バイオインスパイアード多孔質アンカーを介した ポリマー／金属間接合の構造最適化

ゾウ　シャオユン*

Structural Optimization for Bonding between Polymers and Metals via Bioinspired Porous Anchors

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Inspired by the natural interfaces between soft and hard tissues, this work utilized graded structure to address the difficulty of joining dissimilar materials such as metals and polymers. By employing an *in-situ* laser-induced reaction of the Al-Ti-C system on aluminum alloy plates, graded anchor structures were developed to enhance the lap shear strength of aluminum/polymer joints. The joint strength was evaluated using lap shear tests, which showed that positive graded anchor structures exhibited higher lap shear strength.

１．Introduction

The efficient production of highly functional devices and components is essential for modern industries. This objective necessitates the integration of multiple materials with distinct properties, tailored to specific areas of a product or component through a streamlined manufacturing process. A common material combination, consisting of metal and polymer, has been successfully utilized in the engineering and medical sectors. Metal-polymer hybrid structures are typically found in applications such as automobiles, aircraft, electronics, and medical implants. However, the key issue mainly focuses on the differences in the mechanical and physical characteristics between metal and polymer.

In nature, soft–hard tissue interfaces present a diversity of hierarchical transitions in composition and structure to address the challenge of stress concentrations that would otherwise arise at their interface. The concept of functionally graded materials (FGMs) was first introduced during the 1980s by Japanese scholars, which involves gradual transitions in composition, constituents, microstructure, grain size, texture, and porosity. Among others, these transitions occur in one or more directions, resulting in changes to their functional properties. In general, graded structures normally significantly improve the mechanical properties of engineering materials. Profound knowledge of the process and the development of materials with complex structures could pave the way for solutions to interfacial problems of dissimilar materials joining. Drawing inspiration from FGMs with tailored morphological features, the effect of graded anchor structures on Al/polymer joint strength was investigated in this work.

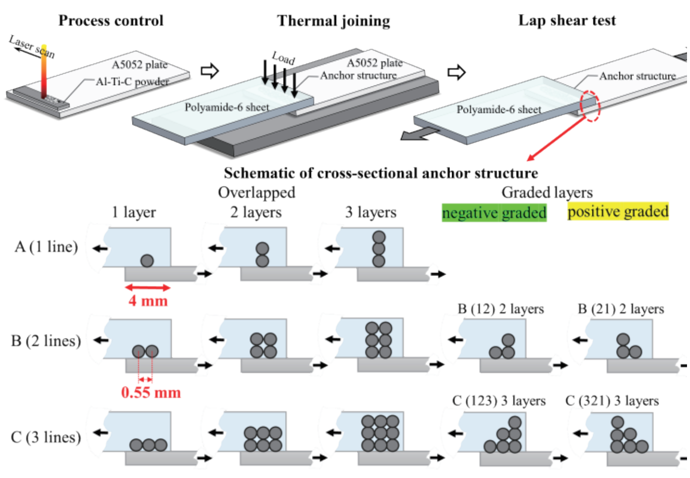

Fig. 1 Joining process and different laser scanning directions.

２．Material and method

Anchor structures for joining with thermoplastic parts were provided on an aluminum alloy (A5052) plate via an *in-situ* laser-induced reaction of the Al-Ti-C system. An

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Al-Ti-C powder mixture with a molar ratio at 1:1:0.6 was bedded on the A5052 plate (1-3). A pulsed diode laser beam (wavelength: 970 nm, pulse frequency rate: 1000 Hz, pulse length: 700 μs, laser beam diameter at work plane: 1.2 mm) was irradiated onto the bedded powder at a laser power of 350 W and a scan speed of 100 mm/s. The powder bedding and laser scanning processes were repeated from 1 to 3 times. Numerous protruding granules, consisting of α-Al, TiC, and Al_3Ti phases, were formed and bonded firmly to the A5052 plate. The areas of anchor structures were changed by multiple laser scanning while shifting the scanning areas (Fig. 1). In addition, by changing both the number of powder bedding repetitions and laser scanning areas, the graded anchor structures were obtained. Subsequently, the A5052 substrates were joined with Polyamide-6 (PA6) sheets via the anchor structures by hot-pressing. The anchor structure formed on Al alloy substrates was set on the hot plate of a hydraulic hot press. The hot plate was heated to 215°C and was later cooled down to 190°C at a rate of 2°C/min (4-5). Throughout the joining process, a joining pressure of 1.8 MPa was applied. After joint specimens were fabricated, a lap shear test was performed using a universal tensile tester to measure the joint strength.

3. Discussion

Fig. 2 and 3 illustrates the changes in ultimate lap shear strength under different laser condition fabrications. The strength gradually increased as the number of laser scanned layers rose. Besides, the lap shear strength also increased with a larger area of anchor structures, which indicated the increased overlapped lines. Notably, the positive graded anchor structure provided comparatively higher lap shear strength. This indicates that the graded structure examined in this study effectively enhances the bonding strength between Al and the polymer. Moreover, microstructural observations were carried out to investigate the failure behavior of different Al/PA6 joints' fracture surfaces. As for single-layer samples, more anchor structures remained after the lap shear test. Overall, this work offers valuable insights into tailored graded structures for achieving high strength of metal/polymer joining.

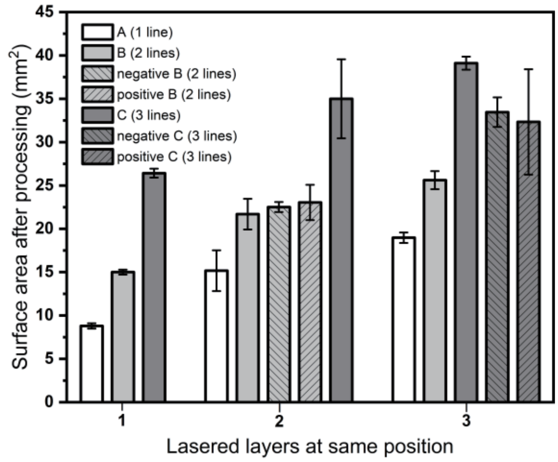

Fig. 2 Surface area of samples.

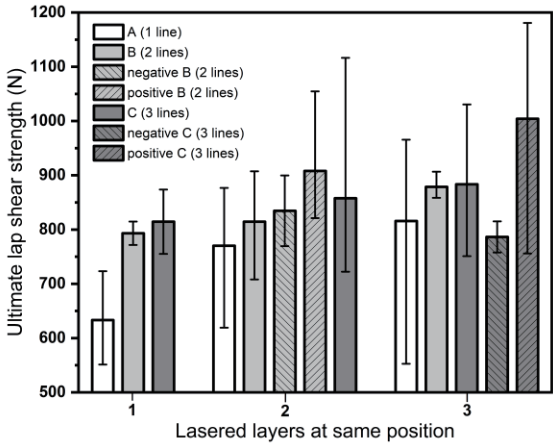

Fig. 3 Lap shear test results.

4. Conclusion

By employing an in-situ laser-induced reaction of the Al-Ti-C system on aluminum alloy (A5052) plates, the graded anchor structures were fabricated to improve the lap shear strength of Al/polymer joints. This work demonstrates the potential of bioinspired anchor structures to optimize the bonding between aluminum and polymer, thereby enhancing the reliability and promotion of the use of aluminum in multi-material structures.

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