Evaluating the effects of reinforcement particles on mechanical and metallurgical properties of friction stir processed aluminum alloy composites

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By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**Evaluating the effects of reinforcement particles on mechanical and metallurgical properties of friction stir processed aluminum alloy composites**" in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of **Mr. Piyush Gulati**, Asst. Professor, School of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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Signature of Examiner

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ABSTRACT

Friction Stir Processing (FSP) is a relatively new surface modification technique for alloys and composites. By using FSP the enhancement in the mechanical properties can be obtained. In this work an over view about the various aluminium alloys, their properties, reinforcement particles and the methodologies followed for fabrication of a reinforced composite aluminium alloy by friction stir processing is given. Review of FSP with reinforcements (SiC, B_4C, and Al_2O_3) on the aluminum alloy done and it has been seen that after employing the reinforcement the properties such as hardness, wear resistance, tensile strength of the reinforced alloy improved significantly.

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CHAPTER 1

INTRODUCTION

1.1 WELDING

Welding is a joining process which is used for joining similar or different kind of materials e.g. metals, thermoplastics etc. For joining, several processes are used some of them are Fusion, Brazing and Soldering etc. In Brazing and Soldering base material remain intact or it does not melt. Sometimes filler material is also used which form a weld pool, which is usually stronger than the base material. Sometimes welding region needs to be protected from environmental conditions e.g. oxidation etc., for this purpose inert or semi-inert gas is used [29].

1.1.1 ARC WELDING

Arc welding is done by creating an electric arc to melt the base metal. The arc is created between the electrode used and base material. The power source used for creating the arc either Direct Current (DC) or Alternating Current (AC). The electrode used can be Consumable or Non-Consumable. Major arc welding processes are Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Gas Tungsten Arc Welding (GTAW) and Submerged Arc Welding (SAW). Cast Iron, Nickel, Copper, Aluminium and other metals are generally welded by arc welding [29].

1.1.2 GAS WELDING

Gas welding is a very common welding process which is widely used for welding pipes and tubes. The mostly used gas welding process is oxyfuel or oxyacetylene welding in which oxygen and acetylene are used for joining purpose. Oxygen and Acetylene form different kind of flames according to ratio of mixture which assist in welding [29].

1.1.3 RESISTANCE WELDING

Heat is the main parameter in case of resistance welding, which is generated by passing the current through resistance caused by contact between two or more metal surfaces. When the high current of around (1000A-100000A) is passed through the metal several weld pool of molten metal are formed at weld area. It is an environment friendly process as it causes a little pollution but it is having limited applications nad the cost of equipment is very high, although resistance welding is very efficient. Spot Welding and Seam Welding are the popular method of resistance welding [29].

1.1.4 ENERGY BEAM WELDING

Energy Beam Welding is very popular for high production rates as it is fast and automated. Laser Beam Welding and Electron Beam Welding are the two main types of Energy Beam Welding process. Power source is different for each technique but processes are quite similar. A highly focused laser beam is used in Laser Beam Welding while Electron Beam and Vacuum are used in Electron Beam Welding. The main disadvantage of Energy Beam Welding is susceptibility of Thermal Cracking [29].

1.1.5 SOLID-STATE WELDING

Meaning by Solid State welding is that it does not involve melting of the base materials which are going to be joined. Most popular solid state welding processes are Ultrasonic Welding, in which material is connected or joined by vibration of high frequency and high pressure, and Explosion Welding, which involve extreme high pressure to join material produced by impact energy of explosion. Ultrasonic Welding is used for fabricating electrical connection of aluminium and copper while Explosion Welding is used for joining dissimilar materials [29].

1.1.6 FRICTION STIR WELDING

Friction Stir Welding (FSW) is also a type of solid state welding because in this technique material does not melt. It is relatively new process with respect to other welding techniques used for the joining of the two metals. FSW was invented in 1991 by Wayne Thomas at The Welding Institute (TWI) of the United Kingdom. The idea of FSW is basic; a non-consumable pivoting tool with a specifically designed pin and shoulder is embedded into the adjoining edges of sheets or plates to be joined and in this manner navigated along the joint line and thus welding takes place [28].

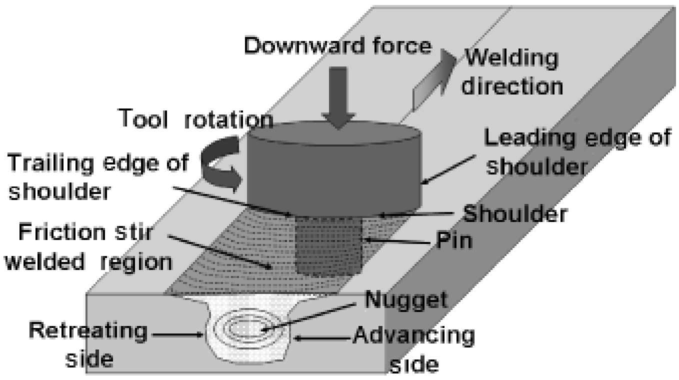


Fig. 1: Schematic Drawing of Friction Stir Welding [34]

Terminology used in FSW:

Fig. 1 represents the process in which various terms related to the process are given such as tool rotation, i.e., the direction in which tool rotates which could be clockwise or anti-clockwise, downward force, Shoulder, Pin etc. Some terms like Advancing Side and retreating side are define as the *advancing side* is on the right, where the tool turning is in the same direction as the tool travel direction (inverse the bearing of metal stream), and the *retreating side* is on the left, where the tool turning is inverse of tool travel direction (parallel to the direction of metal stream) [34].

The tool serves three essential functions, that is, heating of the workpiece, movement of material to create the joint, and regulation of the hot metal underneath the shoulder.

Heating is done inside the workpiece both by contact between the tool pin and shoulder and by extreme plastic distortion of the workpiece [34].

The confined heating softens material around the pin what's more, consolidated with the tool turning and travelling prompts development of material from the front to the back of the pin, in this manner filling the gap in the device wake as the device advances. The tool shoulder confines metal flow to a level proportional to the shoulder position, that is, around to the underlying workpiece best surface [34].

Because of the tool action and impact on the workpiece, when performed properly the resulting nugget zone microstructure reflects different thermo-mechanical changes and is definitely not homogeneous. In resentment of the nearby micro-structural in-homogeneity, one of the noteworthy advantages of this method is the completely re-crystallized, equiaxed, fine grain microstructure made in the stirring zone by the exceptional plastic twisting at hoisted temperature [34].

The fine grain microstructure produces phenomenal mechanical properties, fatigue properties, upgraded formability, and outstanding super plasticity. While performing various zones are obtained due to stirring of tool and heat generated during the process. The zones are as follows [34]:

• Unaffected Material or Parent Metal: This is material remote from the weld that has not been twisted and that, in spite of the fact that it might have encountered a heat cycle from the weld, is not influenced by the heat regarding smaller scale - structure or mechanical properties.

• Heat-affected zone: In this district, which lies nearer to the weld-focus, the material has encountered a warm cycle that has altered the microstructure as well as the mechanical properties. Be that as it may, there is no plastic distortion happening here.

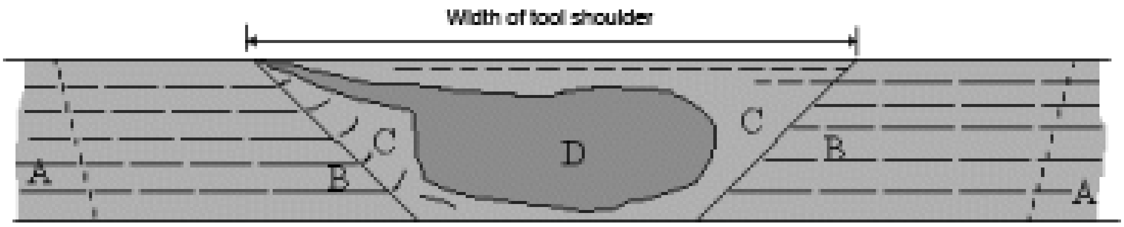


Fig. 2: Various Microstructural Regions obtained in FSP [34]

• Thermomechanically Affected zone (TMAZ): In this district, the FSW instrument has plastically twisted the material, and the warmth from the process will likewise have applied some impact on the material. On account of aluminum, it is conceivable to get huge plastic strain without recrystallization in this region, and there is for the most part a particular limit between the recrystallized zone (weld nugget) what's more, the twisted zones of the TMAZ.

• Stir Zone: The completely re-crystallized region, alludes to the zone already involved by the tool pin. The term stir zone is ordinarily utilized as a part of contact stir handling, where substantial volumes of material are handled.

1.2 FRICTION STIR PROCESSING

Friction stir processing (FSP) is a surface modification technique based on the principle of FSW. In the FSP instead of joining, tool is used for stirring action in the plastic zone of the plastically deformed specimen. By doing so material goes in dynamic re-crystallization and grains of the material becomes finer, also better dispersion is achieved.

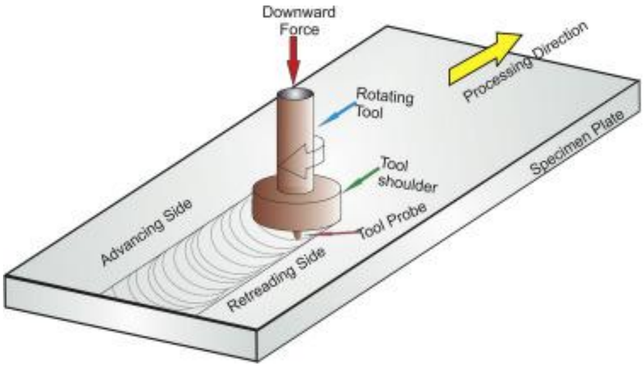


Fig. 3: Schematic view of FSP [35]

1.2.1 PARAMETERS

There are some parameters which affects the efficiency and accuracy of the processed final product, which are as follows:

i. **TOOL DESIGN:**

Tool design is the most critical factor in FSP because it provides the quality and maximum speed that can achieve. So for better mixing a good quality material tool is required. It is undesirable to have a tool that loses dimensional strength, the composed components, or more terrible, cracks.

Some important attributes of tool material are Ambient and Elevated Temperature Strength, Elevated Temperature Stability, wear Resistance, Tool Reactivity, Fracture Toughness, Coefficient of Thermal Expansion, Machinability etc.

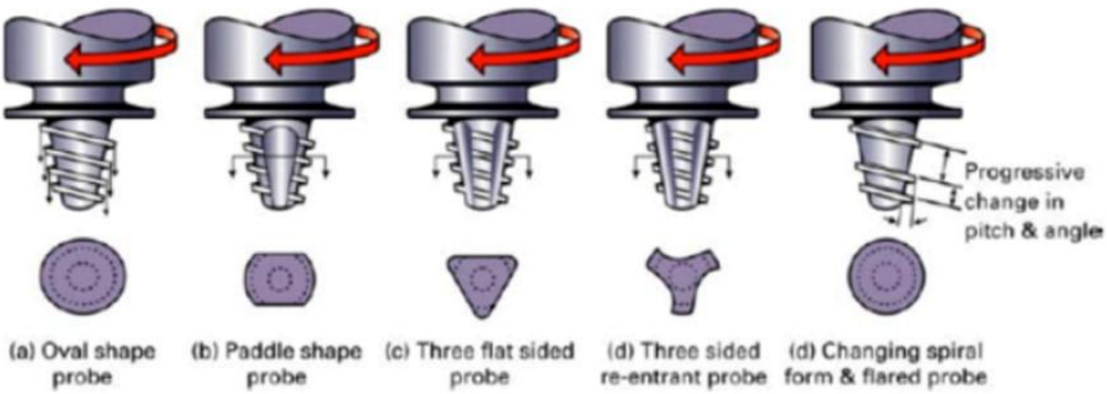


Fig. 4: Schematic drawing of the FSP tool [40]

Tool material used in the FSP are generally made of Tool Steel, Nickel and Cobalt base Alloy, Refractory Metals, Carbide and Metal Matrix Composite, Cubic Boron Carbide etc., but most commonly used tool material is Tool Steel because it's easy availability and machinability, low cost and established material characteristics [28].

AISI H13 is mostly used tool steel material than other tool steel because it is hot worked, air hardening steel which is good at elevated temperature, good thermal fatigue strength and wear resistance.

ii. ROTATIONAL SPEED:

Tool Rotational Speed is the second most influencing parameter. It affects processed area of workpiece as the grain size depends on the speed when it varies from high to low or vice versa, so rotational speed should be chosen with extensive care for well-organized FSP. Because more or less speed than required can generate more heat which can destroy the grain structure [28].

iii. TRAVERSE SPEED:

Traverse speed is the motion which helps tool to cover the workpiece back and forth. It also has same effect as the rotational speed but it is less effective than rotational speed. Generally Lower traverse speed with high rotational speed causes hotter weld which can alter the workpiece property in undesirable manner. So for a sound operation it is essential that material should be at re-crystalline temperature [28].

iv. PLUNGE DEPTH:

The penetration of shoulder below the surface of base material is defined as plunge depth. It is the one of the critical parameter which ensure quality of the processed material. As the shoulder plunges in the material pressure increases and it helps in ample forging of the workpiece [28].

v. TOOL TILT ANGLE:

Tilting of the tool is also assist stirring process. Tilting the tool 2 to 4° from the normal of the workpiece e.g. rear of the tool is lower than the front, away from the direction of travel; this is mandatory to uphold the material reservoir and to facilitate the trailing edge of the shoulder tool to fabricate a compressive forging force on the weld. A majority of the friction stir welds created with a concave shoulder are linear; nonlinear welds are only achievable if the machine design can keep the tool tilt around corners [28].

1.2.2 APPLICATIONS of FSP

Friction Stir Processing is used when some improvement is required in properties of any metal. As metal products produced by casting process are often subject to some flaws like micro-structural defects and porosity while using FSP these defects can be eliminated. It is used for the surface modification of the wings in aerospace industries. It is used in marine industry for surface modification of hulls, aluminum extrusions and offshore accommodations [30].

Fabrication of metal matrix composites is also possible with friction stir processing and properties at nugget zone are found improved [30].

1.2.3 Advantages of FSP

1. FSP is a single step process, easier and less time consuming while other techniques require multiple steps.
2. Super plasticity thickness is produced by fine grain microstructures.
3. FSP increases the ductility and tensile properties of the materials [34].

1.3 ALUMINIUM ALLOYS

Pure aluminium is relatively soft. To overcome this, the metal can be alloyed with other metals (alloying elements). Most of the aluminium reaching the marketplace has been alloyed with at least one other element. Based on the type of alloying element, the aluminium alloys are divided into 8 groups:

1.3.1 1xxx Series:

Contains no alloying components. The extent of aluminium is 99.3 – 99.9% and the rest is framed by little impurities. The blend of material properties, particularly superior conductivity makes these composites appropriate for applications basically in electrical and heat power industry. Materials of this arrangement are considered non-hardenable combinations and have rigid qualities of 40 – 60 Mpa [27], [36].

1.3.2 2xxx Series:

The main alloying component is copper. Alloys of this arrangement are high quality compounds. The quality is accomplished by the heat treatment process. The rigidity is around 400 MPa on finishing of hardening. Composites of this arrangement are considered not appropriate for surface modification and poor for welding [27], [36].

1.3.3 3xxx Series:

The main alloying element is manganese. Alloys of this series are moderate in strength, they have good formability and they are suitable for anodizing and welding. They are non-heat-treatable but having more strength approx 20% than 1xxx alloys [27], [36].

1.3.4 4xxx Series:

The main alloying element for this series is silicon. When silicon is added in adequate quantity about 12% it causes the considerable decrease in melting range with having brittleness. That is why alloy of this series are used in welding wire and brazing alloys for joining aluminium [36].

1.3.5 5xxx Series:

The main alloying component is magnesium. Alloys of this arrangement are moderate in quality (200 – 350 MPa). Magnesium is significantly more effective than manganese as a hardener approx 0.8% Mg is equal to 1.25% Mn. The quality is accomplished by the heat treatment process or forming. Composites of this arrangement have magnificent resistance to corrosion in aggressive environment and seawater [27], [36].

1.3.6 6xxx Series:

The alloying elements are magnesium and silicon. Alloys of this series are moderate in strength (200 – 350 MPa). The strength is achieved by the heat treatment processing or forming. Although these are not as strong as 2xxx and 7xxx series alloys. Alloys of 6xxx series can be easily anodized and have good machinability, weldeability, corrosion resistance and formability [27], [36].

1.3.7 7xxx Series:

The major alloying element in this series is zinc. Alloys of this series have the highest strength among all series. The tensile strengths ranging between 450 – 500 MPa may exceed 600 MPa in some cases. These alloys prone to stress corrosion, especially when welded but when treated in slightly overaged temper provide better corrosion resistance [27], [36].

1.3.8 8xxx Series:

The alloys of this series consist of a wide range of chemical compositions. For example when dispersion-strengthened Al-Fe-Ce alloys or Al-Fe-V-Si alloys, which are produced by powder metallurgy processing, are used improved elevated temperature performance is achieved. Higher stiffness and lower density can be obtained in lithium containing alloys, which has replaced medium to high strength 2xxx and 7xxx alloys in some aerospace/aircraft applications [27], [36].

1.4 REINFORCEMENTS

In the friction stir process for increasing the mechanical properties such as microhardness, wear resistance, tensile strength etc. reinforcements are used. Mostly used reinforcements are SiC, Al_2O_3, B_4C, Graphite etc. The size and density of the various reinforcements are given in the table below.

TABLE 1. DIFFERENTS TYPES OF REINFORCEMENTS WITH THEIR SIZE (µm)

Material	Normal Size (µm)	Density (g/cm^3)
SiC	15-340	3.2
Al_2O_3	40-340	4.0
B_4C	40-300	2.5
TiC	40-50	2.25
Graphite	40-250	1.6-2.2
Boron Nitride	40-50	2.25

For incorporation of the reinforcements particles various method are used, which are as follows [24]:

The first technique is the use of a thin layer of reinforcement particles at first glance of the work piece with the help of a volatile dissolvable, for example, methanol before FSP. Be that as it may, the particles were not consistently scattered and there were noteworthy airborne particles amid situation of the particles and FSP.

The second strategy was to make different surface reservoirs, for example, dimples or grooves and pre-place reinforcement particles in the preceding FSP. A thin Al sheet cover could be utilized to keep the particles from being airborne amid FSP. As dry nano-powders have exceptionally low thickness, the centralization of fortification in a supply volume is additionally low. In order to increase the concentration slurry of nano-particles and volatile dissolvable can be used.

The third technique includes mechanical alloying of the aluminum powders and the reinforcement molecule utilizing ball milling before cold compacting and sintering into billets before FSP. Friction stir processing can be considered as highly effective process used for enhancement of mechanical properties.

TABLE 2: SOME GRADES OF ALLUMINIUM ALLOY [37], [38], [39]

Grade of Aluminium Alloys	Young's Modulus (E) Gpa	Ultimate Tensile Stringth (MPa)	Yield Strength (MPa)	Hardness (HBN)	Applications
1100	70-80	0 - 90 H12 - 110 H14 - 125 H16 - 145 H18 - 165	0 - 34 H12 - 105 H14 - 115 H16 - 140 H18 - 150	28	Heat Exchanger Fins, Light Weight Tools, Cooking Utensils, Rivets, Foils
2011	70	T3 - 275-310	T3 - 125-230	90	Precision Gears, Atomizer and Hose parts, Speedometer Components, Clock Parts
2014	73	O - 186 T4 - 427 T6 - 190-480	O - 96.5 T4 - 290 T6 – 414	O - 45 T4 - 105 T6 - 135	Truck Frames, Aerospace Structure
2017	72	O - 179 T4 - 427	O - 68.9 T4 – 276	O - 45 T4 - 105	Rivets, Fasteners, Gauges, Pulleys, Screw Machining Components
2024	73	O - 140-210 T3 - 400-430 T4 - 469 T6 - 427	O - 97 T3 - 270-280 T4 - 324 T6 - 345	O - 47 T3 - 120 T4 - 120 T6 - 125	Fuselage Skins, Wing Tension Members, Shear Webs & Ribs, Truck Wheels
3003	69.5	95-135	35-125	28-35	Cooking Utensils, Pressure Valves, Heat Exchangers, Chemical Equipments
5005	69.5	105-205	35-135	47	Chemical & Food Equipments, Storage Tanks, Home Appliance, Sheet Metal Work, Electric Conductors
5052	70.3	O - 193 H19 - 330 H32 - 228 H34 - 262 H36 - 276 H38 - 290	O - 89.6 H19 - 325 H32 - 193 H34 - 214 H36 - 241 H38 - 255	O - 47 H19 - 88 H32 - 60 H34 - 68 H36 - 73 H38 -77	Cooking Utensils, Food Processing Equipments, Ladders Fencing, Auto Industry Components and Body Panels, Storage Tanks
5086	71	O - 262 H32 - 290 H34 - 324 H112 - 269 H116 - 290	O - 117 H32 - 207 H34 - 255 H112 - 131 H116 - 207	O - 70 H32 - 78 H34 - 87 H112 - 73 H116 - 78	Drilling Rigs, Patrol and Workboat Hulls, TV Towers, Shipyards

5657	70-80	O - 110 H25 - 159 H26 - 180	O - 40 H25 - 138	O - 28 H25- 40	Aircraft Fuel Tanks, Fan Blades, Refrigeration Liners, Utensils
6013	69	392	379	130	Valves, Roller Blade Parts, ABS Braking System
6020		T8 - 303 T9 - 352	T8 - 283 T9 - 338	T8 - 100 T9 - 120	Automotive Transmission Valves, Brake Pistons, Hinge Pins, Compressor Piston
6061	68.9	O - 124 T4 - 241 T6 - 310 T8 - >310 T91 - 405	O - 55.2 T4 - 145 T6 - 275 T8 - >276 T91 - 395	O - 30 T4 - 65 T6 - 95 T8 - 120 T91 - 108	Drive Shafts, Valves, Couplings, Wings and Fuselages of Aircraft, Brake Components
6063	68.9	O - 89.6 T1 - 152 T4 - 172 T5 - 186 T6 - 241 T83 - 255	O - 48.3 T1 - 89.6 T4 - 89.6 T5 - 145 T6 - 214 T83 - 241	O - 25 T1 - 42 T4 - 46 T5 - 60 T6 - 73 T83 - 82	Pipe Railings, Door Frames, Irrigation Tubing, Windows, Extreme Sports Equipments
6101	70-80	O - 97 T6 - 250	O - 76 T6 - 200	T6 - 75	Power Transmission, Power Stations, Electrical Components, Electrical Bus Conductors and Fittings
6262	69	T6 - 260 T9 - 390	T6 - 240 T9 -360	T6 - 75 T9 - 120	Screw Machine Components, Oil Line Fittings, Valves, Couplings, Nuts, Hinge Pins
7050	71.7	T73511 - 496 T7451 - 524 T7561 - 552	T73511 - 434 T7451 - 469 T7561 - 490	T73511 - 132 T7451 - 140 T7561 - 147	Fuselage Frames, Bulkheads, Various Aircraft Parts
7075	71.7	O - 228 T6 - 572 T73 - 505	O - 103 T6 - 503 T73 - 435	O - 60 T6 - 150 T73 - 135	Aircraft Fittings, Gears and Shafts, Regulating Valve Parts. Fuse Parts
7178	71.7	O - 228 T6 - 572 T76 - 572	O - 103 T6 - 503 T76 - 503	O - 60 T6 - 150 T76 - 152	Marines, Construction, Aerospace
7475	70.3	T61 - 565 T651 - 586 T761 - 517 T7651 - 531	T61 - 490 T651 - 510 T761 - 448 T7651 - 462	T61 - 148 T651 - 150 T761 - 140 T7651 - 140	Aerospace Assemblies

TABLE 3. CHEMICAL COMPOSITION OF VARIOUS ALIMINIUM ALLOYS (wt. %) [31]

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr
1100	0.20	0.25	0.04	0.03	0.03	-	0.054	0.03	
2014	0.50	0.50	3.8-4.9	0.3-0.9	1.2-1.8	0.10	0.25	0.15	
3003	.6	0.7	0.05-0.25	1.0-1.5	-	-	0.10	0.05	
5005	0.30	0.07	0.20	0.20	0.50-1.1	0.10	0.25	0.05	
5052	0.25	0.40	0.10	0.10	2.2-2.8	0.15-0.35	0.10	0.05	
5083	0.4	0.4	0.1	0.40-1.0	4.0-4.9	0.05-0.25	0.25	0.15	
5086	0.4	0.5	0.1	0.20-0.7	3.5-4.5	0.05-0.25	0.25	0.15	
5657	0.08	0.10	0.10	0.03	0.6-1.0	-	0.05		
6061-T6	0.62	0.33	0.28	0.06	0.9	0.17	0.02	0.02	
6061	0.40-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15	
6063	0.20-0.6	0.35	0.1	0.1	0.45-0.9	0.1	0.1	0.1	
6063-T6	0.43	0.2	0.01	0.006	0.5		0.005	0.014	
6066	0.9-1.8	0.5	0.7-1.2	0.6-1.1	0.8-1.4	0.4	0.25	0.2	
6351-T6	0.907	0.355	0.086	0.65	0.586		0.89	0.015	
7005	0.35	0.4	0.1	0.20-0.70	1.0-1.8	0.06-0.20	4.0-5.0	0.01-0.06	0.08-0.20
7068	0.12	0.15	1.60-2.40	0.1	2.20-3.00	0.05	7.30-8.30	0.01	0.05-0.15
7075	0.4	0.5	1.2-2.0	0.3	2.1-2.9	0.18-0.28	5.1-6.1	0.2	
7079	0.3	0.4	0.40-0.80	0.10-0.30	2.9-3.7	0.10-0.25	3.8-4.8	0.1	

CHAPTER 2

LITERATURE REVIEW

S. Tutunchilar et al. [5] studied Surface Transformation of Eutectic Al-Si alloy by using Friction Stir Processing. In this process, they added 10 volume fraction of Si Particles additionally. As the tool for FSP, they used Threaded Pin Tool and Square Pin Tool and they found that at the macro- and microstructure level the threaded pin tool is more effective in comparison with square pin tool and especially at high traverse speeds it is clearly visible. Better particle distribution in the stir zone can be obtained by an increase in rotational speed and a number of pass and decrease in traverse speed. As the number of pass increases size of particles decreases but by raising the traverse speed Si particle size increases. The insertion of 10% volume fraction Si powder increases the hardness on the first pass of FSP but when applied to the next passes hardness is found to be reduced with every pass which is due to fragmentation of precipitates such as Mg_2Si. But increase in traverse speed helps in increase in hardness. The increase in Number of Passes and Rotational Speed increase tensile strength and elongation but the increase in Traveling speed decreases the Elongation yet did not have too much impact on the Tensile Strength. Using FSP on as-cast LM13 Al alloy shows the decrease in brittleness and increase in Ductility after every pass.

Dolatkhah et al. [6] conducted an investigation to find out the impact of tool rotational speed, the number of passes, traverse speed, and switch of rotational direction between the passes and particle size on the mechanical and micro-structural properties of Al5052/SiC metal matrix composite (MMC) produced by FSP. The grain sizes of the SiC particles were taken as 5 µm and 50 nm for the reinforcement purpose. The base material used was having a thickness of 5 mm and a groove is cut down to 2 mm depth and 1 mm width. The tool used made from H-13 hot worked steel. The tool was having shoulder diameter 18 mm, pin height 3 mm, excircle diameter 6 mm and profile type was the square type. The tool used at the angle of 3˚ from the normal axis. The tool is rotated at 700, 1120 and 1400 rpm and traveling speed were 40, 80 and 120 mm/min and it was found that for better powder distribution the combination for rotating and tool travelling speed is 1120 rpm and 80 mm/min respectively and shifting of tool rotation direction between passes lead to better distribution. Due to the FSP, a fine equiaxed grain microstructure is obtained but when SiC particles have used the results were better and best with the 50 nm particle size as a reduction in grain size was found to be from 243 µm to 0.9 µm. These parameters also had the great effect on the hardness of the MMC as the micro-hardness value was found to be raised up to 55% and the wear rate diminished about 9.7 times than that of as-received 5052 aluminum.

M. Salehi et al. [7] studied optimization of process parameters of AA6061 fabricated by SiC nano-composites as reinforcement. The process parameter that investigated were rotational speed, traverse speed, tool piercing depth and pin profile. The plate that was used having 8 mm thickness for that the optimum conditions were found as rotational speed 1600 r/min, transverse speed 40 mm/min, tool penetration depth 0.30 mm and pin profile as threaded type. For checking the optimum parameter Taguchi method was used and it was observed that the rotational speed is the most dominant parameter with 43.70% offering and the other parameters contributed as traveling speed 33.79%, pin profile 11.22% and tool piercing depth 4.21%. With the help of statistical results, it was found that the UTS was larger for the threaded pin than that of a square pin. AA6061/SiC nano-composites (ASNCs) of elevated tensile strength were obtained at notable tool piercing depth and rotational speed and lower traveling speed with the threaded pin tool.

Don-Hyun CHOI et al. [8] studied the impact of SiC particles on mechanical and microstructure property of AA6061-T4 after FSP. The base material AA6061 was having the thickness of 4 mm, which was heat treated to achieve good hemming properties, good weld-ability and formability as in T4 condition. The tool traverse speed was assigned to 80 mm/min and tool rotating speed was 1600 r/min. For inserting the SiC particles a groove of 1 mm depth and 2 mm width was machined out. For performing the experiments double pass method was used in which process is followed both back side and from side. During the process, the SiC particle dispersed and reduced the grain size that caused grain refinement. It is noted that hardness value of AA6061-T4 after FSP without SiC particles is about HV55 and with SiC particles the hardness value was found to be HV75 that is improved due to the finer grains and the dispersion strengthening mechanism.

Devaraju Aruri et al. [9] studied the mechanical and wear properties of 6061-T6 aluminum alloy surface composites produced by FSP. In this work, the influence of tool rotational speed on wear was studied. For the examination of the fabricated surface hybrid composite optical microscope was used. The reinforced particles used were SiC, Gr and Al_2O_3 and they were evenly spread in the nugget zone. The base material used for the work was having 4 mm thickness and the size of reinforcement particles was 20 micrometers. The tool used was made of H-13 steel with 24 mm of shoulder diameter, pin diameter of 8 mm, height was 3.5 mm and the profile was screwed taper pin profile. The micro-hardness improves because of the existence and pinning action of hard SiC and Al_2O_3 particles but the tensile properties after the processing are found to be decreased when compared with the base material, the reason behind this is the brittle matrix because of the existence of reinforcement particles.

R. Dhayalan et al. [10]studied the characterization and properties of AA6063/SiC-Gr Surface Composite Produced by friction stir processing. For processing the experiment surface matrix composite (SMC) was prepared on the surface of aluminum alloy 6063 with ceramic reinforcements, SiC and Gr, using FSP technique. The process is followed with tool rotational speed, traverse speed and axial load 1000 rpm, 30 mm/min and 10 KN respectively. The tool used is formed of HCr with cylindrical threaded profile pin which had the shoulder of diameter 18 mm, length of the pin 5.8 mm and diameter of pin were 6 mm. Three mixtures of surface composites (Al/0.8Vol.%Sic, Al/0.8Vol.%Gr and Al/0.4Vol.%SiC-0.4Vol.%Gr) were prepared. For the inspection of micro-structural changes Scanning Electron Microscope and Optical Microscope were used. The obtained results are the grain Size refinement of the surface composite layer prepared with Gr and SiC ceramic particulate. The micro-structural observation shows the dispersion of the ceramic particulates found to be homogeneous in the Stir Zone and bonding with matrix material is better. The Micro-hardness Analysis shows that the surface composite layer prepared with SiC particle are having higher hardness value than the other reinforcements.

Vipin Sharma et al. [11] studied the micro-structural and mechanical characteristics of AA2014 fabricated by silicon carbide particles as the reinforcement. The tool used was a hot die steel tool (50 HRC) that was having a round bottom conical pin of length 3 mm and the diameter of 5 mm at the top and reduced to 3 mm at the bottom and the shoulder was of 21 mm diameter and concave in shape. The speed of the rotation and the traverse speed of the tool was kept constant at 710 rpm and 100 mm/min respectively. Because of uniform distribution of SiC particles, the defect-free surface is fabricated and the microstructure obtained is re-crystallized equiaxed microstructure, the reason behind is the dynamic re-crystallization during the FSP. During the process, there was the reduction in the reinforcement particles size. The hardness obtained after the friction stir processing was found to be lower than the base alloy because of the precipitation hardening in which the precipitates became coarser but the surface composite showed the increment in the hardness due to the harder ceramic particles incorporation.

Sandeep Rathee et al. [12] studied the process parameters optimization for enhanced micro-hardness of AA6061 reinforced by SiC by friction stir processing. The Taguchi method was used for finding the optimality of the process parameters tool rotational speed, transverse speed and tool tilt angle. For finding out nine experiments were performed and the results obtained were analyzed by the signal to noise (S/N) ratio. The base material that was used for this experiment is an aluminum 6061-T6 alloy sheet with 5 mm thickness that was cut in plate form of 200 mm in length and 60 mm in width. The tool used for the processing purpose was formed of H-13 steel with shoulder diameter, pin diameter and pin height of 20 mm, 6 mm and 2.5 mm respectively and the profile was threaded pin type. After the process, it was found that the fabricated surface was having the more micro-hardness value than the base metal. The reason behind this was the combination of hard nature of reinforcement particles, grain refinement and evenly dispersed reinforcement particles and pinning of grain boundaries. The optimal results for the used work plate were obtained at tool traverse speed 50 mm/min, tool tilt angle of 2.5 degree and tool rotational speed 1400 rpm. It is found that maximum hardness was at nugget zone (116 Hv) which is sufficiently higher in comparison with the hardness of the base material (94 Hv).

C. Maxwell Rejil et al. [13] studied the sliding wear behavior and micro-structure of AA6360 when reinforced by TiC+B_4C by FSP. To fill the particles a groove of 0.5 mm width and depth of 5.5 mm was carried out and the work plate was having 10 mm thickness. Five combinations of particles were prepared as 100% B_4C, 75% B_4C + 25%

TiC, 50% B_4C + 50% TiC, 25% B_4C + 75% TiC and 100% TiC with thoroughly blending. The tool used was made of HCHCr steel and having shoulder diameter, pin diameter and pin length of 18 mm, 6 mm 5.8 mm respectively and the profile was a cylindrical threaded profile and the force applied on the tool downward was 8 kN. The number of passes was two in opposite direction that causes better distribution. The surface composite layer was symmetric about the axis of the tool because of the different directions of passes. Due to that dynamic crystallization occurred and extensive grain refinement obtained (from 80 µm to 3 µm). The dispersal of TiC and B_4C particles was found to be similar as they behave one type of reinforcement. The wear resistance of FSPed surface composite layer was also found to be improved than that of matrix alloy because of the formation of the tribo film.

R. Srinivasu et al. [14] studied the impact of the B_4C and MoS_2 powder on the wear properties of cast A356 aluminum-silicon alloy. The work plate was having 50 mm thickness on which friction stir process was done. The tools used for the process were a) straight cylindrical flat tool (without pin) to filling the powders (size of B_4C powder was 78 µm, 6 µm, and 40 nm and MoS_2 was 30 µm) in the holes of 2 mm diameter and 2 mm depth, b) straight cylindrical tool (with pin) having pin length, diameter of pin and diameter of shoulder of 3 mm, 6 mm and 20 mm respectively. The traveling speed of the tool was 50 mm/min and the rotating speed of the tool was 100 rpm. As it is known that main causes of the poor mechanical properties of the alloy are porosity, coarse silicon needles, and dendrites. During the friction stir processing, there was the breakup of silicon needles, closing of porosity and refining of the dendrites due to the severe plastic deformation and the surface composite is obtained up to a depth of 3 mm that was the length of pin of the tool. Due to the process, homogeneous dispersion of the B_4C particles and MoS_2 particles was observed in the aluminum matrix. The higher hardness was achieved with 40 nm B_4C particles when compared with the 78 µm and 6 µm particle sizes, the reason could be the higher degree of dispersion and the refinement of the grains. The wear resistance is related to the value of the friction coefficient and here that is obtained due to the film formed by the MoS_2 (observed by scanning electron microscopy) that worked as the solid lubricant and decreases the friction coefficient and improves the wear resistance of the alloy.

Narayana Yuvaraj et al. [15] studied the production of Al5083/B_4C surface composite by Friction Stir Processing and its tribological characterization. The analysis of surface composite is done with the help of optical and scanning electron microscope. The tribological performance is checked through a pin on desk test. The mechanical properties of the surface composite after FSP were checked out through universal tensile and micro hardness tests. The fabrication of Al/B_4C composite is done with three pass FSP. When processed surface composite is compared with base material at microstructure it is found that grain size is more fine, hardness is higher (increases from 82 Hv to 124.8 Hv) and higher ultimate strength (increased from 310 to 360 Mpa) and slower wear rate (reduced from 0.0057 to 0.00327 mg/m). The dispersion of Nano particles became uniform in the Al matrix by increasing the FSP passes due to which hardness increased when compared to single pass composite. Due to the existence of nano-sized B_4C particles ultra-fine grain size is obtained which caused the better micro-hardness of Al/B_4C surface Nano composites when compared with B_4C micro particles. The mechanical properties obtained after FSP is far better than Al5083 alloy. The enhancement in the wear properties was found because of the addition of B_4C Nano particles in Al5083 alloy when compared with B_4C micro particles. Nano SCL was having higher wear resistance than the wear resistance of the unreinforced Al5083 alloy.

I. Sudhakar et al. [16] studied the ballistic behavior of AA7075 aluminum alloy reinforced by boron carbide using friction stir processing. As steel is most widely accepted primary material in defence because of its properties like high energy absorbing property, strength, toughness and hardness, Aluminum and its alloys also possess all the required properties but the problem lies with its low melting point, less strain rate sensitivity and poor tribological property. So to improve these properties of AA7075 aluminum alloy friction stir processing with B_4C reinforcements was carried out. The thickness of the work plate was 40 mm and the sizes of the B_4C particles was initially 160 µm and reduced to 60 µm and 30 µm using high energy ball mill and these powder used for the further process. A tool used were of two types a) flat tool and b) tool with a pin having a length of 3 mm. the tool is rotated in varying speed less than 750 rpm to greater than 1200 rpm and it is found that at the higher rotational speed there is severe plastic deformation due to which surface cracks along the tool traverse direction and at the speed less than 750 rpm there was the improper mixing of B_4C particles but at rotational speed of 925 mm to 1000 rpm, plunging speed of 30 mm/min and traverse speed of 50 mm/min surface metal matrix composite (SMMC) is formed without voids along transverse section and surface cracks. Due the heat produced during friction stir process boron carbide particles become smaller and fine in the stir zone than received powder and the proper distribution is obtained as observed by SEM micrograph. A high count of high angle boundaries was found to be developed because of the stirring action of the tool which prevents movement of the dislocation. These factors cause the improvement of the hardness of surface composite. As the 30 µm B_4C particle consists of more particles than coarse grade was the reason of more hardness.

H. G. Rana et al. [17] studied the manufacturing of Al7075/B_4C surface composite by FSP and the wear properties. For processing, Aluminum 7075 had been selected as matrix phase. For the examination purpose of microstructure, image analyzer was being used. In the experiment, three different traverse speeds were used during friction stir processing (FSP). Tool traverse speed had not much considerable impact on the distribution of the particles in nugget zone although best is achieved with lowest traverse speed because an increase in the TS causes insufficient stirring time and this lower powder distribution. Reduction in the micro-hardness with increase in tool traverse speed resulted because of less stirring time and due to that minimization in powder distribution and grain refinement. Highest hardness (144 HV) was recorded at TS of 50 mm/min. Mean hardness of Al7075/B_4C composite fabricated using FSP found to be increased by 1.3-1.6

times greater than base metal (75-80 HV). Wear resistance of the sample processed at lowest tool traveling speed is found to be highest although having highest COF as 0.6. Microstructure study shows the finely dispersed particles in the stir zone for lowest TS sample.

Mohammad Narimani et al. [18] studied the microstructure and the wear behavior of AA6063 reinforced by B_4C and TiB_2 using FSP. The base material of AA6063 was having dimensions 200 x 70 x 10 mm^3. A groove of 1 mm width and 4.5 mm depth were formed to fill with B_4C particles having size varied from submicron to 7 µm and TiB_2 in the form of TiB_2-10 wt. % Al. The tool used for this purpose was hot worked tool steel H-13 having pin length, pin diameter and shoulder diameter of 4.5 mm, 6 mm and 18 mm respectively. The numbers of passes were four, applied in reverse directions in each pass at the tool rotating speed 1000 rpm for first three passes and 710 rpm for the final pass and the tool traveling speed and the tilt angle was 40 mm/min and 2˚ respectively with reference to the normal axis of the tool. For the inspection purpose, optical microscope and field emission scanning electron microscope (FESEM) were used. When FSP is applied on the work plate the rotating tool produces intense thermo-mechanical stresses and plastic deformation and the stirring results in the proper dispersion of ceramic particles. When all the samples (100% B_4C, 25% B_4C-75% TiB_2 and 100% TiB_2) were compared it is found that the increase in the proportion of TiB_2 particles caused the curtailment of gap between fine reinforcement particles, because the TiB_2 particles are more compact than B_4C particles that had the notable impact on the hardness. According to the hall-patch equation, decreasing the grain size cause the enhancement in the hardness. It is known that immanent hardness of B_4C (2800 kg/mm^2) is greater than TiB_2 (2500 kg/mm^2) but 100% TiB_2 surface composite layer when compared with other samples found to be having the highest hardness value, the reason could be the smaller size of the TiB_2 particle than B_4C particles. The B_4C particles are larger having sharp edges when compared to TiB_2 particles so the large B_4C particles inhibit the penetration of round TiB_2 particle and made a mechanically mixed layer when the load is applied, this could enhance the wear resistance of composite layer consisting large percentage of TiB_2.

Dinaharan et al. [19] studied the influence of Ceramic particulate on Aluminum Matrix Composite by Friction Stir Processing. For this purpose, Aluminum alloy AA6082 was used as the base material and different types of ceramic particles such as B_4C, Sic, TiC, Al_2O_3 and WC were used as reinforcement particle. The inspection of microstructure was done by electron back scattered diagram, filled emission scanning electron microscopy and optical microscopy. After inspection, it is found that various ceramic particle produced homogenous diffusion in the stir zone not respected to site and better compound bonding. Alloy AA6082 with ceramic TiC exhibited higher-grade hardness and withstand to wear when compared to different AMCs that are produced at the same set of experimental conditions. FSP is a perfect fabrication method to manufacture AMCs reinforced with different types of ceramic particles with adequate properties.

M. Raaft et al. [20] studied the mechanical, micro-structural and wear behavior of A390/graphite and A390/Al_2O_3 surface composites manufactured using FSP. The effect of tool traveling and rotational speeds was inspected on different behavior and properties of the surface layer. After inspection, hardness is found to be improved of the composite layer with the increase in tool rotational speed. The microstructure of the A390/graphite and A390/Al_2O_3 surface composites depends on traverse as well as rotational speed but traveling speed has least effect on the hardness of the composite layer when compared with the rotational speed of the tool. The Increase in rotational speed and reduction in traveling speed modified the dispersion of the ceramic particulates inside the A390 matrix. The surface composite possesses higher wear resistance in comparison with as-cast A390 alloy and increase in tool rotational speed lower the wear rate of the surface composite. It is also found that the A390/Al_2O_3 surface composite shows the better wear resistance than the A390/graphite surface composite.

M. Sharifitabar et al. [21] investigated the effect of a different number of passes on the 5052Al alloy reinforced by Al_2O_3 by friction stir processing. The base material used for this purpose was aluminum alloy 5052-H32 rolled plate which was having the thickness of 4 mm. The tool used was made of hardened H-133 tool steel whose pin was having the diameter of 5 mm, length was 3.7 mm and the shoulder diameter was 13.6 mm. the tool rotation speed to tool travel speed ratio was varied from 8 to 100 rev/mm and the tilt angle was varied from 2.5˚ to 5˚. The size of nano-size alumina powder was 50 nm which were filled in the groove of 1 mm width and 2 mm depth. Then the specimens were subjected to a number of passes from one to four to investigate the effect on the microstructure. With each pass there was the change in the dispersion of the nano-particles of reinforcement, the dispersion found to be better with each number of pass and the increasing ratio of the tool rotating speed to traveling speed. Due to the stirring and the heat produced during the process the dynamic re-crystallization obtained and due to increased number of passes the grain refinement, the tensile strength and yield strength also improved.

Y. Mazaheri et al. [22] studied the development of the A356 alloy fabricated by Al_2O_3 by FSP. The base material used for the processing purpose, was 10 mm x 50 mm x 250 mm bars. For the reinforcement, a mixture of A356 chips and Nano-sized α-Al_2O_3 powder were used to achieve A356-5 vol. % Al_2O_3 composition. The size of the chips was 200-300 µm and alumina size varied from 50-100 µm to 20-40 nm. The tool used was made of H13 steel rotating at 1600 rpm, traverse speed 200 mm/min and tilt angle were 2˚. It is observed that only peaks related to A356 were visible because, in comparison A356, Al_2O_3 was having low intensity. As the tool pin was having 4 mm diameter and 5 mm length so when tool starts rotating the nano-sized Al_2O_3 particles were dispersed within stirred zone. With help of the optical micrograph homogeneity and uniformity was observed after FSP. When FSP is done on the surface without using Al_2O_3 reduction of hardness and softening was found in stirred zone although having smaller grain size (BM-80Hv and SZ-67Hv), the softening was the result of the dissolution of strengthening precipitates due to heat generated during FSP. But when µ-sized and nano-sized alumina is used there was a significant increase in micro-hardness as 90 Hv and 110 Hv respectively because due to the presence of hard Al_2O_3 particles. So the improved mechanical properties of the A356-Al_2O_3 nano-composite were obtained due to the nanosize of the grain of matrix and due to the fine distribution of Al_2O_3 particles.

J. F. Guo et al. [23] investigated the effect of nano Al_2O_3 particles on the grain evolution and mechanical behavior of Al after FSP. The base material used were rolled annealed AA6061 alloy and for reinforcement purpose, nano-Al_2O_3 particles used (320 nm) and for reservoir purpose of these particles, an array of 960 cylindrical holes was carried out having the depth of 2 mm and diameter of 1 mm. A tool used for the purpose was having a conical pin of 5 mm diameter and 2 mm of length and the tool shoulder was of 12.5 mm and for the inspection purpose of microstructure scanning electron microscope equipped with electron backscattered diffraction was used. It was found that the dispersion was non-uniform after two passes so to improve the dispersion of the particles four passes were performed and after that, the distribution of nano-Al_2O_3 particles was found to be significantly improved. In the base material elongated grains (50µm) were found but in the stirred zone the grains were equiaxed (6.8 µm) in case of without addition of Al_2O_3 after two passes and after four passes without reinforcement grain size was 5.9 µm and after using reinforcement grain size reduced to 2.5 µm, it was because of addition of nano Al_2O_3 particles because other conditions remained same. The micro-hardness in the FSPed alloy was found to be increased mainly because of grain refinement and solution treatment due to the thermal cycle. The tensile strength was also found to be enhanced because of the grain refinement and better dispersion of the nano Al_2O_3 particles.

Zhenglin Du et al. [24] investigated the properties of aluminum reinforced by alumina and carbon nano-tubes by FSP. The base material for the study was rolled AA6061 in annealed condition on which an array of 720 cylindrical holes was carried out for the reservoir purpose for reinforcement. The holes were of 2 mm in depth and diameter was 2 mm also. The increase in the number of passes and rotational speed has a good effect on the dispersion and it is found that carbon nano-tubes (CNTs) uniformly disperse after three passes so three passes were carried out. Al_2O_3 particle size was 320 nm and CNTs were having the varied outer diameter from 10 nm to 20 nm and length varied from 10 µm to 30 µm. for increasing the concentration slurry mixture of Al_2O_3 and CNTs was used. The tool was a threaded conical pin (diameter of 5 m, length of 2 mm), shoulder diameter was 12.5 mm and the tool rotational speed, traveling speed and tilt angle were 1200 rpm, 3 mm/s and 3˚. The dispersion of particles was found to be more uniform as the numbers of the pass were increased. Uniform distribution of Al_2O_3 was observed but in the case of CNTs, it was not visible the reason behind this was the breaking of CNTs during the first pass and after the third pass, they could not be observed. Due to the tool rotation and travelling there was the dynamic re-crystallization because of that significant grain refinement was observed (from 70 ± 3 µ to 5 ± 2 µm) when FSP was done but it was found that adding CNTs cause a minute contraction in grain size but when nano Al_2O_3 was introduced significant contraction in grain size (2.5 ± 2 µm) was observed but when both were added together grain size found to be 3.1±1 µm. Because of the grain refinement, the significant increase in hardness value was found. When Al_2O_3 was added then there was a notable enhancement in yield strength and ultimate strength when compared to AA6061 specimens but in the case of only CNTs added there was an increase in yield strength but ultimate strength was found to be decreased. But when both Al_2O_3 and CNTs were added together as reinforcement the ultimate tensile strength and yield strength increased remarkably.

W. Hoziefa et al. [25] investigated the influence of the FSP on the microstructure and mechanical properties of AA2024-Al_2O_3 composite. The tool used for this purpose was an H13 steel tool with pin length, pin diameter and shoulder diameter of 6 mm, 6 mm and 20 mm respectively and the profile was cylindrical. The rotational speed of the tool was 400 rpm; traveling speed was 20 mm/min and the tool tilt angle 3˚. The AA2024-Al_2O_3 nano-composite was obtained by adding 1 wt. % of Al_2O_3 nano-particles into an AA2024 aluminum matrix at the semi-solid state by mechanical stirring. Due to the addition of nano-particles during compo casting process circular pores were formed as well as some air entrapment during stirring in AA2024-Al_2O_3 nano-composite. But in unreinforced FSPed alloy because of material plastic flow some defined border at advancing side and diffuse interface at retreating side observed that significantly reduced porosities. In FSPed reinforced alloy, there was a significant grain refinement due to dynamic re-crystallization. Grain size reduced from 28 µm to 2.3 µm in as-cast alloy without nano-particles and FSPed nano-composite respectively. The micro-hardness found to be increased due to the grain refinement and another possible reason was the better dispersion of nano-particles. For tensile strength adding nano-particles in the semi-solid zone by simple stirring is not favourable as seen in this work that ultimate tensile strength reduced by 70%. But after FSP on unreinforced alloy, there was an enhancement of 25% in yield strength (YS) and 52% in ultimate tensile strength (UTS) because of the elimination of casting defect. When FSP was done on reinforced nano-composite an enhancement was found in UTS, the reason behind this the presence of Al_2O_3 nano-particles (71% increase in UTS and 30% in YS).

2.1 Conclusion from Literature and Identification of Research Gap

In this study, the effect of the different types of reinforcement such as SiC, B_4C, and Al_2O_3, on the aluminium alloys are described. As aluminium has a great potential of using in defence, automobile, aerospace, and many other fields because it has good strength, light weight, and energy absorbing ability but the problem lies in melting point and poor tribological properties. So to overcome these properties some reinforcements are used. But dispersion of the reinforcement in a uniform manner is a very tedious task but it can be achieved via friction stir processing because it induces intense plastic deformation where true strain can be obtained as high as 40 in the processed zone so the reinforcement particles can be incorporate to form a composite. By doing so the mechanical properties such as hardness, ultimate tensile strength, yield strength and wear resistance of the Aluminium alloy can be increased. Basically, these properties depend upon the combination of various parameters mainly the tool rotating speed and number of passes. It is also seen that when two reinforcements are used at same time improvement in the properties is significant, so for the future work, the combination of more than two reinforcement particles can be used to investigate the effect of using them on the properties at different tool rotating speed and number of passes.

CHAPTER 3

OBJECTIVE AND SCOPE

3.1 Objectives

The development of FSP makes possible modification of the surface of aluminium alloy. The aim of this investigation is to evaluating the effect of FSP on 7075 aluminium alloy to attain the following objectives.

1. To develop a B_4C composite reinforced aluminium alloy through Friction stir processing.

2. Analyze the homogeneous distribution and metallurgical characteristics of reinforcement.

3. Study of selected process parameters on mechanical properties and metallurgical properties.

3.2 Scope

This study gives the scope that friction stir processing (FSP) has many benefits over the conventional methods. Being one of the most efficient techniques for micro-structural alteration to obtain the grain size and other properties but further research has to be done in many areas of FSP. The following can be done:

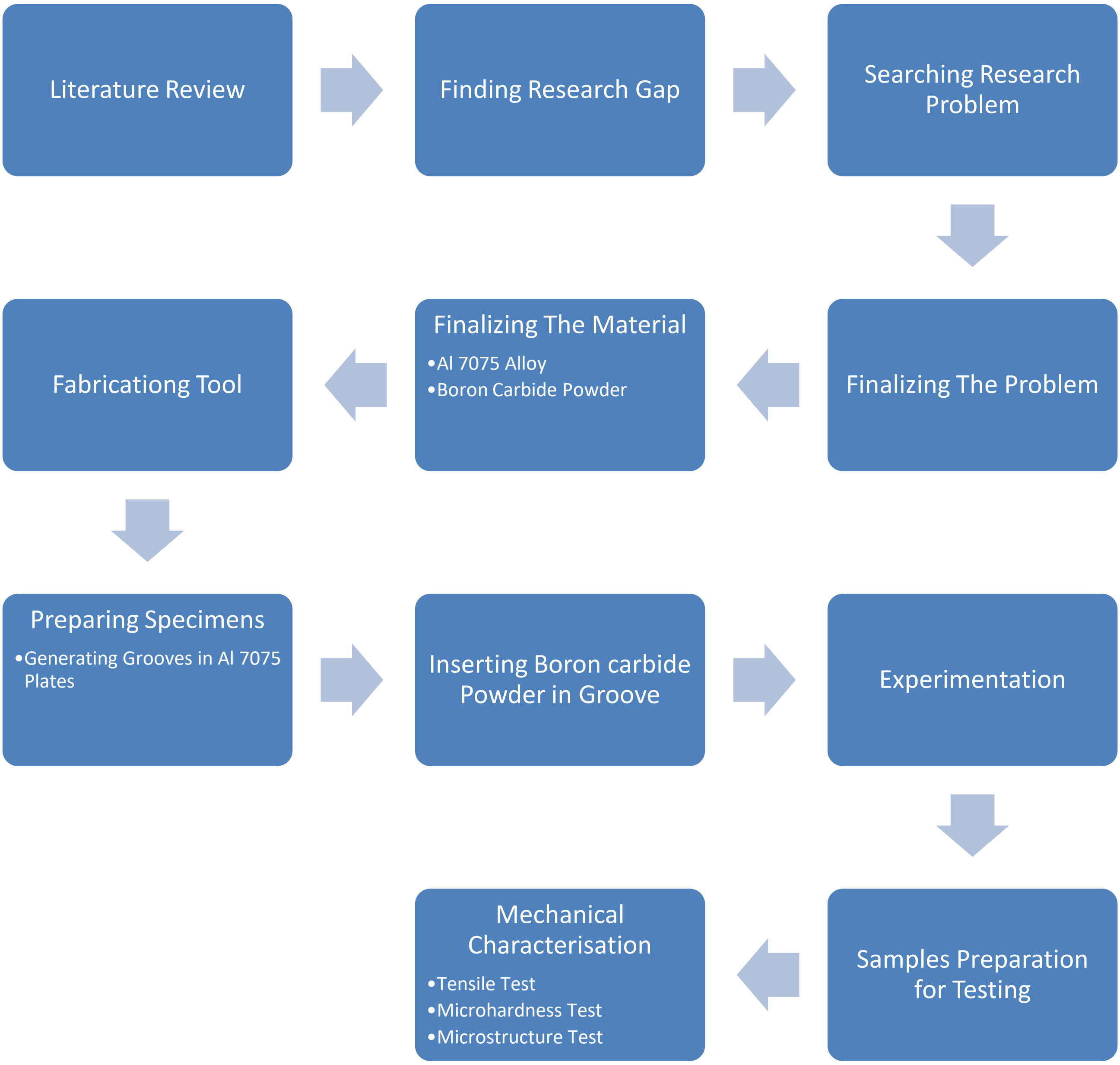
1. Experimentation for the study the effect of tool design on the process and optimizing the process parameters.

2. Investigating important mechanical properties of friction stir processed reinforced composite.

CHAPTER 4

RESEARCH METHODOLOGY

Examination of the impacts of process parameter (Speeds of the tool, Transverse speed and Diameter of pin of tool) on the microstructure, hardness and nature of the friction stir processed pass of Aluminium plate. In this chapter the research methodology and material used have been discussed.



Flow Chart of Research Methodology

4.1 MATERIAL USED:

The material use in the proposed research is aluminium Alloy 7075 and B_4C composite as reinforcement.

4.1.1 Aluminium Alloy 7075:

It is an aluminium alloy, which consist of zinc as the primary alloying element. 7075 alloy is considered as a strong alloy when compared with many steels in terms of strength. 7075 is having moderate machinability and very good fatigue strength. If cons are considered then it is having less resistance to corrosion than other aluminium alloys [27].

7075 is composed of 5.6-6.1% zinc, 2.1-2.5% magnesium, 1.2-1.6% copper and approx 0.5% silicon and chromium. The density of 7075 is approx 2.810 g/cm^3. It is having many tempered states as 7075-0, 7075-T6, 7075-T651. 7075 is having tensile strength varying from 250 MPa to 505 MPa and yield strength 140 to 435 Mpa [27].

7075 is having high strength to density ratio that why it is generally used in marine, automotive and aviation transport applications. Other than these it is used in manufacturing of rock climbing equipment, hand-glider airframes and bicycle component [27].

7075 is having many trade names including Ergal, Aircal and Fortal Constructal [27].

4.1.2 Boron Carbide (B_4C):

Boron carbide is a high performance ceramic abrasive material which is extremely hard. Its chemical and physical properties are similar to diamond [32].

Chemical Properties:

Industrial grade – Boron 77% and Carbon 17% max

Standard Grade – Boron 74% and Carbon 24% max

Nuclear Grade – Boron 76.5% min

High Purity Grade – Boron 75-80%

Boron Carbide powder is generally used for modification of steel, high pressure water jet cutter nozzles, Cutting Tools, Dies and Metal Matrix Composites [32].

Table 4: Specification of Boron Carbide [32]

Molecular Weight (g/mol.)	55.25515
Colour	Black or Dark Gray
Theoretical Density (g/cm^3)	2.51
Melting Point (°C)	2450
Boiling Point (°C)	3500
Thermal Conductivity (W/m-k)	28
Specific Gravity	2.51
Specific Heat (cal-mol-c)	12.5

4.2 Proposed Work Plan

Activities	Sep		Oct		Nov	
	1-15 Sep	15-30 Sep	1-15 Oct	15-31 Oct	1-15 Nov	15-30 Nov
Literature Survey						
Finalizing the Problem						
Finalizing the Workpiece and Tool Material and Reinforcement						
Procuring Material						
Learning Working of CNC						

4.3 MECHANICAL CHARACTERISATION

4.3.1 Tensile Test

Tensile test is performed by gripping a specimen at both ends and subjected it to increase axial load until it break. During the test recording of load and elongation data allows the researcher to determine several characteristics about the mechanical behavior. To perform tensile test the tensile specimens prepared using milling machine according to ASTM standard.

4.3.2 Microhardness Test

In micro-hardness testing Digital Microhardness tester is used. A load of some amount will be employed for a specific loading time (seconds). It determines the hardness of base metal, TMAZ, HAZ and process nugget over small positions on the surface to indicate the deviation in hardness for each place according to ASTM standard.

4.3.3 Microstructure Test

The specimens for microstructure test are prepared with the standard metallographic techniques. Optical microscope and SEM will be used to reveal and study microstructure before/after FSP.

CHAPTER 5

EXPERIMENTAL SETUP AND PROCEDURE

5.1 Experimental Setup

The FSP process is very convenient that can be done on milling machine. In this research work TAL V-350 CNC vertical milling machine will be used.

Fig. 5: TAL V-350 CNC Vertical Milling Machine with Fixture

Tool is also important equipment, which will be used for stirring metal. Tool used will be made of H13 steel.

Design Fixture:

Length – 40 cm

Width – 40 cm

Thickness – 3.8 cm

Material – Cast Iron

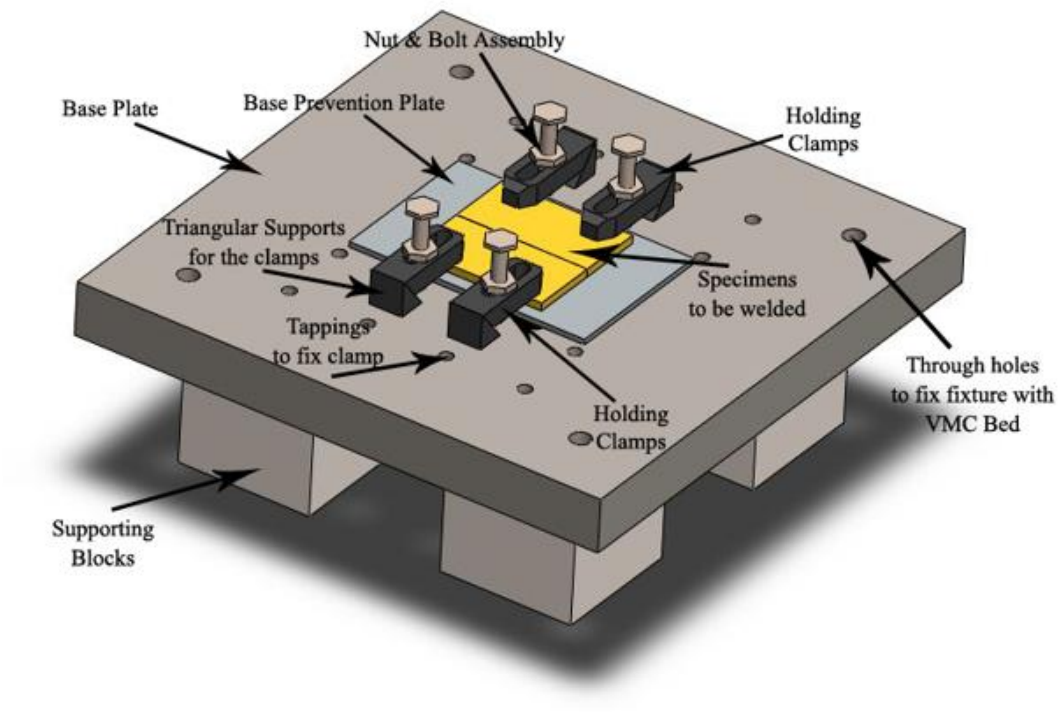


Fig. 6: Schematic View Design Fixture

5.2 Experiment Procedure:

Aluminium Alloy plate which is going to be processed is clamped with the help of fixture before the processing start. The fixture consist a specially designed plate which is having groove to fixing the plate and holding workpiece during process. After clamping, process starts in which a tool which having pin of some specific length drilled into the workpiece and start rotating at desired rotational speed (RPM) and travelling at desired traverse speed to cover the length of workpiece.

When pin of tool penetrate workpiece, shoulder of tool start rubbing surface of workpiece and due to friction heat is generated. Due to that a heated zone formed and the action of pin changes the microstructure of the workpiece at that stirring zone.

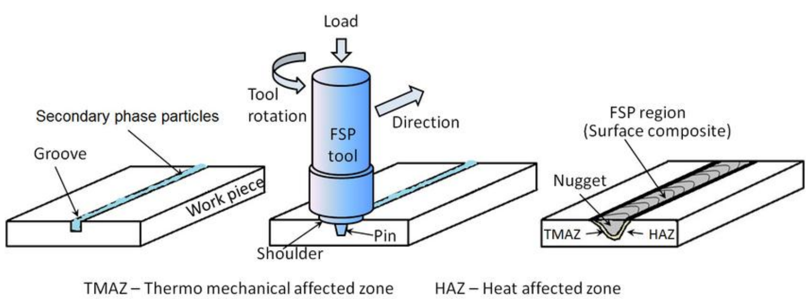


Fig. 7: Schematic View of Experimental Procedure [33]

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