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A Review on Friction Stir Welding for Aluminium Alloy Composite

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Abstract- **Friction stir welding is a relatively new solid state joining process which locale a major role in different industry including the aerospace ,automotive and manufacturing industry field to join aluminium alloy composite that are hard to weld by fusion welding process. Fusion welding of aluminium alloy composite is difficult due to the pernicious reaction between reinforcing the hard particle like carbide, oxide, nitride, boride and molten metal resulting in undesirable phase and these problem associated with this pernicious reaction are eliminated with the use of Friction stir welding. The purpose of the development of this technique was to reduced the common issues associated with other joining mechanism such as fusion welding, brazing and soldering etc. In Friction stir welding, the energy input and distortion are significantly lower than in fusion welding technique, thus improve the welding properties and the resulting joints offers less distortion, less residual stresses, fewer weld defects. This paper reviews the work done in the above mentioned area and concludes by suggesting further scope for research in Friction stir welding.**
Keywords- **Friction stir welding, Aluminium alloy composite, Tool Design, Microstructure and Mechanical properties**

I. INTRODUCTION

The need of joining dissimilar materials often arises in industrial application due to demand for reduced weight and improved performance from engineering structure. Friction stir welding has already been adopted extensively for joining dissimilar metal. Aluminium alloy and aluminium alloy composites in automotive, rail, aircraft, aerospace and shipbuilding industry. Friction stir welding can be performed on a variety of joint configuration including butt joint, lap joint and T joint (Mishra, R.S).

Friction stir welding is a solid-state joining process invented in 1991 at The Welding Institute, U K (Thomas et al.1995). Friction stir welding is an innovative low temperature welding process due to rotation and pressure of a tool, frictional heat is produced and the parts soften plastically in the area of the rotating tool without reaching the melting point thereby joining the parts. Friction stir welding has many advantages over the fusion welding technique because, process temperatures remains below the melting point of the weld material, there is no need for filler material. Friction stir welding is also an energy efficient process that produces no fumes, spatter and arc flash (Cook, G.E). Friction stir welding process includes three phenomena; heating, plastic deformation and forging (Longhurst, W.R). Friction stir welding can produce high quality welds in materials like aluminium, nickel, magnesium, titanium and steel. Friction stir welding is a promising candidate for joining particulate reinforced aluminium composites and a non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint (Fig. 1). The tool serves two primary functions.(a) heating the work-piece and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and the work-piece and plastic deformation of work-piece. The localized heating softens the material around the pin and combination of tool rotation and translation leads to movement of material from the front of the Pin to the back of the pin. As a result of

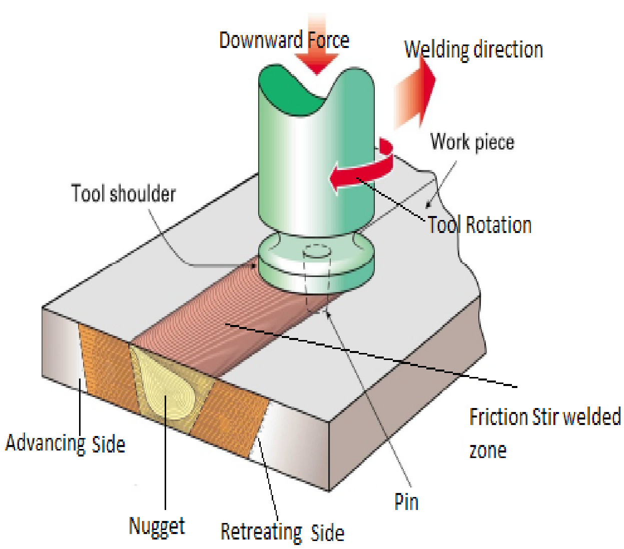

figure 1.schematic view of friction stir welding

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this process a joint is produced in solid state. During FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equiaxed recrystallized grains. The fine microstructure in friction stir welds produces good mechanical properties.

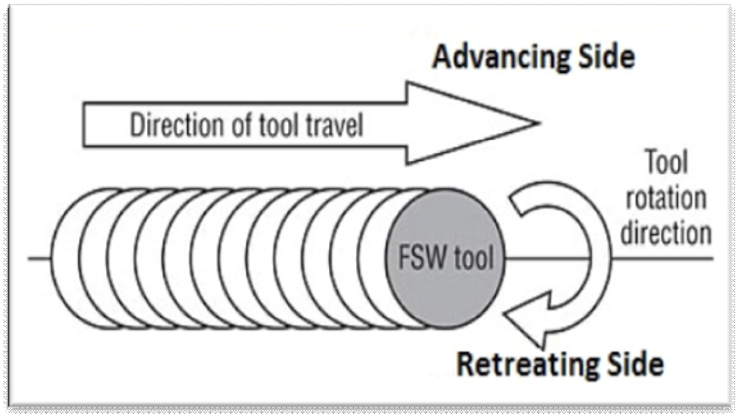

Figure 2. (Advancing and retreating side of FSW)

In Friction stir welding there are two sides one is advancing side and other is retreating side and figure (2) gives the idea of advancing side and retreating side in the transverse direction of welding. Material on advanced side mixed more vigorously than material on retreating side. The Retreating side is the side where the velocity vector of tool rotation and traverse direction are opposite and in the advancing side the velocity vector of tool rotation and traverse direction are similar. The multi-pass joint is formed of at least 2 FSW joints in parallel configuration. The first and second pass joints define transversely opposite advancing and retreating side. The second pass joint is disposed to at least partially overlap the retreating side of the first pass joint. Thus the material at the retreating side of the first pass joint that may be insufficiently mixed during formation of the first pass joint is remixed.
Friction stir weld in its cross-section consist of the three main zones and these three zones pose distinct mechanical properties.

Weld nugget, stir zone (Dynamically recrystallised zone) DXZ

Thermo-mechanically affected zone (TMAZ)

Heat affected zone (HAZ)

The weld nugget zone and TMAZ are the weakest part of the joint. Stir zone marks the area of greatest material deformation region and as such indicates the pin position through the weld process. This region is also representative of the area of greatest heat thus undergoes the highest degree of recrystallization and the structure of stir zone like a onion ring structure. TMAZ located immediately either side of the stir zone and the temperature in this region is lower and resulting in a lower degree of recrystallization. In HAZ a very little grain recovery occurs compared to the central region. The benefits over the fusion welding for HAZ are that since FSW is solid-state, cracking is neglected for these common reasons.

II. ALUMINIUM ALLOY COMPOSITE

Advanced materials like aluminium alloy composite are thus viewed as a new generation of light weight and high strength materials. Aluminium alloy reinforced with this particles such as carbide, oxide, boride, nitride in the form of in the form of particles, fibers and whiskers is known as the aluminium metal matrix composite. Due to the reinforcement of this hard particles resulting in enhanced wear resistance, strength to weight ratio, hardness, toughness etc than the conventional aluminum alloy. Aluminium alloy composite are fabricated by different methods such as stir casting, squeeze casting, liquid infiltration, spray deposition and powder metallurgy. In the recent years, the demand for the Al alloy composite is expected increase for the application of many industrial sectors. In 2001 NASA use composite aluminum AL-Li 2195 rather than AA2219 for the external fuel tank for space shuttles leading to the reduction of weight and this saving in weight increase to transports more than one component in a single flight. In

general welding of Al alloy composites needs more attentions and many of the problems occurs such as incomplete mixing between filler and base metals, reaction between the reinforcement metal in Al alloy and the large size of porosity in the fusion zone and these problems are eliminated with the use of Friction stir welding.
Aluminium matrix composite have been widely studied since the 1920s and are now used in electronic packaging, armors, sporting goods and automotive industry. They offer the large variety of mechanical properties depending on the chemical composition of the Al matrix. By the American Aluminum Association the aluminum matrix composite should be designed by their constituent: accepted designation of the matrix/abbreviation of the reinforcement's designation /arrangement and volume fraction in % with symbol of type of reinforcement. The Al alloy composite may offer specific advantages compared to Al alloy which is higher specific strength, higher specific stiffness and improve high temperature creep resistance, wear resistance but disadvantages of Al alloy composite over the Al alloy is lower toughness and lower ductility and more complicated and expensive production method.

III. TOOL DESIGN

In Friction stir welding a constantly rotated, non consumable welding tool consists of two features, a shoulder and a pin or probe. For a given joint design in FSW the weld quality, cost and tool wear are important consideration in the selection of the tool material and tool geometry. Tool design is the most powerful aspect of FSW process for development joint without any defects such as voids incomplete root penetration etc. In the welding tool, the tool shoulders are designed to produce heat through friction and material deformation to the surface of work-piece. The diameter of shoulders is generally depends on the pin size adopted. Generally the concave, convex scroll, flat shoulders should be used for joining for dissimilar materials. The designs of tool pin are much more complex compared to the shoulders. Tool pin is designed to disrupt the faying surface of the work-piece. Generally the threads, steps, flats pin have been widely used for control the material flow for better mechanical mixing. The welding tool has mainly 3 functions; heating the work-piece, movement of material to produce the joint and containment of the hot metal beneath the tool shoulders. Weld quality and tool wear are two important factors in the selection of tool material. Due to the severe heating of the tool during FSW significantly wear may result if the tool material has low yield strength at high temperature. Stresses experienced by the tool are dependent on the yield strength of the work-piece at high temperature. Temperature in the work-piece depends on the material properties of tool such as the thermal conductivity and co-efficient of thermal expansion which also effect the thermal stresses in the tool.
Tool steel is commonly used a tooling material for joining of the dissimilar materials in both lap and butt configuration. FSW is performed for joining of low temperature material such as dissimilar aluminium alloy or Al to Mg alloy, tool steel especially H13, a chromium-molybdenum hot worked air-hardening steel and high speed steel generally used as a tool materials. When welding is performed between low and high melting temperature materials such as Al or Mg alloy to steel and Al or Mg alloy to titanium alloy, tool steel and alloy steel have been used in both lap and butt joint configuration. In butt joint configuration, the higher melting temperature plate is often placed on the advancing side and lower one is on retreating side and welding tool is offset from the butt interface towards the lower melting temperature materials to prevent over heating of low melting temperature material and tool wear. Tungsten based tools such as tungsten carbide and tungsten rhenium are also used for joining low to high melting temperature of materials. In the lap configuration tool steel use as a tool materials and placing of softer plate on the top for joining the dissimilar materials for avoiding tool wear. When welding is performed for high melting temperature materials such as steel to steel and steel to nickel alloy, tungsten carbide cobalt or polycrystalline cubic boron nitride (PCBN) used as a tool materials.

IV. LITERATURE SURVEY

Researchers have begun to focus attention on Friction stir welding of aluminium alloy composite and this study can be concluded that there are so many parameters which affect the microstructure, mechanical properties of weld produced through friction stir welding. This literature review contains the effect tool parameters, work-piece parameters and welding parameters on weld characteristics.

A. Effect of FSW Parameters On Microstructure, Mechanical Property

I.-Dinaharan et al. [5] had studied the effect of FSW on microstructure, mechanical and wear property of AA6061/ZrB2 in situ cast composite. Three casting were prepared with 0, 5 and 10 wt % of ZrB2 reinforcement and plates of dimension 100×50×6 mm cube were drawn from each casting. A tool made of high carbon high chromium steel oil hardened to 62 HRC with square pin profile was

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used.

B. Effect on Microstructure

The microstructure of FSW AA6061/(0,5 and 10 wt.%) ZrB2 composite was divided into four zones; (i) parent composite, (ii) heat affected zone, (iii) thermomechanically affected zone, (iv) weld zone. Microstructure of as cast AA6061 had shown the typical dendrites structure. The grain size of HAZ did not show appreciable difference com-pared to that of parent composite. TMAZ exhibited parallel band like distribution of ZrB2 particle and rotated elongated grains. The weld zone displayed a homogeneous distribution of ZrB2 particle in the parent composite. The clusters present in the parent composite were fragmented by the stirring action of the tool. It had been noticed that nucleation sites in the weld zone had increased with increase the quantity of reinforcement. Due to increase nucleation sites in weld zone as compared to base material matrix grain size also reduced.

C. Effect on Mechanical And Wear Property (Microhardness And Tensile Strength)

The hardness of the weld zone was higher than that of the parent composite in all the joints. The hardness of TMAZ and HAZ varied between those of parent composite and weld zone. The maximum hardness recorded in the weld joints increased as weight percentage of ZrB2 particle was increased. The hardness variation from top to bottom of the joints was insignificant. The tensile strength of the welded joints was comparable to that of parent composites. Joint efficiency of 99%, 94% and 95% was realized in the welded joints having weight percentage of ZrB2 particle of 0%, 5% and 10% respectively. The strength of the welded joint improved as weight % of ZrB2 particles was increased. The elongation of the welded joints reduced compared to parent composites. The wear behavior of the welded joints was associated with hardening of weld zone. The factors contributed to hardening of weld zone lead to the reduction in wear rate of welded composites. The wear rate of welded composite decreased as weight percentage of ZrB2 particles was increased. The worn surface of welded joints showed resistance to plastic flow and broadening of wear tracks compared to that of parent composites.

X.-G. Chen et al. [6] had studied the microstructure and mechanical properties of Friction stir welded AA6063-B4C metal matrix composites. AA6063 reinforced with B4C particle (o, 6 and 10.5 vol. %) and the average B4C particle size was 17 μm and the extruded material was supplied in T5 temper condition. In order to minimize the FSW tool wear, a conical unthreaded tool made of AISI 4340 steel was used.

D. Effect on Microstructure

The B4C particle size and shape are not significantly altered by the FSW process and the particle distribution in the matrix is kept uniform in the weld zone. The FSW has a beneficial effect on the uniformity of particle distribution as the number and size of B4C particle clusters are reduced in the stirred zone. The grain size of aluminium matrix is considerably refined in the stir zone and there is a continuous evolution of aluminium grain structure from coarse grains of the base metal via sub-grain development occurring within coarse grain to the finally refined, equiaxed grains in the weld centre. An abnormal grain growth was observed in stirred zone after the T6 heat treatment for all specimens with or without reinforcement B4C particles which reduced mechanical properties of joints.

E. Effect on Mechanical Property (Microhardness And Strength)

The mean value of the mechanical properties obtained for the base material (BM), as-welded joint (AW), the artificially aged joint (AA) and the after T6 joint. Micro-hardness measurements performed on welded specimens of the AA6063 in the as welded condition, after ageing and after T6 heat treatment. The hardness of as welded specimen presents a lower hardness in stirred zone, after an artificial ageing for 5h at 185 c, the hardness in the nugget increase and reaches a value similar to that obtained in the base materials and after the T6 heat treatment, the hardness is homogenized along the whole weld profile. The micro-hardness profiles of samples reinforced with B4C do not significantly differ from those obtained for the standard AA6063 alloy both in the as weld condition and after post weld heat treatments. During the tensile test, two distinct failure locations were reported: in the stir zone (SZ) and in thermo-mechanically affected zone (TMAZ). When the fracture occurs in the TMAZ, it is always located on the advancing side of the weld. The efficiency of the as-welded joint is limited to around 60% and for the artificially aged specimens, a noticeable increase of the tensile property such as the ultimate tensile strength and yield strength. For these specimens, the joint efficiency is increased to over 80%. The T6 heat treatment after welding does not lead to an improvement of the mechanical property of the weld. An abnormal grain growth with a huge grain size in the stirred zone was observed after T6 and this leads to decrease the overall resistance of the welded assembly. In this case the T6 heat treatment is less effective than the artificial ageing.

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G. Minak et al. [7] had studied the fatigue properties of friction stir welded joints particulate reinforced aluminium matrix composite (AA6061/ 22 vol. % /Al2O3p). A highly wear resistant steel, heat treated to 64 HRC, was used for the tool. The welding process was performed using different process parameters, also investigating their effect on joint microstructure.

F. Effect on Microstructure and Mechanical Property

FSW led to substantially similar micro-structural modification, for all the welding parameters used. The weld zones appeared substantially defects free and the maximum effect in the particles area was observed in the lower zone of the FSW joint near the pin end, probably due to a stress gradient induced by the tool, where the particles area decreased a slight reduction of the particles aspect ratio in this zones was also observed. A negligible difference in the degree of clustering of the reinforcement particles between the base and welded zones. Different process parameters also had comparable effect on micro-hardness of the welded specimens. The hardness increased from 66 HV for the base material to an average value of 94 HV in the transitional zone and 100 HV in the stirred zones. The tensile tests showed that the FSW process always led to a joint efficiency, evaluated with respect to the ultimate tensile strength, higher than 90% for all the welding parameters used in this work.

G. Fatigue Test and Fracture Surfaces

The slight differences in the fatigue behavior of the FSW specimens belonging to different sets with respect to the base material was explained by the different microstructural homogeneity from the base to the FSW zones. All the different welded specimens sets seems to have a fatigue behavior apparently slightly worse than the base MMC, for the cycle number considered in this state (up to 10^7) and to evaluate the effect of welding parameters on the whole stress-life curve. Fatigue behavior is much more sensitive to microstructural homogeneity than tensile behavior and fatigue behavior can be obtained from an analysis of the fracture behavior. All the other FSW specimens showed a similar fatigue fracture behavior, comparable with that of the base composite materials, as can be seen from the SEM micrographs.

Byung-Wook AHN et al. [8] Microstructure and mechanical properties of SiCp/AA5083 composite fabricated by friction stir welding (FSW) were investigated. FSW tool was tilted by an angle 3º with respect to the normal axis and FSW was performed. A constant tool rotation speed of 1800 r/min and welding speed of 22 mm/min were used during FSW.

H. Effect on Microstructure and Microhardness

The microstructure in the joint was analyzed by optical microscope and scanning electron microscope. To observe the microstructures of the material, it was mechanically ground with abrasive paper, polished with 1 and .3 µm alumina powder. The distribution of SiC particles in the stir zone after 2 passes processing was more homogeneous than that in the stir zone after one passes processing due to the repeated stirring of the joint. The grain size of the stir zone with SiC particles was smaller than that of the stir zone without SiC particles due to the pinning effect by the SiC particles. The FSW with the SiC particles is considered to make fine grains more effectively due to the pinning effect of the SiC particles. As a result, due to their presence, there is a big gap between the stir zone with SiC particles and the stir zone without SiC particles. Grain refinement affects the hardness, but also because the extremely high strength of the SiC particles dramatically increases the hardness in the stir zones. The micro-hardness of the stir zone with SiC particles was higher than that of the stir zone without SiC particles due to the reduction of the grain size and the presence of the reinforcing SiC particles in the aluminium matrix. The hardness distribution of the joint after two passes processing is smoother than that of the stir zone after one pass processing.

L.CESCHINI et al. [9] had studied the effect of friction stir welding on microstructure, tensile and fatigue properties of the AA7005 composite reinforced with 10 vol. % of Al2O3 particles. The as-cast composite was extruded up to a rectangular plate (cross-section of 100×7 mm^2), then was heat treated at the T6 condition. The FSW tool was made of Ferro-Titanic, a high wear resistant material, with a hardness of 63 HRC.

I. Effect on Microstructure and Microhardness

Optical microscopy, scanning electron microscopy with energy dispersive spectroscopy was used for the micro-structural characterization. During the micro-structure analysis, it was noticed that matrix grain size had been reduced from base material to nugget zone after FSW. No micro-structural differences were appreciated between the advancing and retreating side of the weld. Dynamic re-crystallization took place during FSW which had increase the nucleation sites and so responsible for reduced grain size of matrix. The matrix interparticles hardness in the nugget was comparable with that of the base materials, while hardness slightly increases in the TMAZ. The micro-hardness profiles showed a minimum 77 HV at middle line of FSW zone, a maximum of about

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100 HV in the TMAZ, a value of 75 HV in HAZ and then hardness increase up to 84 HV in the base materials.

J. Tensile and Fatigue Test

It can be seen that the FSW process led to a 20% decrease of the proof and tensile strength and also a reduction of the elongation to failure as respects to base materials after FSW. The tensile test showed a joint efficiency of about 80% respect to the UTS. The tensile fracture surfaces showed that failures always occurred at the centre of the weld, along the joint line between the two plates. The low cycle fatigue test carried out on the base and FSW composites. Low cycle fatigue life of the FSW composite was always lower than that of the base materials. The cyclic stress response curves of the FSW composite showed evidence of progressive hardening to failure for high cyclic strain amplitude, while for smaller amplitude, the FSW composite showed neither hardening nor softening. The lower fatigue life of the FSW material could be also related to the microstructural and surface modification induced by the process, which consequently led to a reduction in hardness and tensile strength. In the case of FSW MMCs, the role of surface roughness is still to be investigated, especially in the low cycle fatigue range.

Huseyin Uzun et al. [10] Friction stir welding of SiC particulate reinforced AA2124 aluminium alloy matrix composite. Microstructure, micro-hardness, EDX analysis and electrical conductivity measurements have been performed to evaluate the weld zone characteristics of FSW AA2124/SiC/25p composites. A TiAlN-coated HSS-tool used in FSW and tool rotational and travel speed were 800 rpm and 120 mm/min, respectively.

K. Effect on Microstructure

The microstructure of the welding zone in the FSW AA2124/SiC/25p composite was divided into four zones: (i) parent material, (ii) HAZ, (iii) TMAZ and (iv) weld nugget. EDX measurements clearly show that the parent material and the weld region consist of relatively homogeneous distribution of the fine and coarse SiC particles. FSW can create high fine SiC particle density region in the weld nugget. The weld nugget also exhibits some of coarse SiC particle cracking. The HAZ exhibit a similar microstructure both at the advancing and retreating sides.

L. Microhardness and Electrical Conductivity

The average hardness values reach a minimum in the HAZ (215 HV) at both the advancing and retreating side, the hardness value slightly increases in the TMAZ at advancing and retreating side. The increase in hardness in this zone is attributed to the second phase particle dissolution and coarsening. Weld nugget show higher hardness than TMAZ but lower than base material due to re-precipitation and growth. The electrical conductivity measurements provide a good indication of the presence FSW seam of the AA2124/SiC/25p composite. The electrical conductivity values on the non-welded plate regions follow a linear line, the values increase on the FSW beam region.

D. Wang et al. [11] Friction stir welding of SiCp/2009 Al composite plates. Six millimeter thick hot-rolled SiCp/2009 Al composites plates were successfully joined by friction stir welding using an ultra hard material tool. Six millimeter thick composite plates produced by powder metallurgy and subsequent hot rolling, were cut into 6×75×300 mm along the rolling direction. To study the effect of post-weld heat treatment, some of the FSW samples were T4 treated. The as-FSW joint and T4 treated joint were named as-FSW and FSW-T4, respectively.

M. Effect on Microstructure

After FSW, the distribution of the SiC particles in the nugget zone was more homogeneous than that in the base materials. Most Al2cu particles were dissolved and the remaining Al2cu particles become coarse in the nugget zone. Al2cu was dissolved into the aluminium matrix in the nugget zone due to intense plastic deformation and high temperature during FSW. For the FSW-T4 samples, the distribution of SiC particles in the nugget zone is similar to that of the as-FSW. So there was no extra effect on microstructure were obtained after T4 treatment. Fine and coarse both particles got reduce in quantity after T4 treatment.

N. Effect on Mechanical Property

The ultimate tensile strength (UTS) of the as-FSW sample was 321 Mpa, with the joint failing in the base metal zone (BM) for away from the nugget zone (NZ). The BM plate before welding was of hot rolled temper and had a low strength due to the coarse Al2cu phase. After T4 treatment, the strength of the joint increase up to 521 Mpa close to that of BM with T4 temper. The sample failed in the NZ. For the as-FSW sample, the nugget zone exhibited hardness value of 150 HV. Furthermore, the advancing side of NZ had a

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higher hardness value than the retreating side. Beyond the NZ, the hardness value decrease and the various regions the joint exhibited a similar hardness value of 170 HV. After T4 treatment, the hardness value increase and close to that of BM with temper.
K. Kalaiselvan [12] studied the role of friction stir welding parameters on tensile strength of AA6061-B4C composites joints. The B4C reinforced aluminium matrix composites were fabricated by modified stir casting route. A high carbon high chromium (HCHCr) steel tool oil hardened to HRC 62 having square pin profile were used as FSW tool. The process parameters such as rotational speed (N), welding speed (S), axial load (F) and reinforcement (R) were considered. The process parameters were optimized using generalized reduced gradient method (GRG) method.

O. Microstructure Analysis

The microstructural behavior of FSW AA6061-B4C composite joint was studied and micrographs shown correspond to BM, TMAZ, HAZ and weld nugget (WN) respectively. Microstructure of welded AA6061-B4C composites exhibits fine and recrystallized grains of Al matrix with uniform distribution of B4C particles in the nugget zone. After FSW, the substantial grain refinement of matrix and reduction in B4C particle size were observed in the stir zone. Elongated grains were observed in the TMAZ and no significant change in microstructure was obtained in the HAZ compared to BM. The frictional heat generated during the process is responsible for grain refinement.

P. Effect Of Process Parameters On Uts

The maximum tensile strength was obtained at the rotational speed of 1000 r/min. When the rotational speed was increased from 800 r/min correspondingly the UTS increased and reached a maximum value at 1000 r/min and if the rotational speed increase above the 1000 r/min, the UTS of the joint was decreased. The UTS of FSW joint was increase as the welding speed increase up to 1.3 mm/min and if the speed increase above the 1.3 mm/min the UTS was decreased. The maximum UTS were obtained at the welding speed of 1.3 mm/min. The UTS of composite joint was increased with increase in axial load up to a maximum load of 10 KN. Further increase an axial load decrease in UTS. The maximum UTS were obtained at 10 KN axial load. The increase in the amount of reinforcement of B4C particles in the composite increase the tensile strength and reduce the ductility of composites.
H.J. Liu et al. [13] Wear characteristics of a WC-Co tool in friction stir welding of AC4A (Al-Si alloy matrix) reinforced with 30 vol. % of SiC particles. The FSW tool was made of a WC-Co hard alloy and the tool pin possessed right handed threads. A series of tool photographs was obtained and the variations in tool geometry were accurately calculated in a computer system.

Q. Wear Characteristics

The shoulder size and pin length are changed slightly and the radial wear of the pin is most severe for the whole tool. The radial wear of tool is different at different locations of the tool and maximum wear is produced at a location of about one-third pin length from the pin root. The welding speed also affect on radial wear rate of the pin that is lower the welding speed, higher the wear rate and the maximum wear rate is produced in the initial welding.
Belete Sirahbizu Yigezu et al. [14] on friction stir butt welding of Al + 12Si/10 wt% TiC in situ composites and discusses the effect of varying process parameters. The tool shoulder dimensions, welding speed and tool rotational speed were varied during welding to study their effect on the ultimate tensile strength, percentage elongation and micro-hardness of the butt joints.

R. Effect of FSW Process Parameters

The tool type (1,2,3) represent 18mm, 20mm and 22mm flat tool shoulder diameters with threaded probe. It has been observed the 20mm tool shoulder exhibits a better weld strength while combined with both tool rotational speeds (710-1000 rpm) and welding speeds (20-40 mm/min). It has been realized that 710 rpm and 20 mm/min are the suitable tool rotational and welding speed for better UTS of the weld joint. Similarly the tools of 20 mm shoulder produce maximum percentage elongation (Ductility). At 710 rpm and 20 mm/min tool rotational and welding speed are the preferable FSW process parameters for superior ductility of the composite weld joint.

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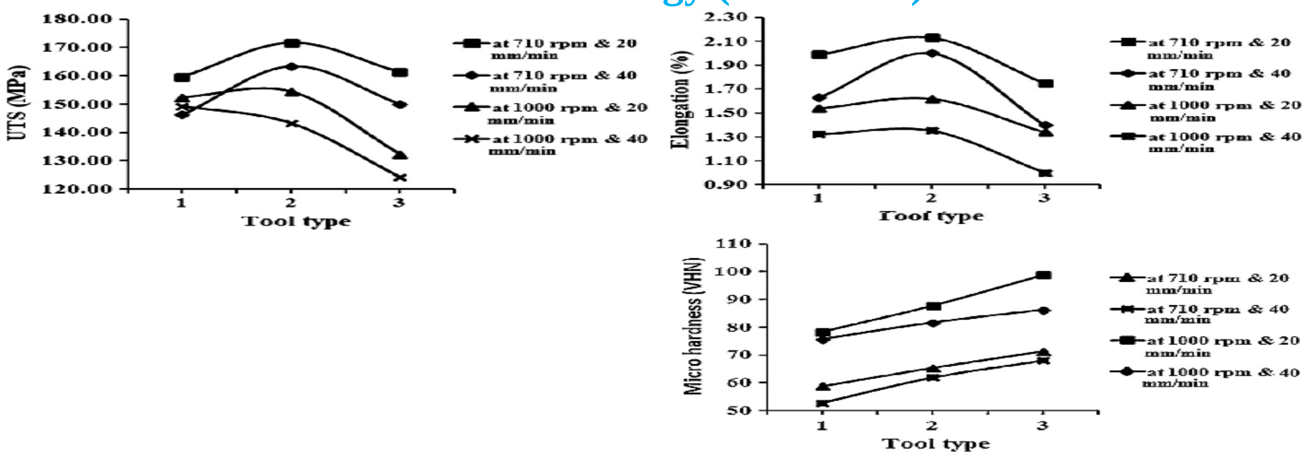

Figure 3. Effect of FSW parameters

Friction stir welds normally consists of 3 different zones, weld nugget zone, TMAZ and HAZ. The grain structure in the weld nugget is very fine and equiaxed and results in better mechanical property. At 710 rpm and 20 mm/min tool rotational and welding speed at 20 mm shoulder exhibited a higher micro-hardness as compared to other parameters. Figure shows these effects of FSW process parameters.

V. CONCLUSIONS AND FUTURE OUTLOOK

The present review has been undertaken, with an objective of FSW of Al alloy composite and to study and effect of the mechanical properties, microstructure and FSW parameters. Compared to the conventional fusion welding process, FSW is found to be a very useful and economical technique for joining Al alloy composites because of the considerable improvement in ductility, strength, micro-hardness, fatigue and fracture toughness and also 80 to 85 % of yield stress of the base material has been achieved. FSW exhibits a higher fatigue life as compare to laser welding and MIG welding but lower than that of the base materials. Tool designs is very important factors for producing the sound and defect free weld and mostly cylindrical threaded pin and concave shoulder are widely used welding tool features. In the present review FSW process parameters such as tool rotational speed, welding speed, spindle tilt angle and tool type should be conduct for improving the ultimate tensile strength, micro-hardness and percentage elongation of FSW joint by choosing optimum weld parameters. In future friction stir welding windows are to be developed to fabricate defects free welds. FSW also useful for joining dissimilar material for the dissimilar base metal and dissimilar melting point temperature. Heat and material floe during FSW are important issues of concern so a wide research should be conducted on these two phenomena.

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