European Journal of Molecular & Clinical Medicine

ISSN 2515-8260 Volume 07, Issue 09, 2020

REVIEW OF HIBRID TOOL TESTING AND MEASURMENT FOR FRICTION STIR WELDING

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Abstract

The foremost goal of the review of literature is to Collect, Study and highlight the previous research works conducted by numerous authors(researchers) in an area of the FSW of an alloy of 13Al. Formulating the problem is a central stage in research work with the objectives. In this literature review, the selected main topics are FSW Process analysis, Mechanical properties, Microstructural properties, Experimental designs, bending strength of the welds, Corrosion of the joints, Analysis of wear and Fatigue strength analysis were reviewed.

1. Introduction

The new joining technique of the FSW was invented and patented in the year of 1991. Wayne Thomas invented this technique.This was invented in the institute of welding,The U.K. His aim is to defeat the issues of the aluminium alloys in the fusion welding process. In his observation the friction stir welding overcomes the formation of oxides very much. Also, it can be used for welding the numerous alike and unlike materials and its mixtures. So, the FSW (friction stir welding) techniques had been employed in numerous industries such as in the field of aerospace,in the field of automotive, in the field of marine,in the field of rail and in the field of transportation.The FSW is a continuous non-consumable welding process. The two materials had been joined by using a tool of the rotation. The material of welding had been welded through the tools.The harder materials welded through hard tools. The rotating tool generates heat of frictional and the distortion takes place at every location in the joining to form the joint in the materials in the state of solid.In the welding process, the materials are heated by the heating of fractional and adiabatic which leads towards the distortion of plastic of the base substance. The tool had been rotated in the plasticized material with an axial force. In this stage, a high strain rate is developed. The recrystallization, which is dynamic in nature, had been promoted by this rate of the strain. The finegrained microstructure had been leaded by these phenomena.The diagrammatic representation of FSW process had been illustrated in Figure 2.1 .

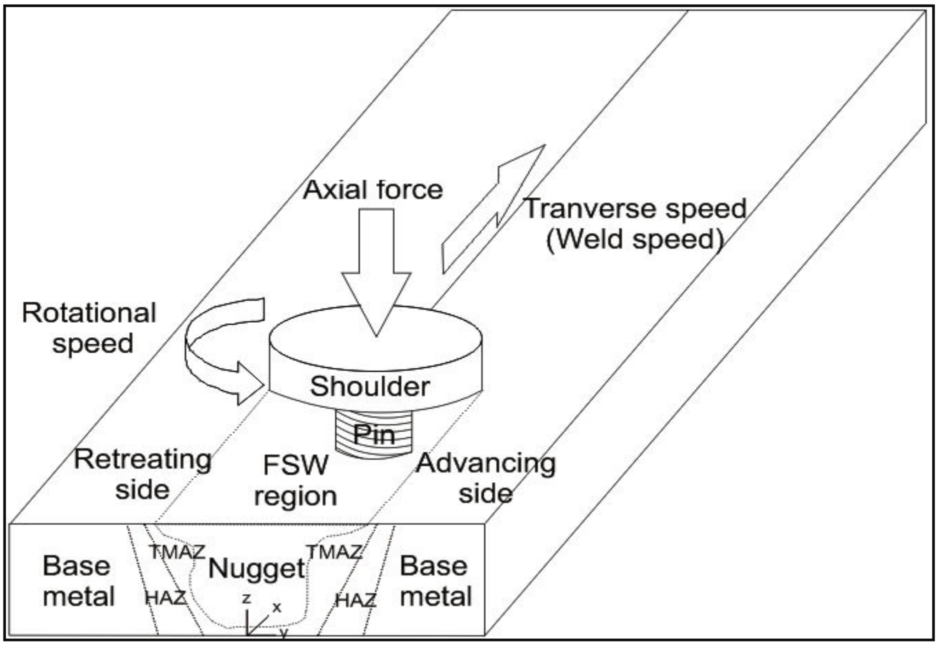

Figure 2.1 Friction stir welding process (Nourani 2011)

Lohwasser (2009) proposed that the substantial flow in FSW was the flow of a sample of pin driven and the flow of a shoulder driven. In process of FSW, the tool had been moved towards the pin and the stirring action is used to transfer the substantial from the pin region of the foremost to the trailing region of the pin. The term advancing side (AS) was used to refer to the path of the adjacent of the rotation of the welding tool were similar to the direction of the travelling. The term retreating side (RS) refer to the opposite side, where the travel direction had been opposed by surface motion .

Çam, G. (2011) classifies the FSW process into three segments. They are the plunge segment, the main segment and the termination segment. Figure 2.2 shows these phases.

a) Plunge segment

The welding had been originated by the joint by inserting the welding rotating tool. After the work piece was inserted by the welding tool, the tool rotates at high rpm. The heat had been generated among the tool and the workpiece. The high temperature was reached by producing the heat. The pin of the tool has been introduced into the interface while waiting for the shoulder to meets the workpiece. For displacing workpiece material, a ring of expelled had been formed, deformed material of plastically towards the pin were included in the pin.

b) Main segment

In this phase, the tool had been moved in the direction of the interface of the workpiece and the joint is made by the pressure and the frictional heat. The tool had been started moving in the direction of the joint. During this process plastic deformation occurs due to friction which produces high temperature. So in the workpiece essential softening had been maintained for tolerating the movement of material round the sample of pin.

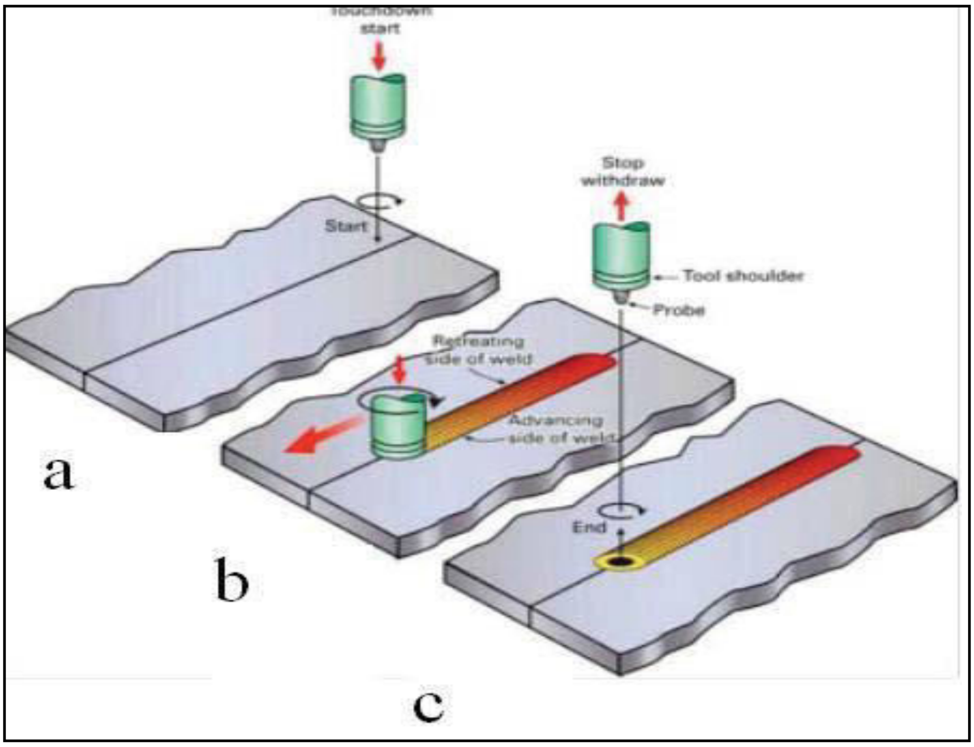

Figure 2. Segments of process in FSW (Lohwasser 2009)

c) Termination segment

In this phase**,** the progressing the tool movement had been motionless. The tool had been released by the workpiece and the weld at the termination was released from a keyhole. The termination of the weld was an area of un-functional which must be clipped left.

2. Mechanical Properties

Many studies are taken with FSW of dissimilar alloys of aluminium, alloys of Cu and alloys of magnesium of the additional metals. In this study, the flow of material visualization and no optimal in parameters of FSW and geometry of tool are recognized (Khaled 2005, Nandan et al 2008, Shukla 2010, Muthu 2016). Even for many of the wrought and cast aluminium alloy combinations the optimum FSW process parameters are not identified. From the weld strength point of view, it is reduced in the combination with very hard aluminium alloy and very soft aluminium alloy. This shows that the position of the two unlike mixtures was employed. The material flow of the proposal and the quality of the resultant of the weld were an important outcomes. For example, FSW of AA5083.0 to AA6082.0(Svensson 2000) and AA6061.0 to Cu . Pashazadeh (2017) had been proved that the material which has low-slung strength was sited over progressing adjacent for producing improved joints in welding.

Vladvoj Očenášek et al (2005) studied the results of analyses of microstructure, measurements of solidity and tension tests of sheets of FS-Welded of two alloys of Al: AA5083 and AA7075. The conclusion is the macrostructure and microstructures of AA5083 and AA7075 was like to this twisted in hot working (extrusion, forging).

Cavaliere et al (2008) proposed that the tensile and the behavior of weakness in FSW of AA2024 and AA7075 aluminum mixtures and the tension test failure over the adjacent of AA2024 had been detected (which contain subordinate solidity) and the joints of two unlike revealed a reduction in life of fatigue with respect to AA7075 joints in FSW. This result opens up scope for further research and provides a way for finding the solution to this problem.

E.E.Feistauer et al (2014) proposed the worldwide and resident mechanical possessions of two unlike materials of aluminium-magnesium alloys of AA5083 and AA5059 used in marine industries by FSW. The aluminium alloys of FSW uses TWB of thickness 6 mm and 8 mm.The FSW of Stir zone (SZ) of the unlike TWB had been substituted. The mechanical properties and the characteristics of the geometric were divergences around the joints in TWB.The local constrains can carry out the strain which was arriving in the region of the HAZ at the diameter of 6 mm of thickness sheet.

Sandeep & Kum, (2017) investigated that the process of probability of AA7075-T6 sheets at a diameter from 3 mm to 5 mm, in between this with the thickness of seven different mixtures by using the analysis of finite element with an analysis of experiments and they conclude the process parameters, the shape and angle of tool face and cutting edge and the angle of inclination in the double utensil gives best tailor welded blank joints.

Khodir, S. A (2008) investigated the unlike alloys of aluminum 2024-T3 and 7075-T6 plates of the diameter of 3 mm breadth had been butt in FSW. The welding had been exposed by a not altered rate of the welding of 100 mm/min and rotational rates of 400, 800, 1200, 1600 and 2000 per min. The impacts of the speed of the rotation and the immovable site of dual unlike mixtures over microstructures especially the element in the homogeneousness were distributed around region of the stir, distributions of solidity, and the properties of the tensile of the joints had been proposed. By using the scanning electron microscope, the elements of the dual mixtures of homogeneity in the stir zone (SZ)had been evaluated.

Pan (2013) report that the strength of the mechanical of the joints was affected by the geometry of the interface for the two dissimilar joints of lap FSW of AA5052-H112 and AA6061-T6 under numerous parameters for the welding. The load of the fracture was decreased at the higher rate of the rotational and at the subordinate rate of the welding.

Zadpoor et al (2008) proposed the mechanical properties and microstructural analysis of alloys of dissimilar aluminium of 2024-T3 and 7075-T6 with numerous thicknesses of the diameter ranging from 1.2 mm to 2 mm of thickness ratios from 1 to 1.7 and observed that, for numerous configuration of the thickness, the mechanical properties and solidity of the specimens with machined had been decreased.

Dinaharan, I., & Murugan, N et al (2012) experimentally studied to join AA6061/ (0, 5 and 10 wt. %) ZrB_2. The FSW process had been used to manipulate the properties of the joint and cast composites were in suited. In their experimental study, a homogenous distribution of ZrB_2 particles had been summarized by the weld zone were concluded. The strength of the tensile of joints in the welded had been compared towards the composites of the base material. The resistance of the wear of the compounds was upgraded towards Friction Stir Welding subsequently.

A.K.Lakshminarayanan et al (2009) conducted the experiments, based on the three factors using three levels of the face centred CCD with the techniques of full replication and the mathematical model were developed in the process of FSW. The ANN model of the results shows that it was robust in nature and the values of strength of the tensile were more accurate when compared to the response of the model on the surface.

Sundaram et al (2010) use pin profiles of five different types,to analysis the two dissimilar aluminium alloys in FSW. The TS results had been attained through the width of the tool of cylinder with tapered sample of pin among the profiles of triangular,the profiles of flat cylinder and the profiles of the threaded tool of cylinder. The 300 to 700 rpm of the speed of the rotational tool, 15 to 35 mm/min of the speed of the welding and4 to 8 kN of the force of an axial force were used.This range employs the imperfection free welds.The strength of the tensile of the joints had been determined by the rate of the rotational tool.

Kulekci et al (2008) directed the experimental study and the comparison is made among the process of FSW for an alloy of AlMg1SiCu aluminium and MIG welding. By using FSW, the tensile,the effect and weakness of the welded joints were increased , instead of MIG welding.The conclusion shows that FSW was a better method.In FSW,the base metal of UTS 290.0 MPa, FSW UTS of 270.0 MPa was less, but the MIG welding of UTS 220.0 MPa was high.

D. M. Rodrigues et al (2010) directed the investigational study of the weldability of AA5083-H111.0 and AA6082-T6.0 alloys of aluminium.The welding process of fabrication uses these alloys.By comparing both dissimilar materials the welding analysis had been determined. The speed of the welding was increased by choosing a huge variety of conditions (varying dimensions of the tool, rotation of the tool and tool welding speeds, axial loads of the tool and tilt angles of the tool) for the welding process.

Chen Yuhua et al (2011) studied the joining of TCI titanium alloy and LF6 aluminium of dissimilar alloys of butt and joints of lap in FSW with varying rate of the rotation of tool and rate of welding. They concluded that when the rate of the rotation of the tool are 950 rpm and the rate of the welding are 118 mm/min, the strength of the tensile of butt joint being 131 MPa which is the highest.

S.Sattari et al (2012) studied the FSW,the diametre of 0.8 mm in thickness AA5083 aluminum sheets by using a special fixture were designed for the sheet with thin diameter. The test for tensile and the test for micro hardness were employed.The samples were tested and these samples were defects free. In this study they resolved that the Mechanical properties show that the stress of the yield for the old samples was beneath the base metal.

Koilraj et al (2012) enhanced the FSW process through the strength of the tensile of the two dissimilar welds AA2219 and AA5083 using five numerous profiles of the tool . The parameters for the process chosen were at the rate of the rotational,the rate of the Transverse and the fraction of D/d where D= diameter of the shoulder and d= diameter of tool pin respectively. The optimum values obtained were 700 rpm, 15 mm/min and 3 respectively for the profile of threaded cylindrical pin profile of the tool.

Prashant Prakash et al (2013) led the FSW test through changing the process parameters to find out the joint efficiency in AA 6061 Aluminium alloy of 6 mm plates for this experiment tool was designed in H13 steel. In this experimental study they resolved that the parameters for the process had been varied within the variety: Situation I: the rate of the rotation of the tool of 1120 rpm,the Welding rate of 20 mm/min and the dimension of the Pin of 5.2 mm. The TS had been obtained as 142 MPa. Situation II: the rate of the rotation of the tool of 1400 rpm,the Welding rate of 25 mm/min and the dimension of the Pin of 5.7 mm.

A.M Khourshid and I Sabry (2013) conducted that the FSW is applied for the construction of two pipes (AA6061), a thin-walled and the thickness variable of the hemispheres of hollow .The process of FSW had been used for regulating the viability to weld two pieces of aluminium pipe. The consequence of the mechanical properties of welding joints was employed. Because of an experiment of the stir welding,the results had been proved that the aluminium pipe (AA 6061) could be joined through the FSW process with extreme fusing with an efficiency of 78.7% in terms of UTS, using 1400 rpm and the rate of the travelling of 4 mm/min.

F. Cioffi et al (2013) conducted the experiments and proposed the joints microstructure and joints mechanical properties in FSW(friction stir welding) process, at unlike rates of rotation (300, 550, and 800 rpm), rate of progressing(75 mm/min) in the plates of breadth (15 mm) of a compound substantial (2124Al/25vol%SiCp) a reinforcement fraction with high dimensions. This indicated that the deformation of the plastic had been carried out during the process of FSW.These techniques was not unfavorable for the matrix reinforcement interface. An extension of the stress of the microscopic residual had been attributed the effect of SD.

H.J. Liu et al (2013) led researches over the diameter of a 4 mm thick of 6061-T6 of an alloy of aluminium which was SRFSW (Self-Reacting Friction Stir Welded) at unalter rate of the tool of the rotation of 600 rpm. The impact of the speed of the welding over the joints of microstructure and the joints of mechanical properties were employed. In their investigation, they concluded that when the speed of the welding improved between 50 and 200 mm/min, the grain size SZ of the nugget had been improved, but the grain size of the high temperature had been exaggerated in the region had been unchanged.

Puneet Rohilla and Narinder Kumar (2013) proposed the experiment for the FSW butt joint. The joints in the Welded had been constructed by using the tool which is made up of an alloy High Speed Steel (HSS) .These tools were constructed by using two dissimilar profiles of the pin such as the profile of straight cylindrical and the profile of square. The joints of the welded had been generated on the grade of aluminum AA 6061 plates of 6 mm dense in diameter.These assessments had been carried out for determining the strength of the tensile, an extension of percentage and microhardness.

Mohsen Bahrami et al (2014) demonstrated that AA7075 Aluminum matrix for the nano-composite when reinforced with the particles of SiC were developed in the zone of the stir and at high speed of the rotational (1250 rpm) the precipitate dispersal had been enhanced because of authentic moving action of the pin.

Ravindra S. Thube (2014) proposed that the impact of the tool rate and the pin profile of the tool over (Friction Stir Processing) FSP. The zone had been formed in AA5083 mixture of aluminium.FSW (Friction stir welding) of AA5083 alloy of aluminium plates with a width of 2.5 mm had been employed. The Five unlike pin profiles of the tool (straight cylindrical, tapered cylindrical, triangular, square and cone) had been fabricating the joints at three unlike rates of the rotation of the tool i.e. 900, 1400 and 1800 rpm with a unaltered rate of the traverse of 16 mm/min.

Ramaraju Ramgopal Varma et al (2014) investigated and assessed mechanical properties of unlike metallic mixture of joints in FSW. The strength of the joints had been obtained through the enhanced parameters for the process in comparison to the parent material. Aluminium 5083 and aluminium 6061 sheets of 5 mm dense have been fabricated the unlike joints. The technique of optimization had been applied to the condition of the existing and condition of the improved.As a result the optimized parameters of the process had been proposed.

Mishra, R. S et al (2005) conducted the experimental study of the AA6061 aluminium alloy forming behaviour of the TWBs made of the process of FSW under two different speeds of the welding (90 mm/min and 100 mm/min). The formability of the FSW sheet made at 90 mm/min had less formability in the drawing side and higher in the stretching side than FSW sheet made at 100 mm/min. Both FSW sheets showed better formability than the base material. The rise in the rate of the welding in FSW sheets,decreases the formability.

Kumbhar & Bhanumurthy (2008) presented a composite picture of the work done at BARC, relating to the developments of microstructure in an FSW AA 5052 alloy. It was observed that the values of the UTS for the specimens had been welded with numerous speed of the traverse (60, 80 and 100 mm/min) at 1120 rpm were in the variety of 260 - 265 MPa, which was higher than the welded at 1400 rpm (UTS values being just above 200 MPa). The present study on aluminium alloy of AA5052 provided an in-depth study for characterizing the microstructure, microchemistry, microtexture and the mechanical properties. In addition, the study convincingly showed that under the optimized condition, the welded specimens show superior mechanical properties. The mode of ductile of fracture had been shown by the specimens.

R. Palanivel et al (2014) proposed that the microstructure and the characterization of the mechanical property of dissimilar FSW of AA5083-H111 and AA6351-T6 mixtures of aluminium . In this study, the conclusion was the speed of the welding of 63 mm/min were produced recovering the mechanical and the metallurgical properties than the other speed of the welding .The zone for the welding consist of three kinds of microstructures. They are the region of authentic(unmixed), region of mechanically mixed and the region of mixed flow . The mode of the fracture had been observed to be a fracture of ductile fibrous.

D.Wang et al (2014) conducted the study diameter of 3 mm thick 17 vol % SiCp/2009AlT4 plates with FSW. They conducted the experiments of the various speeds of the rotational ,the speed of the transverse and hardness. In their experiments they concluded the joints in FSW of 3 mm dense 17vol%SiCp/2009 Al-T4 composite were successfully achieved using a threaded cermet tool at a rate of the rotation of the tool of 1000 rpm and the speeds of the welding of 50, 200 and 800 mm/min. At low speeds of the welding of 50 and 200 mm/min,the zone of the two low-hardness was observed in the HAZ.

Cox D et al (2014) experimentally studied the FSSW on thin plates of an aluminium alloy. Their main objective was to discover the outcomes on how the number of tool rotations affects the quality of the resulting spot weld. The rate of rotation of the numerous combinations and the time of the dwell were investigated. The proposed FSSW of an open loop of the control system with energy had been monitoring with the control of the traditional position, the rate of the rotation,the depth of the plunge,the rate of plunge and extraction were still input into the system. Instead of inputting a dwell time, total weld energy was specified.

Mohsen Bahrami et al (2014) summarized the effect of SiC particle which are in nano-size, on the properties of the mechanical of the joints in FSW. The joint line incorporates the Sic particles which is in nano-size. The combined features of the speed of the three rotational and three speed of the travelling were applied. The UTS of the specimen using precipitate in FSW at 1250.0 rpm and 40.0 mm/min was 31.0% superior than the sample without using precipitate in the FSW. The 76.1% of elongation enhancement was obtained by adding the particles of SiC.

Mohsen Bahrami et al (2014) proposed that the macrostructure of the geometry of the pin was influenced.In this study,the FSW of properties of the mechanical and the microstructure and , SiC of the particles of nano were enforced . The five different geometrically pin tools were used for comportment the FSW. The technique of SEM had been used to examine the exterior of the crack of the samples of the tensile. In this investigation, his conclusions were the SiC of the particles of nano were inserted into the attached strips. The influence of the geometry of pin on macrostructure, microstructure and properties of the mechanical of the joints were employed.

Long Wan et al (2014) proposed,the diameter of thickness of the 5 mm of 6082-T6 alloy of aluminium had been joined through SSFSW. In that study,the upper shoulder of the concave and the reduced and inferior shoulder of convex was present in the SSFSW tool.This had been used to join 6082-T6 an alloy of aluminium which is 5 mm thick in diameter. On the investigation, they extracted the weld shape of the SSFSW joint differed from the conventional FSW of the weld and was slightly hourglass shaped.

3. Microstructural Properties

Liu et al (1997) proposed that the facets of the microstructure of the FSW of AA6061-T6 alloy by varying the speed of the rotation, in the variety of 300 to 1000 rpm and the speed of the translational of 0.15 to 0.25 cm/s.The light microscopy and TEM were used for characterizing the microstructures in the FS zone of the weld. The consequences were associated with the original 6061-T6 aluminium alloy plate. The Microhardness profiles were measured from the workpiece and through the zone of the weld. The results confirmed that the FS weld zone in AA6061-T6 had been characterized through the appearance of dynamic continuous recrystallization microstructure. The zone of the weld of the size of the grain was averaged at 10μm whereas the workspace hardness was averaged at 100μm.

Waldran (2002) proposed the visualization of flow and the residual microstructures of AA2024 to AA6061alloy of aluminium. The joints in FSW had been categorized through enduring, the zone of the weld contains grains of equiaxed and the grains of recrystallization demonstrate the growth of grain dynamically.The average dimension of zone of the weld range between 1 and 15 mm. The flow of superplastic mechanism had been provided by producing flow of lamellar patterns. The observed grain of equiaxed and microstructure of sub grain had been differing.This is because of the assessed profiles of temperature through orientation towards the axis of the tool of the rotation.

Krishnan (2002) conducted the test on PWHT (post weld heat treatment) over FSW at solutioning temperatures of 520, 540 and 560°C followed by aging at 175-200 degree C. It was found that the WN region contained coarse grains after PWHT.

Sakthivel et al (2009) experimented with AA5083 aluminium alloy for FSW by varying the welding conditions like tool design, rotation speed and translation speed. The consequences of the microstructure,the mechanical property and the stress of residual were examined by the four aluminium AA5083 FSW.These were produced under the varied conditions . It was found that the properties of the weld were dominated by the input of the thermal rather than the deformation of the mechanical by the tool.

Kumbhar et al (2008) studied joint properties of the two dissimilar cast A356 and wrought AA6061 by FSW according to the materials at the fixed location. The test for longitudinal tensile revealed that the strength of the zone in the stir showed the highest value when the harder material (AA6061) was fixed at the retreating side.

Sato et al (2004) Studied grain growth by examining the stability of the fine grains in the zone of the stir of FSW in AA1100 aluminum alloy during the solution heat treatment. It was found that the growth of the grain occurred only, when the solution of the temperature was higher than an extreme temperature.

Steuwer et al (2006) stated the effect of the parameter of the process on residual stress in dissimilar FSW of AA5083-AA6082. They showed that the speed of the rotational of the welding tool was more operative than the speed of the transverse on the residual stresses in the welds particularly on the AA5083 side.

Sayer et al (2008) proposed that the influence of the FSW parameters of the process on the microstructure,the mechanical property and the low cycle of weakness of the behaviour of AA6063 (AlMgSi0.5) aluminium alloy plates by selecting three different rotations and welding speeds. The results of the test for the tensile indicated that the specimens with a great majority were broken in the region among the HAZ and the TMAZ. The weld mechanical properties were observed to be about 70 % of those of the base metal. In terms of low cycle fatigue life 40 % decrease had been detected in welded specimens. The fatigue failure was found to occur at the weld zone. Smaller grain sizes of the grain boundary were seen to occur in the nugget region.

Rajakumar, S (2011) analysed the behaviour of the tensile of FSW AA6061-T651 with varying parameters of the welding, including the speed of the rotating and welding. The study of Microstructure proposed that the change in the behaviour of the tensile of FSW AA6061-T651 was related to the coarse clustering of Mg_2Si occasions, due to the whirling and hurling action that occurred due to severe plastic flow in the weld zone. The decrease in an extension of the tensile of FSW of AA6061-T651, with a decrease in the speed of the welding or increase in the speed of the rotation. The Low speed of the welding or high speed of the rotation were occurred for encouraging the flow of the plastic per unit time and the coarse clustering of precipitates in a particular location consequently.

Sakthivel et al (2009) proposed that the consequence of the different speed of the welding were varied from 50 mm/min to 175 mm/min on the alloy of the metallurgical and the mechanical properties. The tensile test results revealed that the UTS decreased with the increase in the speed of the traverse because of the inadequate input of the heat was generated. On the other hand,the higher heat generation took place at the lower the speed of the weld which resulted in an increase in the size of the grain and restoration of the ductility by recrystallization mechanism. The microstructure of the nugget of the weld have consisted with the grains of fine equiaxed. These grains were more homogeneous at lower the speed of the welding than at higher the speed of the welding.

Sidhu et al (2012) investigated effects of the different speed of the welding of FSW on the alloy of the metallurgical and mechanical properties. The result was the microstructure of the weld nugget contains fine eqi-axed grains. Those grains were more homogeneous at lower welding speed than at higher speeds of the welding .

Leitao et al (2009) in his studies on mechanical behaviour on dissimilar joints of AA5182-H111 and AA60616-T4 stated that the strength of the tensile of the joint was mainly dependent on the size of the grain in the TMAZ for AA5182-H111. The report was the loss of ductility of the welded joints. In the case of the A319 and A413 FSW system (Rodriguez 2005), the A319 FSW zone was observed to be roughly 15% harder than the corresponding base metal. The A413 system, in contrast exhibits nearly constant hardness from the base metal through the FSW zone. FSW microstructure comprised of the breakup and redistribution of the base metal phase inclusions in the zone of the weld. The A319 alloy exhibited a micro dendritic cell structure which was completely altered in the re-mixed FSW zone while the A413 alloy exhibits plates and needles which were largely broken and redistributed in the FSW zone.

Park et al (2010) proposed that the effects of placing aluminium alloys 5052 and 6061 on the sides of the proceeding and withdrawing. The results indicated that,the nugget of the thinner weld was reported due to the mixing insufficient when A5052 was placed on the retreating side.

Dhilip et al (2010) proposed that the success of the dissimilar FSW required careful judgment with respect to the placement of the material placement,the positioning of the tool, and the parameters of the process depended on the properties of the materials to be joined.

Sayer et al (2010) proposed that the influence of numerous parameters of the process of FSW on the microstructure,the mechanical property and the low cycle of exhaustion behavior of AA6063 aluminum alloy plates with 3 different speed of the rotational of the tool rotational and feeds. The conclusion of the study was in the WN regions grain boundary, the grain sizes were smaller.

Singh et al (2011) proposed that the consequence of PWHT on the microstructure of FS welded 7079 aluminum alloy joints. The observation was the TMAZ exhibited coarse grains than that of stir zone.

Palanivel et al (2012) in his studies on two dissimilar FSW of AA5083- H111 and AA6351-T6 have examined the influence of the speed of the rotational of the tool rotational and the profiles of the pin on the microstructure and TS of the unlike FSW of alloys of aluminium.The welds were fabricated using the profile of the square tool that gave better the strength of the tensile than that of the profile of cylindrical, the profile of tapered, the profile of hexagonal and the profile of octagonal tool pin. The weld with free defect was found at the profile of the square tool and the profile of the tapered tool and the profile of cylindrical causes the defect of the tunnel at the bottom of the joints

Weifeng Xu et al (2013) studied the microstructure, the second phase of the particles and the mechanical properties of the joint laterally the width of diameter 12 mm plate during FSW AA2219-T62 aluminium alloy of the thick plate using different shapes of the pin were investigated. The pins used for those investigations was threaded and tapered with three spiral flutes and threaded and tapered with the triangle. The shapes of the pin were illustrated in Figure 2.3. In this experimental study the results of the characterization of the microstructure revealedby numerous sizes of the grain in dissimilar locations of WNZ through width. Larger grain sizes were observed in the top section, whereas the bottom section exhibited small grains. An edge TMAZ on both sides of the WNZ had been more dissimilar on the AS and more longwinded on the RS and the size of grains had been decreased and the distribution of the particles in the second phase had been more diffuse at the speed of the rotational of 300 rpm than that of 500 rpm.

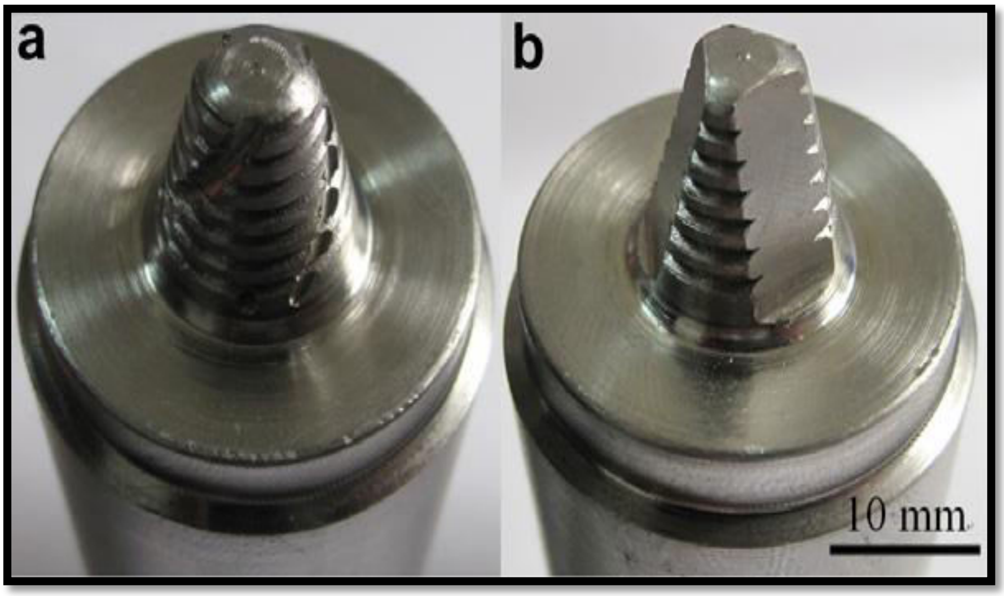

Figure 2.3 FSW tool pin profiles: (a) Threaded and tapered with three spiral flutes and
(b) Threaded and tapered with the triangle.

Comparing to the first tool, the hardness decreased slightly when the second tool was used. The strength and ductility increased with the increase of the speed of the traverse from the 60 mm/min to 100 mm/min or the decrease of speed of the rotational from 500 rpm to 300 rpm, using the first tool.The fracture of the Tensile for the whole and slice of joints had been sheared with the surface of the fracture inclined at an angle of 45° and brittle with failure occurring normal to the far field stress axis in the border area the HAZ on a macroscopic scale. The overall morphology presented the ductile and brittle failure mechanisms.

4. Experimental Designs

The experimental design is a well organized and a structured method used to find out the relationships of the different factors affecting a process and output of that process. It involves designing a group of the experiment in which all the related features had been varied in a systematic manner.

Su et al (2003) defined the Design of experiment as a structured and organized method used to determine the relationship between the different factors affecting a process and the yield for that process.

The advantages of the Design of experiments are as follows.

- Recognition and problem statement

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

Periyasamy, P (2013) proposed that the Response Surface Methodology (RSM), as a collection of mathematical and statistical techniques that explored the relationships between several explanatory variables and one or more response variables. It was useful for analyzing the problems of independent variables that influence dependent variables or response and the aim was to optimize the response variable. RSM was a sequential procedure. It was used for finding the optimum for operating conditions for the system or for finding a region of the space for the factor in which the operating specifications were satisfied.

Arora (2010) commented on the design of the Taguchi ,which was developed by Dr. Genichi Taguchi as a set of methodologies by which the inherent variability of materials and manufacturing processes had been considered at the stage of the design. Taguchi proposed that engineering optimization of a process or product should follow a three step approach of the system design, the parameter design and the tolerance design. The Taguchi parameter of the design steps are: the proper selection of an Orthogonal Array (OA) on the basis of the number of the controllable parameters; running experiments based on the OA; analyzing data; identifying the optimum condition,and; conducting confirmation runs with the optimal level of all the parameters. By using the Taguchi techniques, industries were able to reduce the product development cycle time for both design and production thereby reducing cost and increased profit.

Arif.A et al (2013) highlighted the importance of factorial designs stating that it would have great effects if all the variables are varied together. It facilitated to analyse the interactive effects of the variables on the retort with a similar precision. The Factorial design was more efficient than one-factor-at-a time method of the experiment. Added to it,the factorial design was necessary to avoid misleading conclusions. Finally, the factorial design allowed the effects of a factor which was to be estimated at several levels of the other factors, yielding conclusions that were valid over a range of experimental conditions. The Factorial design experiment was an experiment of the factors for all the level of the possible combinations were realized.

Shercliff et al (2005) experimented with the trial and error approaches to improve the 2000 series of aluminium alloy's welding process parameters in the FSW process. The speed of the welding was optimized. The tool was easily traversed by softening the material which is present on the front side of the tool.

Lakshminarayanan and Balasubramanian (2008**)** applied the Taguchi method to find out the maximum influential control factors that gave improved strength of the tensile of the FSW joints in RDE-40 aluminium alloy. In that approach, the optimum level of process parameters (the speed of the rotational of the tool,the speed of the welding and the force of an axial) was determined. The results had been proved that the speed of the rotational of the tool,the speed of the welding and the force of an axial were the significant parameters through which the strength of the tensile of the joint was decided.

Sarsilmaz and Çaydaş (2008) implemented the design of the experimental of full factorial to study the various effects of FSW parameters of the speed of the rotational of the spindle,the speed of the traverse and the geometry of the stirrer on the mechanical property of A1050/AA 5083 aluminium alloy. The UTS and the hardness of joints in FSW were determined. Analysis of variance (ANOVA) and the main effect plot was used to know the significant parameters and set the optimal level for each parameter.A Linear regression equation was derived to predict each output of the characteristic.

Jayaraman et al (2009) investigated various effects of FSW process variables of the speed of the rotational of the tool,the speed of the welding and the force of an axial by full factorial design using Taguchi's vigorous the concept of the design on the strength of the tensile of A319 alloy of FSW welded joints. In that, the FSW joints were completed by numerous combinations of the speed of the rotational of the tool,the speed of the welding and the force of an axial, respectively at all the four levels. The analysis of macrostructure and microstructure was used to analysis the quality of the zone of the weld. The strength of the tensile of the joints had been appraised and interrelated with the zone of the weld of microstructure.

A.K.Lakshminarayanan et al (2009) Conducted the experiments based on three factors of three levels with the central composite face of the centered design with the technique of full replications and the model for mathematics had been constructed. The results obtained through response to the methodology of the surface were compared through the network of artificial neural by using AA7039 aluminum alloy. Their conclusions were the speed of the rotational was the factor that had a greater influence on tensile strength followed by the speed of the welding and the force of an axial.

Nourni et al (2011) proved that the optimization problems absorbed in the FSW were obtained by considering a set of parameters for the process (in many cases, the speed of the welding and the speed of the rotational), few constraints and objective functions.

Palanivel et al (2011) proposed that the FSW on AA6351 aluminium alloy based on the 3 factors of 5 level with a central composite of rotatable designs with the technique of full replications .The selected process variables were the speed of the welding,the speed of the rotational of the tool and the force of an axial. The Mathematical model was developed for the consequence of three process variables at five levels using the response of the methodology of the surface. The developed model of the mathematical tolerability was checked by the technique ANOVA.

5. Bending Strength of the Welds

Gungor et al (2014) conducted the experiments to examine the test results over the mechanical properties like a tensile test, bent test, X-Ray test and microstructural evaluation by using AW-6082, 5 mm thickness plate in FSW. The Tension tests had been achieved over a cut of the models which was located up and down to the weld line. The strength of the tensile strength FSW welds was unswervingly comparative to travel (welding) speed. The reason for this phenomenon was the kinetic and thermal asymmetry of the process of the

FSW .An initial stage of a longitudinal, the defect of the volumetric was originated at the juncture of the nugget of the weld and the zone which was affected by thermomechanical.

Amir Abbas Zadpoor et al (2009) studied the bendability of machined tailor-made blanks. A high strength aluminium alloy, namely 2024-T3, was selected for the study. In their study, they concluded that the minimum bending radius slightly (10-12%) increased when thickness ratio increases from 1 to 2. The effects of pre-stretching (in a direction in parallel with the bend line) on the minimum bending radius were found to be minimal.

Campoli et al (2011) studied that the minimum the ratio of the bending and the minimum the radius of the bending in the material of 2024-T3.0 and 7075-T6.0 aluminum alloys. In this study, the minimum ratio of the bending ratio had been increased with respect to the increases in the width of the sheet. Also the minimum radius of the bending radius had been increased with respect to the increase in the ratio of the width.

S.Ravikumar et al (2013) Investigated that the strength of the bending for dissimilar FSW of AA6061-T651 and AA7075- T651 aluminum alloy butt joint of 6.35 mm thick with three pin profiles of taper cylindrical threaded pin, taper square threaded pin and a simple square pin. This research reveals the tool of the taper cylindrical threaded gives the good result of the bending strength.

6. Corrosion of Joints

Fontana et al defined corrosion as

1. The material had been destructed or deteriorated through the environmental reaction.
2. An opposite of an Extractive metallurgy
3. The material interaction had been undesirable with its environment.

Arunprasath et al (2018) in his studies identified that pitting corrosion was influenced by the numerous parameters such as environment (concentration of ion, pH, and inhibitor concentration),the composition of the metal,the temperature of the potential and the condition for the surface.

Wolfensberger (1998) identified that the oxide layers form protective a coating of 2-3 nm thick and if this oxide film was damaged by any external means, a new oxide layer would be immediately formed on the bare aluminium metal.

Amancio-Filho (2008) in his studies on pitting corrosion of aluminium alloys referred to pitting as a highly localized type of corrosion in the occurrence of aggressive chloride ions. He found that pits were initiated in the protective oxide when it was weak in thickness due to chloride attacks. The pits of the propagation reactions were stated as

$$Al = Al_3^+ + 3e^- \qquad (2.1)$$

$$Al_3^+ + 3H_2O = Al\,(OH)_3 + 3H^+ \qquad (2.2)$$

$$Al^+ + 2H_2O > Al_3^+ + 2OH^- \qquad (2.3)$$

In the intermetallic cathodes,the two important processes of reduction was the evolution of hydrogen and reduction of oxygen.

$$2H^+ + 2e- = H_2 \qquad (2.4)$$

$$O_2 + 2H_2O + 4e^- = 4OH^- \qquad (2.5)$$

The pH value decreases as per reaction # (2.2). The ions of the Chloride were migrating into the pit for balancing the charge of positive generated by response #s (2.1) and (2.2). Thus accelerated pit propagation inside the pit was caused due to HCl formation. Thus local alkalization around the cathodic particles caused by the reduction reaction and as a result, the aluminium oxide, which was once a protective coating against corrosion,were instigates to dissolve and form alkaline pits. Once the protective layer was dissolved, particles of the active aluminium component also dissolve which in turn enriched the surface with Fe thereby increasing the cathodic activity.

G.S.Frankel and Z.Xia (1999) conducted experiments in Al 5454 aluminium alloy in 'O' and 'H34' conditions of the susceptibility in FSW in the conditions for welded and un-welded. The FSW welded samples were compared to the process of the welding of the Gas-Tungsten arc. The result was FSW samples were displays the resistance of the superior to the corrosion in pitting comparing to the base metal and gas-tungsten arc-welded samples.

Mishra (2005) investigated that the pitting and stress corrosion cracking behaviours of friction stir welded AA5454 and compared them with those of base alloy and GTAW samples. The central annotations were made that in samples of the FSW, the formation of the pits were in the HAZ.In samples of the GTAW, the formation of pits were in the region of the large dendritic with the interior part of the zone of the fusion.The FSW welds showed a pitting resistance higher than those of base alloy and GTAW welds

Szklarska et al,; (2004) justified that the particles of intermetallics such as iron present in the medium of aluminium were influenced by the behaviour of the corrosion of aluminium alloys. These particles were present in the microstructure that reduced the resistance to the corrosion of localized. The difference in the potential through the matrix in the solution had been affected the particles of the intermetallic behaviour i.e. the matrix underwent anodic dissolution, if the particles were electrochemically more decent than the matrix which controls the corrosion of the localized.

Elangovan et al (2004) examined that the corrosion potential of FSW AA7075 aluminium alloy by exposing 1 cm^2 area of the weld zone , TMAZ and base metal had been unprotected to 3.5% of solution of the NaCl with the value of pH adjusted to 10, where the region changes from passive to active was very sharp in nature. The rate of the scan of 0.166mV/s had been used for scanning potentiodynamic by using BES potentiostat.These techniques works under the measurement of the corrosion software of 352 SoftCorr III .The Saturated Calomel Electrode (SCE) and graphite electrode were used as a reference and auxiliary electrode respectively. The current was increased with respect to the potential.This had been referred to as critical pitting potential (Epit).The Specimens had been exhibit more potential of the positive through the better pitting resistance of the corrosion .The outcomes exposed that pitting resistance of the corrosion of the metal used for weld was improved compared to the TMAZ and the BM.

Hua-Bin Chen et al (2006) proposed external factor on the FSW, in the material of 5456 aluminium alloy. The defects had been produced by changing the angle of the tool tilt and the condition for the material. These defects were predictable (absence of infiltration or vacuums), or idle,which can be exclusive to FSW. An area of uncertainty persists the defects in the origin. The formation of these defects had been examined.The typical defects of the welding of the FSW joint for 5456 aluminium alloy had been analysed.

Jariyaboon et al (2007) calculated the consequence of welding parameters of the rate of the rotation and the rate of the travel on the behaviour of the corrosion of FSW in high strength of an alloy of AA2024–T351 aluminium. The attack had been employed with the location of the corrosion.It had been controlled by the rate of the rotation. The region of nugget undergoes the attack of localized intergranular at a low welding rate of the rotation. There was an attack largely in the HAZ for higher welding rate of the rotation.

C.S.Paglia and R.G.Buchheit (2008) conducted the tests of the corrosion susceptibility when the microstructure sensitization occurred in FSW aluminium alloys. They concluded that a similar condition of welding temperature modified the microstructure and reduce the corrosion.

Jayaraj et al (2017) studied the effect of pH and chloride concentration on pitting corrosion of AA6061 aluminium alloy and found that AA6061 exhibits excellent resistance of the corrosion in the solution of aqueous except for the corrosion of pitting in the occurrence of reactive elements like chlorine.

Surekha et al (2009) examined that the effect of parameters used for processing such as the rate of the rotation and the rate of the traverse on the behaviour of the corrosion of friction stir processed with high strength precipitation hardenable alloy of AA2219-T87. The results had been proved that the speed of the rotation had a major influence were used to determine the rate of deterioration, which had been accredited to the breaking down and the intermetallic particles had been terminated.

Ahmed S. Hassan et al (2010) investigated that the behavior of the corrosion of two unlike alloys A319 and A356 cast aluminum plates had been welded by using a method of FSW was evaluated. The behavior of the Corrosion of welding had been examined to immerse for 6 hours in the solution of (sodium chloride) NaCl and the solution of (hydrogen peroxide) H_2O_2.The result of this study showed that the better corrosion resistance was obtained by using both theASHT(heat treatment of as-welded) and PWHT(post-weld heat treatment) of A319 and A356 base alloys.

P.Bala Srinivasan et al (2010) proposed research that the resistance of the corrosion and the corrosion of the stress behaviour of an AA2219 friction stir welded specimens. They concluded both the parent metals and FSW welded specimens have good resistance to cracking corrosion in 3.5% of the solution of NaCl .

Kcuik et al (2010) suggests 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. Kciuk et al (2007) in his studies on corrosion properties of an alloy of AlMg5 and AlMg1Si1 alloys generalizes that, the layer of the oxide forms a natural layer of the protection from corrosion through the dullness. However, corrosion was prone to succeed, when it was exposed to the higher corrosive environment.

Hussion et al (2010) analysed that the behaviour of the corrosion of two dissimilar alloys of A319 and A356 in FSW, cast plates of aluminium had been joined.These technique uses three dissimilar rates of the rotation of the tool (typically, 1120, 1400 and 1800 rpm) and the two rates of the welding (typically, 80 and 112 mm/min). The consequence of the rate of rotation of the tool and the rates of the welding and the post-weld heat treatment (PWHT) over the behaviour of the deterioration had been examined .

D.R.Ni et al (2010) conducted research for the modification of the microstructure in cast alloy of Cu-9Al-4.5Ni-4Fe NiAl of an alloy of bronze (NAB). After the FSW process, the cast NAB microstructure was transformed from coarse to fine without any porosity defects. This change of microstructure, changes the behaviour of the Corrosion.

Malarvizhi et al (2011) investigated the divergence of the specimens for the weld of an alloy of AA2219 in non-deaerated of 3.5% of a solution of the NaCl with the values of pH of 04, 07 and 11. The pitting potential (φ-pit) is considered as the norm for comparison of the resistance to the pitting corrosion. The Joints that display the lower potential of the negative (i.e., higher positive potential) values of the potential of the pitting considered more resistant of the corrosion. The microstructural studies showed that the intermetallics such as $CuAl_2$, Al_7Cu_2 Fe and (Al,Cu)6(Fe,Cu) were the initiation sites for pitting in alloys of Al-Cu.

Changbin Shen et al (2011) conducted experiments in AA 5083 and AA6082 aluminium alloys of FSW welds of the anti-corrosion properties. This result had been showed the property of the anti-corrosion of two dissimilar welds was more for the given parameters of the process.

M.Guerin et al (2015) conducted an experiment in susceptibility of Aluminium-Copper-Lithium alloy 2050 to deterioration in the solution of Chloride in T34 and T84 condition. They concluded that the life of the weakness of the T34 state was mostly affected by the fatigue-corrosion.

7. Analysis of Wear

Adel Mahmood Hassan et al (2012) experimentally studied, the wear characteristics in AMC (Aluminium Matrix Composites) had been strengthened by the particulates of the metal graphite and silicon carbide in FSW Techniques. The result showed that the resistance of the wear of the joints in FSW were affected by the parameters of the process.

LingyuGuo et.al (2015) Investigated that the lubrication consequence of annealed $Fe_{78}Si_9B_{13}$ glass particles in the FSW process of the metal AA6061. The resistance of the wear had been improved by using these particles.

Syed KhajaNaimuddin et al (2016) Conducted that the experimental study analysis of FSW in similar and dissimilar joints of welds in the materials of (AA6061-AA6061.0), (AA6082-AA6082.0) & (AA6061-AA6082.0) under the conditions of T6 to find the wear behaviours. They concluded low wear and high wear resistance in FSW welds.

Kumar.R. et al (2016) experimentally studied that the characteristics of the wear and the defects in the FSW process in AA6061-T6 alloy of Aluminium with the different rate of rotation of tool and the rate of welding. In that study, they concluded that comparing to the base material the wear resistance was increased in the FSW joints.

8. Fatigue Strength Analysis

S. Missori and A. Sili (2000) proposed the microstructure and the characteristics of mechanical properties of the joints. This was joined by using the metal arc gas of the procedure for welding.This was made of a 6082-T6 alloy of plates diameter of 10 mm thick. A fractography ,Vickers microhardness test, tension test, fatigue, bending test, **Charpy V**-notch **test** and SEM (Scanning electron microscopy) are included in this study.A **Charpy V**-notch **test** had been used to evaluate the toughness in fracture through an relation of empirical. In WM,the minimum value and the similar values in both HAZ and parent metal had been displayed through this technique.The toughness in fracture is in the term of KIC.

P.Cavaliere et al (2008) conducted a cyclic fatigue test in the direction of an axial with R=0.1, Where “R” is the Stress ratio (σ_{min} / σ_{max}). In the study of fatigue test research, the conclusion was the life of the weakness was increased in the high rotation regime through the joints in FSW of alloy 2024-T3 and a life of weakness through an alloy of 7075-T6 in FSW are also reduced.

Cavaliere et al (2008) proposed that an alloy of 2024 and 7075 aluminium behaviour of the fatigue in FSW and the tensile . The tension test failure had been detected over the side of 2024 (It contain lesser HV (solidity)) and the varying joint displays a decreasing life of the weakness through the joints of 7075 FSW.

L. Ceschini et al (2007)proposed that the consequence of the process of the FSW on the microstructure and subsequently, on the tensile and low-cycle behaviour of the fatigue of an aluminium matrix (AA7005) composite reinforced with 10 vol. % of Al_2O_3 particles (W7A10A). In their experimental study they concluded that an effect of the coarse of the pin on the ceramic reinforcement had been controlled by the reduction of the size of the particles, while no reduction in the particles of the shape-factor was observed.

G. Minak et al (2010) proposed that in the FSW of joints the resistance of the fatigue over the reinforcement of the cast particulate through the alloy of aluminium (AA6061/ 22 vol. % / Al_2O_3P). The process of the welding had been performed by using different parameters for the process, also examing their consequence on the microstructure of the joint. The comparison is made between the base material and the composite mechanical properties of the FSW. The results had been associated for the adjustments of the microstructure encouraged by the process of the FSW on the matrix of an alloy of aluminium and the reinforcements of the ceramic

Soran Hassanifardet al (2014) examined that the effect of an expansion of cold is based on the upgrading of weakness life of FSSW joints in AA 7075-T6 plates. The high cycle in all load ranges in the weakness life of joints in FSSW were regimes to improve the weakness of life up to 6 times. This was the conclusion of this study.

G. D’Urso et al (2014) proposed the weakness of the crash behavior of test of the growth. According to ASTM – E647 standard on the specimens of CT with respect to the dissemination at the center of the joint laterally the nugget of the weld ,this was performed. The parameters for the welding process welding were influenced by the property of mechanical and fatigue strength. This was proved in this result.

9.Summary

It is obvious that the FSW has more fabrication potential of like and unlike alloys of aluminium. Moreover, the following gaps had been identified in the FSW of two dissimilar alloys of aluminium of AA7075-T6.0 and A384.0-T6.0 processes from the previous published technical articles.

1. Most of the literature studies are limited to the FSW of the impact of process parameters on similar materials of AA 7075-T6 and A384.0-T6 mixtures. FSW of the dissimilar joint of AA7075-T6.0 and A384.0-T6.0 has not been analysed.
2. Numerous explorations had been employed by the researchers to examine the effect of one parameter at a time, but the interaction effect of the parameters of the process has not been extensively studied.
3. The microstructure analysis for the combination of AA7075-T6.0 and A384.0-T6.0 in

ISSN 2515-8260 Volume 07, Issue 09, 2020

the FSW weld has not been done. Very few literatures are available for the bending strength studies on dissimilar FSW joints. The FSW strength of the bending of AA7075-T6 and A384.0-T6 aluminium mixtures by varying parameters for the process were studied.

4. Very little literature is available for the corrosion studies of dissimilar FSW joints. The review of the literature constructed that scope for doing an investigation, on FSW characteristics of AA7075-T6 and A384.0-T6 aluminium alloys by varying process parameters have been evolved.
5. The literature reviews in the wear studies on dissimilar FSW joints are available is limited. From the basis of the literature survey this investigation is made to study the FSW wear characteristics of AA7075-T6 and A384.0-T6 aluminium mixtures by varying the process parameters.
6. Only very few literatures are available in the fatigue strength analysis of dissimilar FSW joints. On this basis, the existing examination is made an attempt to study the fatigue strength analysis in the FSW combinations of AA7075-T6 and A384.0-T6 mixtures of aluminium through varying parameters of the process.

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