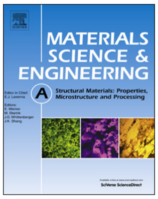
Materials Science & Engineering A 590 (2014) 314–317

Contents lists available at ScienceDirect

Materials Science & Engineering A

journal homepage: www.elsevier.com/locate/msea



Rapid communication

A novel testing approach for interfacial normal bond strength of thin laminated metallic composite plates

Jianjun Zhang [a,b], Wei Liang [a,*], Yiming Liu [a], Xingguo Zhao [a], Xianrong Li [a], Bin Zhou [a]

[a] College of Materials Science and Engineering, Taiyuan University of Technology, Taiyuan 030024, PR China
[b] School of Science, North University of China, Taiyuan 030051, PR China

ARTICLE INFO

Article history:
Received 12 June 2013
Received in revised form
16 October 2013
Accepted 17 October 2013
Available online 25 October 2013

Keywords:
Thin laminated composite plates
Interfacial normal bond strength
Adhesive butt-joint
Four-point bending

ABSTRACT

This short communication presents a novel approach for testing the interfacial normal bond strength of thin laminated metallic composite plates. The upper limit of the interfacial normal bond strength measured by four-point bending test on butt-joint specimens is about 1.5 times higher than that by uniaxial tension test.

1. Introduction

Sufficient interfacial bond strength is needed for almost all of the laminates and cladding plates because it strongly affects the overall mechanical performance of these composite materials. In order to determine the interfacial bond strength, various measurement techniques have been developed such as peeling, bend, shear and microindentation test [1–18]. However, there is no proper method for testing the interfacial normal bond strength of thin laminated metal clad plates.

In our previous work [19], the uniaxial tension of the specimen with an adhesive butt-joint was adopted to measure the interfacial normal bond strength in the thin laminated clad plates AZ31B/Al. Nevertheless, this method is invalid when the interfacial normal bond strength of the clad plates is higher than that of the adhesive. To overcome this limitation, a new method based on four-point bending test is developed for measuring the interfacial normal bond strength of clad plates.

2. Materials and experiments

2.1. Fabrication of the laminated composite plates

In this experiment, magnesium alloy AZ31B and aluminum alloy 5052 were respectively used as the base plate and the cover plate. The compositions of both alloys are shown in Table 1. The laminated composite plates were fabricated as follows: (1) magnesium alloy AZ31B plates of $100 \times 50 \times 2.5$ mm^3 and aluminum alloy 5052 plates of $220 \times 70 \times 0.5$ mm^3 were cut from as-received magnesium and aluminum alloy sheets, respectively; (2) all of the surfaces of these plates were ground with 600 grit SiC paper, and then AZ31B plate was folded by 5052 plate; (3) hot rolling was conducted at 350 °C with a thickness reduction ratio 35% for the first pass (1-pass) and at 400 °C with a thickness reduction ratio 40% for the second pass (2-pass). The mechanical properties of the aluminum and magnesium sheets as well as the composite plates were measured using a CMT5205 electronic universal testing machine according to ASTM E 8M-04, and the results are presented in Fig. 1.

The microstructures were examined by a MIRA 3 Field Emission Scanning Electron Microscope (SEM) equipped with an energy dispersive X-ray spectrometer (EDS).

2.2. Normal bond strength testing of adhesive

Stainless bars of 10 mm diameter and 60 mm length were used as specimen holders. TS 802 adhesive was smeared on the polished end surfaces of two stainless steel specimen holders. The adhesive and the two adhered holders form a butt-joint specimen, which was cured at room temperature for 24 h. According to ASTM D6272-10, the normal bond strength of adhesive was measured in two loading modes, uniaxial tension and four-point bending with a constant displacement rate of 0.5 mm/min, as shown schematically in Fig. 2.

2.3. Normal bond strength measurement of thin laminated composites

The disc samples of Al(5052)/Mg(AZ31B)/Al(5052) of 10 mm diameter were ground with 600 grit SiC paper prior to being

---

* Corresponding author. Tel./fax: +86 351 6018398.
E-mail addresses: liangwei@tyut.edu.cn, zlsyspaper@126.com (W. Liang).

0921-5093/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.msea.2013.10.042

Table 1
Specifications of the commercial Al 5052 and AZ31 B sheets.

Material	Chemical composition (wt%)
5052 Al	96.3Al, 2.4Mg, 0.25Si
AZ31 B	95.2Mg, 3.2Al, 0.8Zn

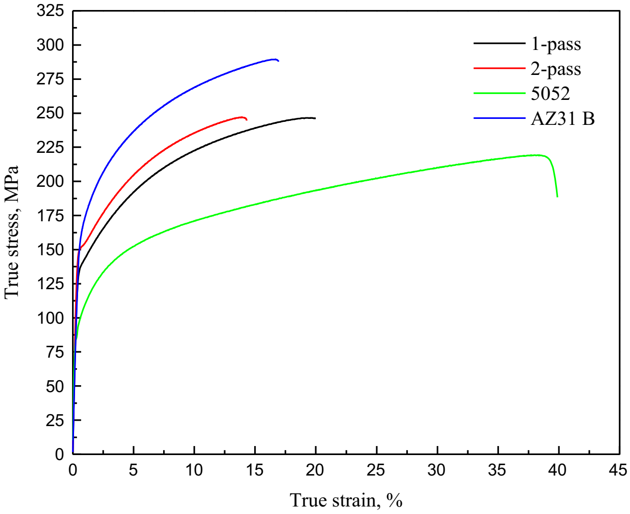


Fig. 1. The tensile true stress–strain curves of the composite plates fabricated by 1-pass hot rolling and 2-pass hot rolling, respectively, as well as the magnesium alloy AZ31B and aluminum alloy 5052 sheets.

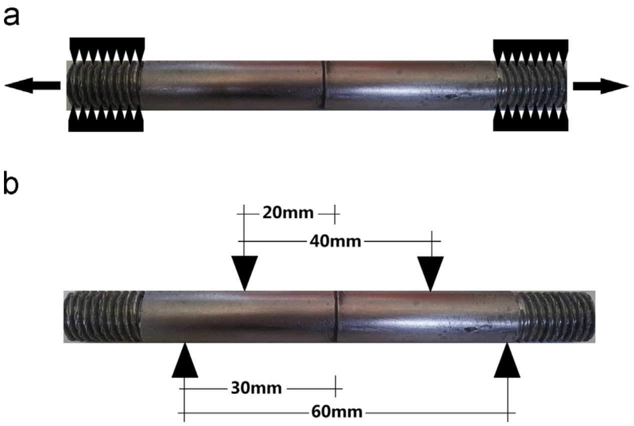


Fig. 2. Schematic sketch of normal bond strength testing of butt-joint specimens: (a) uniaxial tension and (b) four-point bending.

adhered to the specimen holders to form a butt-joint specimen. After 24 h-curing at ambient temperature, the butt-joint specimens were measured under uniaxial tension and four-point bending to evaluate the interfacial normal bond strength.

3. Results and discussion

3.1. Normal bond strength of the adhesive

Fig. 3 shows the normal bond strength of TS 802 adhesive in the two loading modes. Under the conditions of the same bonding condition and loading rate, the average normal bond strength of the adhesive determined by uniaxial tension and four-point bending are respectively 24.15 and 100.86 MPa, with the corresponding standard deviation of 3.019 MPa and 9.310 MPa, and the coefficient of dispersion of 0.125 and 0.092. This result indicates that the adhesive exhibits a significantly higher normal bond strength and stability under four-point bending test than under uniaxial tension test.

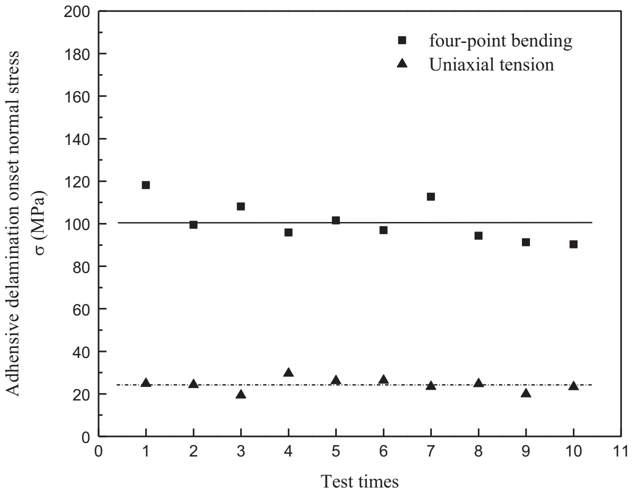


Fig. 3. Comparison between the normal bond strength of uniaxial tension and four-point bending of TS 802 adhesive.

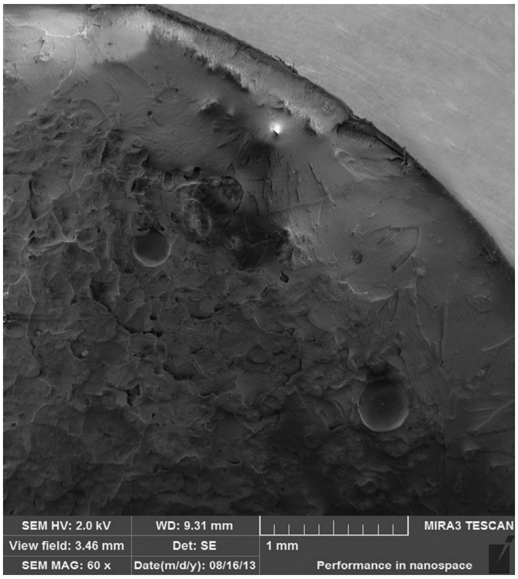


Fig. 4. Representative fracture interfacial morphology of adhesive.

The fracture morphology of the adhesive produced by uniaxial tension and four-point bending test was observed by SEM, and the fracture surface of the adhesive produced by the uniaxial tension is shown in Fig. 4. The common feature of the both fracture was that lots of micro-voids are randomly distributed in the center region, while the edge region with 0.5–1 mm width was relatively smooth, i.e., without voids, due to the fact that the volatile gas can escape easily from the edge region rather than from the central region during the adhesive curing. This is the reason for the significant higher normal bond strength exhibited by the adhesive under four-point bending test.

During the uniaxial tension, the normal stress is homogeneously distributed at the adhesive interface, as shown in Fig. 5(a). The existence of micro-voids not only decreases the bonding area, but also acting as microcracks under loading, which results in a lower strength according to the Griffith crack theory. So the measured normal bond strength of adhesive is far less than its real strength σ^R,