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STUDY OF FRICTION STIR WELDING- A REVIEW

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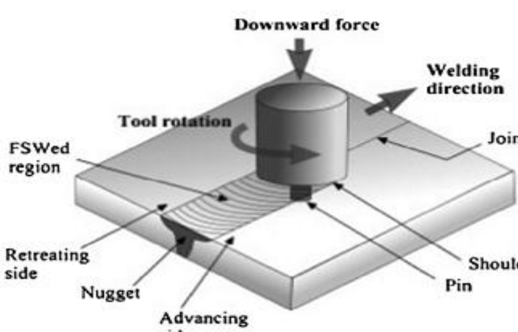
Abstract-Friction stir welding is a newer solid state welding method which is usually applied for the different grades of different ferrous and non- ferrous materials. In this review paper, various research papers are studied and discussed. It has been trying to understand the joining of aluminum alloys and other different materials under different welding conditions. Friction stir welding plays a vital role to get the defect free welds. In this paper, different friction stir welding process parameters and their effect on mechanical and microstructural properties of the joints are also summarized.
Keywords: Aluminum alloys, Rotation speed, Tool geometry, Mechanical properties, Microstructures, friction stir welding (FSW), Fixture.

1. INTRODUCTION

Friction Stir Welding (FSW) is a latest method of bonding of two similar dissimilar metal which was developed by Wayne Thomas at The Welding Institute (TWI), UK, in 1991 [1]. Friction stir welding is also called a solid-state joining operation of two light-weight metals with lower melting point in such way that increased tensile strength of the weld joints with increasing friction time and on average highest strength could reach up to 101MPa when friction time was 5 s. All the friction welded joints failed at the friction interface in tensile test. Friction stir welding is quickly received the attention of many researchers around the world traditional, FSW process performed a joint by a rotational tool which is inserted into works pieces to be joint and moved beside the weld joint.



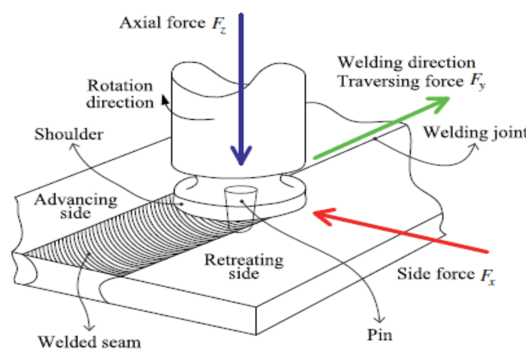


Fig1. Schematic drawing of FSW process [2] Fig2. Schematic drawing of FSW process [3]

In unlike fusion welding, FSW does not melt the material which is require a consumables electrode like a filler rod, shielding gas and uses less energy to make the weld joint [4]. Govindaraj Elatharasan et al observed (FSW) process with a cylindrical tool which contain pin and shoulder and tool parameters are also play an important role in determining joint's characteristics. The friction stir welding process makes a plastic flow and frictional heat so that it may be regarded as mechanical process. FSW welding is a continuous process to join the two metals by a non- consumable rotating tool on base materials. [5].Most of literatures is focusing effect on mechanical properties and different tool shapes and rotational speed by using friction stir welding. Therefore, in this study, it has been tried to understand the tool shapes and parameters play an important role to determine tensile strength of weld joints by friction stir welding [6][7].

2. WORK DONE

Some of the researches are discussed here. Li H, MacKenzie D and Hamilton R studied on tool variation effect in a tool parameters, like as the diameter of tool shoulder and pin angles etc., on the FSW method for (AA2024) [9]. The diameter of a tool shoulder is designed for principle of maximum utilization torque for fraction and find out mechanical properties of joint [10]. Li H et al investigated numerically tool variation effect in tool geometry parameters, such as the tool angles etc., for the FSW operation method on AA2024 [11]. Jamshidi Aval et al investigated numerically and experimentally for altering the tool shape variables on thermo-mechanical characteristics of AA5086 in the friction stir welding [12, 13]. Some parameters are require to make the joint such as temperatures, traverse force and stresses on the work piece during FSW, tool variations

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are also affected on the base metal such as tool speed, welding speed, and pin diameters, tool material and pin length. The numerous numbers of variables carried out the experimental to examination of their intractable effects. Mannvatkar VD et al proposed a group of five neural networks to determine high temperature, traverse force and equivalent stresses on the tool for aluminum alloy [14]. A latest approach was proposed for the FSW operation on the thin plate for Al with a pin less tool [15]. Experiments were conducted by rotating tools having, a concentric-circles-flute shoulder, an inner-concave flute shoulder and a three-spiral-flute shoulder respectively. The grain size in the weld nugget zone is produced by the tool with three-spiral-flute shoulder while the grain sizes decreases at the high tool speed.

Johnson used a Kistler rotating dynamometer to find out the effects on tooling geometry and parameters in friction stir welding process of AA5083- AA6082 alloys. However, Johnson only examined on shoulder and pin shape with variations in the tool geometry and did not correlate results with a post weld joint assessment of mechanical properties achieved [17]. M. K. Bilici studied on tool profile effect on friction stir spot welding for quality of plastic sheets. For study purpose author considered various tool pin geometries such as pin lengths, shoulder diameters and shoulder angles to determine the weld strength, and finally author concludes that cylindrical taper pin provide the sound strength and cylindrical pin provide the minimum lap-shear fracture strength [18].

D.Raguraman et al studied on dissimilar metals AA6061 and AZ61by using different tools geometry friction stir welding process. Tool performed an important role in weld quality of the welded joints. The tool shapes are as follows: (i) Taper threaded too, (ii) Inverse tapered tool (iii) Straight threaded tool. These geometries are analyzed for the identification of good weld joint through ANSYS and finally they concluded that concave tool and fluted type tool geometry can be consider for welding of two different material i,e AA 6061 and AZ61 alloys for good quality of welding joints [19].Lakshman Rao et al studied on Tri flute design FSW tools are complex when compared to the Trivex designs for friction stir welding process . Author told about the tool speeds on the properties of FSW joints to determine good strength and microstructure of weld joints by friction stir welding. The low speed is commonly used to get the better performance of joint by using the taper design tool [20].

K. Elangovan et al try to find out the mechanical properties of AA6061 by using the friction stir welding and they told that tool pin profiles such as (threaded cylindrical, tapered cylindrical and, triangular) have been applied to determine tensile strength, micro hardness, and microstructure and also evaluate joints have been performed by square pin with a speed of 1200RPM to get good quality mechanical properties as compared to other welded joints [21]. Zhengwei Li et al studied on thread tool and tool concept in friction stir spot welding by using with a half-threaded pin and full- thread tool to get better strength, finally they concluded that bonding width of the FSSW (friction stir spot welding) by half-threaded pin is larger than full-threaded pin, which results is larger tension failure [22].

Puneet Rohilla and Narinder Kumar conducted experiment on AA6061by different shapes of tool to find out the tool geometry effect on properties by FSW and finally they concluded that cylindrical tool pin profile performed best tensile properties of aluminum alloy as compared to other joints, irrespective of tool speed in double pass [23].

T. Pavan Kumar et al studied on effect of tool profile for material flow in friction stir welding by using aluminum and copper. Different types of tool geometry use to get the better result in FSW and analyzed flow patterns, finally give a patter for material flow. Metal flow system from advancing side to retreating side is examined to metal flow speed at advancing side is faster than retreating side [24].B.Arunprasath and B.G.Sivakumar worked on two different square and taper cylindrical threaded in tool geometry by suing friction stir welding and observed the better result by using HSS square tool to weld AA6063-T6 and AA7075-T6 [25].

Mao Yuqing et al studied on effect of eccentricity tool pin for mechanical and microstructure properties in friction stir welded process of AA7075 and they find out the nugget area increases and the maximum area is also achieved with a pin eccentricity of 0.2 mm [26].

Dongxiao Li et al worked on AA6061-T6 welded joints by rotating tool for friction stir welding (FSW) to find out mechanical and microstructure properties of AA606;T6 and verified defect-free weld joint with smooth surface of rotating tool and chosen welding parameters and weld transverse sections are completely different from conventional FSW welded joint [27]. Hamed Jamshidi Aval studied influences the pin on microstructural and mechanical behaviors in dissimilar Al of AA6082–AA7075 butt Joint welded by friction stir welding process and author concluded that a conical tool probe with three grooves generate highest heat than a square frustum probe [28].

A. Hamdollahzadeh et al welded AA7075 by using a square pin tool to determine microstructure and mechanical properties of above said material role of second pass processing and they informed that particles distribution in 2-pass processed specimens was better than superiorto1-pass processed specimen [29]. C Subramanian studied for microstructure and mechanical properties of AA7075 aluminum alloy by using FSW and finally author concluded that joint fabricated by using threaded tool profile which gives greater weld zone hardness value as compared to the other tool [30]. Nabeel Gharaibeh et al investigated on tool effect for pin shape and welding process parameters on metallurgical and mechanical properties of AA 606 joints in (FSW) and they told that fine grain microstructure and higher strength weld joints obtained by hexagonal pin profile. [31].

N. A. A. Satharil et al investigated to the influence of material location and tool speed is also effect ultimate tensile strength of dissimilar aluminum alloys welded of AA707 1 and AA6061 and observed that the speed of tool and material position influenced on tensile strength value of dissimilar weld joint [32]. N. Dialami et al studied for effect on different materials

and tool shapes, author told that influences on thermal behavior, metal flow, during the welding and get good quality weld joint by using the friction stir welding [33]. C. N. Suresh et al studied to tensile strength of weld for tool effect on pin profiles tool by using FSW and author determined that tool shapes and the tool speed exhibits more effective on tensile strength than weld traversing speed (welding speed) and plunge depth, conical tool profile has been given better joint aspects of the weld joints than the square tool profile [34]. Pragya N. Banjare et al studied for welded of plastic through different tool speeds to test the material efficiency under tensile loading and finally they told that tool selected for improvement for ultimate tensile strength of plastic and also perform good welded joint with more ductility material than the conventional FSW tool without addition of heat [35]. Mouloud Aissani et al optimized a tool design for friction stir welding on AA2024-T4 - AA7075-T6 sheets to evaluate weld joint quality. Finally they observed that obtained better results for good qualities of weld joint [36].
Sandeep Rathee et al the studied plunge depth on reinforcement particles distribution in surface composite fabrication by using the FSW and they told low plunge depth results in less material flow and cavity formation at center of SZ owing to less heat generation at low contact area between tool shoulder and base metal [37]. K. Kumar et al the studied on effect of tool geometry on friction stir welding (FSW) and author find out the highest tensile strength of the weld joint [38]. M.M.Z. Ahmed et al studied on similar and dissimilar aluminum alloy AA7075 and AA50 by using FSW and they concluded that two metal welded joints to provide a good result in welding quality using the same FSW parameters of the two alloys exhibited various responses in terms of recrystallized fine grains after friction stir welding process [39]. A. Kumar et al the studied to be influence on tool pin profiles for copper and they concluded that the weld performed by using square tool pin shapes for better result in mechanical quality as compared to other tool pin profiles which is only due to more effective actions of the metal compared to the other pin [40].
Mojtaba Rezaee Hajideha et al investigated to tool geometry effect on mechanical and microstructure properties of dissimilar plastic by FSW process, author told that threaded cylindrical pin profile had the best performance for each welding process condition and also provide more laminar and the uniform material flow regime during welding than the other tool pin shapes [41]. K.H. Kima et al determined to weld joint properties of ultra-thin 430M2 ferrite sheet with pin-less tool in friction stir welding and authors suggest that the low input friction stir welding operation is more suitable process for the conventional fusion welding GTAW in ultra-thin ferrite steel sheet [42].
S.Prasath et al used different tools to optimize process parameters to joining ZM 21 to AZ 31of dissimilar magnesium alloys and author told that tool pin profile plays a vital role, and contributes 69.35% to the overall effect [43].
Pankaj Sahlot et al analyzed tool wear of H13steel in (FSW) of Cu-0.8%Cr-0.1%Zr alloy and authors told during FSW of Cu Cr Zr alloy, higher tool rotational speed leads to greater tool wear due to enhanced relative surface velocities. However, studies have revealed that the amount of tool wear decreases with increase in tool traverse speed [44].
Jannik Goebel et al worked out on Semi-stationary shoulder bobbin tool friction stir welding ofAA2198-T851 and author informed that flawless welds featuring a high surface finish on the stationary shoulder side were achieved featuring an ultimate tensile strength efficiency of 82%, a yield strength efficiency of 56% and a hardness efficiency of 77%. A weld pitch (rotation/mm) of one and high pressure between the shoulders led to the best results [45]. Ashu Garg, and Anirban Bhattacharya studied for influence on different tools and pin geometries of similar and dissimilar friction stir spot welds for strength and failure analysis and author informed that when tools with pins are used lap shear strength decreases with increase in tool plunge depth but increases with pin diameter as observed from the finite element analysis may be responsible for quick failure when higher plunge depth of pin is used [46]. P. Ganesh and V. S Senthil Kumar studied on AA6061-T6 alloy plate with FSW for various superplastics forming and author informed that hardness in the welded zone was noticed to be mostly same over the top surface of the welded portion but smaller than the base plate. The strain rate increases drastically in initial stage of forming joints which around about 7.95% at various tool speed [47].K. Kumar1 et al conducted an experiment using different rotating tools on Aluminum Alloy 7020 by friction stir welding and author told that different diameter of tool shoulder for analyzing the intrinsic influence on the tool geometry for formation of the weld if take the optimum shoulder diameter then the weld does not uniformly overall of the weld joint [48].Joaquín M. Piccini and Hernán G. Svoboda optimized tool geometry of Al-steel joints in friction stir spot welding and the author informed that fracture loads increased when the tool penetration depth goes up then tool geometry optimization also increased the fracture loads [49]. Arun Kumar Kadiana and Panda Biswas proposed to a lot of different tool requirements for the defects formed during the welding. Since, each tool rotate the weld material in a different way, therefore, the current study considered seven different types of tool pin geometries and studied their effects on the material flow[50].
Jiye Wea et al observed the different effect on titanium alloy Ti–6Al–4V by three types of tool and they carried out tool degradation cause by plastic deformation in the W–1.1%La2O3 and shear stress can be decreased by diameter with the pin tip and tool debris was left in the flow metal. The mechanical properties of weld joints were affected along with diffusion of tool weight loss [51].

Author(s)	Years	Material used	Method used	Major findings	Conclusion
Colligan, K[5]	1999	AA 6061 and AA7075	Tool rotational , welding speeds and change of tool materials	Flow of materials and developing a model for metal deformation.	From result it was find out that model developed for predicting tool performance was satisfactory

T.S. Mahmoud [95]	2008	A319 cast Al alloy	Welding speed and tool rotational, hold the work piece in fixture	Effect on welding velocity and tool rotational for mechanical and microstructural properties	It has been observed that increasing the tool speed then reduces both the tensile and ultimate tensile strengths of the welded joints
K. Kumar et al[38]	2008	AA7020-T6	Tool geometry & welding parameters	To analysis the tool geometry effect on the FSW of AA7020-T6	The maximum power of the weld joints performed by frustum tool shapes which was 92% for a tool contained a 20mm shoulder diameter and 6 mm pin diameter.
K. Elangovan et al [6]	2008	AA6061	Tool Pin Profile and Tool Rotational Speed	To study on tool effect e shapes and speed on microstructure and material behavior by FSW (AA6061) aluminum alloy	Tensile strength of welded joint was found optimum at 1200RPM and hardness of FSP higher than other joint by square profile tool
H. Jamshidi Aval et al [12]	2011	AA 5086–AA 6061	Tool shapes and tool rotational speed	To study the tool effect on different parameters to microstructure and mechanical behaviors in dissimilar by using friction stir welding of 5 mm thick plate of AA 5086 - AA 6061-T6.	Authors reported that higher temperatures given more uniformly zones than the different tools. The grain sizes of the stir zone in AA 6061l, welds are finer than those performed in AA 5086 side and decreasing the weld pitch.
Y. N. Zhang et al [97]	2012	Review paper	FSW tool	Different tool are used to make the weld in FSW Processing	To calculate long life and low value welding and processing, tools have been better produced the low strength of materials in Al and Mg alloys.
H. Izadi et al [94]	2013	dissimilar Al alloy I, e Al 2024 and Al 6061	Tool geometry	Optical microscopy utilized to study for material flow when small changings are made with the tool pin. It is carried out result with three flat features on the pin impose vertical metal flow which can produced good quality of weld joints properly.	Decreasing the travel speed for promote intermixing the material in affected zone by increasing the residence time to compensate in material speed.
R. Hariharan and R.J. Golden Renjith Nimal[76]	2014	AA6061-AA7075	tool tilt angle ,tool geometry, CNC	To understand the micro structural and the associated mechanical properties of AA6061&AA705	It is find out that, the tool speed is 1250 rpm and a welding speed of 120 to get the 485Mpa tensile strength with 2 degree angle for joints.
S.Ugender & A.Kumar [29]	2014	AZ31B Magnesium Alloy	rotational speeds of welding & changing of tool materials	To study the effect of tool material with tool speed for metal quality and microstructure in welding process	Stainless steel tool material given fine grain to better quality of microstructures and mechanical properties as compared to high speed steel (HSS)
J.F. Guo[56]	2014	AA6061 and AA7075 Al	Operation parameters	To find out the result on material flow, microstructure and hardness distribution and tensile property of	It was determined the properties of dissimilar weld joints increases tensile strength with decreasing heat input.

				the joints	
B.Arunprasat, B.G.Sivakumr [25]	2014	Al 6063 &Al 7075	Tool Geometry & welding parameters	To determine the effect of tool geometry , parameters and mechanical properties	Concluded the best tool profile of a HSS tool to weld AA6063-T6 and AA7075-T6 using FSW Process.
Saadat Ali Rizvi et al[2]	2015	Review paper		Review the FSW process for different materials	Over all discussion of FSW process
H. Shirazi, Sh. Kheirandish, M.A. Safarkhanian[75]	2015	AA5456	Rotational speeds and welding speeds	To understand the mechanical and macrostructure properties of metal flow and defect formation by rotational tool in FSW	It was observed from result that hooking height decreased as the welding speed increased while kissing bond was formed at higher welding speeds.
B. Ratna Sunil et al [47]	2015	AZ31 and AZ91 Mg alloys	process parameters feed	To investigated the hardness and mechanical properties of two different materials.	Hot cracking can be removed with choosing appropriate method parameters by (FSW) process to get better weld joint.
Hasan I. Dawood [61]	2015	6061 aluminum alloy	surface roughness	To study the different parameters that effects on the surface roughness.	It was investigated that spherical Nano sized grains of the joint was improved mechanically betters
K. Elangovan[26]	2015	AA6061 Aluminum Alloy	Welding parameters such as tool geometry ,welding speed and temperature	To find out the parameters such as tool rotational speed, welding speed, axial force, etc., and tool geometry used to get the mechanical properties.	It is find out that tensile strength, micro hardness and microstructure of welded joints are better by square pin tool with 1200RPM of tool speed.
Z. Zhang et al[54]	2015	2219Al-T6	Welding parameters	To showed the microstructure and metallurgical properties of welded joint by using the welding parameters.	It was obtained to get the better result on 2219AI-T6 with welding speeds of 100–800 mm/min at a uniform rotational speed of 800 rpm under both air- and water-cooling conditions.
Takuya Miura et al[56]	2015	Fe–Ni–C steel		To study the enhancing the tensile properties and microstructure of welded joints.	The refinement of grains size and accumulation of dislocations in austenite of the SZs are accelerated by decrease the tool speed.
Md. Reza-E-Rabby et al [96]	2015	AA2050 and AA6061	Tool pin features & rotational speed	To study of tool pin shape on process by geometry variables on AA2050 and AA6061	To study on defect free weld joints with effective metal in the weld nugget zone and it was find out when welding joints was per with AA2050 on the advancing side.

Biswajit Parida et al studied for operations on a milling machine so that a holding device is necessary to grip the work pieces on the milling machine so that no gap should be formed between the plate and work piece during clamping the work piece. It should also give us too easy and safety operation with less setup time [53]. Rajnish Singh et al studied on manufacture specified fixture to get good weld quality it is essential to manufacture specified fixture having accurate clamping capacity, strength of base plate, flexibility in the welded plate dimension and easy to operate before and after FSW process and author observed that there is no sifting of aluminum plates during FSW welding process. This material has sustainable vibration absorbing capacity at high rpm due to tool rotation. It can weld up to 12 mm thick plates. It has good axial load carrying capacity in above fixture

3. STUDY OF MECHANICAL PROPERTIES OF ALLOYS

J.F. Guo et al studied on two dissimilar materials i.e. AA6061 and AA7075 Al alloys for mechanical properties and they selected the some process parameters which affect the mechanical properties, micro harness and microstructure [55].Tensile properties of the dissimilar joint between AA6061 - AA7075 are shown in Table 3.

Condition	Material on Adv. Side	UTS (MPa)	YS (MPa)	% elongation	Joint efficiency	Failure location
6061T6	7075	310	276	12	-	HAZ 6061
D1	7075	215±2	160±5	7±1	69	HAZ 6061
D2	7075	221±4	152±3	7±0	71	HAZ 6061
D3	6061	235±3	168±3	6±1	76	HAZ 6061
D4	6061	228±2	159±3	8±1	74	HAZ 6061
D5	6061	254±3	177±6	6±1	79	HAZ 6061

Farzad Heirani et al studied on FSW for A Al5083 under various processing parameters was per-formed and effect of welding environment (water and air) on the mechanical properties was investigated and author informed that increase in the tensile strength of water-cooled samples can be due to the increase of hardness in the SZ resulted by an ultrafine-grain structure [56]. Z. Zhang et al try to understand the enhancing different mechanical properties of welded joints of (2219Al-T6) for this purpose they considered the welding speeds of 100–800 mm/min in both air-cooling and water-cooling conditions and finally they concluded that increasing welding speed from 100 to 800 mm/min then tensile strength increase [57]. F.C Liu and Z.Y Ma proposed for an isothermal dissolution-layer (ITDL) model, which was experienced on the thermal cycles at the high temperature of 360–370 °C. The isothermal dissolution- layer (ITDL) model was proved by numerical simulation and also proved to be acceptable weld joints of other precipitation hardened aluminum alloy by the friction stir welding (FSW) [58].Takuya Miura et al studied for tensile properties and microstructure of the SZ of Fe–Ni–C steel and they obtained that the retained austenite in the SZ by friction stir welding process and also pro-motes both elongation and strength of the aluminum alloy base metal at room temperature because of the trip effects [59-61].

Mohammad W. Dewan et al predicted the tensile strength of AA-2219-T87 material by the application of neuron-fuzzy inference system (ANFIS) and neural network; finally they showed that all three operation parameters have direct effect in tensile strength of the welded joints [62]. Huabing Li et al investigated for microstructure and mechanical properties of super-austenitic stainless steel (S32654) under different parameters, author find out that the combined action of grain refinement, high density dislocations and substructures improves the hardness and strength, but greatly reduces the plastic deformation capacity of joints. The more suitable welding processes are determined as 300 rpm and 100 mm/min [63]. Ning Guo et al worked on 5A06 aluminum alloy to find out mechanical and microstructural properties under different welding conditions and they told that tensile strength is 201 MPa equivalents to 60% of base metal and elongation is 15.2%, Indicate poor strength in heat area zone (HAZ). The SEM analysis demonstrates on fracture which is in all tensile specimens due to the presence of a small hollow with various sizes [64]. Mustafa A. Abdulstaar et al studies on 6061-T6 aluminum alloy and find out the mechanical properties under the different conditions surface skimming to 0.5 mm from crown and root sides of the joint was made and SP was later applied on the two sides using ceramic shots of two different lame intensities of 0.18mmA and 0.24 mm A. microstructural examination by electron back scattered diffraction (EBSD) indicated variation in the grain refinement of the weld zone of AA 6061-T6 joint by the friction stir welding [65]. UEMATSU Yoshihiko determined the fatigue behavior of welded of AA7075-T6 aluminum alloy under the solution in 3% NaCl and air and they find out the fatigue strength of welded joint which was lower than the base metal[66].Ramaraju Ramgopal Varma et al obtained the mechanical behavior of dissimilar aluminum alloy welded joints by Taguchi Technique to optimize the operation parameters and they carried out that when axial force is increased then tensile strength is also increase [67] Renjith CR et al determined different variables of AA6061-T6 , AA7075-T6 in friction stir lap welding by application of Taguchi Technique and they find out that shear strength increases with increase in tool rotation speed and welding speed[68] .Youbao Song, et al studied on dissimilar AA2024- AA7075 aluminum alloy metal by FSW to find out the mechanical properties and author observed that lap shear strength increased with the increase of welding speed [69] G. Elatharasan et al conducted an experiment to optimize and analysis the process parameters by FSW process for AA 6061-T6(aluminum alloy) by application of RSM and author developed an empirical relationship to find out Yield strength ,Tension elongation and Ultimate tensile strength of AA 6061-T6[70]. E Maleki1 developed a model on artificial neural networks to find out the welding effects parameters of AA7075-T6 aluminum alloy, According to results, Author can be obtained when the artificial neural networks are tuned finally and the result are better in admissible agreement with the experimental results [71]. D.Muruganandam et al studied on behavior of welded joints for microstructural and mechanical properties of AA 2024 and AA7075 by FSW process and author told that the fatigue behavior of two metals are acceptable and allows considering as another bonding technique use for the aluminum alloys material [72].

4. MICROSTRUCTURE:

Q.D. Qin et al find out properties of weld joint on unmodified and P-modified Al-Mg2Si-Si alloys by using friction stair welding and author identified as equiaxed crystals and polygonal particles in unmodified and P-modified Al-Mg2Si-Si alloys in the BMZ, respectively. In the WN, the equiaxed primary Mg2Si crystals in the unmodified alloys are transformed to significantly smaller polygonal/irregular particles; the corners of the polygonal primary Mg2Si particles in the modified alloys become smoother and smaller[73]. B. Ratna Sunil et al studied on two different alloy of (Mg) alloy sheets, one having low aluminum (AZ31) and another having with high aluminum (AZ91) and they found that a good quality mechanical properties of joint and achieved by optimized (FSW) operation parameters (1400 rpm with 25 mm/min feed) which was having fine grains and distributed (Mg17Al12) phase in the weld zone[74].

H. Shirazi et al studied to defect formation while doing the friction stir welding operation of AA5456. They concluded on tool rotation effect, welding speed and defect formation, i.e. hooking, kissing-bond and cavity for the aluminum alloy welded joints by scanning electron microscope and optical microscopy. The find out that the hooking height decreased as welding speed increased while kissing-bond was produced at maximum welding speeds [75].

Jicheng Gao et al studied for properties of two dissimilar weld joints of HDPE and acrylonitrile butadiene styrene (ABS) as traditional tools fail to get superior quality and to obtained the effect of the multi walled carbon Nano- tubes (MWCNTs) on the morphology and tensile strength of the various metal weld joints of high density polyethylene (HDPE) and acrylonitrile butadiene styrene (ABS) in SFSW(submerged friction stir welding) and they performed that adding of (MWCNTs) to increased properties of metal elongation and decreased the hardness of joints. The area of the groove is used to fill the MWCNTs; however, it is very easy to find cracks in the welded joint when it was too large [76].

F.F. Wang et al studied for tool speed effect for mechanical and microstructure properties of Al–Li alloy for which uniformly hardness have achieved in weld joint, in which the joints having uniformly mechanical properties on thickness. As tool speed increases, the grain size of the heating zone increases and then the density of particles are decrease and finally they found that tensile strength of the welded joint increased with tool speed. Three fracture modes have been observed that cracking initiates at the joint line remnant propagating towards the heat-affected zone, and last the thermal-mechanically affected zone and stirred zone are found on border area of metal [77-80].

T. Srinivasa Rao et al investigate microstructure on AA7075−T651 aluminum alloy plates by different process parameter and results showed that TEM images of sample cleared the heat-affected zone to be composed in precipitate-free zones beside the grain and partial dissolution of precipitates in the grain interiors [81]. K. Mroczka et al analyzed on microstructure properties of (AA 2017-AA6013) aluminum alloys sheets with friction stir welding and they informed that the decrease the temperature to welding joints and it was increasing cooling during the friction stir welding (FSW) causes reduction of the size of the nugget and domination of the AA 6013 alloy in the joint (AA6013 was located on the retreating side of welded joint) and it was observed that grain were refine especially in the weld nuggets zone and adjacent regions [82]. Huabing Liet al evaluated for mechanical and microstructure properties of S32654 by friction stir welding (FSW) process and finally they told that stir zone of weld joint was characterized by fine-grain microstructure and mostly no nitrogen content loses during FSW processes in welding joint [83].

K. Mroczka et al analyzed microstructure of AA 2017 aluminum alloy by using friction stir welding and authors informed that central portion of the weld nugget zone is composed of the equiaxial grains with a diameter of 5 μm, which contain the Nano metric precipitates in the weld nugget zone [84]

P. Vijaya Kumar et al studied of metallurgy properties and microstructure behavior of (AA7075) by (FSW) and the authors showed that microstructure in T6 metal, condition has the other coarse and pressed the spaced along the grain boundaries [85]. Zhitong Chen et al investigated to (AA 6061) aluminum alloy and they observed that dynamic recrystallized structures, grain sizes of nugget zone (NZ), thermo mechanically-affected zone (TMAZ), heat-affected zone (HAZ) and base metal (BM) [86-89].

Farzad Heirani et al investigated under various effects of processing parameters of Al5083 alloy for microstructure and mechanical behaviors by friction stir welding and they informed to show the results higher cooling rate in the TMAZ and the HAZ makes the microstructure be similar in all of the specimens while existence of peak values of temperature in the SZ makes changes in the microstructure so that the shape and size of grains and distribution of precipitates are completely different for each sample [90]. Guoqin Sun et al analyzed life prediction on microstructure and mechanical characterization for aluminum alloy AA2219 and authors show the result that the fatigue lives were predicted based on numerical simulation for the FSW joints. The results show that the simulation method considering the characteristic of the microstructure for the FSW joint and it can be evaluated the local stress and strain reasonably [91]. Hasan I. Dawood et al observed influence on surface roughness for the mechanical and microstructures properties for (AA6061) aluminum alloy by using FSW and authors told that characterizations' of microstructure shows that the heat affected zone (HAZ) was narrow causes effect of reduced surface roughness of the work piece, which produced lower shear stress under the rotational period . This system decreases the heat generation and heat carrying out through the work piece, which is responsibility for promotion of a narrow heat affected zone (HAZ) [92].

5. CONCLUSION

In this research article it has made to study the various aspect of friction stir welding. Tool geometry, Different materials, Gripping device (Fixture), Optimization technique, Temperature distribution, Impact of process on environment, Mode of fracture, Microstructure of weldment and different mechanical properties of different material studied in detail. Various optimization technique can be employed such as Taguchi technique, factorial design and Mat lab etc to get better FSW on various parameters. FSW having its own unique aspects for small distortion and shrinkage even in long welds joints, no arc generation, no filler metal, and no shielding gases, very low heat affected zone, free from spatters and porosity defect is emerging as another metal to fusion welding. Numerical analyses for Friction stir welding as well as latest trends also review in this research article. But still there are some challenges remain in numerical analysis to discuss. Hence it can be concluded that FSW is an economical and environment friendly welding process for the industrial applications.

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