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Aluminium Metal Matrix Composites and Its Mechanical and Tribological Properties: A Review

Dhananjay Tiwari[1], Neeraj Kumar[2]
[1]*M.techScholar, Dept. of Mech. Engineering, PKGCET PANIPAT,Haryana.*
[2] *Assistant Prof., Dept.ofMech.Engineering, PKGCET Panipat,Haryana.*

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ABSTRACT
The material selection for the various components of the automobiles,power plants, aviation,sheet metals and defence industries are highly complex and challenging because of the concerned related to the economy of the fuel,improvedsafety,overall cost, material availability,energy efficiency and global warming[1].
Aluminium metal matrix composite(AMMCs) plays a crucial roles in various fields due to its unique properties. Properties like good strength to weight ratio, elevated wear resistance as well as truncated cost shows rise in the order of aluminium based composites. Numerousmanufacturing facilities are accessible to produce these composites. In the phase of liquid, Stir casting process widely accepted to manufacture aluminium based composites or composites having aluminium as the matrix phase. The paper i am writing is going to review the effects that reinforcements are contributing to improve the mechanical as well as tribological behaviour of the casted aluminium based composites or one can see how the changes has been noticed when reinforcements were added the natural aluminium alloys.The reinforcements used wereB4C(Boron carbide),SiC(Silicon carbide),Al_2O_3(aluminium oxide) to produce composites. As our targets to identify or to find out the changes in the behaviour of mechanical and tribological characteristics of the MONOLITHIC COMPOSITE(if single reinforcement is used) or HYBRID COMPOSITE(if more than one reinforcement are used) [2].

Keywords-Aluminium Metal Matrix Composites (AMMC), Metal Matrix Composites(MMC), Boron Carbide(B_4C), Silicon Carbide(SiC), Al_2O_3 (Alumina),Stir Casting, Mechanicalcharacteristics, Tribological characteristics.

I. INTODUCTION

Composite materials specially metal matrix(or base material is metal) composites (MMCs) were manufactured with two, three or many different base and reinforced materials to have the desired or needed characteristics. We know that the composites were widely used or you can say that now it is being highly preferred material because of it's improved properties like improved in the stiffness as well as strength,dimentional stability being improved, also increasement in the toughness, increase in compressive and impact strength , reduced expansion due to heat(or thermal expansion),lowered weight, enhancement in the corrosive nature and reduction in the wearing of the composite, and the best thing that a research scholar or a manufacturing unit or a consumer is looking for is the cut off in the price of the material[3]. Now a days aluminium matrix based composites are in a huge demand for both internal and external uses.One can see the uses or the applications of such composites in the sheet metal industries, automobile industries, aviation industries, aerospace engineering, military and different engineering sectors. The natural aluminium (Al) is being classified into the various grades as per the major or highly added elements like Cu, Mn, Si, Mg…and so on. These are the different grades of aluminium with the majorly alloying elements 1XXX (purely Al- alloys), 2XXX(Al-Cu alloys), 3XXX(Al-Mn alloys), 4XXX(Al-Si alloys), 5XXX(Al-Mg alloys), 6XXX(Al-Mg-Si alloys), 7XXX(Al-Zn alloys), 8XXX(Al-Li alloys)[4]. Composites will be formed with the two different phases that is continuous or matrix phase and discontinuous or reinforced phase. We can classify the composite materials as per the reinforcement phase into three sub class as: a) Dispersion strengthened, in this the

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reinforcement particles distributed with uniformity, b) Fiber reinforced, in this the continuous fibres were distributed in entire composite and c) Particle reinforced, in this the particles with size larger than one micron(>1µm) are presented in the manufactured composites[5]. There are numerous methods such as casting, extrusion, spraying, forging and so on to fabricate or manufactured an aluminium based composite. There are other processes too which are used as a manufacturing methods for the aluminium based composites like powder metallurgy(PM technique). Now a days the widely used process for the fabrication of the composite based material(like MMCs) due to least cost of fabrication is stir casting method. In the fabrication of aluminium based composites we added the reinforcements like SiC, SiO_2, Al_2O_3, TiC, B_4C, graphite powder, flyash so on, for the improvements in all the mechanical as well as tribological properties of the composites. Also we do heat treatment process on the fabricated composite for the enhancement of its properties and the inner granular mechanism of the casted aluminium based metal matrix composite(AMMC). As we know that before the process of heat treatment the composite formed having flexibility for different shape formation while the heat treatment awarded better strength and wear resistance[6]. There are some researchers who had examined the thermal ageing effects on the mechanical as well as tribological properties of the composites.The improvements in the mechanical as well as tribological behaviours of the composites with the help of various strengthening mechanisms like dispersion strengthening, solid solution strengthening, as well as grain boundary strengthening will be done. The metal based matrix composites(MMC) is being frequently used as the strengthening tool to enhance the properties of the material. In Aluminum based metal matrix composite(AMMC) the base or matrix phase is aluminium alloy of any series while the addition of foreign material into it is in the reinforcement phase as reinforcements like aluminium oxide(Al_2O_3), boron carbide(B_4C), silicon carbide(SiC), graphite powders or flyash. Advanced metal based matrix composites(MMC) such as Aluminium metal matrix composites(AMMCs) are widely used in underwater application, transport engineering, sheet metal manufacturing, aerospace industries, military aviation and many more that is we can say that aluminium metal metal matrix composite(AMMC) is a solution to all above applications of these days.Adequate interaction among reinforcements and the matrix phase is necessary to have strong bonding.The emergence of tribo-layer and mechanically mixed layers is being attributed to cut down the wear rate that's been affected by the sliding speed, loads level and the contents of the reinforcements. The end results could be adverse or depending upon the bonding between the matrix phase and reinforced phase as well as the wear characteristics.This work of the review paper is to read thechanges in the properties of the composites when added with the different-different reinforcements with the base material is aluminium alloy of different grades.

Table 1:Different cast aluminium series,with their strength information shown.[7]

Aluminum Alloy Series	Major Alloying Elements	Heat Treatable	Utimate Tensile Strength UTS (ksi)	Yield Strength (ksi)	Corrosion Resistance
1xxx	Pure Aluminum	No, but work hardenable	10 to 27	4 to 24	Excellent
2xxx	Copper (Cu)	Yes, Precipitation Hardenable	27 to 62	10 to 66	Poor
3xxx	Manganese (Mn)	No, but work hardenable	16 to 41	6 to 36	Moderate
4xxx	Silicon (Si)	No, but work hardenable	25 to 55	-	Good
5xxx	Magnesium (Mg)	No, but work hardenable	18 to 58	6 to 59	Excellent to good
6xxx	Magnesium and silicon	Yes, Precipitation Hardenable	18 to 58	7 to 52	Good
7xxx	Zinc with Cu, Mg, Cr, or Zr	Yes, Precipitation Hardenable	32 to 88	14 to 73	Poor
8xxx	Lithium, tin, and iron	Varies with specific alloy	17 to 60	-	Varies with alloy
9xxx	Unused for future alloys	NA	NA	NA	NA

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Aluminium forming process involved drawing, forging, cold rolling so on and with the various alloying elements we will be able to make the different series of aluminium that could be used for the matrix phase of the composites as required by the manufacturer. you can see below the table 2:[8]

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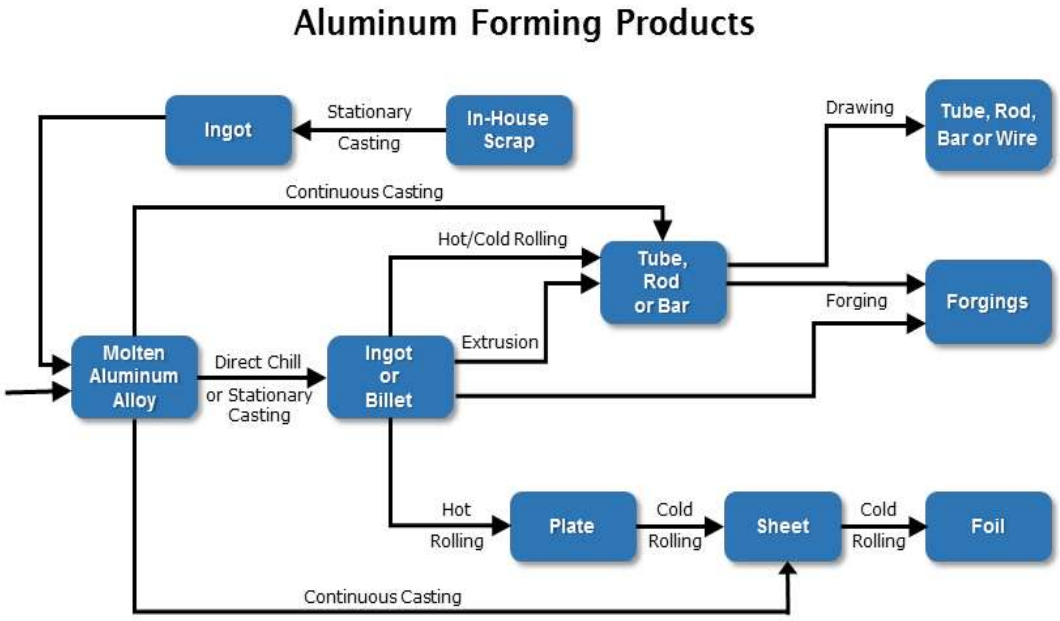

Table 2: Manufacturing aluminium shapes-bar, rod, sheet, plate, tubes, ingots, wire.

II. LITERATURE REVIEW AND OBJECTIVE

During the literature studies of various work on the AMMC; i found that there are many scholars worked on hybrid AMMC or mostly worked with the silicon carbide(SiCp) reinforcement or aluminium oxides(Al_2O_3) or boron carbide(B_4C) in our country as well as abroad. but very few researchers had worked with the monolithic composite with the boron carbide(B_4C) . The contributions of the AMMCs in the fields aerospace engineering, military applications,automobile industries,sheet metal manufacturing and many more[9]. so i started reading and collecting some more informations on this interesting topic and some paper that i gone through had helped me so much from various universities sites, different books, international journals as well as google and other media plateforms to write this review paper,and here i would like to mentioned some among many as:

Table 3: A brief literature review on AMMC and its mechanical and tribological properties:

S. No.	Authors	Descriptions	Remarks
1.	Arunkumar,Et al.[3]	Investigation of mechanical as well as tribological characteristics of aluminium metal matrix: a review.	Study of the changes in properties.
2.	Rajatkumar,Et al.[1]	Advances in the development of aluminium based metal matrix composite as alternative piston material: a review.	AMMC application as alternative for piston use.
3.	Kavianomarcooke.[9]	Aluminium Alloys and Composites.	Application of AMMC.
4.	Dr.syedahamed,Et al.[10]	A review of the literature on aluminium-7075,metal matrix composites.	AMMC-7075 and different reinforcement.
5.	R.Ranjithkumar,Et al.[11]	Optimizing of properties in the molybdenum di-sulphide as well as titanium carbide reinforced with Al-composites.	Reinforcement optimized properties.

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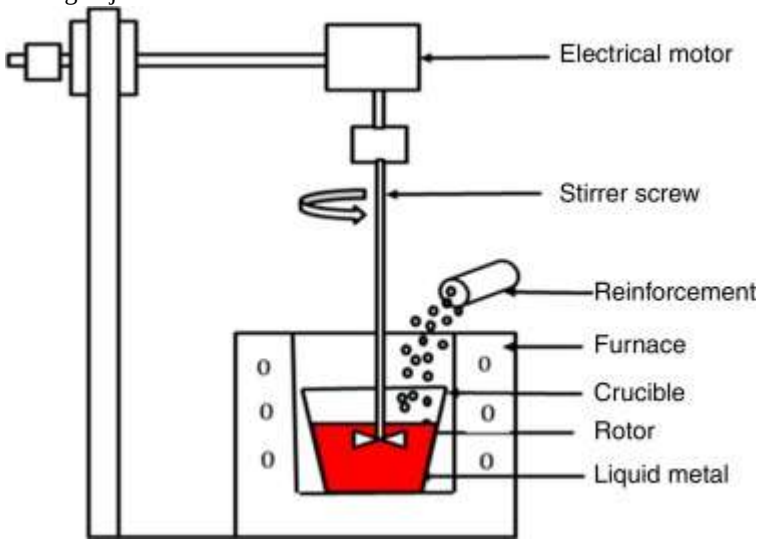
6.	N.Makhaldiani,Et al.[2]	Coating of Cordierite Monolith Substrate by Washcoat and Hybrid Nanocomposite.	Monolithic and Hybrid composites.
7.	Diptikanta, Et al.[6]	Fabrication& heat treatment process of ceramic reinforced aluminium based matrix composites: a review.	Heat treatments of the AMMC

III. METHODOLOGY

In the recent times the worlds necessity of the least cost, best performing and high quality composites had been increased; this increased demand pushed the researchers across the globe to shift their idea of manufacturing of monolithic composites to the hybrid composites.[12]
As we know the aluminium is available in a huge quantity but its least hardness and flexibility cause problem at the higher temperature applications as it mostly failed functioning. When the idea of different reinforcements came into picture then only this sector had been revolutionalized.

Stir casting method of formation of composites: The piece of composite developed by the stir casting method using mechanical stirrer or sometimes it could be the manual stirring of the molten aluminium based alloys of any grade. The powder forms of the different reinforced materials were pre heated and being injected to the molten aluminium alloys around 750^0C-800^0C, at the any type of resistance under a controlled atmosphere of argon.The very fine powders of chosen reinforcements will be added to the molten metal has been taken as the weight percentage of the base material in a 0, 3,6,12 weight percentage or 0, 5, 10, 15 and 20 weight percentage [13]. As i discuss above the temperature of the furnace has been taken into the range of 750^0C to 800^0C and the stirring continued for almost 10 to 15 minutes for the production of a homogeneous molten metal mixture at a stirring speed of 400 rpm(or it might be chosen a manual stirring with a stirrer) and after that the crucible taken out of the furnace and the molten metal had been poured into the desired shape of the mould and allowed to solidify and then it had been taken out of the mould. We can see the other composite casting methods in table:4 below:-
See schematic diagram of stir casting technique for AMMC.[14]



Procedures of experiment: The very fine microstructure surfaces prepared with the help of grit papers of 200-1000 and sometimes it had been polished with the paste of diamond. Optical microscope had been used to investigate the microscopic structure of the casted composites, the other mechanical properties like hardness of the composite is tested on Brinell hardness tester or Rockwell or Vickers methods. For the strength test of the material the researchers used universal testing machine (UTM) either it would be tensile or compressive strength of the material and for the tribological property like wear test which could be used further to examine the coefficient of friction

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the researchers opt for Pin on Disc tribometer. S.E.M(Scanning electron microscope)investigation were being conducted for the reinforced powders and the casted composites.The modelling of wear rates by the R.S.M.(Response surface methodology) were done: The factors that influenced friction coefficient as well as wear rate are the weight percentage of the added reinforcement powders and load along with the sliding distance[15].

Table:4 different methods of casting od metal matrix composites[16].

Route	Cost	Applications	Comment
Powder metallurgy	medium	For the productions of the objects like bolts, different valves, piston bodies and high strength and heat resistance objects.	Matrix as well as reinforcements added were best in the particulate form because here no melting is involved,not any zone of reaction found and it showedgreat strength of the composites.
Ultrasonic assitedcasting	expensive	Applied in the casting of the complex structured components for the mass production.	We can say it's in uniform distribution as well as better dispersion of the reinforced particles.
Diffusion bonding	High	Used for the productions of the sheets, vane, blades, shafts, and structural components.	Used in foils, matrix sheet or filaments of the elements of reinforced.
Fractioned stir casting.	medium	Automobile as well as aviation industries.	Applicable in the modifications of the surfaces because the micro hardness had been improved as well as wear resistance improved too.
Stir casting.	Low expensive	Applied for the mass production and for the commercial uses of aluminium based composites.	Applicable for the particulate reinforcement in AMMC and depends on the properties of the base material and process parameter.
Squeezed castings.	moderate	Hugely used in the automobile applications, for the productions of the parts like connecting rods, piston-cylinder, rocker arms, heads of the cylinders as well as some other complex parts of the engine.	Preferred for mass production and applicable for any type of reinforcements.
Sprayed casting.	moderate	Mostly preferred to produce friction material, electric brushes, grinding as well as cutting tools.	Reinforcements used were particulate types. High density materials could be casted.
In-situ (Reactive) processing	Expensive	Automobile applications	Homogeneous distribution of the reinforcing particles.

Liquid metal infiltration.	Minimum cost.	In the production of structural objects like rods, tubes, beams.	Reinforcement filaments were used.

IV. CONCLUSIONS

There is an ample scope of research gap exists in the development of AMMC for the various uses with the effective reduction in cost and without the invention of the new material that seems to be the need of the hour. The scholars working in the fields of the composite materials can expand this very interesting ideas of reinforcing the hybrid aluminium based metal matrix composite that enhances its mechanical as well as tribological attributes of the materials which are in a huge demands from the different sectors like automobile, aerospace, military and manufacturing industries because of the low cost, high performance ratio and less or no effect on the environment.

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