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Review on Friction Stir Welding Process

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Abstract

Friction stir welding is the solid type welding which uses consumable tool that is used to join two workpieces without melting the workpiece. Heat is produced by the friction between the workpiece and the tool. This heat only softens the metal but not melting it. The tool moves along the soften surface for joining purpose. The scope of welding is increasing day to day according to their needs. This paper reviews based on FSW process analysis, Mechanical properties, Microstructural properties, Post weld heat treatment of the joints, Design of experiments and Corrosion of the joints in Aluminium and its alloys

Keywords: Solid type welding, Nonconsumable tool, Welding properties, FSW process analysis, Mechanical properties, Microstructural properties, Post weld heat treatment of the joints, Design of experiments, Corrosion of the joints.

INTRODUCTION

The main objective of the literature review is to show previous research works carried out by various researchers in the field of friction stir welding of Aluminium alloys. The purpose of formulating this literature review is to help other researchers who need clear information regarding previous research on Stir Welding process.

Friction Stir Welding (FSW) is a solid type welding used to join plates developed by The Welding Institute (TWI) located at Cambridge in the UK. The workpiece was placed on a backup plate and clamped by using fixtures to prevent lateral motion. A tool with a pin is extended from the shoulder which rotates at several hundred rpm. The pin is forced into workpiece until the shoulder touches the surface of the workpiece. Due to this shoulder contact, a friction is developed between them. The tool moves in the interface between two faces. As tool moves, weld cools and joins. A hole is left in the workpiece after withdrawal of tool.

There is a great challenge in welding Aluminium and its alloy using conventional welding methods such as fusion welding because of the formation of the oxide layer, high thermal conductivity, high coefficient of thermal expansion and solidification shrinkage. The main drawback behind Fusion welding is that after welding, there is a complete alteration in microstructure and loss of mechanical properties. This problem can be completely avoided in FSW since it is solid state welding. Further, when FSW is compared with conventional welding methods some of the advantages are

- FSW is done without any filler material.
- FSW does not require any shielding gas.
- Arc and fume are not formed.
- FSW produces lower residual stress and distortion on the base material.
- Skilled labors are not required.
- Porosity and cracking are not formed due to solid type welding.

Based on microstructure, FSW welded region is classified into four regions namely unaffected region, Heat affected zone (HAZ), Thermo-mechanically affected zone (TMAZ), Stir zone (SZ).

An Unaffected region is a region where microstructure and mechanical properties are not affected by heat. Heat affected zone (HAZ) is the region where both microstructure and mechanical properties are affected by heat similar to fusion welding process. Thermo-mechanically affected zone is the region where the mechanical properties are affected by heat.

Stir zone is the region where original grain boundaries are affected by heat.

RESEARCH DISCUSSION OF FRICTION STIR WELDING PROCESS

FSW Process Analysis

Thomas et al. (1991) [1] of The Welding Institute (TWI) reviewed the problem using fusion welding of Aluminium alloy. By using Friction Stir Welding (FSW), the formation of surface oxides in the base material is avoided. FSW uses non consumable tool which produces heat by friction effect of the base material which results in joining of metal.

Lohwasser (2009) suggested that two types of material flows are possible in FSW such as pin driven flow and shoulder driven flow. The formation of oxide layer affects the firm bonding of material. This oxide layer formation is prevented in FSW by using tool shoulder. The approximate working temperature for FSW is 0.6 to 0.9 times of melting temperature.

Cavaliere et al (2006) investigated the tensile and fatigue behavior of FSW of 2024 and 7075 alloys. It was found that 2024 fails in tensile test due to lower hardness and 7075 fails due to decreased fatigue life.

Lee et al (2003) made study based on the joint properties of dissimilar cast A356 and wrought AA6061 by varying the fixed location of materials. While doing the longitudinal tensile tests, and absorbed that the stir zone strength for AA6061 is greater than A356 when placed on the retreating side.

Leitao et al (2009) studied mechanical behavior on dissimilar joints of AA5182-H111 and AA60616-T4 and found that the tensile strength of the joints mainly dependent on the grain size for AA5182-H111. It is studied A319 and A413 and reported that there is a loss of ductility in the welded joint.

Koilraj et al (2012) optimized FSW process with respect to the tensile strength of the dissimilar welds AA2219 and AA5083 using five different tool profiles such as rotational speed, Transverse speed and D/d ratio where D= shoulder diameter and d= tool pin diameter are the parameters considered for the study.

Palanivel et al (2012) revealed that dissimilar FSW of AA5083-H111 and AA6351-T6 based on the influence of tool rotational speed, pin profile, and tensile strength aluminum alloys. The cylindrical pin, the tapered pin, hexagonal pin and octagonal tool pin, the square tool pin are the important parameters to improve tensile strength and defect-free weld. It was found and recorded the three material flow region namely mechanically mixed region, unmixed regions, and mixed region.

Park et al (2010) evaluate the effects of placing aluminum alloys 5052 and 6061 on the advancing and retreating sides. It was stated that A5052 placed in retreating side which produces thinner weld nugget due to inadequate mixing.

Dhilip et al (2010) justified that the welding of the dissimilar metals in FSW is influenced by the material placement, tool positioning and process parameters based on the properties of the materials to be joined.

Lee et al (2008) reported that the mechanical strength of the joint is affected by interface geometry for AA5052-H112 and AA6061-T6 under different welding parameters. It is found that fracture load decreases at higher rotational speed and lower welding speeds.

Steuwer et al (2006) revealed that the great effect of process parameters on the residual stress of AA5083-AA6082. They found that the rotational speed of the welding tool is more effective than the transverse speed of the residual stresses, particularly in AA5083.

Sundaram et al (2010) analyzed the friction stir welding for AA2024-T6 and AA5083-H321 using five different pin profiles. By examine the triangular pin, flat cylindrical pin and cylindrical threaded profile, the cylinder with taper tool pin diameter are the significant parameters responsible for the better tensile strength. They also found that at the range of 300 to 700 rpm, 15 to 35 mm/min and axial force of 4 to 8 kN, defect-free weld exists.

Sayer et al (2008) studied the influence of the FSW process parameters on the microstructure, mechanical properties and low cycle fatigue behavior of AA6063 aluminium alloy plates by selecting three different rotations and welding speeds. It is found that the most of the specimens broke in the region between Heat Affected Zone (HAZ) and Thermo-Mechanically Affected Zone (TMAZ) during the tensile test. It is observed that the 70 % of the welding properties is based on the base metal. Also, there is 40 % decrease in low cycle fatigue life in the welded specimens.

Sunggon et al (2008) analyzed the tensile behavior of friction stir welded for AA6061-T651 by varying welding parameters including rotating and welding speeds. The tensile test reveals that the percentage elongation of friction in AA6061-T651 decreases with decreasing welding speed or increasing rotating speed. The yield and ultimate tensile strength are also affected by the effect of process parameters.

Peel et al (2003) use AA5083 aluminium alloy for FSW by varying the welding conditions like tool design, rotation speed, and translation speed. The results of microstructural, mechanical property and residual stress investigations of four aluminium AA5083 revealed that welding properties are influenced by the thermal input rather than the mechanical deformation by the tool.

Sakthivel et al (2009) investigate the effect of different welding speeds of friction stir welding by varying traverse speed from 50 mm/min to 175 mm/min on the metallurgical and mechanical properties of the alloy. During the tensile test, it was found that there is a decrease in ultimate tensile strength with the increase in traverse speed due to the generation of insufficient heat input. On the other hand, higher heat generation occurs at lower weld speed.

Post Weld Treatment

Krishnan (2002) carried out post weld heat treatment (PWHT) of Friction Stir Welds (FSW) at solutionizing temperatures of 520, 540 and 560°C followed by aging at 175°C or 200°Cand found that the coarse grains were formed in the weld (stir) region after the PWHT and also found that solutionizing temperature of 6061 will increase the hardness across the whole welding.

Genevois et al (2005) studied that it is difficult to join aluminum alloys by using fusion welding techniques. Aluminium alloys form the dendritic structure in fusion zone leading to significant deterioration of strength. This problem can be overcomed by using FSW since there is no formation of fusion zone in it.

Chen et al (2005) investigated that, the tensile strength of the FSW joints of 2219-O aluminium alloy can be improved by the PWH process. The tensile properties of the joints were observed at different welding speeds, before and after the heat treatment are evaluated. From the results, it is revealed that the heat-treated joints possess a higher tensile strength and a lower elongation than the arc-welded (AW) joints. Also, it is found that joint fracture occurs in stir zone (SW) for PWHT joints while the AW joints fracture occurs in the base material zone. It implies that the PWHT process has a significant effect on the fracture locations of the joints.

Elangovan & Balasubramanian (2008) observed on the influences of various post-weld heat treatment procedures on tensile properties of friction stir welded AA6061 aluminium alloy joints. Solution treatment, an artificial aging treatment and a combination of both are applied to the welded joints. Mechanical properties such as yield strength, tensile strength, elongation and joint efficiency were evaluated. A simple artificial aging treatment was studied and attempted method was more beneficial than other post weld treatment methods.

Singh et al (2011) talk about the effect of post weld heat treatment (T6) on the microstructure and mechanical properties of friction stir welded 7039 aluminium alloy joints. FSW parameters were optimized by making welds at the constant rotary speed of 635 rpm and the welding speed of 8 and 12 mm/min. It was observed that the thermo-mechanically affected zone (TMAZ) exhibit coarse grains than that of stir zone. The results revealed that PHWT lowers the yield strength and ultimate tensile strength but improves the percentage elongation of the joints.

Sato et al (2004) studied the grain growth of 1100 aluminium alloy by using solution heat treatment. It was found when the solution temperature is higher than the maximum temperature, grain growth occurs.

Feng et al (2006) made set of experiments based on the effects of post-weld heat treatment on microstructure and mechanical properties of 2219-O aluminium alloy. It was found that the when solution temperature increases, the tensile test of heat-treated regions increases and reaches the maximum of 260% of the base metal (BM). During reprecipitation of the strengthening precipitates PWHT, resulted that in the increase in micro-hardness increases the tensile strength of the joints.

Charit et al (2002) state that the grain growth occurs largely due to the imbalance between thermodynamic driving forces and the pinning forces leading to grain boundary migration during solution hardening. It was stated that the pinning forces decrease with the increase in the solution temperature phase during solution heat treatment. With the decrease in pinning forces, the precipitate phases break down and the grains are coarsened. It is found that higher the solution temperature, the greater the dissolvability of the precipitate and greater the degree of grain coarsening.

Malarvizhi & Balasubramanian (2011) welded AA2219 aluminium alloy square butt joints using gas tungsten arc welding (GTAW), electron beam welding (EBW), and friction stir welding (FSW) processes. They exposed the fabricated joints to post-weld aged at 175°C for 12 hours. The effects of three welding processes were reported. It was found that the post-weld aged FSW joints show superior fatigue performance when compared to EBW and GTAW due to the formation of very fine and uniform distributed fine precipitates in the weld region.

Priya et al (2009) investigated the effect of post-weld heat treatment on the microstructure and mechanical properties of dissimilar friction stir weldments of AA6061 and 2219 in peak aged T6 temper. It is found that hardness is the reason for the increase in weld zone alone and there is no effective improvement in HAZ hardness in On doing direct post weld aging, there is no effect on hardness but when post weld solution treatment is done at 520°C followed by ageing at 165°C results in significant improvement in hardness. From this, it was found that the post weld solution heat treatment followed by ageing results in grain coarsening.

Aladdin et al (2011) examined the effects of the welding parameters and the post weld aging treatment of FS welded AA6063-T4 at various tool rotations (800, 1120, and 1600 rpm) and welding speeds (200 and 315 mm/min) using a special tool with a height-adjustable and right-hand threaded pin. The post weld aging process is carried at 185°C for 7 hours. Using scanning electron microscope (SEM), the specimens fracture surfaces were noted. It is noted that after the post weld aging process, the hardness values decrease below the hardness value of the base metal. It is observed that the after the post weld aging process at the at welding speed of 315 mm/min, F max values increase whereas. at the welding speed of 200 mm/min, its value decreases.

Sato et al (1999) studied the precipitation sequence in friction stir weld of AA6063 aluminum during post- weld aging. It was seen that FSW produces a softened region in the weld. The dissolved region contains a minimum hardness region. It was noted that when post- weld aging is done there is an increase in hardness. He did the post weld aging at 443 K is conducted for 12 hours which gives greater hardness in the welded region.

Shigematsu et al (2003) joined cold rolled 5083 with AA6061 by FSW under varying rotational speed and traversing speed of the tool. He observed that aging improves the hardness at the interface with no effect in the soft heat affected zone.

Hassan et al (2010) investigated the microstructure and mechanical characteristics of dissimilar A319 and A356 cast Aluminium alloys plates joined by using FSW. He investigated based on the effect of tool rotational welding speeds and post-weld heat treatment. Post-weld heat treatment is done at a solutionizing temperature of 540°C for 12 hours followed by aging at 155°C for 6 hours. It is found that the hardness at the weld zone is found to increase by increasing the tool rotational speed or decreasing the welding speed. From their research they concluded saying that increasing in the tool rotational speed, increases the ductility of the joint but its tensile and yield strength decreases.

Analysis of Microstructural Properties

Lee et al (2003) welded A356 alloys sheets using friction stir welding by varying the welding speeds. The microstructures of the weld zone consist of SZ (stir zone), TMAZ (thermo-mechanical affected zone) and BM (base metal). The microstructure of the SZ was very different from that of the BM. The microstructure of TMAZ is characterized by dispersed eutectic Si particles. The mechanical properties of the weld zone are greatly improved by varying welding speed in comparison to that of the BM.

Ghosh et al (2010) attempted on friction stir welding of A356 and A6061-T6 aluminum alloys and studied that by varying shape and size of dispersion of Si rich particles and observed the disappearance of original phase and grain refinement in the 6061 matrix of welded specimens.

Cáceres et al (2003) made a comparative study of the mechanical properties of Al-Si-Cu-Mg alloys. It was noted that when Cu and Mg content increases and there is increase in strength and decrease in ductility takes place whereas when Fe content is increased dramatically, its ductility property decreases and strength increases.

Boonchouytana et al (2012) analysed the butt joints of semisolid A356 using the welding speed 160 mm/min with tilt angle tool at 3° and straight cylindrical tool pin. The heat treatment conditions are divided into (1) As welded (AW) joints, (2) T6 Weld (TW) joints, (3) Weld T6 (WT) joints, (4) T6 Weld T6 (TWT) joints, (5) Solution treated Weld Artificially aged (SWA) joints and (6) Weld Artificially aged (WA) joints. The results revealed that increasing rotating speed and different heat treatment conditions have made an impact in the tensile strength. At a rotating speed 1320 rpm and the welding speed 160 mm/min, the highest tensile strength is obtained. The microstructural studies revealed that the microstructure of the base metal consists of primary phase α-Al and a eutectic mixture of Al and Si. In the stir zone (SZ), the globular and eutectic phases disappear due to the occurrence of friction between the shoulder and the pin.

Da Silva et al (2011) investigated on the effect of joining parameters on the mechanical properties, microstructural features and material flow of dissimilar FSW of 3 mm-thick AA2024-T3 and AA7075-T6 joints. He investigated performance in terms of hardness and tensile testing using stop action technique to investigate features of the mixing. The results from the SEM observations disclosed that there is no formation of onion ring. At the stir zone, there is no material mixing takes place. A non-stable rotational flow leads to the formation of a cavity on the rear of the pin.

Touen et al (2003) and Kaufman et al (2004) improved the properties in the Al-Si alloys by adding certain elements.

a) Antimony, Strontium, Calcium and Sodium are added to modify eutectic silicon into a lamellar or fibrous form.

b) Phosphorus is added in order to reduce the size of the primary silicon phase particles.

c) Titanium and Boron are added for grain refining purposes.

d) Copper is added to increase strength and hardness.

e) Magnesium when added with aluminium forms the hardening phase Mg2Si forms potent hardening and strengthening effects on it.

f) Iron is considered as an impurity, forms insoluble brittle intermetallics (AI5FeSi) that has a direct effect in reducing the ductility of the alloy.

g) Manganese is added to neutralize the effect of the brittle AI5FeSi intermetallic phase.

h) Beryllium is added in order to to prevent oxidation losses.

i) Silver and Zinc are used to increase the age-hardening response of the alloy.

Liu et al (1997) studied the microstructure of the friction stir welded AA6061-T6 alloy by varying the rotating speeds from 300 to 1000 rpm and traverse speeds of 0.15 to 0.25 cm/s. The microstructures were characterized by using light microscopy and TEM. The results confirm that the FS weld zone in AA6061-T6 was characterized by the two phases. The first phase is based on the appearance of dynamic continuous recrystallization microstructure. The second phase is made by using the residual hardness varies from 55 WHN near the top of the weld to 65 WHN near the bottom. The grain size in weld zone is approximately 10μm whereas the work piece hardness is 100μm.

Taylor et al (1999) analyzed AI-Si-Cu type alloys containing Fe. They found that results revealed that the iron forms the β-AI5FeSi intermetallic phase. When examined under an optical microscope, these platelets appear as needles with shrinkage pores due to the difficulty in feeding the liquid metal into the spaces.

Li et al (1998) studied the flow visualization and residual microstructures for AA2024 aluminum to AA6061 alloy. It was observed that the FSW joint is characterized by residual, equiaxed grain ranging from 1 to 15 mm provides a super plastic flow. It was revealed in the AA6061 at higher speeds (> 800 rpm) results in a 40% reduction in the residual micro hardness and 50% reduction in the AA2024**.**

Reviews on Design of Experiments of FSW

Adler et al (1975) attempted that the design of experiment is a structured and organized method used to determine the relationship between the different factors affecting a process and output of that process. The advantages of design of experiments are as follows.

- Recognition and statement of the problem
- Selection of the response variables
- Selection of experiment design
- Selection of factors, levels and ranges
- Conducting the experiment
- Statistical analysis of the data
- Determination of the experimental error and fit
- Identification of optimal setting of the parameters

Peace (1992) commented about the Taguchi design developed by Dr. Genichi Taguchi as a set of methodologies should be taken into account at the designing stage based on the inherent variability of materials and manufacturing processes. Taguchi proposes that engineering optimization should follow a three-step approach: system design, parameter design, and tolerance design. By using the Taguchi techniques, industries are able to reduce product development time thereby reducing cost and increased profit.

Panday et al (2003) highlighted the importance of factorial designs. Factorial design experiment was used in all possible combinations were realized.

Montgomery (1984) stated the response surface methodology (RSM) which gives the relationships between several explanatory variables and one or more response variables. It is used to determine the optimum operating conditions for the system, in which the operating specifications are satisfied.

Mohamadreza et al (2011) made optimization studies focusing in the literature for FSW, by varying the process parameters such as translational welding speed and the rotational speed.

Shercliff et al (2005) made the trial and error approaches to improve the welding process parameters for 2000 series aluminium. For easy tool traversing, front of the tool is softened by optimizing the welding speed.

Lakshminarayanan and Balasubramanian (2008) applied Taguchi approach to determine the factors affecting the tensile strength of the joints of friction stir welded RDE-40 aluminium alloy. Through this approach, the optimum level of process parameters (tool rotational speed, traverse speed and axial force) is determined. From the results, it was found that the tensile strength of the joint is mostly influenced by rotating speed, welding speed and axial force.

Sarsilmaz and Çaydaş (2008) applied the full factorial experimental design to study the effects of friction stir welding (FSW) of AA1050/AA 5083 alloy. Analysis of variance (ANOVA) and main effect plot are used to \ the find the significant parameters and the optimal level for each parameter. Linear regression equation is used to predict output characteristic.

Jayaraman et al (2009) investigated the effect of FSW process based on the tool rotational speed, welding speed and axial force using full factorial experimental design A319 alloy welded joints. In this, the joints are made using different combinations of tool rotation speed, welding speed, and axial force, each at four levels. A 1200 rpm tool rotation speed, 40 mm/min welding speed and 4kN axial force gives superior tensile strengthwere considered for the FSW study.

Mustafa (2012) analyzed the experimental and numerical results of friction stir spot welding of high density polypropylene. The welding parameters such as tool rotation speed, plunge depth and dwell time played an important role for the weld strength. As a result, initial welding parameters to the optimal welding parameters were about 47.7%.

Palanivel et al (2011) conducted FSW on AA6351 aluminum alloy based on three such as welding speed, tool rotational speed and axial force and found that on increasing tool rotational speed, welding speed and axial force, increases the ultimate tensile strength, yield strength and percentage of elongation.

Mohanty et al (2012) studied the effect of welding parameters such as tool rotational speed, traverse speed and probe geometries on various mechanical properties of AA1100 aluminium alloys. Analysis of variance (ANOVA) is used to observe parameters on mechanical properties. A mathematical model is developed to establish the correlation between factors and responses such as tensile strength, percentage of elongation and nugget hardness of friction stir welded AA1100 aluminium alloy joint by using design of experiment, analysis of variance and regression analysis. It is found that the tensile strength, percentage of elongation and nugget hardness increase with increasing welding speed and tool probe geometry is highly responsible for deciding the weld quality.

Corrosion Studies on FSW

Fontana et al defines corrosion as

1. Destruction or deterioration of a material due to reaction with its environment.
2. Extractive metallurgy in reverse.
3. Undesirable interaction of a material with its environment.

Kcuik et al (2010) suggested that corrosion studies should be considered as an appropriate way of improving the corrosion resistance of aluminium alloy as it is considered as the better replacement for steel in the ship building industry.

Kcuik et al (2007) observed from the research, the corrosion properties of AlMg5 and AlMg1Si1 alloys generalizes that in aluminium, the oxide layer forms a natural protection layer from corrosion due to its inertness. However, corrosion is prone to succeeds, when it is exposed to higher corrosive environment.

Frankel & Xia (1999) investigated the pitting and stress corrosion cracking behaviors of AA5454 by comparing them with GTAW samples. For FSW samples, the pits are formed in the HAZ, whereas in GTAW samples the pits are formed in the fusion zone. Also pitting resistance for FSW is higher than GTAW welds.

Wolfensberger (1998) studied about the oxide layers for about 2-3 mm thick. He found that if this oxide film is damaged by any external means, a new oxide layer will be immediately formed on the bare aluminium metal.

Zaid et al (2008) studied that effect of pH and chloride concentration on pitting corrosion of AA6061 aluminium alloy. It is found from the research that AA6061 exhibit excellent corrosion resistant in aqueous solutions except for pitting corrosion. This is due to the presence of reactive elements like chlorine in it.

Davis et al (1999) stated that the pitting corrosion is a localized type of corrosion in the presence of chloride ions. He found that pits are initiated due to the presence of chloride ions in it. The reactions of the propagation of the pits are stated below

$$Al = Al^{3+} + 3e \quad (1)$$

$$Al^{3+} + 3H_2O = Al(OH)_3 + 3H^+ \quad (2)$$

$$Al^+ + 2H_2O \rightarrow Al^{3+} + 2OH^- \quad (3)$$

In the intermetallic cathodes, hydrogen evolution and oxygen reduction are the important reduction processes at the intermetallic cathodes

$2H^+ + 2e = H_2$ (4)

$O_2 + 2H_2O + 4e = 4OH$ (5)

Due to this, pit formation increases and propagates inside the oxide layer. Since the protective layer is dissolved, particles of the active aluminium component also dissolve thereby increasing the cathodic activity.

Baroux et al (1986) identified that pitting corrosion is influenced by many different parameters like environment (ion concentration, pH, and inhibitor concentration), metal composition, potential, temperature and surface condition.

Szklarska et al (2004) analyzed that intermetallic particle like iron present in aluminium matrix influences the corrosion behavior of aluminium alloys. These particles reduce the resistance to localized corrosion. The potential difference in the solution affects the behavior of these intermetallic particles i.e. the matrix undergoes anodic dissolution, if the particles are electrochemically more noble than the matrix which leads to the localized corrosion.

Malarvizhi et al (2011) investigated the polarization of the weld specimens of AA2219 in non-deaerated 3.5% NaCl solution with pH values of 4, 7 and 11. It was found that for lower negative potential (i.e., higher positive potential) values, pitting potential are considered to be more corrosion resistant.

Jariyaboon et al (2007) studied the effect of welding parameters (rotation speed and travel speed) on the corrosion behaviour of friction stir welds in high strength aluminium alloy AA2024–T351. It was found that the localized intergranular attack in the nugget region is more at low rotation speed welds and lowers at high rotational speed.

Surekha et al (2009) examined the effect of processing parameters such as rotation speed and traverse speed on corrosion behaviour of friction stir processed high strength precipitation hardenable AA2219-T87 alloy. From the results, it is found that rotation speed has a major influence in determining the rate of corrosion, breaking down and dissolution of the intermetallic particles.

SUMMARY OF THE LITERATURE REVIEW

- It is evident that friction stir welding has more potential in the fabrication of similar and dissimilar aluminium alloys when compared with other conventional welding methods.
- Most of the literature studies are limited only to the effect analysis of similar materials. However, FSW of dissimilar joint not been analyzed in all FSW parameters.
- Many researchers have studied that the effect of one parameters at a time. However, the combined effects of the process parameters had not been studied extensively.
- No literature was available for the study of the post weld heat treatment of the dissimilar metal joints.
- The effect of secondary phase alloys in affecting the quality of the weld has not been extensively analysed.
- Only very few literature survey were available for the corrosion studies on dissimilar FSW joints.

It is concluded that in the present investigation made to study the FSW. Further studies are to be conducted using nontraditional optimization methods.

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