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Evaluating Bending Strength of Future Structural Material in Automobile Industries: Al-SiC composite Weldment during different Variants of TIG Welding such as ATIG, PCTIG & PCATIG Welding

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Abstract: In TIG welding of Al-SiC composites, reduced mechanical properties and lesser weld penetrations are the commonly observed problems. To overcome these challenges, Activated TIG (A-TIG) welding and pulsed current TIG (PCTIG) welding techniques are being used. PCATIG welding is a combination of ATIG and PCTIG welding process. This approach of combined mode of welding has the advantage of increased weld penetration and improved bending strength. Comparing the CCTIG, ATIG, PCTIG and PCATIG welding conditions, the following results are observed. ATIG with SiO_2 as flux (ATIG- SiO_2) and ATIG with TiO_2 as flux (ATIG- TiO_2) show positive effect of increased bending strength. The conditions ATIG-CaO, ATIG-MgO and ATIG-MnO₂ shows slight improvements with slight sacrifice in bending strength than the normal CCTIG welding. It is also observed that the usage of Al_2O_3 as active flux coating in ATIG welding results in reduced bending strength. During PCATIG welding on Al-8%SiC composite, PCATIG welding shows improved bending strength than the normal ATIG welding process. Hence PCATIG welding with both SiO_2 and TiO_2 shows improvement in bending strength than the other welding conditions.

Keywords: ATIG welding; PCATIG welding; Al-SiC composite; Bending strength.

I. INTRODUCTION

Aluminium is extensively used as a metal matrix material because of its ease in processing with SiC, TiB_2 , TiC and B_4C reinforcements on aluminium metal matrix [1]. Aluminium metal matrix is well known for its good wear resistant and higher strength to weight ratio [2]. Aluminium silicon carbide composite (Al-SiC) shows improved strength & stiffness to the weight ratio. It can also retain these properties in elevated temperatures than the base material [3]. Stir casting facilitates for higher production rate than other manufacturing process. Stir casting is possible by minor modifications in conventional casting process [4]. Stir casting used for manufacturing of Al-SiC composite shows more suitable and economical way compared to other manufacturing processes such as powder metallurgy route [5] and spray coating process [6].

Gas Tungsten Arc Welding (GTAW) also known as Tungsten Inert Gas (TIG) welding shows high quality welds when compared with other arc welding process. Non ferrous metals requires the quality weld with reduced defects and improved mechanical properties of the weld for which TIG welding is more suitable approach of welding of even thin sections. However, its shallow weld penetration requires more number weld passes which in turn leads to lesser production rate [7].

Welding of Al-SiC composite using TIG welding shows poor weld mechanical properties. This is due to higher heat input in Al-SiC, leading to SiC dissociation and forming (Aluminium Carbide) Al_4C_3 + (Silicon) Si. Al_4C_3 phase which is brittle in nature [8]. This results in considerable loss in weld strength and ductility. Restricting aluminium carbide formation during TIG welding on Al-SiC composite improves strength and ductility [9]. To restrict the aluminium carbide formation lesser heat input is needed during TIG welding.

In order to reduce the heat input into weld, Activated TIG welding (ATIG) a new variant was developed in early 1960's by the Paton Welding Institute, Ukraine which improves the weld penetration [10]. In this ATIG welding many variants are found of which adding fine layer of active flux is one of the most widely used method. Here active fluxes like chlorides [11], titanium oxides [12], fluorides [13], silicon oxides [14], calcium oxides [15], magnesium oxides [16] and sulfur [17] are commonly used.

The above surface active element is coated on the plate before normal TIG welding for the creation of the new variant ATIG welding. Addition of active elements like oxygen, carbon di oxide along with shielding gas of argon [18] and helium [19], tends to increase in weld penetration. This ATIG welding doubles the weld penetration than the normal TIG welding along with reduction in heat input and increased production rate [20]. Coating of active flux before welding gains more popularity than active shielding gas mixture due to its ease of application in the existing system and more cost effective.

The activated flux TIG welding follows two types of mechanisms which are mostly accepted, first one is based on the reverse Marangoni convection effect, and the other one is based on arc construction effect.

Pulsed current TIG (PCTIG) welding shows improved weld properties [21] through grain refinement in weld zone microstructure from coarse grain structure to fine grain structure [22]. PCTIG also reduces the width of the heat affected zone & thermally induced stresses through increasing cooling rate of the weld zone & reduced the heat input compared to TIG welding leading to improvement in tensile properties [23] and fatigue behavior [24]. This pulsed current TIG welding reduce the formation of aluminium carbide which in turn increases the weld properties of Al-SiC composite.

Intensive work has been done with ATIG on stainless steel alloys and few studies have been carried out on non ferrous metals such as magnesium, titanium, aluminium and nickel alloys. So investigation of weld strength of Al-SiC composite with ATIG shows significant importance in the manufacturer of aluminium composites. An attempt has been made by combining the pulsed current TIG and activated TIG welding (PC-A-TIG) on Al-SiC composite for getting superior weld properties with improved weld penetration.

II. EXPERIMENTAL PROCEDURE.

Autogenous welding has been performed on Al-8%SiC composite material with a plate dimension 100 x 100 x 5 mm using ADOR CHAMPTIG 300AD welding machine. The welding parameters considered during welding are provided in table 1. Different active fluxes of Al_2O_3 , CaO, MgO, SiO_2 , TiO_2 , MnO_2 are coated before welding process to perform ATIG and PCATIG welding variants.

Table 1: Welding parameter during CCTIG, PCTIG, ATIG and PCATIG welding

Parameter	Condition
Current Type	AC Current
Electrode Diameter	3.2 mm
Electrode Material	2% Th - Tungsten Electrode
Arc Length	2 mm
Arc Voltage	18V
Welding Speed	2 mm/s
Argon Flow Rate	18 l/min
Active Layer Coating	0.5-1 mg/cm ²
Heat Input	990 J/mm
Constant Current TIG	110 A
Peak Current	160A
Base Current	60A
Pulse On Time	50%
Pulse Frequency	5Hz

Pulsed current TIG welding parameters are optimized [25] and compared with constant current TIG welding. Here in both the CCTIG and PCTIG welding constant heat input is maintained. Bend test is performed using a special bend test attachment in Universal Testing Machine with the standard of ASTM E190 on the specimens with dimensions of 100mm x 30mm x 5mm (L x W x T) in Figure 1. Sample before and after bend test are shown in figure 2 and figure 3 respectively.

Figure 1: Attachments for bend test in UTM



Figure 2: Samples before bend test



Figure 3: Samples after bend test



III. RESULTS AND DISCUSSION

Table 2: Results – Bending Strength

Description	Bending strength (KN)
CCTIG	0.91
ATIG -Al ₂ O ₃	0.79
ATIG -CaO	0.66
ATIG -MgO	0.59
ATIG -SiO ₂	0.99
ATIG -TiO ₂	0.82
ATIG -MnO ₂	0.56
PCTIG	1.5
PCATIG -Al ₂ O ₃	1.2
PCATIG - CaO	1.19
PCATIG -MgO	1.21
PCATIG -SiO ₂	1.48
PCATIG -TiO ₂	1.37
PCATIG -MnO ₂	1.12

Table 2 shows the bending strength value of different variants of TIG welding processes. ATIG welding, CCTIG and ATIG-SiO₂, shows higher bending strength of 0.91KN & 0.99 KN. Other variants of ATIG-TiO₂ and ATIG-Al₂O₃ have intermediate value in the range of 0.79KN to 0.82KN. ATIG-CaO, ATIG-MgO and ATIG-MnO₂ show lesser bending strength ranging from 0.5KN - 0.6KN. In PCATIG welding, PCTIG shows the highest bending strength of 1.5KN followed by PCATIG-SiO₂ of 1.48KN. Other PCATIG welding variants has 1.1KN - 1.4KN as their bending strength.

It is inferred that higher the bending strength shows higher ductility and toughness of the weld. Bending test is performed as face bend test since, the face of the weld having higher micro hardness value than the root of the weld.

IV. CONCLUSION

From the above study it is clear that active flux coating of CaO, MgO, SiO₂, TiO₂, Al₂O₃ & MnO₂ on TIG & PCTIG welding have significant influence on bending strength. In ATIG welding SiO₂ and TiO₂ have positive effect of increase in bending strength. Fluxes such as CaO, MgO, MnO₂ & Al₂O₃ shows slight reduction in bending strength than the normal CCTIG welding. PCATIG welding shows improved bending strength and weld penetration than the normal ATIG welding while using same active flux. In PCATIG welding, active fluxes of SiO₂ and TiO₂ shows improved bending strength than the ATIG welding, PCTIG welding and CCTIG welding conditions. Combination of PCTIG welding with ATIG welding results in advantages of improved bending strength through pulsed current TIG welding parameters and increased weld penetration by reverse Marangonic effect & arc constriction effect in ATIG welding.

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