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Laser brazing of inconel 718 alloy with a silver based filler metal

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ABSTRACT

In the presented study laser brazing of an inconel 718 alloy with silver based filler metal using 400 W pulsed Nd:YAG laser is investigated. Laser brazing was performed with varying laser frequency, pulse width, process speed and gap distance. The effect of preheating on wetting and spreading also was studied. Brazing geometrical images were observed using an optical microscope. The composition analysis and microstructure of the filler metal and brazed joints were examined using X-ray diffraction analyzer (XRD), scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS). Micro-hardness and tensile test were performed for investigation of mechanical properties. The experimental observations show that filler metal consist of α-Ag solid solution, ά-Cu solid solution surround by the α-Ag solid solution and eutectic structure. Phases of the brazed joint are similar to the filler metal. The results indicate that the filler metal has adequate wetting and spreading on inconel 718 and the wetting angle depends on the heat input significantly. Interdiffusion occurs in laser brazing and the average thickness of reaction layer is approximately 2.5 μm. Whenever the gap is big, it is needed to use longer pulse width in order to have a better melting flow. Preheating has significant influence on wetting and spreading of the filler metal.

1. Introduction

Nickel is the base element for most of the high temperature heat resistant alloys. While it is more expensive than iron, nickel provides an austenitic structure that has greater toughness and workability than ferritic structures of the same strength level. Inconel 718 is a vacuum-melted, precipitation-hardened nickel-base alloy. It can be welded easily and excels in its resistance to strain-age cracking, [1]. Brazing is a widely used joining process for nickel and high-nickel alloys. An important precaution is the susceptibility of nickel and high nickel alloys to attack by both sulfur and low-melting-point metals, and liquid metal embrittlement in contact with molten brazing filler metals, [2]. Many commercially available brazing alloys, such as BAg, BCu, BAu, BNi can be used in brazing Ni and Ni alloys. Silver based braze alloys are also suitable choice for brazing Ni alloys, [2,3].

Rodriguez et al. [4] investigated laser brazing of steel–aluminum assembly. Li et al. [5] studied microstructure and mechanical properties of laser welded–brazed Mg/mild steel and Mg/stainless steel joints. The effect of Ti serving as an activator in a eutectic Ag–Cu alloy filler metal on the laser brazing joint strength and also the interface structure of the joint were examined by Nagatsuka et al. [6]. Munez et al. [7] carried out laser brazing for joining tungsten based alloys to reduce activation of ferritic–martensitic steels (Eurofer) using a 55Ni–45Ti alloy as a brazer and a high power diode laser (HPDL) as a power source. Fatigue properties of laser-brazed joints of dual phase and transformation induced plasticity steel with a copper–aluminum consumable were investigated by Janssen et al. [8]. For lap joining of zinc coated steel (DP600) with aluminum alloy (AA6016) using a filler wire composed of 85% Zn and 15% Al, Dharmendra et al. [9] used a CW Nd:YAG laser with varying laser power, brazing speed, and wire feed speed. Mathieu et al. [10] used a continuous-wave Nd:YAG laser with maximum power of 3.5 kW for laser brazing of a steel/aluminum assembly with hot filler wire (88% Al, 12% Si). Markovits et al. [11] investigated laser brazing of aluminum using CO_2 laser beam as an energy source. Sisamouth et al. [12] studied the effect of varying indium content on melting temperatures and brazeability of Ag–Cu–In alloys on copper substrate. Chan et al. [13] compared the microstructure of Ti–6Al–4V and TZM joint in furnace brazing and infrared brazing processes. Möller et al. [14] combined laser beam welding and brazing process for joining aluminum and titanium. Heilmann et al. [15] in their investigation used a 3.1 kW continuous wave diode laser with two different infrared wavelengths (808 and 940 nm) for joining Fe_2O_3-doped forsterite ceramics ZrO_2 with glass solders.

Present study investigates the effect of laser brazing on microstructure, preheating on flowing the filler metal and different gaps

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on mechanical properties of inconel 718 joint. Also spreading and wetting of the filler metal were attended. The purpose of this investigation is to indicate the minimum preheating and reveal the relationship between gap and laser brazing parameters, and also to choose some bases for selecting proper laser parameter for brazing.

2. Experimental work

2.1. Material

An inconel alloy, inconel 718, as sheet with a thickness of 1 mm and chemical composition presented in Table 1 was used as base metal in this investigation. The size of each sample was 120 mm long × 25 mm wide. One side of the samples was ground to provide a channel for flow the melted filler metal and the samples degreased prior to brazing.

2.2. Filler metal

Silver based alloy as wire with a diameter of 0.5 mm and chemical composition presented in Table 2 was used as filler metal to join inconel 718. Solidus and liquid temperature of the filler metal are 618 °C and 652 °C, respectively.

2.3. Experimental setup

A pulsed Nd:YAG laser with a maximum mean laser power of 400 W (Model IQL-10) was used as the laser brazing source for the experiments. The standard pulse shape of this laser is square. For measuring average power and pulse energy, a 5000 W-Lp Ophir power meter and LA300 W-LP joule meter were used. The available range for the laser parameters was 1–1000 Hz for pulse frequency, 0.2–20 ms for pulse duration, and 0–40 J for pulse energy. Peak power of laser pulses in this study was set 1000 W, so any arbitrary combination of pulse energy and pulse frequency could be used. Fig. 1 shows the schematic geometry used for laser brazing. The edges of samples were prepared and the filler wire was placed on the top of the samples. Filler wire was fixed on the surface of work piece before the test. The laser beam was irradiated on the filler wire vertically. Argon gas was used to prevent oxidation of molten filler metal. The laser brazing parameters used in the experiments were set according to Table 3 to identify the effects of pulse frequency, pulse width, process speed, gap distance and preheating.

2.4. Tension test and micro-hardness

Tension test was carried out at a cross-head speed of 1 mm/min according to ASTM E8M standard. The micro-hardness measurements were performed using Vickers micro-indentation tester with the load of 100 g according to ASTM E384 standard.

Table 3
The laser brazing parameters.

Parameters	Value
Pulse frequency (s^{-1})	15, 20, 45, 80, 90, 100
Pulse width (ms)	2, 5, 10, 13, 15, 17
Laser brazing speed (mm/s)	1.67, 2, 2.67, 3
Focal position (mm)	2
Flow rate of shielding gas (L/min)	30
Gap distance (mm)	0.02, 0.05, 0.08, 0.1, 0.013, 0.15, 0.17, 0.20
Preheating (°C)	Without preheating, 150, 300, 400

Table 1
Chemical composition of inconel 718.

Elements	C	Mn	Si	p	S	Cr	Ni	Nb
Weight percentage (wt%)	0.07%	0.08%	0.16%	0.015%	0.002%	18.03%	53.16%	5.48%
Elements	Al	Co	TAt	B	Cu	Fe	Mo	Ti
Weight percentage (wt%)	0.66%	0.23%	0.008%	0.0028%	0.07%	balanced	3.11%	1.15%

Table 2
Chemical composition of filler metal.

Elements	Ag	Cu	Zn	Sn
Weight percentage (Wt%)	57%	22%	16.5%	4.5%

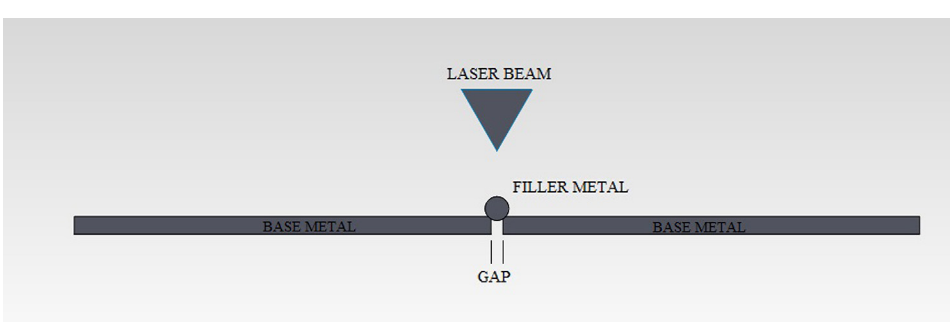

Fig. 1. Schematic geometry of the laser brazing set-up used in the experiments.