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# A Comprehensive Review of Friction Stir Welding on Metal Matrix Composites

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**Abstract:** Friction Stir Welding (FSW) is a novel process to facilitates various welding joints for different applications. It is an attractive technology for solid state material joining have many advanteges over conventional welding methods, like ability to produce welds with higher integrity and minimum induced distortion and residual stresses. In this paper, the operation of FSW on metal matrix Composites (MMCs), history, advantages, and limitations were discussed. Effect of different reinforcement on MMCs on the mechanical properties like tensile strength, strain hardness wear and fatigue are discussed. Further different applications of the process are presented along with critical review of literature.

**Keywords:** Friction Stir Welding(FSW), Aluminium Metal Matrix Composites (MMCS), Mechanical Properties.

## I. INTRODUCTION

Friction stir welding (FSW) was invented and experimentally proven by Wayne Thomas and a team of his colleagues at The Welding Institute UK in December 1991. It is an innovative technique for joining two pieces of metal. A rapidly rotating tool is inserted between two pieces of metal causing friction heating which in turn softens the material. This softening cause a flow around the tool, which leads to greater friction heating and as a result welded joints occurs.[1]

Composite materials appear everywhere in life, both man-made (such as fiberglass) and biologically produced (like mammalian bones). The purpose of a composite man-made material is to alter and improve the properties of the matrix material, by the addition of some second material with very different chemical and structural properties.

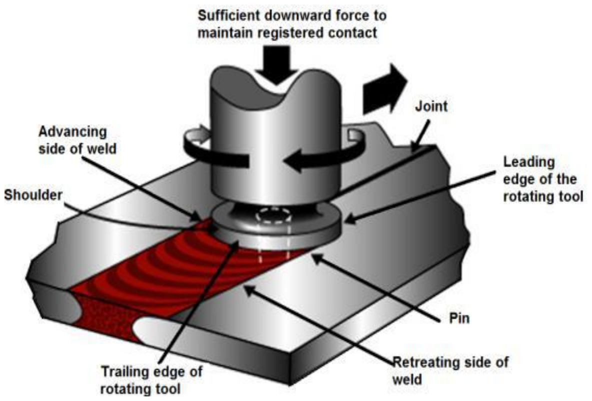


Fig.1: Diagram of friction stir welding

A metal matrix composites is composite material, one material is metal and another material is ceramic or organic compound. MMC materials have a combination of different, superior properties to an unreinforced matrix which are; increased strength, higher elastic modulus, higher service temperature, improved wear resistance, high electrical and thermal conductivity, low coefficient of thermal expansion and high vacuum environmental resistance. For example carbon fibre is used in aluminium matrix to enhance the properties which shows high strength and low density. Therefore carbon reacts with aluminium to make a brittle and water soluble compound. The carbon fibres are coated with nickel or titanium boride for prevention to the chemical reaction. The reinforcement can be two types contineous and dis-contineous. There are classification of the MMCs on the basis of reinforcement.

A- Particle Reinforcement B- Short Fibre Reinforcement C- Contineous Fibre Reinforcement D- Laminate Reinforcement

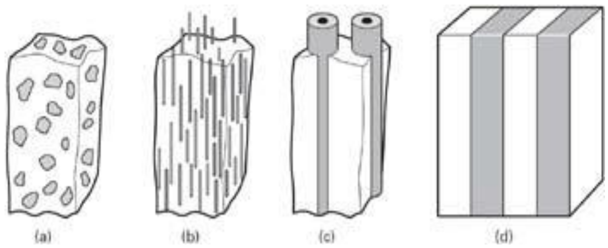


Fig 2. Types of Metal Matrix Composites

## II. LITERATURE REVIEW

Hartaj Singh [2] analysed that metal matrix composites are self-processing of metal matrix (aluminium, magnesium, copper, Iron, silicon, cobalt) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. These are various aluminium matrix composites, magnesium matrix composites, titanium matrix composites and copper metal matrix. Aluminium

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matrix composites mainly depend on aluminium- silicon alloys and on the 2xxx and 6xxx series. AMC are reinforced by alumina $AL_2O_3$ or silicon carbide particle in amount of 15-70 volume per cent. Continuous fibre of alumina is silicon carbide and graphite is long fibre reinforced composite parameter considered for given matrix dispersed phase system-concentration, size shape distribution orientation.

A. Particle Reinforced MMCs

Particle used for reinforcing includes ceramics and glasses such as small mineral particles, metal particles such as aluminium and amorphous materials, including polymer and carbon black. Particles used to increase the modulus of the matrix to decrease the permeability and ductility of the matrix.

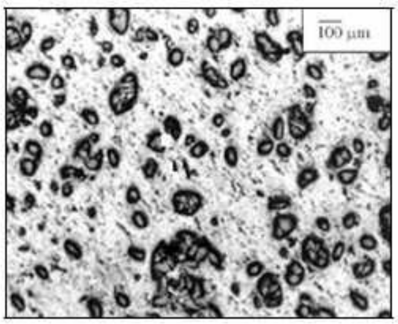

Fig 3. Photo Micro-graphic image of Al-SiCP

B. Short fibre –reinforced MMCs

Production rates for short fibre composites (both aligned and randomly oriented) are rapid intricate shapes formed which are not possible with continuous fibre reinforcement. The reinforcement does not provide a purely structural task (reinforcing and compound) but is also used to change physical properties such as wear resistance, frictioncoefficient and thermal conductivities. Discontinuous MMCs will be isotropic and worked with standard metal working techniques such as forging, rolling extrusion.

C. Long Fibre MMCs:

Long-fibre reinforced composites consist of matrix reinforced by dispersed phase in the form of continues fibre. Continues reinforcement uses monofilament are large diameter (about 100 to 150 micrometre).Wires of fibres such as carbon fibre or silicon carbide.

D. Cermet's

Cermet are composite material and the composition of ceramic (cer) and metallic (met) materials. cermets are ideally designed to have the ideal properties of both a ceramic such as high temperature resistance and hardness and those of a metal such as the ability to undergo plastic deformation.

B. Vankatesh& B Harish :[3] observed that the density and hardness properties of the metal matrix is increased due to increasing in sintering temperature. Heat treatment after sintering is increasing hardness as well as density. After heat treatment, the percentage of density is increasing as the SiCp reinforcement weight per centand mesh size increasing. Metal matrix composites hardness also increases due to increase in weight per cent and mesh size.

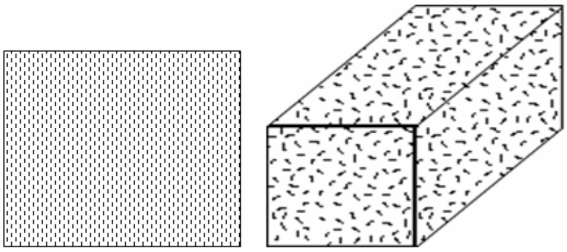
Fig 4. Short fibre reinforces composite (a) Aligned and (b) Random.

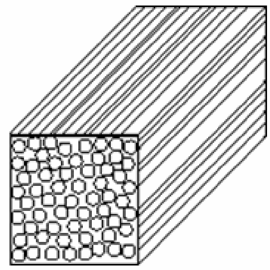
Fig 5. Long fibre reinforced fibre.

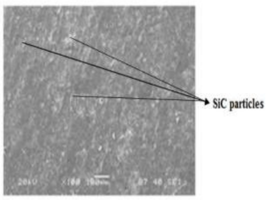

Fig 6. 10% SiC (300 Mesh size)

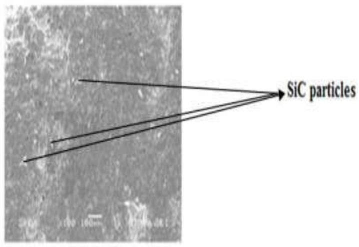

Fig 6- 15% SiC (400 Mesh size)

Rama Rao : [4] examined that aluminium alloy boron carbide composites fabrication takes place with the help of liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5 per cent). Phase identification are carried on boron carbide by x-ray diffraction studies microstructure analysis which is characterised by hardness and compression test. The density of composites decreased when the hardness is increased.

Qiang Liu et al. (5) were concluded that the tensile strength increases with the increasing multi-walled carbon nanotubes (MWCNTs) content in the composite but on the opposite, the elongation decreased. They also found that when 6 vol. % MWCNTs were added then the maximum ultimate tensile strength reached up to 190.2 Mpa, and this value was two times greater than aluminum matrix.

MahendraBoopathi [6] evaluated the physical properties of aluminium 2024 in the presence of fly ash, silicon carbide and its combination. Therefore, aluminium MMC combination the strength of the reinforcement with the toughness of the matrix to adoption of combined desirable properties which are not available in any single conventional material. The mechanical behaviour of MMCs like density, elongation, hardness, yield strength and tensile test were curtained by performing lab experiments. Bhaskar Chandra Kandpal [7] studied about various processes are to manufacture metal matrix composites. These processes are classified on the basis of temperature of the metal matrix composites.There are five categories (1) Liquid phase processes (2) Solid liquid processes (3) Deposition techniques (4) In situ processes (5) Two phase (solid liquid processes)

Uzun H. [8] demonstrated the feasibility of FSW for joining of AA2124/SiC/25p composite materials. Microstructure, microhardness, EDX analysis and electrical conductivity measurements have been performed to evaluate the weld zone characteristics of friction stir welded AA2124/SiC/25p composites. Author studied the presence of both fine and coarse SiC particle reinforced AA2124 matrix alloys. The weld nugget exhibits the relatively homogeneous SiC particle distributions but has fine particle density bands.

MohsenBarmouz et al. [9] studied FSP and attempted to incorporate nano-sized Al2O3 into 6082 aluminum alloy to form particulate composite surface layer. They were evaluated microhardness, microstructure and wear resistance. The results show that the increasing in number of FSP passes causes a more uniform in distribution of nano-sized alumina particles. Fig. 5 shows the micrographs al- alloy composite.

Kalaiselvan[10] K. et al. [10] on friction stir butt welding of AA6061-B4Ccomposites and discusses the effect of varying process parameters. The tool shoulder dimensions, welding speed and tool rotational speed were varied during welding to study their effect on the ultimate tensile strength, percentage elongation and micro-hardness of the butt joints.

Vijayavelet al.(11) concluded that at lower D/d ratio, less amount of heat is generated which is not enough for the better material transport on LM25AA-5% SiC (MMCs) plate . At higher D/d ratio, excess amount of heat is generated which leads to unsteady type of material flow which results in the phenomenon of defects in the processed zone. Therefore, optimal heat generation and successive material flow yields the superior tensile strength.

## III. CONCLUSION

From the literature review metal matrix composites concluded that pure metal matrix with sum other material through the processes like stir and different fabrication processes. Therefore, the result shows the material which formed increasing better mechanical properties and reducing the weight and cost. From the above discussion, following conclusions can be drawn:

1. Unlike fusion welding, FSW has been successfully employed to join Aluminium matrix composites.
2. Tool pin profile and materials are very critical parameters. From the literature, it can be concluded that multi face tool pin profile is used in most studies as it gives better mixing of softened material.
3. Welding parameters such as tool rotational speed and welding speed, tool tilt angle and axial force have a significant effect on the different weld properties such as hardness, tensile strength and fatigue behaviour.

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