

Temperature Distribution Analysis of Friction Stir Welding of Al-SiC-Gr Hybrid Composites

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ABSTRACT: Metal matrix composites are appreciated as the better option in numerous applications both in terms of property and cost. Development of these new materials elicits the evolution of their joining methods. Friction stir welding is the result of that necessity which is the most suitable for welding metal matrix composites. In this research the joining of Al-SiC-Gr hybrid matrix composites through friction stir welding is analyzed numerically. Temperature distribution in the hybrid metal composite is obtained by employing transient thermal analysis. A moving heat source with a heat distribution simulating the heat generated from the friction between the tool shoulder and the work piece is used in the heat transfer analysis. Three dimensional models for moving heat source and changing boundary condition are developed and analyzed using ANSYS APDL software.

KEYWORDS: Friction Stir Welding, Al-SiC-Gr Hybrid Composites, Ansys

I. INTRODUCTION

Friction welding (FW) is a class of solid-state welding processes that generates heat through mechanical friction between a moving work piece and a stationary component, with the addition of a lateral force called "upset" to plastically displace and fuse the materials. According to the American Welding Society, the origins of friction welding date back to 1891, when the first patent on the process was issued in the USA. More work progressed throughout Europe as more patents were issued from 1920 to 1944 and in the USSR in 1956. In the 1960's, friction welding was further developed in the USA by AMF, Caterpillar, and Rockwell International. Rockwell built its own machines to weld spindles to truck differential housings, AMF produced machines to weld steering worm shafts, and Caterpillar's machines welded turbochargers and hydraulic cylinders. The latest applications are discussed with an emphasis on recent advances in aerospace, automotive, and ship building. Finally the direction of future research and potential application are examined [1]. composite material based on aluminum alloy (Al 2024) reinforced with 10% volume fraction of Silicon Carbide Particulates (SiC) and 5 % composite is tested in order to find tensile strength and hardness and analysis is carried out using Ansys software version 10.0 [2]. The thermal expansion and thermal conductivity behaviors of hybrid composites with various graphite contents (5.0; 7.5; 10 wt.%) and different silicon carbide particle sizes (45 μm and 53 μm) were investigated. Results indicated that increasing the graphite content improved the dimensional stability, and there was no obvious variation between the thermal expansion behaviors of the 45

μm and the 53 μm silicon carbide reinforced composites. The thermal conductivity of hybrid composites was reduced due to the enrichment of the graphite component [3]. The fracture occurred along the LHZs. Under investigated welding parameters, no welding defect was detected in the joints [4].

Xiao Cong He, Fengshou GU the latest Developments in the numerical analysis of friction stir welding processes, microstructures of friction stir welded joints and the properties of friction

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stir welded structures. Some important Numerical issues such as materials flow modeling, meshing procedure and failure criteria are discussed [5]. C.M. Chen, R. Kovacevic a three-dimensional model based on a finite element method (FEM) is proposed to study the thermal impact and evolution of the stresses in the weld by considering the mechanical effect of the tool this study is accomplished by parametrically studying the effects of varying welding parameters, primarily the traverse speed of the tool. The entire welding process is simulated using the commercial finite element package ANSYS [6]. S. Malarvizhi, V. Balasubramanian the tensile properties of dissimilar magnesium (AZ31B)–aluminum (AA6061) joints were evaluated. Of the five joints fabricated using tools with different shoulder diameters, the joint fabricated with a tool shoulder diameter of 21 mm (3.5 times the plate thickness) yielded maximum tensile strength of 192 MPa and the joint efficiency is 89% compared with the lower strength base metal [7].

M. Song, R. Kovacevic a moving coordinate has been introduced to model the transient three dimensional heat transfer process for FSW. The coordinate is chosen stationary with the moving tool. Therefore the difficulty of modeling the complicated stir process can be greatly reduced, thus making this model more accurate [8]. BinnurGörenKıral presents A moving heat source with a heat distribution simulating the heat generated from the friction between the tool shoulder and the work piece is used in the heat transfer analysis. Three-dimensional models are carried out by using ANSYS and Hyper extrude commercial software’s. APDL (ANSYS Parametric Design Language) code is developed to model moving heat source and change boundary conditions [9]. The thermal expansion behavior of Al-Sic-Gr composites is investigated and its response is studied between 50°C to 350°C using Horizontal Platinum Dilatometer. The assessment of thermal parameters of composites will benefit to analyze heat capacity, variation in the intensity of heat, heat diffusion and heat release rate. The density of the composites is also determined using water displacement method. The theoretical and experimental values are determined to check the porosity of composites. Using Rule of Mixtures, the theoretical density is determined and the same is compared with the experimental value, which help to understand the distribution of reinforcements [10].

II. MATERIAL DESCRIPTION

Metal Matrix Composite (MMC) is rapidly becoming prime candidates as structural materials in engineering as well as in electronic application. Aluminium (Al) reinforced by SiC is used in various industries due to its excellent properties such as in table I. Al-SiC’s high thermal conductivity offers superior reliability and longevity by preventing the bowing and flexing of packaging and substrate material. Traditional packaging materials with lower thermal dissipation can cause delamination, leading to air gaps and failure. Unlike baseplates which have been made from aluminium, Al SiC MMC baseplates survive thousands of cycles without delamination of the substrate from the baseplate. Addition of graphite as particle reinforcement improves the wear characteristics of the composite since it is a solid lubricant and makes the material suitable for applications requiring high strength and wear resistance.

TABLE I - PROPERTIES OF METAL MATRIX COMPOSITES

Thermo-physical Properties	Mechanical Properties
Low coefficient of thermal expansion (CTE) High thermal conductivity	Higher specific strength Better wear resistance Desirable Specific modulus

III. NUMERICAL SIMULATION

The numerical simulation of the process is considered as axis-symmetric. ANSYS finite element package was used for the analysis purpose. The transient thermal analysis was done to determine the temperature distribution on the welded parts. The heat loss due to radiation is ignored because it is so small. The temperature dependent material properties for

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different materials are considered for the analysis.

A. THERMAL CONDUCTIVITY OF COMPOSITES

The thermal conductivity results obtained at different temperatures for SiC reinforced Al-SiC based hybrid MMCs with various graphite contents [3] are required to simulate the heat distribution in the composite plates. Thermal conductivity values (W/mK) of the Al-Si hybrid composites between 50 °C and 300 °C is given table II

TABLE II
THERMAL CONDUCTIVITY OF Al-Si HYBRID COMPOSITE

Composite	Test temperature, °C					
	50	100	150	200	250	300
Al-Si 20 vol.% SiC (45 µm)/5.0 wt.% graphite	186.4	178.8	171.1	165.4	161.2	158.1
Al-Si 20 vol.% SiC (45 µm)/7.5 wt.% graphite	181.2	173.5	157.6	148.2	138.8	130.5
Al-Si 20 vol.% SiC (45 µm)/10 wt.% graphite	176.4	165.5	152.4	136.3	128.8	118.4
Al-Si 20 vol.% SiC (53 µm)/5.0 wt.% graphite	202.2	195.5	188.4	171.5	168.3	158.6
Al-Si 20 vol.% SiC (53 µm)/7.5 wt.% graphite	194.8	190.4	181.1	170.5	162.1	150.8
Al-Si 20 vol.% SiC (53 µm)/10 wt.% graphite	185.6	175.5	166.2	155.3	146.2	136.7

B. HEAT DISTRIBUTION

The heat distribution and thermal gradient results are provided below for the developed model. The model when analyzed with a moving heat source produced the thermal flux and thermal gradient by conduction as shown in the figure 1.

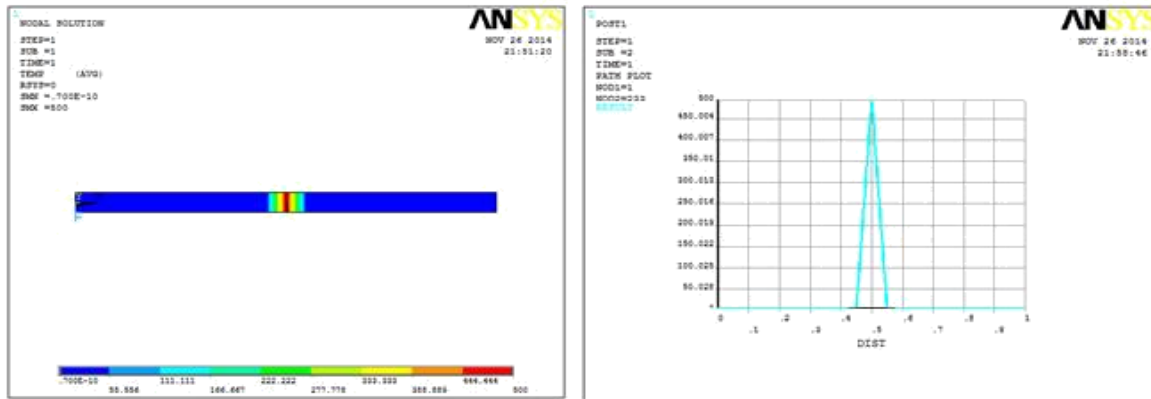


Figure1. Temperature distribution in HMC material using Ansys software and temperature graph at Convection

From the above figure shows temperature distribution in the hybrid composites specimen during welding.

Results were generated By ANSYS APDL Software for Figure 1.

TableIII. Thermal Flux and Thermal Gradient for Convection

Thermal Flux	X	Y	Z	Vector Sum
Minimum	-1.936e+006	-122.1	0	2.854e-006
Maximum	1.936e+006	122.1	0	1936e+006

Thermal Gradient	X	Y	Z	Vector Sum
Minimum	-9939	-0.6268	0	1.465e-008
Maximum	9939	0.6268	0	9939

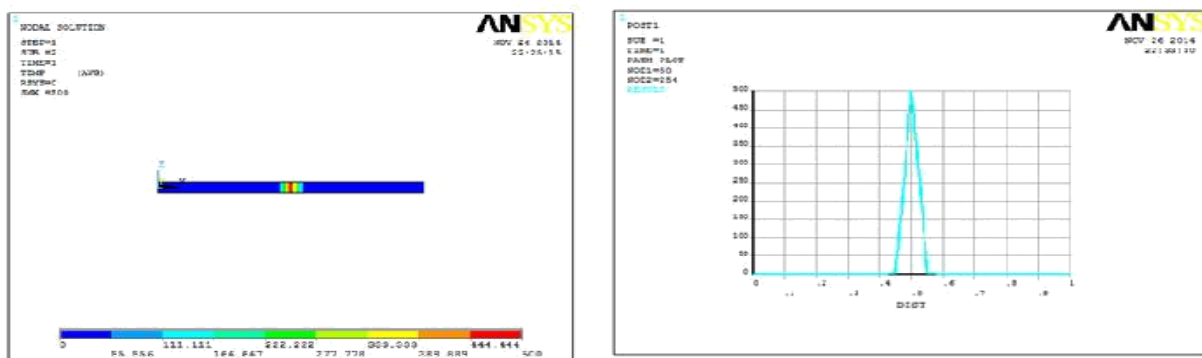


Figure 2. Temperature distribution in HMC material and temperature distribution graph at Conduction.

TableIV. Thermal flux and Thermal gradient for conduction

Thermal Flux	X	Y	Z	Vector Sum
Minimum	-1.936e+006	-1.936e+004	0	4.681e-030
Maximum	1.936e+006	-1.936e+006	0	2.171e+006

Thermal Gradient	X	Y	Z	Vector Sum
Minimum	-1e+004	-1e+004	0	2.404e-032
Maximum	1e+004	61.24	0	1.114e+004

These were the results numerically obtained for the joining of Al-SiC-Gr hybrid matrix composite solved under the condition of single moving heat source by ANSYS software.

IV. CONCLUSION

In this research the joining of Al-SiC-Gr hybrid matrix composites through friction stir welding is analyzed numerically temperature distribution in the hybrid metal composites is obtained by employing transient thermal analysis. by this analysis the thermal temperature distribution are maximum in the specimen maximum heat distribution in the specimens are reduce the defects. Al-SiC-Gr hybrid matrix composites Three dimensional models for moving heat source and changing boundary condition and heat flux and thermal gradient developed and analyzed using ANSYS APDL software.

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