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Effect of welding processes on AA2219 aluminium alloy joint properties

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Abstract: AA2219 aluminium alloy square butt joints without filler metal addition were fabricated using gas tungsten arc welding (GTAW), electron beam welding (EBW) and friction stir welding (FSW) processes. The effects of three welding processes on the tensile, fatigue and corrosion behaviour were studied. Microstructure analysis was carried out using optical and electron microscopes. The results show that the FSW joints exhibit superior tensile and fatigue properties compared to EBW and GTAW joints. It is also found that the friction stir welds show lower corrosion resistance than EB and GTA welds. This is mainly due to the presence of finer grains and uniform distribution of strengthening precipitates in the weld metal of FSW joints.

Key words: AA2219 aluminium alloy; gas tungsten arc welding; electron beam welding; friction stir welding; tensile properties; fatigue properties; pitting corrosion

1 Introduction

AA2219 alloy is an Al-Cu-Mn ternary alloy with excellent cryogenic properties. It has a unique combination of properties such as good weldability and high specific strength. The preferred welding processes for AA2219 aluminium alloy are frequently gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) due to their comparatively easier applicability and better economy. Plasma arc welding (PAW) with a positive polarity electrode and high welding current allows aluminium components to be joined economically with excellent weld quality[1]. In comparison with electric arcs, electron beam is characterized by a higher power density and thus permits a single pass welding speed up to more than 1 m/min of square butt joints with thickness up to approximately 8 mm in a flat position at welding. The electron beam welds of most weldable materials including aluminium alloys exhibit superior mechanical properties compared to the welds made using GTAW[2].

Though AA2219 alloy has better weldability compared to other grades of age hardenable aluminium alloys, it also suffers from poor welded joint strength. This is true both in autogenous welds as well as those welded with the matching filler. The loss of strength is due to the melting and quick resolidification, which renders all the strengthening precipitates to dissolve and thus the material is as good as a cast material with solute segregation and large columnar grains[3−4]. Compared to many fusion welding processes that are routinely used for joining structural alloys, friction stir welding (FSW) is an emerging solid state joining process in which the material being welded does not melt or recast[5]. Also, FSW process is widely applied in joining of most aluminium alloys and is observed to offer several advantages over fusion welding due to the absence of parent metal melting. During welding, the frictional heat associated with thermal cycle varies in transverse direction of the weld. Maximum temperature observed in the FSP zone causes alteration in the precipitate distribution present in the base material due to the stirring of the plasticized material. These changes in the heat and temperature distribution in welding process alter the strength and ductility of the joints[6]. In this investigation, the tensile, fatigue and corrosion behaviours of GTAW, EBW and FSW joints of AA2219 aluminium alloy were compared.

2 Experimental

The rolled plates of AA2219-T87 aluminium alloy were cut and machined to a size of 300 mm×150 mm×

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5 mm by power hacksaw cutting and grinding. The chemical composition of base metal is listed in Table 1. Square butt joints were prepared to fabricate GTAW, EBW and FSW joints without filler metal additions, and the dimensions are shown in Fig.1(a). GTAW joints were fabricated using Lincoln welding machine (USA) with a capacity of 400 A. EBW joints were fabricated using an electron beam welding machine (Techmeta, France) with a capacity of 100 kV. FSW joints were fabricated using an indigenously designed and developed FSW machine (11 190 W; 3000 r/min; 50 kN) using a non-consumable high carbon steel tool. Welding conditions were optimized to fabricate the joints without defects. The welding conditions and process parameters are presented in Table 2.

The welded joints were sliced using power hacksaw and then machined to the required dimensions. Two types of tensile test specimens, smooth unnotched and notched specimens were prepared as per the ASTM E8M-04 specification. Tensile test was carried out on an electro-mechanically controlled universal testing machine at 100 kN (FIE, India; UNITECH 94001). The 0.2% offset yield strength, ultimate tensile strength, elongation and joint efficiency were recorded from unnotched specimen, and the dimensions are shown in Fig.1(b). Notch tensile strength and notch strength ratio were evaluated using notched specimen, and the dimensions are shown in Fig.1(c).

Table 1 Chemical composition of base metal (mass fraction, %)

Cu	Mn	Fe	Zr	V	Si	Ti	Zn	Al
6.33	0.34	0.13	0.12	0.07	0.06	0.04	0.02	Bal.

Table 2 Welding conditions and process parameters

Parameter	GTAW	EBW	FSW
Current	150 A	51 mA	
Voltage	30 V	50 kV	
Speed	3 mm/s	16 mm/s	
Polarity	AC	DC	−
Vacuum	−	10 Pa	
Shielding gas	99.99% Ar	−	−
Gas flow rate	14 L/min	−	−
Tool rotational speed			1400 r/min
Welding speed			1.5 mm/s
Axial force			12 kN
FSW tool details			Threaded pin with size of *d*6 mm×4.8 mm made of high carbon steel

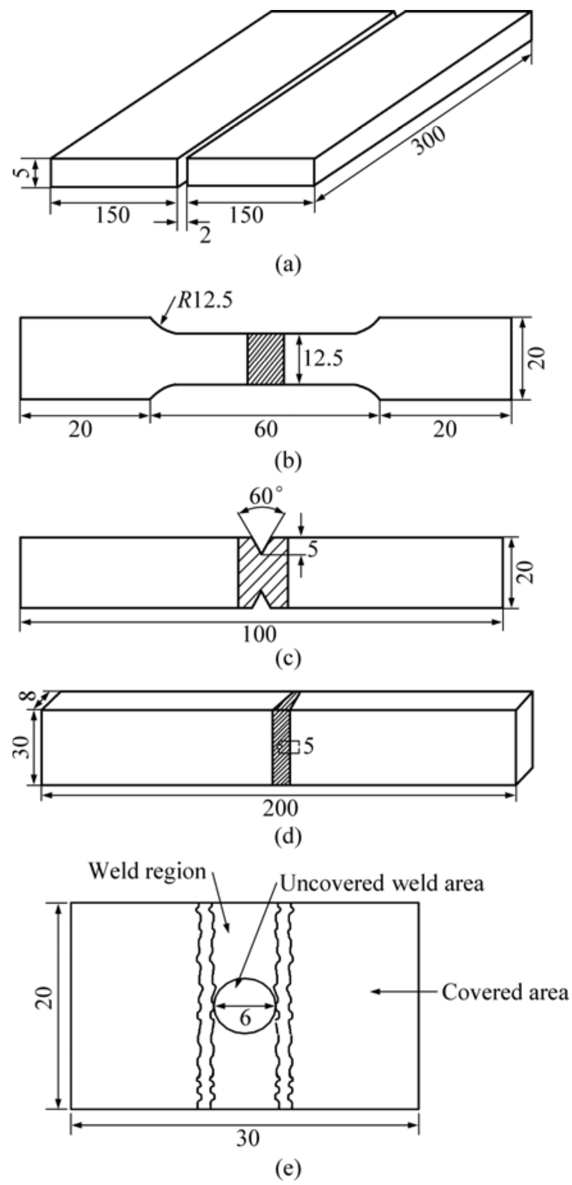

Fig.1 Dimensions of various test specimens (Unit: mm): (a) Square butt joint; (b) Unnotched tensile/fatigue specimen; (c) Notched tensile/fatigue specimen; (d) Centre cracked tensile (CCT) specimen; (e) Pitting corrosion specimen

Unnotched (smooth) specimens were taken from welded joints in transverse direction (normal to the welding direction) to evaluate the fatigue life, and the dimensions are shown in Fig.1(b). Notched specimens were also taken from welded joints to evaluate the fatigue notch factor and notch sensitivity factor, and the dimensions are shown in Fig.1(c). The fatigue testing experiments were conducted at different stress levels and all the experiments were conducted under uniaxial tensile loading condition (stress ratio=0) using servo hydraulic fatigue testing machine (INSTRON, UK; Model: 8801). At each stress levels three specimens were tested and the average values of the test results were used to plot *S*—*N*