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Effect of copper and aluminium addition on mechanical properties and corrosion behaviour of AISI 430 ferritic stainless steel gas tungsten arc welds

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ABSTRACT

The influence of grain refining elements such as copper (Cu) and aluminium (Al) on mechanical properties of AISI 430 ferritic stainless steel welds through gas tungsten arc welding process was studied. Cu (foil form) and Al powder of −100 μm mesh was added in the range from 1 to 3 g between the butt joint of ferritic stainless steel. In order to investigate the influence of post-weld heat treatment on the microstructure and mechanical properties of welds, post-weld annealing was adopted at 830 °C, 30 min holding followed by water quenching. Corrosion behaviour of ferritic stainless steel welds was also studied. From this investigation, it is observed that the joints made by the addition of 2 g Al (2.4 wt.%) in post-weld annealed condition led to improved strength. There is a marginal improvement in the ductility and pitting corrosion resistance of ferritic stainless steel welds by the addition of 2 g Cu (0.18 wt.%) in post-weld annealed condition. The observed mechanical properties have been correlated with microstructure, fracture features and corrosion behaviour of ferritic stainless steel weldments.

1. Introduction

Ferritic stainless steel (FSS) in the absence of nickel provides moderate corrosion resistance at lower cost. The higher chromium grades offer good resistance to oxidation at high temperature [1]. Ferritic stainless steels are commonly used in automobile exhaust systems [2], furnace parts and combustion chambers because of their excellent resistance to stress corrosion cracking, good toughness, ductility and weldability compared with austenitic stainless steels [3]. For many of these applications welding is a major route adopted for fabrication of components made by these alloys. Gas tungsten arc welding (GTAW) is generally used for fabrication of ferritic stainless steel components because it produces a very high quality weld. Ferritic stainless steels exhibit the problem

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Table 1 – Chemical composition of the base material and filler material (wt.%).

Material	C	Mn	Si	P	S	Ni	Cr	Fe
Base material (AISI 430 FSS)	0.044	0.246	0.296	0.023	0.002	0.164	17.00	Bal.
Filler material (ER 430)	0.044	0.246	0.296	0.023	0.002	0.164	17.00	Bal.

Table 2 – Mechanical properties of base material.

Material	Ultimate tensile strength (MPa)	Yield strength (MPa)	Elongation (%)	Impact toughness (J)	Microhardness (HV)
AISI 430 ferritic stainless steel	424	318	13	22	220

of grain coarsening in the weld zone and heat affected zone of fusion welds and consequent low toughness and ductility [4]. This is due to the absence of phase transformation during which grain refinement could occur. The problem of grain coarsening in the weld zone of FSS welds is addressed by limiting heat input by employing low heat input welding processes [5–8]. Studies have been conducted to grain refine FSS welds by electromagnetic stirring [9] by employing alternate current gas tungsten arc (GTA) welding process [10–12]. Grain refining elements such as aluminium (Al) and titanium (Ti) are added to transform the columnar grains in the centre of the weld to equiaxed microstructure in GTA welds. This has been reported to result in elimination of weld centre line cracking and also improve the toughness of welds. The transition from columnar to equiaxed grains is reported to be due to fine precipitates of carbonitrides aiding heterogeneous nucleation. It has also been suggested that nitrogen (N) in the shielding gas can refine the weld metal grain size by the formation of nitride (Ni) [13]. It was attempted to achieve grain refinement in the welds of these steels by addition of elements, such as, Ti, Al and Cu [10,14].

From the reported work it is observed that the grain refinement in the weld zone of FSS joints by the addition of Cu and Al with specified weight percentage has, so far, not been studied. The objective of the present study is to investigate the influence of Cu and Al addition on mechanical properties and corrosion behaviour of AISI 430 FSS welds.

2. Experimental procedure

The rolled plates of 5 mm thick AISI 430 FSS were cut into the required dimension using CNC cutting machine. The chemical composition of the base material is given in Table 1 and its mechanical properties are presented in Table 2. GTA welding was carried out using a TIG AC/DC 3500W welding machine. A single V butt-joint configuration shown in Fig. 1 was selected to fabricate the joints. The base metal plates were wire brushed and degreased using acetone and preheated to 100 °C. A filler material conforming to the composition given in Table 1 is used. Copper (in foil form) was added between the butt joint of FSS after the root weld. Aluminium powder of −100 μm mesh (99% purity level) was added to the molten pool in the range from 1 to 3 g through hopper and a fine pipe by the controlled way using the motor mechanism over a length of 300 mm of the FSS joints. Weld joint is completed in three passes. The welding parameters are given in Table 3. In order

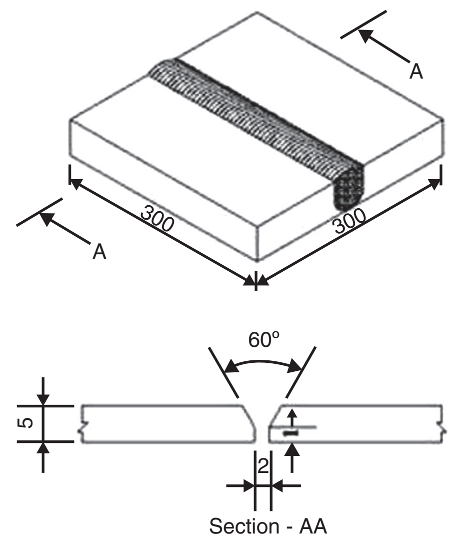

Fig. 1 – Schematic sketch of the weld joint (all dimensions in 'mm').

to investigate the influence of post-weld heat treatment on microstructure and mechanical properties of welds, the post-weld annealing at 830 °C, 30 min holding followed by a water quenching was adopted [15].

2.1. *Mechanical testing*

Microhardness testing was conducted using a Vickers digital microhardness tester in transverse direction of the weld joint. A load of 300 g was applied for duration of 10 s. The

Table 3 – Gas tungsten arc welding parameters.

Parameter	Value
Welding current (A)	120
Welding speed (mm/min)	50
Electrode polarity	DCSP
Arc voltage (V)	10–13
Arc gap (mm)	2
Filler wire diameter (mm)	1.6
Electrode	2% thoriated tungsten
Number of passes	3
Shielding gas (argon) flow rate (L/min)	10
Purging gas (argon) flow rate (L/min)	5
Preheat temperature (°C)	100