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Effect of Quenching of mechanical aspects of Friction Stir Spot Welded Aluminium 2024 alloys

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***Abstract*— In this paper, Al 2024 was Friction stir spot welding by Vertical milling machine. This phenomenon was used to investigate the strengths of both quenched aluminium friction stir spot welded joints and unquenched friction stir spot welded joints. Quenching was done in distilled water quenchants and studying the effects on mechanical properties such as tensile strength, shear strength, hardness of the weld area as well as the microstructure like Scanning Electron Microscope (SEM) Test, was done. An attempt was made to evaluate the strength of friction stir spot welded Aluminium alloy (2024) joints and the strength was evaluated. The Test specimens were prepared as per ASTM standards to conduct Tensile and Compression test. The specimens are tested for tensile and compression strength as per ASTM standard E8-82 and E9 respectively using Universal Testing Machine.**

***Index Terms*—quenching, Micro composites, friction stir spot welding, microstructure**

I. Introduction

Friction stir spot welding is a latest technique that is being used by many industries and researchers for effectively joining similar and dissimilar joints. Malas et al. found that the use of A2024, therefore, has been growing gradually in industry as a material of aero plane constructions, automobiles, and pulling wheels. AA 2024 alloy is the most widely used aluminium–copper alloys in forging as well as rivets for aircraft industry [1]. Cheng et al. developed an effective approach in achieving both high strength and high ductility in a 2024 Al alloy. The approach involves solution-treatment to partially dissolve T-phase particles, cry rolling to produce a fine-structure containing a high density of dislocations and sub micrometer sub grains and aging to generate highly dispersed nano precipitates. Such a high density of precipitates enabled effective dislocation pinning and accumulation, leading to simultaneous increases in strength, work-hardening ability and ductility [2]. Mazahery et al. investigated the optimal solidification conditions to manufacture AA 2024 alloy with minimum wear and maximum strength. Mechanical and wear properties of unreinforced AA 2024 alloy and 24 its composites with different vol. % of coated boron carbide particles were also experimentally investigated. It was seen that the incorporation of hard particles to 2024 aluminium alloy contributes to the improvement of the mechanical properties and wear resistance of the base alloy to a great extent [3]. Rohatgi et al. observed as compared to aluminium, aluminium/fly ash composites possess higher specific hardness and specific strength. Composite was harder than that of aluminium alloy. Due to the presence of spherical fly ash particles in the composite no significant change in the aging kinetics was observed. Time required for Aging is of the order of 104 to 105 seconds to reach the improved compressive strength and peak hardness [4]. Surappa et al. found that it is possible for different variety of molten aluminium alloys which can contain 30% ceramic particles in the size range 5 to 100 µm. After complete solidification the melt ceramic particle slurry directly takes the shaped mound or it may be in the form billet or rod shape. Further it can be reheated to the slurry form by using various techniques such as die casting, and investment casting. The process is limited to the incorporation of sub-micron size ceramic particles or whiskers [5].

In this research the following issues were attempted to be addressed.

To study the effect of Quenching during the Friction stir spot welding then check the characteristics and compare the characteristics between Quenching and Non-Quenching welded AL2024 alloy.

To study the effect of Quenching on aluminium particles through Friction stir welding process to find its deformation of microstructure by using Scanning Electron Microscopy.

To investigate the integrated properties of said aluminium hybrid metal matrix composite

To examine the effect of chilling, particle content and heat treatment on mechanical and Microstructural properties of developed composite

To study the fracture analysis of chilled base metal matrix and hybrid metal.

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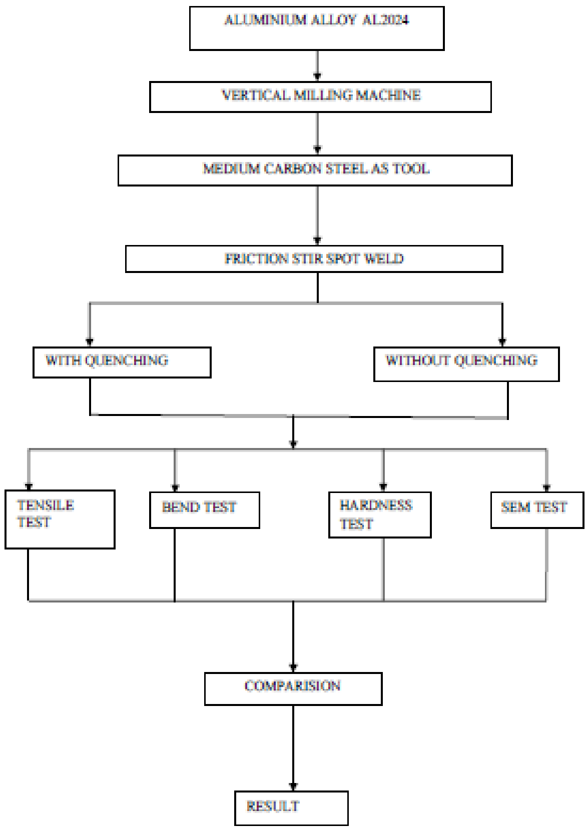

Figure 1. Flow chart for the experiments

The friction stir spot welding used in this research were three step method. In the first method, non-consumable tool was plunged. In the second step, stirring was done and in the third step withdrawal was done. The process of welding is done by using Vertical Milling Machine. The vertical milling machine offers the rotational motion to the tool. This rotational motion helps the tool to weld the work piece.

II. Materials and Methods

a) Base Materials and Tool Selection

H13 Tool Steel is a versatile chromium-molybdenum hot work steel that is widely used in hot work and cold work tooling applications. The hot hardness (hot strength) of H13 resists thermal fatigue cracking which occurs as a result of cyclic heating and cooling cycles in hot work tooling applications. The tool uses were medium carbon steel of diameter 12 mm. It contains a tool pin profile of circle projection. The tool length was 125 mm. The pin length was 2 mm.

The chemical composition of the tool material was found as

Carbon: 0.32- 0. 45%
Chromium: 4.75- 5.5%
Manganese: 0.2- 0.5%
Molybdenum: 1.1- 1.75%
Phosphorus: 0.03% max
Silicon: 0.8- 1.2%
Sulphur: 0.03% max
Vanadium: 0.8- 1.2%

Volume of tool (V):
V = pin volume (V1) + Shoulder Volume (V2)
$V = (4 \times 0.0042 \times 0.0015) + (\pi 4 \times 0.0122 \times 0.1235)$
$V = 1.39 \times 10\text{-}5$ m3
Weight of the tool(W):
W = Density of tool material × volume of tool
$W = 7850 \times 1.39 \times 10\text{-}5$
W = 0.10 Kg.

Figure 2 – FSSW tool used in the research

2024 aluminium alloy is an aluminium alloy, with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. Ths was selected. Due to poor corrosion resistance, it is often clad with aluminium or Al-1Zn for protection, although this may reduce the fatigue strength. In older systems of terminology, this alloy was named 24ST.Al. The chemical poperties of this material was found to be

Copper - 4.3 to 4.5%
Manganese - 0.5 to 0.6%
Magnesium - 1.3 to 1.5%
Silicon - 0.2 to 0.4%
Zink - 0.2 to 0.3%
Chromium - 0.3 to 0.4%
Bismuth - 0.1 to 0.3%

The mechanical properties were found to be

Density - 2780 kg/m^3
Ultimate Tensile Strength - 469 MPa
Fatigue Strength - 138 Mpa
Melting Range - 502-638 deg C
Thermal Conductivity - 121 W/m-K

In materials science, quenching is the rapid cooling of a workpiece in water, oil or air to obtain certain material properties. A type of heat treating, quenching prevents undesired low-temperature processes, such as phase transformations, from occurring.

It does this by reducing the window of time during which these undesired reactions are both thermodynamically favorable, and kinetically accessible for instance, quenching can reduce the crystal grain size of both metallic and plastic

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materials, increasing their hardness.

In this project we used distilled water as a quenching medium. Because non-purified water could cause with chemical reactions as well as leave mineral deposits on the work piece. But distilled water is highly purified and there is no minerals.

In their project sudden cooling process is accompanied that means after welded a work piece the work piece must dipped the distilled water within 3 to 6 seconds.

b). Joint Nomenclature

Lap joint was selected. The following reasons are plays important role in the selection of joint type.

i. Easy to prepare (does not require cut faces to be parallel or perfectly flat) Can be formed between two dissimilar metals, such as aluminium and copper

ii. Accommodates different thicknesses (thinner piece must be welded on top)

iii. Thin material such as diaphragms and foils can be joined

iv. Most of the automobile superstructure are having the lap joints

c) Welding Operation

In this project 2mm thickness AL2024 alloy was used. The various stages during the operation is followed one by one

1. Cutting the material at the dimension of Length – 100mm, Breath -30mm.

Figure 3 – Base material Specimen

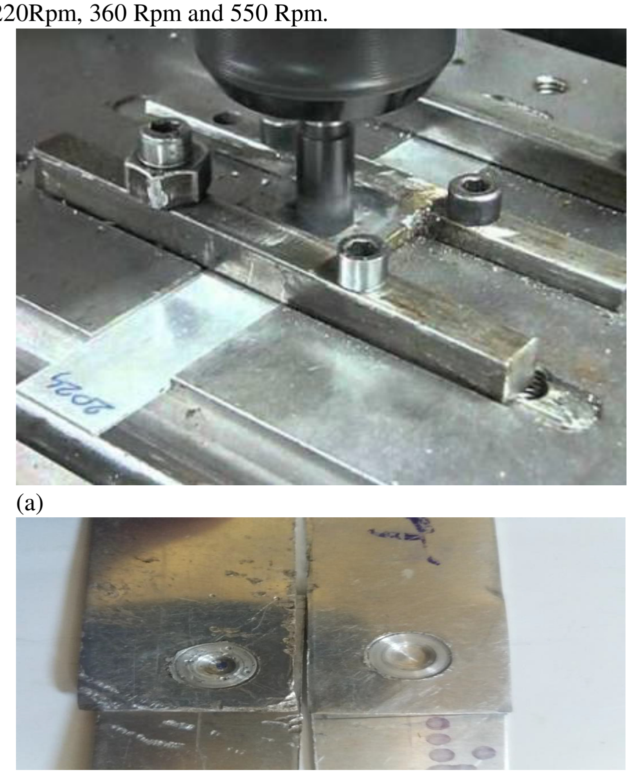
Preparing the tool at the dimension of Height - 125mm, tool pin – 2mm, pin radius – 1mm.

Figure 4 – Tool prepared

Tool was held in the vertical milling tool holder and the workpiece was placed the vice at the position of lap joint.

Figure 5 – Joint configuration

Then the welding was carryied by high depth weld and low depth weld at the rotational speed capacities are 160 Rpm, 220Rpm, 360 Rpm and 550 Rpm.



(a)

(b)

Figure 6 (a)– Friction Stir Spot Weld Setup, (b) Fabricated joints

III. Results and Discussion

Then the joints were quenched in etchants and then the different tests were conducted to compare the difference between the quenched and unquenched samples.

Table 1 – Tensile test between of low depth welded joints

SI.NO	OUTPUT DATA	QUENCHED	NON-QUENCHED
1	Load at yield.	4.94 kN	4.94Kn
2	Yield stress	82.33mm	82.333mm
3	Load at peak	5.52Kn	5.26Kn
4	Elongation at peak	1.620mm	2.830mm
5	Tensile strength	92.00N/mm2	87.67N/mm2

Tensile tests were conducted as per ASTM E 08 standards and the joints which were fractured were evaluated.

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Table 1 – Tensile test comparison of high depth welded joints

SI.NO	OUTPUT DATA	QUENCHED	NON-QUENCHED
1	Load at yield.	4.28 kN	3.10kN
2	Yield stress	71.33mm	51.667mm
3	Load at peak	5.68kN	5.62kN
4	Elongation at break	0.390mm	0.290mm
5	Tensile strength	94.667N/mm2	92N/mm2

Table 1 indicates the tensile test comparison of low depth welded and Table 2 indicates the tensile test comparison of high depth welded specimens.

The strength variations between quenched and unquenched specimens are indicated in Figure 7

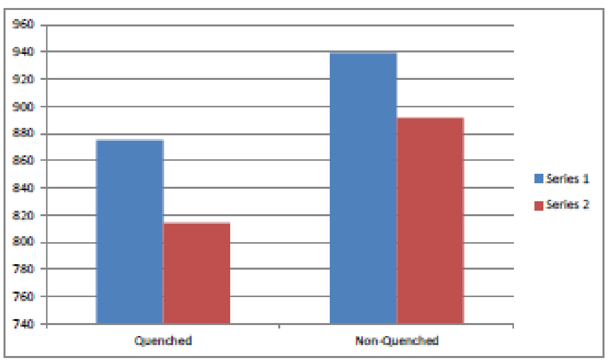
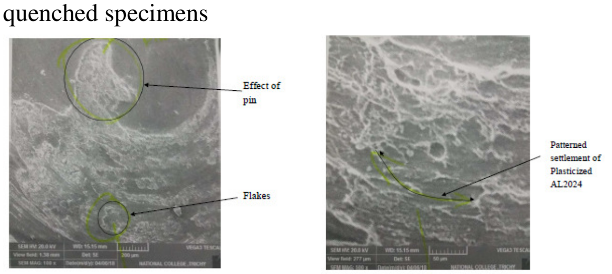


Figure 7 – Comparison of strengths of unquenched and quenched specimens



(a) (b)

Figure 8 – SEM analysis of quenched joint for high depth joints

For Figure 8 (a), the pattern of variations due to the effect of quenching can be observed in the form of flakes. In Figure 8 (b), the pattern of quenching can be observed in the form of patterned settlement of plasticized materials.

For bending experiments, the percentage of increase in shear strength was from 2.5 to 7.5 percentage on quenching. The hardness was found to fluctuate according to the changes in the re solidification pattern across the weldment

IV. CONCLUSIONS

From the above observations

Tensile strength for the quenched welded Aluminium 2024 Alloy was higher than the non- quenched welded Aluminium 2024 Alloy.

Hardness of the material was found to be inversely proportional to the tensile strength of the material.

From the above observations, shear strength for the quenched welded Aluminium 2024 Alloy was higher than the non-quenched welded Aluminium 2024 Alloy.

From the above observations the Hardness of Material of Quenched welded Aluminium 2024 Alloy was lower than the Non- Quenched welded Aluminium 2024 Alloy.

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