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# Weldability and mechanical properties of ultrasonic welded aluminum to nickel joints

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ABSTRACT

Dissimilar aluminum to nickel joints with and without Al2219 particle interlayer were performed using ultrasonic welding technology. Interlayer was beneficial to improve the temperature of the weld interface, leading to the increase of weldability, by which sound aluminum to nickel joint was successfully obtained. Meanwhile an interface diffusion layer (~60 nm) was generated in the weld interface, and a significantly amount of welded regions were observed at the fracture surface. The maximum tensile shear load of joint with interlayer could reach 2.92 kN, which was 67.8% higher than that (1.74 kN) of joint without interlayer, meanwhile the welding time became shorter.



## 1. Introduction

Aluminum and aluminum alloys, including excellent properties such as lightweight, sound corrosion and specific high strength performance, have been paid more attentions in the automotive and aerospace fields [1–4]. Due to their high corrosion resistance, nickel (Ni) and Ni-base alloys have a widely application in aeronautics, space, nuclear, chemical and petrochemical industries [5]. Meanwhile, Al and Ni sheets can be also used as the battery pole flakes. Therefore, sound dissimilar joint of Al alloy and Ni alloy is indispensable to scale out the engineering applications of both metals in advanced manufacturing industries.

However, joining Al/Ni is a huge challenge due to their significant differences in metallurgical and physical properties. The melting points of Al and Ni are 660 °C and 1453 °C, respectively. This results in difficulties to obtain sound Al/Ni joining by conventional fusion welding processes. In comparison with other solid-state welding technology, ultrasonic spot welding (USW) is an emerging spot welding process with advantages of lower energy consumption and higher efficiency [4,6].

One of the most critical issues during USW is temperature of the weld interface [7]. Since moderate interface temperature can improve the weldability via lowering the yield strength of materials and controlling the intermetallic compounds. It was reported that weld interface temperature has relation to interface friction [8,9]. Numerous studies were reported about USWed joining of Al to Mg [4], Al to steel [3,8], Al to Ti [10], Al to Cu [11] and Mg to Cu [6] in recent years. However, there are few reports on the dissimilar joining of Al to Ni [14]. In this paper, a layer of Al2219 alloy particle is added between the Al and Ni sheets for improving the friction coefficient of the faying interfaces. Therefore, the objective of this paper is to comparatively investigate the interfacial microstructure and mechanical properties of joints with and without Al2219 particle.

## 2. Experimental method

The materials used in the present study were sheets of Al1100 alloy (wt. 99.99%) and pure Ni (wt. 99.99%) with dimensions of $100 \times 25 \times 1.0\text{mm}^3$ and $100 \times 25 \times 0.5\text{mm}^3$, respectively. Prior to welding the sheet surfaces were ground with 600# and 1000# sand paper. Then the samples were cleaned in acetone and dried. The USW system employed was a SONICS MW-20 machine, its schematic illustration is shown in Fig. 1a. The size of the sonotrode tip is 8mm × 8mm. Al2219 alloy particle with some asperities and valleys on the surface is near spherical shape, and its average diameter is 8μm. Al2219 particle and alcohol with a 1:4wt ratio were mixed. The mixture was coated in the surface of pure Ni on one end of the welded side, and dried prior to welding. The average thickness of the interlayer was 30μm. The welding was

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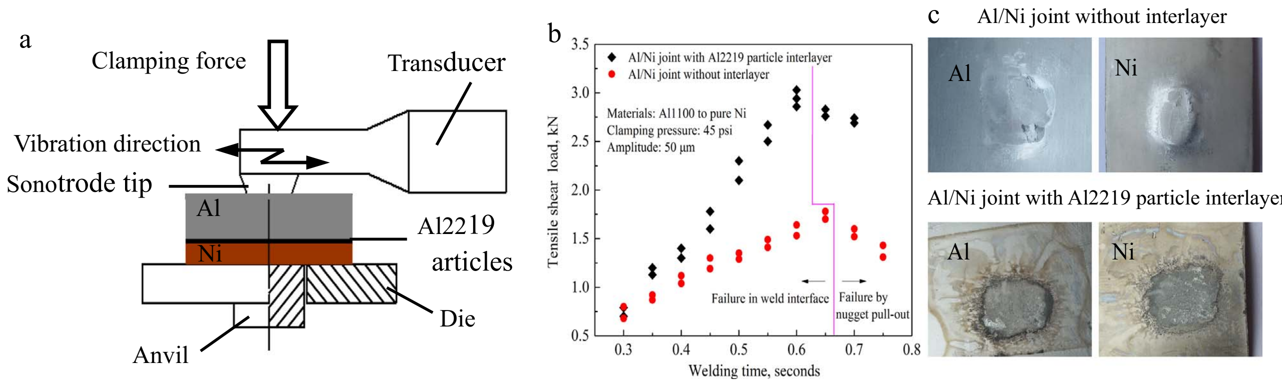


**Fig. 1.** (a) Schematic illustration of ultrasonic welding; (b) relationship between the tensile shear load and welding time in ultrasonic welding of Al/Ni; (c) the typical fracture surfaces of joints with optimal tensile shear load in a welding time of 0.65s (top) and 0.6s (below).

performed in a time mode at 20kHz, where welding time values range from 0.3s to 0.7s with a constant power setting of 2500W, an amplitude of 50μm and a clamping pressure of 45psi. The temperature was measured via utilizing a type-K thermocouple embedded on the interface between the Al1100 and pure Ni sheets.

Microstructure was observed by scanning electron microscopy (SEM, FEI, Holland) and transmission electron microscope (TEM, JEM-2100) equipped with energy dispersive X-Ray spectroscopy (EDS). The spatial resolution of the JEM-2100 is 0.194 nm, 0.23 nm and 0.25 nm in UHR, HR and HT configuration, respectively. And the solid angle of EDS is 0.24 sr, 0.28 sr and 0.23 sr in UHR, HR and HT configuration, respectively. To evaluate the mechanical strength of the joints, tensile tests were carried out using an AG-100KNA test machine with a constant displacement rate of 1 mm/min at room temperature.

## 3. Results and discussion

Fig. 1b demonstrates the relationship between the welding time and tensile shear load of the Al/Ni joints; Fig. 1c shows the typical fracture surfaces of both joints with optimal tensile shear load. It can be obtained that the tensile shear load of both joints increases with increasing the welding time up to a peak value, and then decreases with a further increase of welding time. Al/Ni joints with Al2219 particle interlayer have a peak tensile shear load of ~2.92 kN in a welding time of 0.6 s, which is higher compared with that without interlayer (~1.74 kN) in a welding time of 0.65 s, indicating that the Al2219 particle not only enhances the tensile shear load, but also cuts down the welding time.

Fig. 2 shows the weld interface microstructure and fracture morphology of Al/Ni joints with and without Al2219 interlayer in the optimal condition. It can be seen that the weld interface exhibits some gaps (Fig. 2a), however, there is no any gap exhibited in the weld interface (Fig. 2b–d). It is conformed that sound joint is obtained by adding Al2219 particle between the Al and Ni sheets.

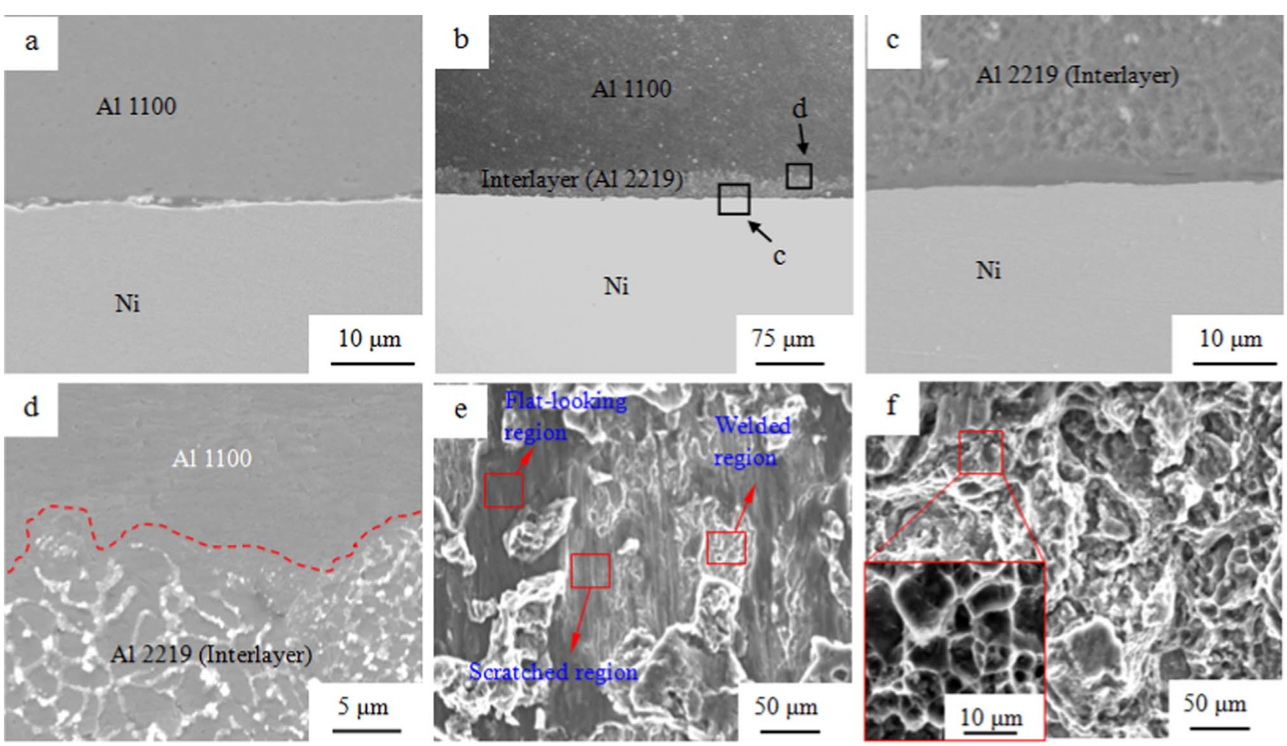


**Fig. 2.** Weld interface microstructure and fracture morphology of Al/Ni joints (a) and (e) without Al2219 interlayer in a welding time of 0.65 s; (b) and (f) with Al2219 interlayer in a welding time of 0.6 s; (c) and (d) show the magnified area of the box in (b), respectively.