effect of mismatch speed ratio to the interfacial microstructure and mechanical properties of clad sheet were studied.

* Corresponding author. Tel.: +86 24 83686462; fax: +86 24 83682912.
E-mail address: zugy@smm.neu.edu.cn (G. Zu).

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