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Proposal of bond criterion for hot roll bonding and its application

X.P. Zhang [a,b,*], T.H. Yang [a], S. Castagne [b], C.F. Gu [a], J.T. Wang [a]

[a] School of Materials Science and Engineering, Nanjing University of Science and Technology, Nanjing, PR China
[b] School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore

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ABSTRACT

The aim of this work was to develop a bond criterion for laminated composites prepared by hot rolling. 7075 Al/AZ31B Mg/7075 Al laminated composites were fabricated by hot rolling at different reduction ratios and temperatures, and the hot rolling process was also simulated by finite element methods (FEM). The FEM results show that two stages existed for an option position of the interface during hot rolling, viz. the bonded interface forming period and the post-bonded period. Bonded interface would be damaged during the latter due to second tensile stress and tear stress (due to the sticking friction between the Al plates and the rollers during the rolling). A bond criterion for laminated composites fabricated by hot rolling was proposed, which includes a strain threshold and a critical bonding strength. The predicted bond results of the 7075 Al/AZ31B Mg/7075 Al laminated composite fabricated by hot rolling from the proposed bond criterion agreed with the experimental data.

1. Introduction

Laminated composites are being applied in various fields due to their advantages in combined properties, such as strength, workability, corrosion resistance and economical efficiency. Among various cladding techniques, roll bonding has been adopted in various industrial areas because of its capability of continuous production of clad sheet and its economy of fabrication. Many kinds of laminated composites have been fabricated by roll bonding at room temperature or elevated temperature, such as Cu/Cu [1], Cu/Fe/Cu [2], Ti/Al [3], Fe/Al [4,5], Al/St/Al [6], Al/Zn [7], Ti/Fe [8] and Al/Mg/Al [9] laminated composites.

During hot roll bonding, plastic deformation of the base metal plates is a key factor to create the bond. Several methods have been used to analyze stress and strain distribution during roll bonding process, such as including the stream function method and the upper bound theorem [10], the extended upper bound theorem [11], the upper bound theorem [12], finite element method [13–15], and the slab method [16–18]. The bond mechanisms include the film theory [19,20], Bay's theory [21], the energy barrier theory [20], and the joint recrystallization theory [22]. One of the most important conclusions drawn from the experiments and the models is that a bonding could be assessed as correct only when the plastic deformation of the base metal plates exceeds a critical limit.

During hot roll bonding, two zones exist in the interface of the base metal plates. One is the bonded zone where the metal plates are bonded. The other is the un-bonded zone where the plates are still un-bonded. In our recent research [23], it was found that the bonded interface of Mg-based laminated composites made by explosion cladding method will be separated during a subsequent hot rolling. A can be drawn that the bonded zone will be influenced by the plastic deformation of the un-bonded zone. For an extreme case, the bonded interface will be separated and the plates cannot be bonded after hot rolling. A basic requirement for obtaining an un-separated composite material is that a strong bond between the base metal plates occurs during the roll bonding process [24]. However, the existing bond criterions with a threshold deformation [19–22] only indicate that a bonded interface can be formed during roll bonding process. These criterions cannot predict whether the bonded interface would be separated, which is mainly caused by the plastic deformation of the un-bonded zone in the following rolling. Thus, bonding strength of the bonded zone needs to be taken into account when a bond criterion is investigated.

In this work, a bond criterion of hot roll bonding was studied. To verify the bond criterion, hot roll bonding tests of 7075 Al/AZ31B Mg/7075 Al laminated composite and their simulations were performed.

2. Bonded criterion

According to the film theory mechanism in roll bonding [16], the surface layers of the metal plates are subjected to increasing normal pressure during deformation and some surface cracks are produced. The underlying metals are exposed through these cracks

* Corresponding author. Address: School of Materials Science and Engineering, Nanjing University of Science and Technology, Xiaolingwei 200, Nanjing 210094, PR China. Tel./fax: +86 025 84303983.
E-mail address: xpzhang@mail.njust.edu.cn (X.P. Zhang).

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