Introduction of Reinforcement Material into the Weld Joint During Joining Process of Aluminium Metal Matrix Composite

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ABSTRACT

The aim of coating the aluminum electrode is to introduce SiC into weld pool so that the weld metal becomes a Metal Matrix Composite (MMC) of Al and SiC. In this paper, the coating of silicon carbide is carried out by dipping the aluminum electrode filler wire in the slurry prepared by using distilled water, sodium silicate and silicon carbide powder. During experiment the water content is maintained constant (100ml). The present investigation reveals the coating of silicon carbide on filler wire is uniform and with the increase of % of silicon carbide and sodium silicate, thickness of the coating also increases. The coating on top of existing coating was carried out and again the thickness of coating was studied. Results show that the thickness of coating increases substantially after second coat. This type of coating of filler wire with SiC helps to introduce SiC into the weld pool.

INTRODUCTION

Aluminum and its alloys can be joined by several methods. The primary joining method is gas shielded arc welding processes. Aluminum has several chemical and physical properties that need to be understood when using the various joining process. The specific properties that affect welding are it's thermal, electrical and nonmagnetic characteristics, it's lack of color change when heated and it's wide range of mechanical properties and melting temperatures that result from alloying with other metals.

Gas tungsten arc welding can be used to weld thinner aluminum products with the thickness ranging from 0.75 to 9.375 mm. Alternating or direct current power source may be used: but alternating current is preferred for manual and mechanized applications.

Filler metal may not be required, depending on the joint geometry and application. Thin materials are frequently welded without filler metal. Choice of filler metal is based on ease of welding;corrosion resistance, strength, ductility, elevated temperatures service and color match with the base metal after welding.

Argon is the shielding gas generally used during welding; but argon-helium gas mixtures are also used to achieve good penetration and faster travel speed. Argon - helium mixtures are preferred with Direct Current Electrode Negative (DCEN). Al-MMC, because of their greater ease of manufacture, lower production costs and relatively isotropic properties is now finding wide application as light weight structural material. The most commonly used reinforcement materials in dis-continuously reinforce-ment materials (DRA) composites are silicon carbide (SiC) and aluminum oxide.

Welding of Al-MMC is not a mature technology and many important details are not well understood. Relatively little work has been directed toward furthering the understanding of Al-MMC joining. Much of the work has been either proprietary or protected for national security reasons and is not available in the open literature.

The present work is focused on discontinuously reinforced (particle) Al-MMC composites.

The welding of Al-MMC's differs from the welding of monolithic aluminum alloys in that the weld pool of the composite contains a solid phase, because the material added for reinforcement does not necessarily melt at welding temperatures. As a result, the weld pool does not flow and wet as readily as that of monolithic aluminum alloys. Therefore, heat flow by convection in the weld pool is believed to be less effective than it is for aluminum alloys. The differences in heat flow in the MMC, relative to monolithic aluminum alloys, can affect the resulting microstructures and the stress distributions in the MMC weld.

One of the major challenges in joining MMC is the development of suitable consumable. Metal matrix composites electrode is not generally used for the welding purpose. However electrodes with bare Al rods with a coating of silicon carbide can be used for this purpose. Suitable binder materials are used for providing SiC coating used. Thickness of coating is increased by increase in binder material and this help in introducing more of silicon carbide in the weld pool.

AIM OF THE STUDY

The aim of the study is to introduce SiC particulate directly into the weld metal. SiC powder coated filler wire / electrode which may help in introducing SiC to the weld pool.

Experimental Details

The parent material is an Al 6061 alloy. The welding electrode is 4043 Aluminum alloy. To introduce SiC into the weld pool an attempt is made to coat the particulate powder onto the welding electrode. The steps in the experiments are shown in Fig1

Slurry Preparation
↓
Electrode Coating Study
↓
Study SiC Slorry Viscosity
↓
Select optimum Slurry Composition
↓
Make coat on Al 4043 Electrode
↓
Measure Coating Thickness
↓
Welding

Fig. 1 : Experimental steps to optimize silicon carbide powder coating on the filler electrode

It is observed that the first step is to prepare slurry of silicon carbide suspension in water. Following were the steps for the preparation of silicon carbide water slurry with sodium silicate as binder. The amount of binder was varied from 5 to 15% in steps of 5%. It is observed that the viscosity plays significant role in the control of coating thickness and viscosity depends on amount of silicon carbide in the slurry. Hence, in order to know the optimum amount of silicon carbide which will give proper control the coating thickness, it is essential to measure the effect of slurry viscosity on coating thickness. Hence, the preliminary experiment was designed to examine the effect of filler (filler is silicon carbide powder) to binder. The amount of silicon carbide was varied from 20 to 100 gms in steps of 20gms for every 100 ml water containing sodium silicate as binder. A term called filler to binder ratio which is the weight of silicon carbide in grams to the volume of binder solution (g/cc) is defined to study the variation of viscosity with variation in binder and the SiC content of the coating.

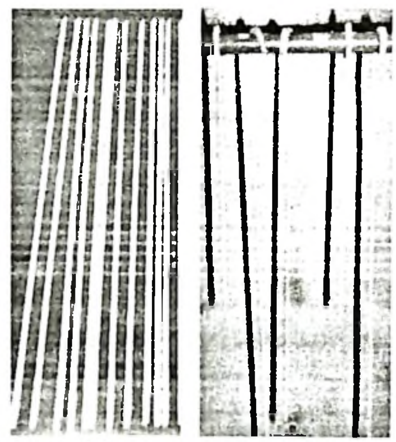
Viscosity was measured using ASTM standard Ford cup 2B viscometer the detail of which is shown below.

1. Ford Cup2B with orifice Dia 4.12 mm
2. Capacity is 100 cc

Viscosity $V = 3.85\,(t - 4.49)$

where t = flow time in sec of the slurry in viscometer

Before filling the slurry to viscometer it is thoroughly cleaned with distilled water and dried with acetone. It then filled with the slurry and the flow time of slurry discharge is tabulated for various values of filler to binder ratio. The slurry is prepared by taking requisite amount of filler (SiC) and thoroughly mixing it with 100 ml distilled water and stirring it well. Then, it was poured into Ford viscometer and the flow time of slurry out of the viscometer orifice was recorded for different composition. In fig. 2 (a) uncoated filler wire of 4043 Aluminum alloy and fig. 2 (b) silicon carbide coated filler wires are shown



(a) (b)

Fig. 2 : (a) Uncoated Weld Wire
(b) Coated Weld wire with SiC

The electrode coating with SiC was done by dipping it to a length of 300 mm into the slurry held in cylindrical pipe. The pipe has a nozzle connected to the carbon dioxide gas cylinder. Carbon dioxide is passed for 60 s to gel and harden the sodium silicate binder in the coating mixture. The electrodes with coating were taken out and dried for two minutes. Thickness of the coating was measured using digital vernier at three different places and average value is recorded for all compositions of slurry.

RESULTS AND DISCUSSIONS

The effect of filler to binder ratio on the viscosity of the slurry is presented in Table 1. It is seen from the figure that for filler to binder ratio of 0.2 to 0.6 (F/B) there is no appreciable change in viscosity even though the amount of binder is 5 or 10 or 15 percent. But, at

0.7 to 1.0 filler to binder ratio, the binder percentage influences the viscosity. In fact it is directly proportional to viscosity of slurry. Effect of filler to binder ratio on coating thickness is shown in Table 2. For a given binder content say 5% the coating thickness increase gradually up to a filler to binder ratio from 0.5 to 1.0 where in rapid increase in coating thickness was seen. It is observed that the coating thickness is not influenced by the quantity of sodium silicate in the slurry, except for 15% binder and filler to binder ratio of 0.8 Results showed that filler to binder ratio of 0.1 to 0.5 did not provide enough viscosity to give good coating thickness. This may be due to the quantity of silicon carbide is less in the slurry and also the flow of the slurry was like a water. This means that there is a minimum filler to binder ratio that has to be maintained for obtaining sufficient coating thickness.

The purpose of providing second coating is to increase the coating thickness using a slurry of given viscosity. The method adopted is to repeat the coating process using an already coated electrode. The results of the second coating trials are given in Table 3. It is clearly observed that the thickness is once again directly proportional to filler to binder ratio Overall the second coating thickness is slightly higher than the first coat thickness as shown in Table 3. This tendency may be due to the absorption of liquid by the existing coat and this absorption of liquid may result in an increase in the viscosity of second coating layer which in turn causes increase in thickness.. Figure 3 shows the weld bead produced by the bare electrode of 4043 and Fig.4 shows the weld bead produced by coated electrode. The smooth bead appearance indicates the performance of coated electrode is satisfactory. Further studies are on to find out the vol% SiC impregnated into the weld metal and also the effect of impregnation on the performance of the joint.

Table 1: Filler to Binder ratio on Viscosity, cp

Filler to binder ratio	5% sodium silicate	10% sodium silicate	15% sodium silicate
0.2	15.44	15.60	15.60
0.4	19.29	19.38	19.60
0.5	20.45	20.60	20.69
0.6	21.01	21.21	21.55
0.7	23.14	25.06	25.06
0.8	25.06	25.83	26.99
0.9	25.50	25.83	28.91
1.0	26.01	26.99	31.73

Table 2 : Coating Thickness of single coat, mm

Filler to binder ratio	5% sodium silicate	10% sodium silicate	15% sodium silicate
0.2	0.014	0.015	0.02
0.4	0.019	0.02	0.025
0.5	0.022	0.025	0.029
0.6	0.036	0.04	0.04
0.7	0.051	0.055	0.06
0.8	0.068	0.07	0.075
0.9	0.08	0.085	0.09
1.0	0.091	0.1	0.15

Table 3 : coating over Coating (Double Coat) in mm, 15% Sodium Silicate

Filler to binder ratio	First Coat	Second Coat
0.2	0.02	0.04
0.4	0.025	0.055
0.5	0.029	0.067
0.6	0.04	0.07
0.7	0.06	0.09
0.8	0.075	0.1
0.9	0.09	0.11

Fig. 3 : Weld bead formation when using uncoated filler wire 4043 alloy

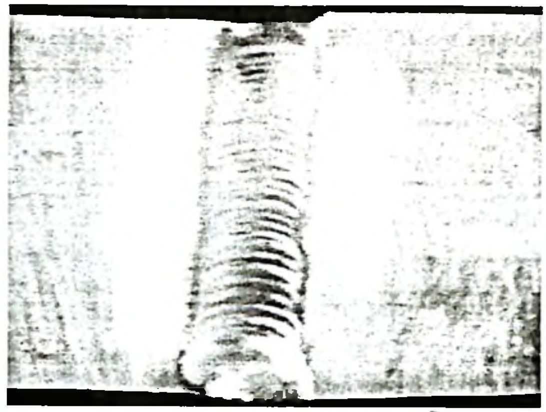


Fig. 4 : Weld bead formation on plates using coated filler wire

CONCLUSION

1. For obtaining a workable viscosity it is preferable to use filler to binder ratio higher then 0.5
1. A binder content of 15% sodium silicate was most suitable to produce sound coating
2. To increase the silicon carbide content in the coating more than one coat is necessary on the electrode

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