Fabrication and characterization of metal matrix composite by Friction Stir Additive Manufacturing (FSAM): A Review

Ratnesh Verma[1, a)], Abdhesh Jha[2, b)] and Pulkit Shrivastava[3, c)]

Department of Mechanical Engineering Noida Institute of Engineering and Technology, Greater Noida, Uttar Pradesh, Pin-201306

[1]Department of Mechanical Engineering, Noida Institute of Engineering and Technology, Greater Noida, India;

[2]Assistent Professor, Department of Mechanical Engineering, Noida Institute of Engineering and Technology, Greater Noida, India;

[3]Assistent professor, Department of Mechanical Engineering, Noida Institute of Engineering and Technology, Greater Noida, India;

[a)] *ratneshverma006@gmail.com*

[b)] *akjhak83@gmail.com*

[c)] *p.shrivastava@niet.co.in*

Abstract: Lightweight structures have evolved into the material joining technique known similar to friction stir welding (FSW). A novel method of joining metals that are impossible or challenging to fuse using conventional techniques is friction stir welding (FSW). This process will have always environmentally friendly, that have different technology for manufacturing with high efficiency of energy. In this manufacturing process approach tool shoulder with rotating tools applied. The tool shoulder will be applied to workpiece with a required pressure, that's generates heat around the tool probe, and plastic deformation found that place. The spinning tool firstly pushes in lateral direction, plasticizes, and after cooled it will be mixed in stir zone, and finally got a non- fusion junction.

Friction stir processing (FSP) is a novel method of dealing with metal that may enable regionalized microstructure manipulation and control in near-surface layers of treated metallic components. That is founded on the fundamentals of friction stir welding (FSW), a solid-state joining method developed originally for metal alloys. The FSP results in considerable microstructural improvement, residential development, and homogeneity of the treated area as a result of significant material mixing, heat exposure, and plastic deformation.

Friction stir additive manufacturing (FSAM) is a method of solid-state joining. This method takes innovation approach to multiple plates additive manufacturing. Few of these technologies are highly established, while others are in the process of emerging. And the FSAM has Several types of metal plate and several forms of reinforcement using metal plate and reinforcement particles are used in this technique. The reinforcement particles are nanometres in size and are employed with metal in the form of melting and other physical and chemical combinations of the tool material, as well as the influence to parameters use as tool profile angle, rotational speed and traverse speed of tools.

We explored friction stir processing (FSP), friction stir welding (FSW), and friction stir additive manufacturing in the preceding abstract (FSAM).

Keywords: Friction stir additive manufacturing, Reinforcement, metal matrix, structural performance, process, parameter nanoparticles, deformation, microstructure etc.

INTRODUCTION

Friction stir welding by utilising a revolving, non-consumable welding equipment to locally soften a workpiece by friction and plastic works. As a result, the tool can vibrate the joint surface. Because the heat source is based on friction and plastic works, considerable melting in the workpiece is minimized, as are many of the problems associated with a change in condition that commonly affects fusion welding techniques, which including variations in gases solubility and dimensional change. [1]. The tool is often composed of a material that has adequate strength at the FSW temperature while not chemically reacting with the work components. Finally, the tool dimensions are engineered to withstand breaking during the FSW process. Specific design characteristics of the FSW tool are frequently based on basic assumptions, the details of which are frequently concealed [2].

Friction stir processing (FSP), microstructural modification based on the fundamental ideas of FSW, was recently introduced. In this scenario, the parameter of tool, A single piece of material is put on a rotating tool with a pin and shoulder for focused microstructural modification to enhance certain qualities.[3]. FSP, for example, that has been employed to produce a perfectly alright substructure that enabled the high-strain-rate method frequently used in the commercial 7075Al alloy.

The FSP approach is developing as a very successful solid-state processing technology capable of providing targeted microstructure alteration and control in the near surface layers of treated metallic components.[4] Friction additive manufacturing technologies have been covering the most regions alloy metal additive that are accessible technology will be fusion based [5]. These techniques have been used to weld alloys that are similar and different alloys. This technology may be used to construct structures made of pure metals, non-ferrous and ferrous alloys, composite materials, and metals [6]. Due to fusion-based limitations, these techniques can be employed to tackle additive manufacturing applications that are difficult to reach [7]. Increasing low weight requirements, particularly in industries such as aeroplanes, automobiles, and marine [8]. Friction Stir Additive Manufacturing (FSAM) used as a customised way of friction stir manufacturing in which many layers are added repeatedly to obtain the required thickness. [9]. Friction stir is a method that plastic deformation or dismembers a material by producing heat to its melting temperature [10]. Where the rotating tool with the required dimension shoulder and pin traversed the desired path on the composite surface [11]. The tool pin is put into the metal composite and provides the tool with both rotational speed and traversal speed. Heat is produced by the tool, and plastic deformation is observed [12-13]. By drilling desired holes and creating holes, reinforcement particles were cemented in the matrix surface. Due to the considerable reinforcing particle waste caused by the use of shoulder and pin type tools during friction stir additive manufacturing [14]. FSAM are characterized by shearing and compression with deformation state, this effectively lowers the possibility of internal flaws during deposition [15In comparison to others AM process, it lessens re-solidification and any other melting defects including porosity, shrinkage, and micro voids caused by microstructure [16]. For effective joining, the depth of the pin is typically designed to enter 25–30% of the bottom plate; other parameters are modified as necessary. [17]. In fig.2 Because of the complexities involved with heat exposure deformation, and material movement from the deepest layer to the highest layer, microstructural characterisation is of particular relevance for FSAM. The material is strongly mixed, plastically deformation, and then dynamically recrystallized (DRX) during FSAM. Welding four plates in a lap arrangement to construct a structure, the various stirring zones, formed in different stir zone 1, 2 and 3rd have distinct microstructures [18-21].

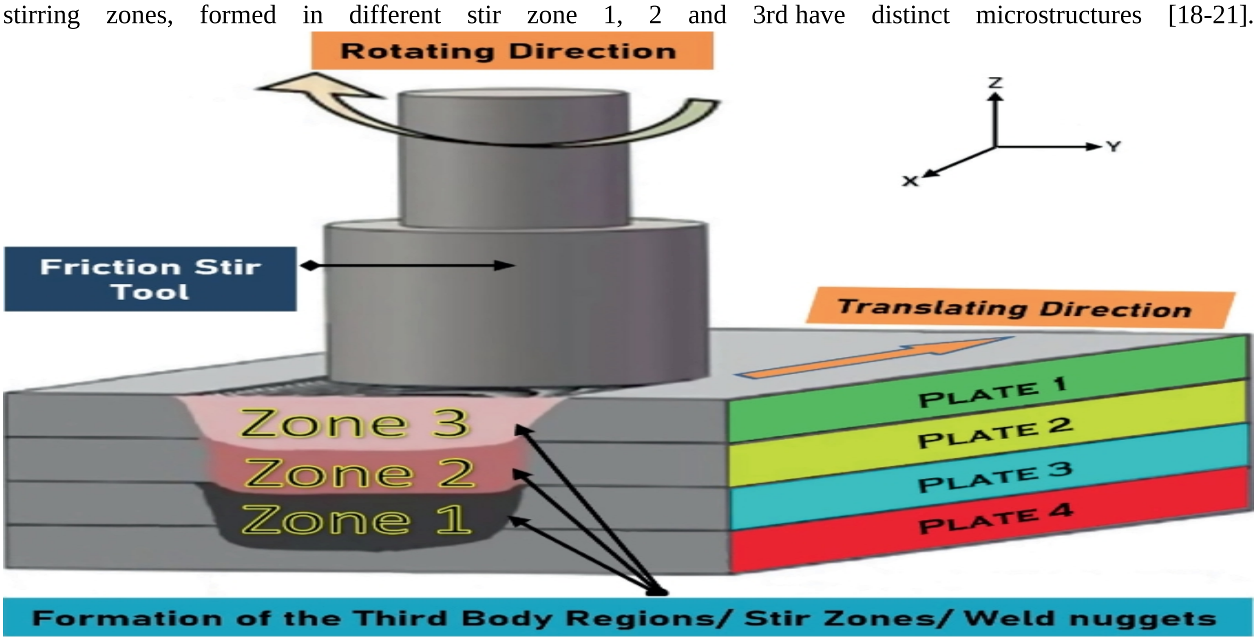

Figure.1. Schematic process for multiple plate additive manufacturing, with different stir zone [17-19].

INNOVATION

The rapid industrial revolution a rise in the need for a new class of specially engineered materials with certain properties. This manufacturing approach seemed quicker and more effective than the earlier one procedure employed throughout both the first and second industrial revolutions. The first industrial revolution occurred in the 18th century, from 1760 and 1840 [20]. The initial or first industrial revolution will be known as Industry 1.0. It was defined by profound developments that disrupted several continents' current economies. However, as the revolution increased rapidly, industries began to change toward new production techniques, corporations, and automated production. Additionally, new industries emerged that utilised modern systems, cutting-edge power sources, and even novel organisational structures for different corporate divisions. [21]. The 1870s had seen start of the second industrial revolution, known as Industry 2.0. Additionally, Industry 2.0 uses a more effective technique for mass production. This happened when the first production line was created, which made it simpler to make items in bigger quantities and with higher quality. Mass manufacture of items was then seen as normal procedure [22]. The "Digital Revolution" or "First Computer Era" are other names for the Third Industrial Revolution. It began in the 1970s of the 20th centuries. Industry 3.0 began with partial automation, a technological procedure carried out using simple computers and Control System Processors (or memory-programmable controls) [23]. Earlier in the revolution, some minor automated systems had been built. Industry 4.0 refers to the current industrial development in our modern world. The current age of change has dramatically impacted how people work. It facilitates more productive work by connecting individuals in smarter networks. The manufacturing industry is practically completely digitalized, making it easier to provide information to the right people at the right time. Additive manufacturing (AM) would be a fast-expanding manufacturing technique that is one of the primary resources offered by Industry 4.0. In vital technology areas such as medical, construction, aircraft, and automotive, additive manufacturing is exploding [24]. Following extensive development and research in the fields of substances, mechanisms, applications, machinery, and incorporation, additive manufacturing is used in a variety of ways to produce prototype components with adequate material properties for testing and evaluation, as well as tooling, dies, and moulds. In AM technology, direct manufacture of functional endues objects is becoming the dominating trend. particularly for polymeric and metallic materials, and it is rapidly being used to make parts in small or medium numbers [25].

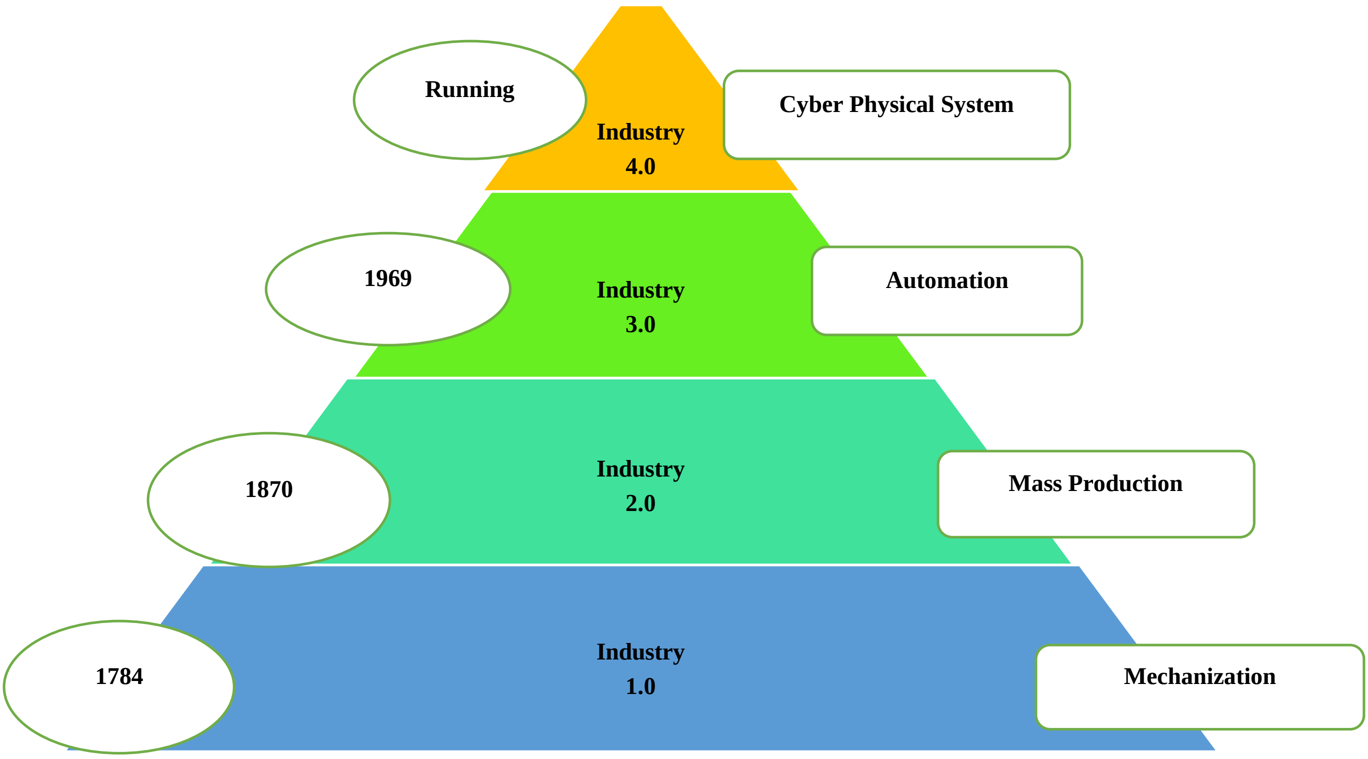

Fig.2. Industrial revolution in manufacturing sector.

LITERATURE SURVEY ON FRICTION STIR WELDING (FSW)

J. Sai Sashank et.al studied the effect of friction stir welding on the structural, mechanical, and physical characteristics of an aluminium alloy 6063 is primarily studied. They used to foundation material was 300mm*80mm*3mm with square edges. The welding was done at the parameter of rotational speeds 700, 1000,1500 rpm, as well as traverse rates of 60,100 mm/min with a tool shoulder diameter of 15 mm. For AA 6063, the best friction stir welding conditions were determined. When the weld was conducted at a traverse speed and rotational speed 60 mm/min,700 rpm respectively, the specimen's tensile strength increased. According to this rate of stirring action and higher heat input, tensile strength was observed to be decreased at 1500 rpm [26].

Sunil Sinhmar et.al Explored the effect of the weld heat cycle on the mechanical and corrosive characteristics of a friction stirred weld joint constructed of AA2014 aluminium, For the FSW, plates of AA2014 aluminium with dimensions of 70mm length, 27.5mm width, and 6mm thickness were utilised. Four distinct rotational rates with constant traverse speeds of 41 mm/min, as well as four distinct traverse speeds with a continuous rotating speed of 931 rpm. Increased rotation speed (508 rpm - 1216 rpm) and decreased traverse speed (90 mm/min - 13 mm/min) created considerable -Al matrix grain and coarse precipitates in the nugget zone and heat impacted zone. [27]

Matthieu B. Lezaack et.al In their research Kept aberrant grain formation using aluminium alloy T6 past-heat treatment by thick aluminium alloy using friction stir welding. This investigation used the 7475-aluminum alloy in the T7351 condition. The material received would be a rolled plate with a thickness of 12 mm. The composition of the alloy is determined using the remote sensing applications coupled radiofrequency optical emission spectroscopic (ICP). Make usage of a separate FSW machine. For FSW, the machined conical pin tool is manufactured of H13 tool steel. The pin is 10 millimetres long, 6 mm in breadth, and has a root diameter of 10 mm. Previously, the tool shoulder was 22 mm in diameter. The resultant morphology becomes substantially more uniform throughout the weld nugget. The initial structure is the most crucial. If the starting grains be smaller than a 2.5m threshold, none of the SHT criteria can prevent coarsening or AGG. [28].

Arameh Eyvazian et.al Experimented the rectangular 200*150*5mm^3 plates were AA5182 aluminium and metal sheets were cross-sectioned using a universal sawing machine, tool shoulder 20mm, conical bore range 10to 6mm, and a length of 7.6mm tool tilt angle 20, plunge depth 0.4mm. The tool rotates at 950,1300,1650,2000rpm, and the tool traverses at 40,70,100 mm/min. A model used for this process known as 3D volume of fluid. Experiments were also carried out to ascertain the impact the influence of UFSW processing factors on the microstructure and mechanical characteristics of various weldments. These essential processing parameters of tool rotation traverse velocity (40,100 mm/min) and speed (950,2000 rpm) have a substantial influence on According to the simulation results, thermal history, material movement, and intermixing [29].

Gurmeet Singh et.al Evaluated the weld connections with identical dimensions, a comparison of the friction stir welding technique and the TIG welding process for the aluminium alloy 6082-T6 AA-6082-Ts651 Al alloy plate 300mm*75mm*6mm was performed. There are numerous parameter combinations available, including tool rotation speeds of 300,700,500rpm and welding speeds of 25,15,35mm/min, with an axial tension of 6KN constant throughout the operation. Following sample preparation, the sample was cut into precise structure for microstructure study. The joint strength of FS welds was equal to the underlying material's strength. An FSW weld with a joint efficiency of 85% was created in this study. In comparison, TIG welds have a combined efficiency of 65%. The impact strength of FSW joints was about double that of the base metal, but TIG weld joints were roughly half the impact strength of the base metal [30].

Jianing Li et.al Observed the Mechanical attributes and characterisation of friction stir-welded 7A04-T6 aluminium alloys Process specifications for 7A04-T6 aluminium alloy plate 160*75*3mm3 shaft shoulder press 1.5-2.5kN, rotational speed 600-1200rpm, and traverse speed 40-200mm/min. Mechanical attributes and characterisation of friction stir-welded 7A04-T6 aluminium alloys Process specifications for 7A04-T6 aluminium alloy plate 160*75*3mm3 shaft shoulder press 1.5-2.5kN, rotational speed 600-1200rpm, and traverse speed 40-200mm/min. The 7A04-T6 Al alloys may be restricted using the FSW technique at a rotating speed of 1000rpm and a travel speed of 120mm/min, resulting in a tensile strength of 77.93% of the base metal and an elongation of 4.24 percent, exhibiting great dependability. NZ fine grain is the consequence of dynamic recrystallization [31].

Mahmoud Abbasi et.al Explored the effect of the fabrication environment on the flexible re - crystallization concept Superior fatigue resistance when an aluminium alloy is being friction stir welded AA-6061-T6 alloy plate cut in 200*100*3mm3 with parameters speed of rotation 1200rpm, traverse speed 95mm/min, tool tilt angle 20 and axial load 3.9kN was investigated. The grain size drops from roughly 57m in the FSW to 34m in the SZ. While conducting FSW underwater, workpiece vibration produces material deformation in the SZ and promotes dynamic recrystallization [32].

Kethavath kranthi kumar et.al studied the effect of the friction stir additive parameter on the material flow, mechanical characteristics, and rust behaviours of a heterogeneous AA-5083 and AA-6061 junction, dimensions 300*70*6mm3, H13 tool shoulder diameter of 18mm, pin tip 4mm, pin length 5.5mm, tilt angle 1degree , This traverse speed has values of 40,60, and 80mm/min while keeping the rotational speed constant at 800rpm, and the other has parameters of 1100,1400, and 1700rpm while maintaining the traverse speed constant at 60mm/min. The ultimate tensile strength (UTS) is about 197Mpa with a 67 percent efficiency during the tensile test when the rotation speed is 1000rpm and the traverse speed is 60mm/min. The notch tensile strength is active and offers stronger mechanical resistance when the rotation speed is 1400rpm and the traverse speed is 60mm/min. The corrosion resistance of weld joints decreases as traverse speed increases; however, at 1400rpm, there is greater corrosion resistance owing to fragmentation and dispersion of intermetallic phase [33].

M. Ilangovan et.al Evaluated the Stir-welded connections between dissimilar aluminium alloys AA-6061 and AA-5086: microstructure and tensile properties There are numerous combinations for the first one in this method, including AA-6061 with AA-6061, AA-5086 with AA-5086, and AA-6061 with AA-5068 alloy characteristics. rotating speed 1300rpm, 500rpm, and 500rpm, correspondingly, traversal speed 35mm/min, 5mm/min, and 10mm/min, Under the microscope, black spots form in each pit after combining two comparable alloys AA-6061 with AA-6061 and AA-5086, and the shoulder- and pin-influenced parts of the two dissimilar alloys AA-6061 and AA-5086 have bigger grain sizes than the unaffected portions [34].

R. Pandiyarajan et.al Experimented reinforcement was % ZrO2 and% C, the rotation speed was 800rpm, the transverse speed was 50mm/min, the axial force was 5KN, and the weld nugget hardness was discovered during the characterization of AA6061-ZrO2-C in FSW composite joins. At 800rpm, 4mm/min, and an axial force of 6KN, the maximum microhardness of 62.3HBR was observed [35].

D. A. Dragatogiannis et.al Observed with Different Friction Stir Welding Using Tic Nanoparticle Reinforcement Between the Alloys Al-5083 and Al-6082, The best parameters were obtained by altering the tool tilt angle (2°), rotational speed (1150 rpm), and traverse speed (85 mm/min). This specimen was also used as a control to see how nanoparticle dispersion affects mechanical behaviour. The goal of this study was to assess the strengthening of friction stir welds produced of various alloys. The use of nanoparticles increased the percentage of elongation, Young's modulus, yield stress, ultimate tensile strength (UTS) [36].

P.N. Korkes et.al Studied the influence of Sic and Tic nanoparticles mostly microstructure, microhardness, and tensile behavior of a friction stir weld made of Al-6082-T6, using AA-6082-T6 alloy to join the two specimens with Sic and Tic nanoparticle reinforcement between them; Sic has higher elongation while Tic has higher microhardness. The process settings are 750 rpm and 75 mm/min. The tool has a 3° tilt angle and dimensions of 200*100*3mm3. The Sic reinforcement specimen has a higher elongation, making it ideal for applications requiring a more ductile material, whereas Tic specimen has a greater microhardness value, making it suitable for applications requiring a server surface. During FSW, the dynamic recrystallization phenomenon results in significantly smaller grain sizes [37].

PROCESS PARAMETER

S.N.	Rotational speed (rpm)	Traverse speed (mm/min)	Tilt angle (degree)	References
1.	700,1000,1500	60,100	0	[26]
2.	508,1216	90,13	0	[27]
3.	300	100	0	[28]
4	950,1300,1650,2000	40,70,100	0	[29]
5.	300,700,500	25,15,35	0	[30]
6.	600,1200	40,20	0	[31]
7.	1200	95	0	[32]
8	1100,1400, 1700	40,60.80	1	[33]
9	1300,500 500	35,10,5	0	[34]
10	1150	85	2	[36]
11	750	75	3	[37]
12	1000	300	0	[38]

Table.1. process parameter of FSW

Shengke. Zou et.al Observed parameters for microstructural and mechanical processing of 2024-Aluminum alloy multi-track friction stir lap welding are 1000 rpm and 300 mm/min, with a depth of 0.2 mm. The best result was obtained after one pass at 300 mm/min rotation, and the hole flaws were eliminated after two passes. This repeated pass achieved a high ductility of elongation of around 35.05%. [38].

Literature survey on Friction stir processing (FSP)

Akbar hadarzadeh et.al studied in-situ Friction stir processing produces Zn ionic compounds in the Cu-Zn matrix, the Cu-30Zn plate has a dimension of 100*100*2mm3. For the H13 tool, maintain a rotation speed of 1120rpm, a traversal speed of 50mm/min, a tool shoulder diameter of 12mm, a tool pin diameter of 3mm, and a length of 1.75mm. The FPS is divided into two main stages. After closing the surface of the groove with the rotating pin less, The material and manufacturing line both received the pin and the shoulder. The microstructure zone of the sample exhibited a larger average grain size. Because of the action of Al_2O_3, the stir zones differed greatly, with the SZ having the maximum strain and temperature [39].

Li Zhoo et.al. Observed stir methods for friction's mechanical characteristics TA5 alloy and their microstructure, TA5 plate (Titanium alloy) with dimensions of 250*150*5mm 3 rotating speed 150mm-300rpm and tool shoulder 12mm, plunge depth.02mm, root diameter 4.5mm 75mm/min, tilt angle 3 The microstructure looks inhomogeneous when the rate of rotation is 150rpm; when the rotational speed is 200rpm, the FSP creates a high strain rate and a homogeneous surface; and when the rotational speed is 250rpm, it forms a tiny overlap retreating side[40].

W. Cheng et.al Evaluated the Al-Si alloys' mechanical properties can be improved via rolling and the friction stir process, Al-7Si and Al-12Si pure alloys at tool rotation 800rpm, traverse speed 100mm/min, at this alloy the evenly distributed in metal matrix after FSP The structure of FSP samples arises the unpolished grain and low density of dislocation during deformation due to their optimised crack and high work hardening rate [41].

Lakshay Tyagi et Experimented AA-7075 alloy additional reinforcement Alovera AA-7075-T6 metal matrix composite reinforcement was created via friction stir processing and is a naturally occurring medicinal plant with ceramic particles and Alovera ash. The H13 tool shape is square and flat, with rotating speed of 600,900 rpm, groove length 160mm, width 2mm, depth 3.5mm, and tilt angle 2. When a 20N load was applied to the Al+Si at 600rpm, the Alovera ash composite was found to have the superior wear resistance at higher tool rpms. Microhardness improves with reinforcement as tool rpm increases due to finer grain [42].

S. Arokiasamy et.al Observed mechanical characteristics of a magnesium-based hybrid metal matrix composite were explored experimentally using Mg-alloy and Sic/Al_2O_3 reinforcement rectangular plates with dimensions of 200*80*12mm3 and varying rotational and traversal speeds of 220,360,540rpm and 10,20,30mm/min, respectively. Whenever Mg and Sic are combined, a heterogeneous the tool has a tool shoulders diameter of 16.5 mm and a pin diameter of 5.5 mm produced. The Mg-bas hybrid composite has a microhardness of 59.3HV. It improved the composite's resilience to wear [43].

Hongmei chen et.al Explored the effect of ZrO_2(20-50m) addition on FSP manufacture of ZrO_2/Mg composite, the base material cut into a specimen of 300*160*4mm3, groove depth 2.5mm and breadth 0.6, 0.8, and 1mm along its centreline, tool shoulder diameter 16mm, pin diameter 4mm, and height 3.8mm. The rotation speed was 1500rpm, the travers speed was 50mm/min, and also the tilt angle was 2.50 degrees. The sample's grain, microhardness, and mechanical properties improved when the reinforcement was introduced. In the strain damping test, the damping behaviour of ZrO_2/Mg composite matched the G-L theory, with 0.8mm groove width having the best damping capabilities [44].

K. Sekar et.al Evaluated Stir and squeeze casting AA-6082/Sic/ZrO_2 hybrid composite fabrication mechanical and welding characteristics, The current investigation sought to investigate the weld strength of an AA-6082/Sic/ZrO_2 hybrid composite junction using FSW. With a rotating speed of 1000rpm and a transversal speed of 20mm/min, this hybrid composite prepares for microstructural examination, hardness, impact, compression, and welded tensile testing. When 1% Sic and 0.5% ZrO_2 are added to a hybrid composite reinforcement, the ultimate tensile strength rises when compared to the base alloy. When 1% Sic and 1% ZrO_2 are added to the welded composite, the hardness rises by up to 17% when compared to the basic alloy [45].

Shivalisingla et.al Experimented WE43/Tic surface composite development and characterization using friction stir processing, Mg base alloy, rotation speeds 800rpm and 1700rpm, travers speeds 30mm/min and 60mm/min. Taper cylinder, square, and triangular tool pin geometries were used. The specimen measures 100*50*6mm3, has a hole diameter of.5mm, and a depth of 5.2mm. The diameter of the tool pin was 5mm and the depth was 4mm for taper cylinder, 5mm*5mm for triangular and square tools, and the tilt angle was 20 after the FSP the grain size of the composite was greatly decreased from 22.42 to 6.6m [46].

Thangarasu et.al Studied theAA-6082 Al alloy composite synthesis and characterisation utilising FSP, 100*50*10mm3 and groove 5mm deep using Tic (0,6,12,18,24% volume), rotating speed 1200rpm, the composite has a traverse speed of 60mm/min, an axial load of 10KN, a tool shoulder diameter of 18mm, a pin diameter of 6mm, and a length of 5.5mmThe microhardness as well as ultimate tensile strengths (UTS) have been tested using a pin on disc apparatus, and the wear test research study will focus. As the quantity as the number of Tic particles increased, the rate of wear reduced. Tic particles were evenly dispersed throughout the composite [47].

Thangarasu et.al Experimented the influence of traversal speed on the microstructure and mechanical characteristics of friction stir-processed materials. materials AA-6082/Tic surface composites. In this process, Tic particles and AA-6082 alloy were used as reinforcement, The traversal speed varied between 40,80 and 20 mm/min, while the other operation needs to be considered as groove width and tool rotating speed—were constant, and axial load— were maintained. Tool length is 5.5mm, thread pin profile is M6*1mm, and shoulder diameter is 22mm. The surface composite's Tic particle distribution was impacted by the traverse speed, which decreased as traverse speed increased. The surface's microhardness and wear rate were modified by the traversal speed, composite, with 112HV being discovered at 40mm/min and 135HV being found at 80mm/min [48].

Sudarshan Kumar et.al Studied the Al- alloy used Because of their excellent Al-alloys show potential for structural applications due to their high strength-to-weight ratio and corrosion resistance, and light weight; 3.5 micrometre size was used as Tic reinforcement with 2%, 4%, and 6% by volume, Degradation characteristics of an Al-7075/Tic composite treated by friction stir. The axial load is 10KN, the tilt angle is 20, the tilt speed is 30mm/min, and the rotation speed is 1200rpm. The groove had three distinct widths and a depth of 3.4mm (0.5mm,1mm and 1.5mm). The size and hardness of the nugget zone range were found to be 2 to 5 m greater than those of the heat impacted zone and thermo-mechanical zone [49].

Zinjun Zhao et.al Observed the interfacial bonding property of the friction stir additive was created for the 2195-T8, Al-Li alloy, using the parameters of 800 rpm and 100 mm/min. The Al-Li alloy's highest tensile strength. Its 56.6% of the ultimate strength properties of the base metal, and the composition of the alloy's hardness profile is asymmetrical [50]

PROCESS PARAMETER

Table.2. Process parameter of FSP

Literature survey on Friction stir additive manufacturing (FSAM)

Mounarik Mondal et.al Observed the parameters 800rpm and 50mm/min were set to proceed with the combination of light weight material such as Al-1060 plate and reinforcing Al-7075 powder in order to locally improve the material qualities of aluminium sheets. That there is excellent bonding between the matrix and the assistive

S.N.	Rotational speed (rpm)	Traverse speed (mm/min)	Tilt angle (degree)	References
1	1120	50	0	[39]
2	150,200,250	75	3	[40]
3	800	100	0	[41]
4	600,900	50	2	[42]
5	220,360,540	10,20,30	0	[43]
6	1500	50	0	[44]
7	1000	20	0	[45]
8	800,1700	60	0	[46]
9	1200	60	0	[47]
10	1200	40,80,20	0	[48]
11	1200	30	2	[49]
12	800	100	0	[50]

manufacturing layer at the interface between the Al-1060 metal and the layer used in additive manufacturing, and that no tiny flaws were found in the stir zone [51].

Abhay Sharma et.al Studied a novel method for creating functionally graded composites on demand using friction stir additive manufacturing, commercially available pure aluminium plate, Tic reinforcing particles mixed with ethanol, and parameters of 1000 rpm rotation speed, 50 mm/min traverse speed, and H13 tool, after several passes and stirring removal, voids and cracks were identified. Hardness diminishes as the percentage of Tic decreases. Because of the large stored energy, the continuous dynamic recrystallization encourages grain formation, which is supported by the crushing of the original matrix grain, during high-temperature distortion in consecutive passes. [52].

Ahamad Araddanniy et.al Explored the aggregation of reinforcement particles diminishes as the traverse speed increases from 40 - 100 mm/min at the 800-rpm rotation speed while building the lamination Al-Zn-Cu(p)/Al-Cu structure using friction stir additive manufacturing. However, travers speed well be 40 mm/min, raising the rotating speed from 800 to 1250 rpm reduces agglomeration of reinforcement particles and improves reinforcement dispersion. The fundamental reason for a dramatic shift in the hardness profile is the build-up of copper-rich reinforcing particles close to the laminated composite's interface. [53].

Zhijum Tan et.al Observed the size of Al_2O_3 nanoparticles has to have a direct influence on microstructure and hardness. The tool rotates at 1000 rev/min and moves at 100 mm/min. Temperatures are determined using an infrared radiation thermometer during the FSAM technique (IRT). This particle size drops from 100mm to 10nm, the grain size drops from 14.8 to 12.12 micrometres, and the rigidity improves from 50 to 87.34HV in the friction stir additive fabrication of nanoparticles matrix composite. In FSAM, materials manufactured with Al_2O_3 nanoparticles exhibit finer grain distributions and greater hardness than samples without Al_2O_3 nanoparticles. [54].

R. Joey Griffiths et.al A studied of MELD Al-6061 reinforcement using Al-Sic in solid-state additive manufacturing of an aluminium matrix composite. A board range alloy, such as an addition to aluminium alloy, should be able to be deposited by it variables in the process, such as tool diameter frequency, travel speed, rotational speed, Heat movement related flow of material processes may be affected by temperature, layer thickness, and other factors, which are crucial in regulating aperture, good adhesion, and reinforcement distribution. Because relate the conditions to the temperature progression and rapid modulus of elasticity of AMCs, a real production relationship must be developed. When compared to pure metal additive manufacturing utilising MELD, problems develop due to the presence of reinforcing particles with high strength that might obstruct the flow of the matrix metal. [55].

S. Palanive et.al Observed through microstructural Mg-based WE43 alloy parameters 800 to 1400rpm and 102mm/min, friction stir additive manufacturing for superior structural performance. The origin of the high uniform elongation of 10% FSAM at 1400rpm and 102mm/min residual stress is immoderate, Superior strength, comparable to Al alloys, is the consequence of exceedingly fine, homogeneous, and densely packed coherent precipitates with sizes ranging from 2 to 7 nm. [56].

J. Jehkrishman et.al Studied the used of stir Al-6082 and titanium dibromide, fabrication and characterisation of an aluminium di-bromide metal matrix composite (TiB_2), By adding 6% TiB_2 reinforcements to Al alloy, better attributes may be generated, including tensile strength, flexural strength, hardness, and impact strength. However, when the TiB_2 particle weight increases, the mechanical characteristics tend to decline. The flexural stress was high in original sample and decreased further as the TiB_2 particle concentration increased, as a result of excellent assignment of TiB_2 particles. [57].

R. Joey Griffiths et.al Studied of MELD Al-6061 reinforcement using Al-Sic in solid-state additive manufacturing of an aluminium matrix composite. It should be able to deposit an alloy for use in boards, such as an addition to aluminium alloy. Process factors such as feed rate, layer thickness, tool rotation frequency, and transverse speed can affect heat flow and material flow processes, which are critical for controlling porosity, interfacial bonding, and reinforcement distribution. [58].

Mao Yuiging et.al Used of Al-7075 alloy, the friction stir additive manufacturing technique had utilised to develop the microstructure and mechanical performance of the aluminum-based composite. Dynamic recrystallization produced fine and equiaxed grain, significantly increased tensile strength, and decreased elongation in the agitated zone. The strength eventually grew to a high of 279 MPa. The fractography indicate that the upper specimen has several dimples of various sizes and shapes, as well as thicker ripping ridges, whereas the bottom slice has a brittle failure pattern of semi with river patterns. [59].

Z. Zhang et.al Evaluated the Mechanical proportional operations of re-stringing and re-heating in friction stir additive manufacturing have already been investigated both experimentally and numerically. The temperature field in the FSAM is tracked using an in (IRI) infrared radiation images system that uses AA-6061 T6, Mg-based Al+Tic, and all parameters of 1000rpm and 100mm/min. Because of the re string action in FSAM, at the peak temperature freshly added layer decreases as increases. [60].

Hang.Z.Yu. et.al Explored the AA-5083, Al-Mg-Si was routed under tool head with severe deformation with the tool head material sliding at full conditions for additive friction stirring installation deformation method for the preparation to metal additive manufacturing. Instead of producing a rigid interface, co-plastic distortion and mixing between the new fully material and the layer underneath will result in a diffuse interface with progressive changes in composition, microstructure, and phase fraction. [61].

R. Joey Grifftish et.al Observed as demonstrated by a gradual transition from the AA-7075 plate elongation grain, Solid-state additive manufacturing was enabled by additive friction stir for the restoration of Al-7075 alloy, T055 plate the parameters 400rpm and 0.42mm/min. Adding friction Stir deposition successfully fills the whole volume of through-holes and broad grooves in AA 7075. This is notably noticeable in the later situation, when the groove width is 33% more than the feed rod width. [62].

Zijun Zhao et.al Studied the friction stir additive manufacturing design for 2195-T8 Al-Li alloy, with a perimeter 800rpm, has an attribute called interfacial bonding. The weak bonding faults caused by improper tool stirring are typically linked to the presence of oxide at the lap contact and may be seen in the hardness profile of a five-layered inhomogeneous material. By using a welding technique where the welding orientations of two adjacent layers are opposite, the interfacial bonding characteristics and material mixing of the whole NZ may be somewhat enhanced. [63].

Akash Mukhopadhyay et.al Explored the average ultimate tensile strength of the deposit was somewhat greater than that of the solution both in longitudinal and transverse directions when created by friction stir additive manufacturing, according to mechanical parameters of pure aluminium AA-6061 T6 alloy depositions. The deposit's average ultimate tensile strength was marginally higher in both the longitudinal and transverse directions than that of solution zed aluminium 6061 alloy. The readings in both directions were comparable, demonstrating the deposit's isotropic nature. In comparison to Al6061-O, which has a value of 64 HV, the deposit's average Vickers's micro-hardness was determined to be 60.25 and 70.25 HV in both the longitudinal and transverse directions. [64].

H. Aghajani Derazkola et.al Evaluated the order to evaluate a Friction stir additive manufacturing (FSAM) was used to create a polymer-steel laminated sheet composite structure, A poly-methyl-methacrylate (PMMA) sheet with such a thickness of around 5 mm was provided. Prior to application, the material was chopped into tiny pieces with 60 * 100 mm2 dimensional cross-sections. The optimal operating parameters are as follows: The rotational speed (w) is 850 revolutions per minute, the traverse velocity (v) is 45 millimetres per minute, and the tool tilting angle is 2.5 degrees, and the material feeding rate is 420 rpm through mandrel rotation. Later microstructural studies demonstrated the influence of steel fragments when the weld nugget strengthens the layered composite structure was fed with PMMA materials. use of a stir tool to provide friction to promote the evaporation-related loss of polymer material [65].

PROCESS PARAMETER

Zinjun Zhao et.al Experimented the interfacial bonding property of the friction stir additive was created for the 2195-T8, Al-Li alloy, using the parameters of 800 rpm and 100 mm/min. The Al-Li alloy's highest tensile strength has the alloy's hardness profile is asymmetrical, with 56.6% of the maximum tensile strength of the base metal. [66].

Application of FSAM

AM is widely utilised, notably in the consumer products industry, automotive, aerospace, biomedicine, and many others. It is anticipated that new uses and advantages will emerge over time. We'll give a quick overview of AM's uses in the aerospace, automotive, and biomedical industries even though its applications are spreading into a variety of industries, including food engineering [67]. Other related studies and papers have more details on applications. The assemblies of aerospace components have been complex geometry and incorporate complicated material such as nickel alloy, titanium alloy, or many more alloy that are typically made by more laborious, while using FSAM reduces the all-consuming process [68]. Also, the aerospace industry has been produces a smaller number of components, have limited number of plants. Automotive Additive manufacturing technique have been applied to reduce manufacturing and production cost [69]. AM is being used to build a limited number of components for premium, low-volume vehicles such as marathon, racing, homologated sports cars, and race trucks, such as exhaust valves, start-up motors, gear boxes, drive shaft systems, and braking systems. In addition, AM has been used to create components that can be produced to function and perform effectively. Companies and research organization have also used AM method to effectively build functioning components for automobile. Vehicles for racing, as opposed to passenger automobiles, typically use lighter alloys (e.g., titanium), has extremely complicated construction, and limited manufacturing quantities.[70].

S.N.	Rotational speed (rpm)	Traverse speed (mm/min)	Tilt angle (degree)	References
1	800	50	0	[51]
2	1000	50	3	[52]
3	800,1250	40,100	0	[53]
4	1000	100	2	[54]
5	700	35	0	[55]
6	800,1400	102	0	[56]
7	800	80	0	[59]
8	1000	100	0	[60]
9	850	45	0	[61]
10	400	.42	0	[62]
11	800	100	0	[66]
12	850,420	45	0	[65]

Future scope

Technologically, additive manufacturing (AM) has allowed for incredible flexibility over through the structure, content, and operation of manufactured objects, as well as a high degree of personalisation for people. This new manufacturing technology offers amazing potential for a revolution in manufacturing technique [71]. Additive manufacturing has ability that can reduces the cost effective which cannot be manufactured easily using conventional techniques, that can have greatest control out over design, content, and operation of created products because to additive manufacturing. AM techniques, called the "Fourth Industrial Revolution," [72].

This has the possibility to change the cost-effective mass customization of complicated things that are difficult to produce using current technology. AM is capable of producing objects with a wide variety of dimensions (with nanometre/micrometre), components (materials, polymeric, ceramic, nanocomposite, and organic particles), and functions [73]. In general, additive manufacturing enables the manufacturing of complicated structures with variable compositions and active functionality. AM can specifically enable part manufacturing with functionally graded materials (FGM). Some AM procedures may transport diverse materials to the construction regions (often via several feeding units) and can produce components with FGM, which is one of the key benefits of AM technology that conventional manufacturing techniques cannot do.[74].

It's having capacity enables composition control in order to provide versatility (for increasing the ductility compare to other material) and to manage the characteristics of the manufactured component. A pulley with more carbide around the hub and rim to make it tougher and more wear resistant, and less carbide in other regions to promote compliance, is one such use. With terms of economy and environment, additive manufacturing (AM) provides various advantages over conventional manufacturing processes, such as decreased material waste and energy consumption, quicker duration, kind of production, and manufacture of previously unattainable structures. [75].

Adding materials individually in order to make 3D things, in particular, decreases waste significantly. Titanium pieces, for example, are cut to size from large platinum slabs in standard aerospace manufacturing, producing in more than 90% waste products that cannot be economically utilised. AM has the potential to significantly minimise waste formation, hence lowering the energy required to manufacture titanium material and components. [76]. Furthermore, because AM is digital, firms will be able to implement innovative product designs without paying the additional expenditures associated with old approaches. It could be noted that for some applications, additive manufacturing is neither materially neither resource. [77].

It must be expected that FSAM will be a viable additive manufacturing technique option for a wide range of implementation based on historical data, present circumstances, and future projections, and that its growth will accelerate in the near future with research-based advancements. Based on prior data and outcomes, Figure.4 indicates the predicted expansion of the FSAM process. According to recent times, it is presently relevant for 28% of engineering goods that can be efficiently created using this technique, and by 2030, it is expected to viable replacement for more than 50% of existing products with exponential development [78].

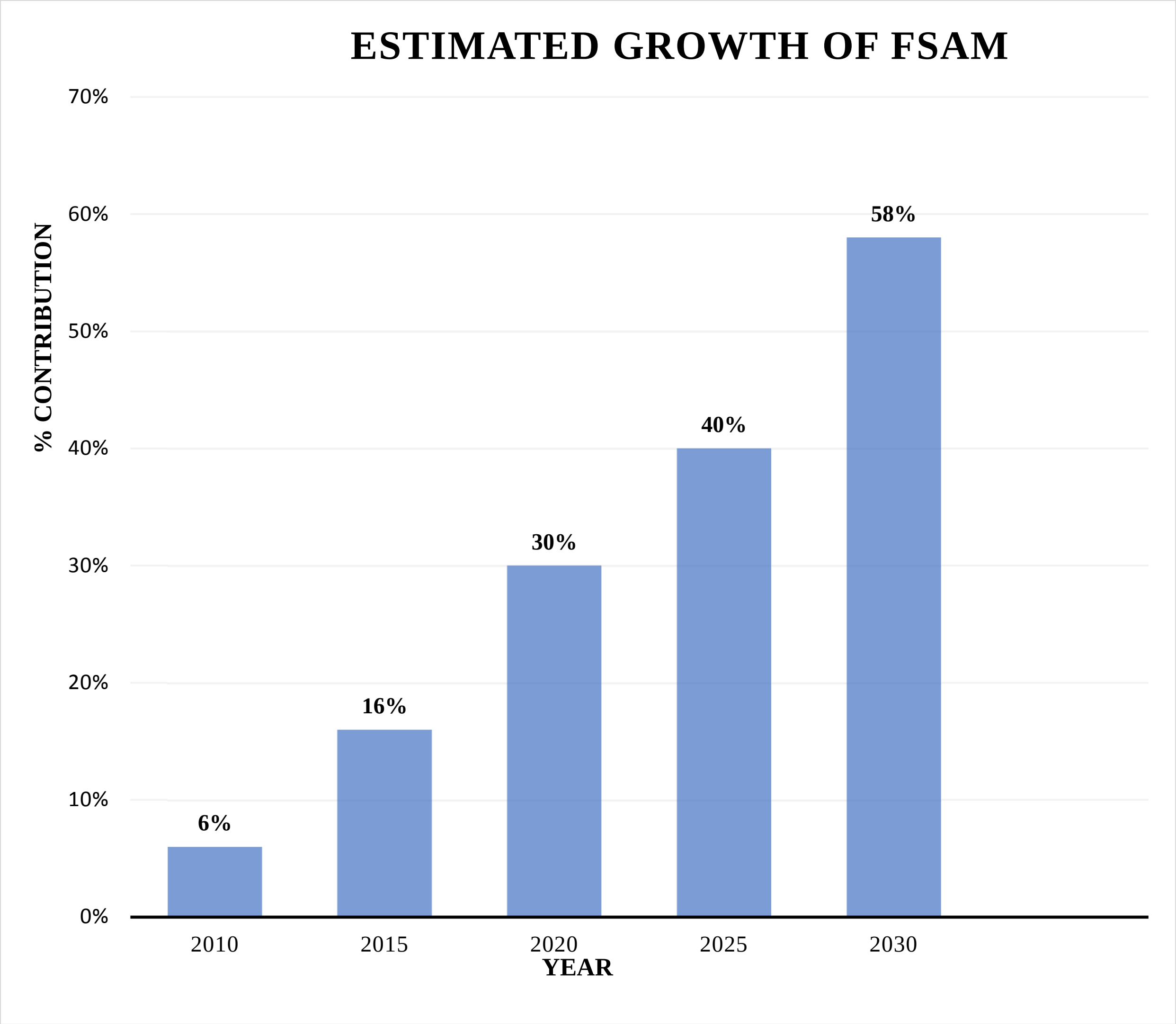

Fig.3. Estimate growth of FSAM in future

CONCLUSION

To be widely recognised by industry, manufactured components must be repeatable and consistent over the whole range, between produces on using several types of manufacturing machine. To be widely employed in industry, additive manufacturing technology must be capable of ensuring spending contributed. However, new AM techniques must be studied and developed, such as those for biomaterials as building blocks, as well as those for nanoscale and micro, in order to broaden and generate new applications. To meet these objectives, additive manufacturing technologies and applications will design, materials, production procedures and machineries, simulation, process improvement, and sustainability and energy applications will necessitate significant more research and development. Friction stir additive manufacturing (FSAM) is the very fine method for the production of surface composite, after review the above articles found that Al-alloy is widely used for this process and several types of reinforcement particles, work with their suitable parameter. And tool use for this process has highly melting point compare to their alloy sheet and reinforcement matrix.

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