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EXPERIMENTAL INVESTIGATION ON CONTINUOUS DRIVE FRICTION WELDING OF COMPOSITE MATERIALS

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ABSTRACT

Ceramics contain a distinctive property of completely absence of slip planes and have least probability of deforming by the application of force. Among these ceramics, the silicon carbide occupies a competent place to be used as a reinforcing agent for aluminum or its alloys. It has the density close to aluminum and is best for making composite having good strength and good heat conductivity. Stir casting has been used to synthesize Al/SiC MMCs by reinforcing silicon carbide particles into aluminum matrix. The reason for using stir casting is to develop technology for the development of MMCs at affordable cost. The selection of SiC as reinforcement and Al as matrix is chosen of their easy availability.The present work was mainly carried out to characterize the SiC/Al composite which was produced by reinforcing the various proportions of SiC (3, 6 and 9%) in aluminum matrix using stir casting technique. Aluminum-Silicon Carbide composites have been studied using metallographic and mechanical testing techniques. It was observed that as the volume fraction of SiC in the composite is gradually increased, the hardness and toughness increase. However, beyond a level of 25-30 percent SiC, the results are not very consistent, and depend largely on the uniformity of distribution of SiC in the aluminum matrix, Aluminum-Silicon Carbide composites are welded using Friction welding process and investigation is made to analyze the quality of weld using SEM and XRD. The design of experiments like ANOVA is done for selecting the various welding parameters like heating pressure (HP), Heating Time (HT), Upsetting Time (UT) and Upsetting Pressure (UP) and to find the best process parameters to get good quality joints.

Keywords: AA7075, SiC, Stir Casting, Friction Welding.

1. INTRODUCTION

Metal matrix composites (MMCs) offer several advantages. They have high strength in spite of having a low density, and they have high wear resistance, a large coefficient of thermal conductivity, a small coefficient of thermal expansion, and can be strengthened by plastic working. These materials are used not only in the field where the working costs are mainly influenced by weight, such as aerospace and aircraft, but also in other industrial fields like the automotive Industry.

Many of research works that include the fabricating processes and properties estimation for this kind of materials has been done, the further investigation on practical applications of secondary processing technologies (such as machining, joining, plastic forging, joining and so forth) is also becoming considerably important and urgent. Extensive efforts have been devoted to investigating the appropriate Processes to join the similar or dissimilar composites. There are still many problems on the joining of discontinuously reinforced aluminum matrix composite materials. In the melting state, the liquid welding pool of composite had great viscosity with poor wettability, and it is difficult for composite itself to mix with the filler materials. When the molten welding pool was cooled down, the reinforcement phases were rejected by the solidification front, and the normal solidification processes of the welding pool had been broken down, and this would lead to micro segregation or inhomogeneous distribution of the reinforced phases. In the case of friction welding with MMCs, which

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involves the formation of the solid bond, this problem does not occur, and the strength of the part welded is comparable to that of the base metal under specific conditions.

2. TYPES OF METAL JOINING PROCESS

There are different ways of categorizing the joining processes. According to American Welding Society (AWS) the joining processes fall into three major categories.

- Welding.
- Adhesive Bonding.
- Mechanical fastening.

The following Figure 1.1 shows the major classification of metal joining processes

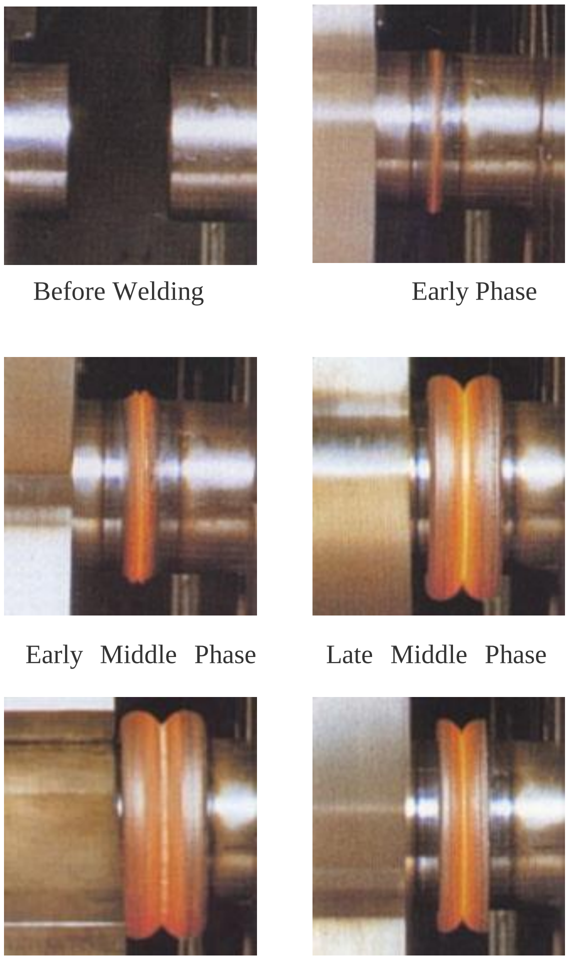
2.1 FUSION WELDING PROCESS

The fusion welding process involves the partial melting and fusion of the joint between two metals. It is defined as melting together and coalescing the materials by means of heat. The thermal energy required for these welding operations is usually supplied by means of chemical or electrical energy. Filler metals are added to the weld area during welding. This process constitutes a major category of welding; it comprises consumables or non consumable electrode arc welding and high energy beam welding processes.

Typical parameters for Inertia Friction Welding

Base Material	Peripheral speed (m/s)	Min. weld energy Kg/m/mm^2	Axial pressure for 25 mm Kg/mm^2
Similar Materials			
Low Carbon steel	2.5 to 5.0	6.6	11.2
Medium Carbon steel	2.5 to 5.0	7.7	12.8
Chromium steel	3.0 to 4.5	8.2	13.8
Dissimilar materials			
Stainless steel to low C steel	3.0 to 4.0	3.2	13.8

Table 1.1 - Typical parameters for Inertia Friction Welding



Before Welding — Early Phase

Early Middle Phase — Late Middle Phase

Late Phase — Finished Weld

Fig 1: Different phases of Friction welding processes

Wysocki .J et al (2007) had made Continuous drive friction welding of cast AlSi/SiC(p) metal matrix composites in systems AlSi11-AlSi9/SiC/21$_{(p)}$, AlSi9/SiC/21$_{(p)}$-AlSi9/SiC/21$_{(p)}$ AlSi11/SiC/15$_{(p)}$-AlSi11/SiC/15$_{(p)}$. Examination of welds microstructure revealed that during friction welding process three different zones of size and distribution reinforced particles in the metal matrix appeared. Discernible effect of friction welding parameters on the microstructure matrix has been noticed. Subsequent hardness tests confirmed changes in matrix microstructure and influence particles redistribution on the weld mechanical properties.

Lin C. B., et al (1999) investigated the rotation friction welding system with 360Al and360Al/5v-%-10v-% (v-% = volume fraction percent) SiC particulate composites utilizing both identical and different materials and two joint designs. In joint design I, one side is a lead angle and the other is

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a plane. In joint design II, both sides are planes. From the experiment, it was noted that using joint design I achieved better joint strength. The joint strength is best with 360Al-360Al and worst with 360Al/10v-%-360Al/10v-% SiC particulate composites. 360Al-360Al has a ductile fracture with dimples, while the 360Al/10v-%-360Al/10v-% SiC particulate composite has a low-ductile fracture. The 360Al/10v-%-360Al/10v-% SiC particulate composites are fractured in the Zpl zone, while the others are fractured in the interface between the Zpl zone and the Zpd zone. For the joint systems using different materials, the fracture is in the interface between the Zpl zone and Zpd zone, where the quantity of SiC particulate is higher. In the heat-affected zone (HAZ) for identical materials, the Zpl hardness value is smaller than Zud; for the different materials, the hardness in Zpl is half of the two Zud hardness total values.

3. MATERIAL SELECTION

Pure form of aluminium is soft in nature. Therefore the tensile strength, hardness strength is usually low. In order to have wide range of mechanical properties small amount of alloying element are added to the pure form of aluminium .According to the international specifications of wrought alloys, the commercially available alloys are classified as heat treatable alloys and non-heat treatable alloys .with this perspective here on attempt was made in order to have high strength, good resistance to corrosion. Therefore aluminium 7075 with 3%, 6%, and 9% of silicon carbide was selected.

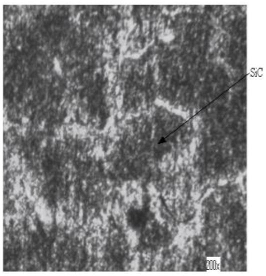
WELD WORKPIECES

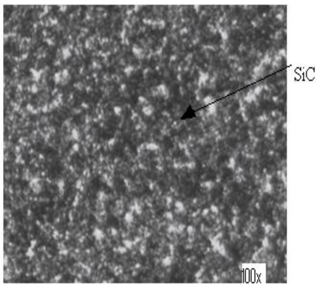
The images of the welded samples are shown in figure 3.3. The welding was done by ETA made friction welding machine. Welding was done on the samples with different SiC concentration. The three combination of the samples are Al7075/3% SiC- Al7075/3% SiC , Al7075/6% SiC- Al7075/6% SiC and Al7075/9% SiC-Al7075/9% SiC respectively.

3. RESULTS AND DISCUSSION

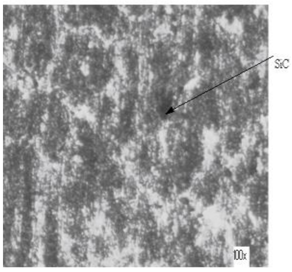
3.1 Homogeneous distribution analysis

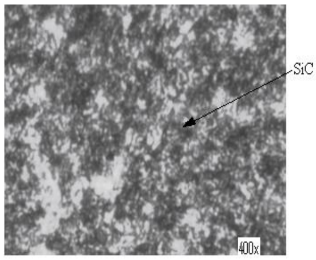
The homogeneous distribution of composite materials was analyzed and the microstructure is shown in figure 3.1 (a) and 3.1 (b) Homogeneous distribution of silicon carbides in the matrix was observed. The microstructure of Al7075/3% SiC, Al7075/6% SiC and Al7075/9% SiC was analyzed using optical microscope.



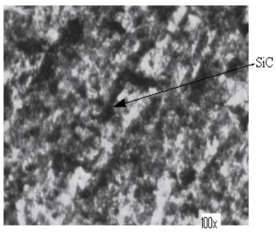


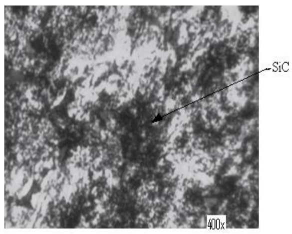
(a) 3% SiC **(a) 3% SiC**





(b) 6% SiC **(b) 6% SiC**





(c) 9% SiC **(c) 9% SiC**

Fig 3.1 (b) Homogeneous distribution of casting Al7075/SiC

3.2 Structure of Heat Affected Zone

As established by Wysocki et al [1], the heat affected zone in the friction weld of Al/SiC metal

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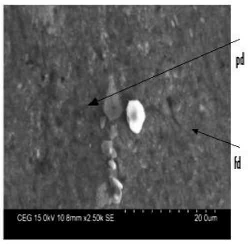
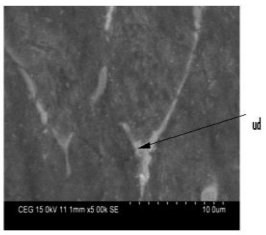
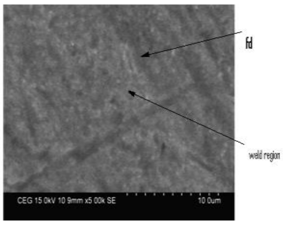
matrix composite is divided into three separate zones: fully deformed region, partially deformed region and undeformed region. The different combination of 3%, 6%and 9% of silicon carbide is welded with aluminium 7075 alloy respectively. The ETA made friction welding machine was used to weld the composite materials. The friction pressure, rotation speed, burn off length, friction time was kept constant while the percentage of silicon carbide was varied. During welding, the heat affected zone was formed which reduces the welding efficiency. By decreasing the heat affected zone, the welding efficiency could be increased. After completing the experiment, images of the Al7075/3% SiC- Al7075/3% SiC, Al7075/6% SiC-Al7075/6% SiC, Al7075/9% SiC- Al7075/9% SiC specimen were taken using scanning electron microscope which is shown below in fig 4.3 Under the influence of material mixing and simultaneous application of high pressure SiC particles are found to be evenly distributed in matrix. The particle size of silicon carbide in the welded region is smaller than the unwelded region where the efficiency of the welding increases as the particle size decreases. Here, welding region silicon carbide particle size was reduced and homogeneous distribution of silicon carbide between two mating parts was identified. Three different welding regions were identified namely fully deformed region (fd), partially deformed region (Pd), and undeformed (ud) in the specimen. The macrostructure welding zone shown in the in fig 4.2 the bonding interface was analyzed. During micro examination of the bonding interface between two mating parts and friction welding of composite materials, it was found that the reinforcing particles close to bonding line got changed in size and distribution compared to the base material region. This effect can be seen clearly in Fig 4.3 (a). Where the particle size in the welding zone is significantly smaller and its distribution is more homogeneous than that in the base composite material.

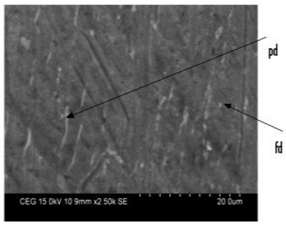
fd =fully deformed zone **pd** = partially deformed zone **ud** = undeformed zone



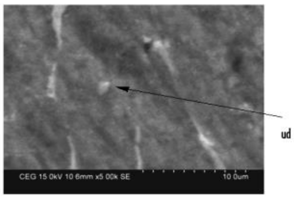


3%SiC 3% SiC





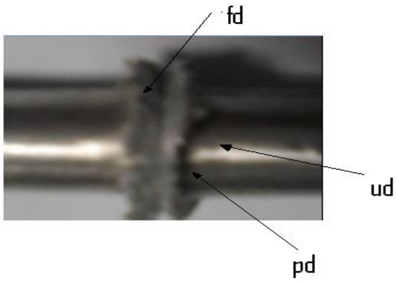
6%SiC 6%SiC



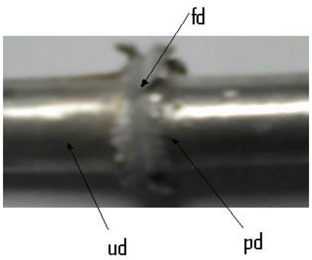
9%SiC

Fig 3.3 microstructure analysis of Al7075/SiC 3%, 6%, 9 %

(a) 3% SiC



(b) 6% Sic



(c) 9% SiC

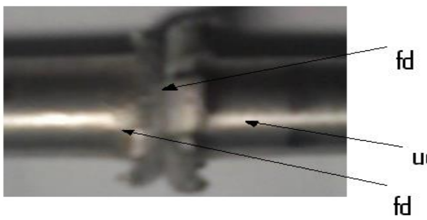


Fig 3.4 Macro structure of welding zone Al7075/SiC

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4. CONCLUSIONS

- For all welds (Al7075/3% SiC- Al7075/3% SiC , Al7075/6% SiC- Al7075/6% SiC , Al7075/9% SiC- Al7075/9% SiC) three regions differing in structure can be distinguished namely fully deformed region, partially deformed region and undeformed region.
- In the weld systems, partially deformed region was characterized by band distribution of reinforced particles and reduced hardness of matrix.
- For fully deformed region Al7075/9% SiC- Al7075/9% SiC systems hardness was lower than that in the undeformed regions. Most probably, high density reinforced particles in fully deformed region is effective to barrier dislocation moment. Hence the high density SiC particles and restriction of dislocations shift must act against annealing effect and prevent the loss of hardness in fully deformed region.
- The welding efficiency was increased for reduced heat affected zone.
- From the three zones, fully deformed zone, partially deformed and undeformed zone it was found that the reduction rate of particle size increased as the welding efficiency was increased.

After micro-examination of the bonding interface, the base metal showed some second particulate formed by condensed silica particulate. However, discoloration part distributed minute silica particulate without second particulate.

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