A Review on Mechanical properties of Aluminium 2024 alloy with various reinforcement metal matrix composite

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Abstract

Since last few years, metal matrix composites (MMC'S) have shown a prominent class of materials for structural, wear, thermal, transportation and electrical applications. There are numerous techniques available for making particle-reinforced Metal Matrix Composites (MMCs) starting from powder metallurgy method to casting techniques. Among the whole liquid stir production route is versatile because of its simplicity. Same as there are several base metals to produce MMCs among them Aluminium plays a vital role. The present work is focused on to study the various mechanical properties such as ultimate tensile strength (UTS), yield strength, hardness and microstructure behavior of composite of aluminum 2024 alloy and also determine the best reinforcement material and best suited method to fabricate the aluminum 2024 composites.

Keywords: **Aluminum 2024 alloy, mechanical properties, fabrication techniques, Reinforcement material.**

1.1 INTRODUCTION

Nowadays the transportation industries such as automobile and aerospace industry always demand a material which is light in weight and ability to work under high temperature condition (1-5). Composite fulfill this demand in very appropriate manner. The metal matrix composites are combinations of two or more different materials with at least one as a metal and another one as a ceramics or organic compound. Because of its mechanical properties such as very high strength to weight ratio, superior wear resistant, greater stiffness, better fatigue resistance, and good stability at elevated temperature, the Aluminum matrix composites and hybrid Aluminum matrix Composites becomes great choice for automobile and aerospace industries(5-8). Aluminum matrix composites are basically used with the reinforcement of extremely hard materials like, Silicon carbide(SiC), Alumina (Al_2O_3),Boron nitride (B_4N), Boron carbide (B_4C), AlN, TiB_2 and organic reinforcements such as fly ash(8-12). All These reinforcement material have prominent properties over base metal alloy such as improved thermal conductivity, abrasion, low density, high toughness, higher

fatigue endurance, durability, machinability, corrosion resistance etc. The main object of this study is to observe the characteristic behavior and mechanical properties like as tensile strength, hardness, toughness of aluminum 2024 alloy matrix composites with the use various reinforcement during the different ways of fabrication process.(12-16)

Suitability of Aluminum Alloy 2024 In Transportation Industry

Aluminum alloys is the most widely used matrix materials in MMCs, both in R&D and in industrial applications. This is due to the low density of Aluminum alloys, strong corrosion-resistant property and less costly if compared with other low density alloys such as Mg or Ti(17-18). In addition Aluminum alloys have excellent mechanical and technological properties like high strength to wear ratio, cast ability, weld-ability and machinability. There are various types of aluminum alloys exist from which Alloy 2024 is one of the most prominent aluminium alloy, with copper as the primary alloying element. Alloy 2024 continues to maintain strength characteristics and high corrosion resistance(19-21). Because of its high strength and fatigue resistance, 2024 is widely used in aircraft, especially wing and fuselage structures under tension, aircraft fittings etc.(22-24) aluminum alloy 2024 is used basically in two forms such as plate form and sheet form. The first one means Plate forms require properties such as stiffness, good fatigue strength for the used in shear webs and ribs, fuselage structures, wing tension members and other structural areas of the aircraft. On the other hand, in sheet forms, are used in commercial and military aircraft for fuselage skins(25-28).

Suitable Method To Fabricate Metal Matrix Composite

After the observation of different type of research paper and articles it was found that there are several techniques to produce aluminum matrix composites, starts from powder metallurgy to casting method(29-31). Another prominent aim of this review article is to recognize a fabrication method which is best to produce a composite of aluminum alloy 2024 with cheap and simple production method. Among the entire liquid state production route stir casting route are simplest and cheapest(32-34). Because of its better stirring action, stir casting processes improve the bonding strength between the reinforced particles and matrix.

2.1 CURRENT STATUS OF RESEARCH

Many researchers and their fellows have done the research on metal matrix composites. The available literature is related to the Aluminum matrix composite with various reinforcement and different fabrication method. **K G Sagar *et al.* [1]** investigated the mechanical property of Aluminum alloy 2024 with beryl as the reinforcement. Study reveals that there is an up gradation of ultimate tensile strength by 107%, hardness by approx 11% and the toughness increases almost 300%. Hence it is clearly visible that Al 2024- beryl composites have improved significant property than Al2024 As-cast material. **Ch. S. Vidyasagar *et.al.* [3]** developed Aluminum alloy 20024 based metal matrix composites with yttrium reinforcement through SPS method. In this study it was found that at 0.3 wt% yttrium reinforcement achieved peek properties but when yttrium content increased beyond 0.3% the property tend to decrease gradually. In this investigation the mechanical property such as hardness, UTS, YS are found to be 114 HV, 388, and 343 MPa respectively. **S Venkatesh *et. al.* [4]** investigated synthesis Aluminum - silicon agro wasted based hybrid metal matrix composites. In this investigation Al 2024 reinforced with SiC and anacardium occidentale ash to enhance the mechanical properties. The result shows that the

hardness of the hybrid composites decreases slightly with increase in cashew nut shells ash content with maximum reduction.

Preetam Kulkarni et.al [6] developed the Aluminum-E- glass fly ash composites. In this investigation Aluminum alloy 2024 is used as a metal matrix and E-glass fly ash as reinforcement. The specimen was tested for tensile and compression strength using UTM and it was found that the aluminum matrix composites has obtained better tensile and compression strength when compared to metal alloy itself. **A Albiter *et.al.* [9]** fabricated an aluminum metal matrix composite reinforced with Tic via pressureless melt infilteration and investigated the microstructure study and heat treatment response of composite. The study reveals that after heat treatment there is an enhancement in Mechanical properties of the composites Such as increased in hardness from 28.5 to 38.5 HRC; whereas UTS increased from 379 to 480 MPa. **Huabing Yang *et.al.* [10]** developed an aluminum(2024) metal matrix composites with the reinforcement of TiC via casting method. The result shows that the increment in mechanical properties like ultimate tensile strength increased from 105 MPa to 151 MPa and the value of yield strength increased 84% of its previous value whereas the elongation of material decreased.

P. Egizabal *et.al* [12] developed metal matrix composites Al alloy 2024 and reinforced TiC by stir casting process. The results obtained in the metallurgical analysis and mechanical tests confirmed that the presence of TiC particulates has a positive effect on mechanical properties through different mechanisms such as grain refining and reduction of porosity. Small agglomerations as well as individual particulates are mainly located in the intergranular region. Most of the particulates present a size ranging from 1 to 5 microns. **P.B. Li *et.al* [13]** developed an aluminum alloy 2024 with reinforcement of SiC particles by powder thixoforming method and investigated the mechanical properties and microstructural behavior of the composite. In this investigation it was found that the tensile properties of the composite increased by 235.4% and elongation decreased by 31.0% when compared to those of the as-cast 2024 alloy. **Shashi Prakash Dwivedi *et.al.* [14]** developed a composite of Al 2024 alloy by utilizing ground nut shell ash as reinforcement material to enhanced the mechanical property. It was observed that waste groundnut shell (agricultural residues) is inexpensive which can be used as reinforcement for the development of the metal matrix composite as well as its enhanced the mechanical properties of the composites.

Sairam Varma G *et.al.* [15] fabricated a metal matrix composites AA 2024 reinforced with TiC by using stir casting method. The main purpose of this study was to evaluate the microstructure and mechanical properties of the material. It was found that an incremental value of mechanical properties such as UTS, YS and hardness.**S. Suresh Kumar *et.al.* [16]** developed an aluminum(2024) metal matrix composites reinforcement of B4c-Tic via casting procedure and investigated mechanical properties of the composites and further investigate its machinability. In this investigation it was found that the fabricated hybrid composite, AL2024-TiC-B4C is having the improved mechanical properties such as hardness, tensile strength, ultimate strength and yield strength and decreases the impact strength due to the increased ceramic fillers. **Huabing Yang *et al.* [17]** fabricated an aluminum(2024) matrix composites reinforced by TiC fabricated by casting method and investigated the mechanical properties of 2024 Al matrix nanocomposite network architecture. The experimental result shows that an enhancement in mechanical properties such as the ultimate tensile strength was increased from 105 MPa to 151 MPa, whereas elongation reasonably decreasing from 9.5% to 7.1%. In this investigation, 2024 Al matrix composite

reinforced of TiC nanoparticles. The 2024Al–TiC nanocomposite exhibited enhanced mechanical properties compared to 2024 base alloy.

N. Muralidharan et.al [21] prepared Aluminum matrix composites with the reinforcement of ZrB2. In this experimental investigation it was found that there was a refinement of grains in the composite due to ZrB2 particles. The mechanical properties such as UTS, YS were improved remarkably by the reinforcement of ZrB2 particles. **Nassim Samer *et.al*. [24]** developed a metal matrix composite reinforced by nanometer sized TiC particles obtained via a novel synthesis route. This study observed that the high reinforcement volume fraction, with a Young's modulus of 110 GPa, an ultimate tensile strength of about 500 MPa and a maximum elongation of 6%.**Bo Chen *et.al* [26]** fabricated aluminum (2024) matrix composites with reinforcement of TiB_2 via laser-powder directed energy deposition method and investigated the microstructural study and mechanical properties of the composites. The experimental results showed that the material have reached the maximum tensile strength of 453.65 MPa after 10h aging and the yield strength and microhardness reached the maximum value of 245.73 MPa and 133.50HV, respectively.

Ashish Kumar Srivastava et.al [27] developed metal matrix composites Al2024 reinforced SiC by friction stir process and evaluate effect of multiple Passes on micro-structural and mechanical Properties via SEM method and to identify the presence of SiC particle energy dispersive spectroscopy (EDS) analysis had also performed. In this investigation it was found that the Improvement in tensile strength of the specimen with a maximum of 443 MPa and the hardness of 121 HRB. **Vinod K. Pandey *et al.* [31]** discussed the role on mechanical properties and fracture behaviour of Aluminum matrix composites with reinforcements of ceramic particulate. In this investigation the result of different microstructural test such as X-ray diffraction (XRD), X-ray fluorescence (XRF) and energy dispersive spectroscopy (EDS) shows that the yield stress increases from 121.21 MPa to 224 MPa and fracture toughness reduces with the increase of percentage of ceramics and size of the particles. **Mahendra Boopathi *et al.* [34]** developed an aluminum(2024) matrix composites with reinforcement of SiC and fly ash through stir casting method. The experimental investigation reveals that the yield strength increases to 257 N/mm^2, 252 N/mm^2 and finally 287 N/mm^2 for different wt% of reinforcement material as SiC and fly ash.

S. Gopalakrishnan *et al.* [36] developed aluminum matrix composites of Al–TiC particulate reinforced by stir casting method. The present analysis reveals the improvement in specific strength and wear resistance. It was observed that there are very few wear losses were found in terms of volume when compared with no. of different studies of Al–TiC composites produced by in situ process. **Atul Kumar *et al.* [38]** fabricated the composites of Al(7075) with reinforcement of SiC through micro-structural refinement by friction stir processing and investigated the micro-structural evolution through Optical, scanning and transmission electron microscopy. The result shows that simultaneous improvement in mechanical properties like tensile, yield and corrosion resistance. **K.R. Ramkumar *et al.* [41]** developed an aluminum(7075) matrix composites with reinforcement of TiC by stir casting route and investigated micro-structural, mechanical, and tribological behaviour of composite. The experimental investigation showed that measured gain in average hardness of around 248 HRC and the bending strength significantly increased by 5.8 times of its previous value.

Pradeep Kumar Krishnan *et al.* [42] developed a metal matrix composites using aluminum as a scrap material, via stir casting route and also investigated the microstructure and various mechanical properties of the composite. In this study a scrap of Aluminum alloy in form of a

wheel used as a matrix material and spent alumina catalyst from oil refineries used as a reinforcement material and got successfully result.

Table 1.1 Values of mechanical Properties containing different types of reinforcement material and method of fabrication

Researcher's	Metal matrix	Reinforcement	Method of fabrication	Composition	Ultimate Tensile strength (MPa)	Yield Strength (MPa)	Hardness
K G Sagar *et al.*	Al2024	beryl	Stir Casting Technique			Elongation	
				Al–6 wt% beryl	186	11.3	100 VHN
				Al–8 wt% beryl	182	10	99 VHN
				Al–10 wt% beryl	174	9.5	89 VHN
S.Venkatesh *et.al.*	Al 2024	Silicon Carbide and Anacardium occidentale ash	Stir Casting Technique	As Cast Al		Elongation	58.31
				Al+15%Si+2%AO	129	4	67.05
				Al+15%Si+4%AO	145	3	70.09
				Al+15%Si+6%AO	159	2	85.95
P kulkarni *et.al.*	Aluminum alloy (2024)	E-Glass-Flyash	Stir Casting method	Al 2024+2% E-Glass + Varying 1% of Flyash	247	Compression strength 458	
				Al 2024+4% E-Glass + Varying 1% of Flyash	253	469	
				Al 2024+6% E-Glass + Varying 1% of Flyash	255	481	
Huabing Yang *et.al.*	2024 Al	TiC	Stir Casting method	Al 2024–1.5TiC(R)	375 ± 11	346 ± 8	
				2024–1.5TiC(N)	392 ± 12	370 ± 10	
J.W. Kaczmar *et.al.*	2024 Al	δ alumina fibres	squeeze casting method				160HB
P. Egizabal *et. al.*	2024 Aluminum alloy	TiC	self propagating high temperature	A2024/TiC 1 wt.%	514	468	Elongation 6.7
				A2024	483	414	10

			synthesis (SHS) process And stir casting process					
P.B. Li *et.al.*	2024 Al	SiC	Powder Thixoforming PM	SiCp/2024 composite	Sic 10 vol.% 10%	379 308	Elongation 4 6	
Sairam Varma G *et.al.*	AA 2024	TiC	Stir Casting Technique	AA20,2%TiC AA2024,4% TiC AA2024, 6% TiC		166 170 178	148 156 164	
S. Suresh Kumar *et.al.*	Al2024	B4c-Tic	Laser Beam Machining	AL2024-B4C-TiC composite		222 MPa	121.6 MPa	89.2 BHN
Huabing Yang *et.al.*	2024 Al	TiC	casting method	At 25® 2024–1.5TiC(R) At 25® 2024–1.5TiC(N) At 350® 2024–1.5TiC(R) 2024–1.5TiC(N)		375 ± 11 392 ± 12 118 ± 6 151 ± 6	346 ± 8 370 ± 10 109 ± 6 142 ± 5	
Mahendra Boopathi *et.al.*	Aluminum 2024	Sic-fly ash	Stir Casting Method	AL- 100 gm, Mg 1.5% SiC 10%, Fly ash 0% Al(%)-100 gm, Mg 1.5%, SiC 5%, Fly ash 10%		265 278	257 269	Elongation % 18.2 13.8 % Hardness
S.E. Shin *et.al.*	aluminum alloy 2024	few-layer graphene (FLG)	ball milling and hot rolling	Al2024/0.3 vol.% FLG Al2024/0.5 vol.% FLG Al2024/0.7 vol.% FLG		445 MPa 550 MPa 700 Mpa		Elongation to failure 4%
N. Muralidharan *et.al.*		ZrB2 particles		ZrB2 2.5wt% ZrB2 5 wt% ZrB2 wt7.5%		180 220 280		80 100 120
Hongming Wang *et.al.*	2024 aluminu	$FeCoNi_{1.5}Crcu$ High entropy	lowtemperature			Compressive		65.5 HV

	m	alloy (HEA)	sintering		strength 248.7		
Nassim Samer *et.al.*	Al	TiC particles	Stir casting	T1 T2 T3	481 498 493	Elongation(%) 5.8 5.9 6.4	
Bo Chenn *et.al.*	Al 2024	TiB2	directed energy depositio n		453.65	222.94 MPa	118.40 HV.
Ashish kuamr srivastava *et.al.*	Al 2024	SiC	Friction Stir Processin g		443 MPa		(121 HRB)
A. Canakci *et.al.*	Al2024 alloy	B4C particles		Al2024—3 vol.% Al2024—5 vol.% Al2024—7vol			89.58 90.84 89.89
Utkarsh Pandey *et.al.*	Al 6061	Titanium carbide	Ultrasonic Assisted Stir Casting method		258 MPa	Modulus of elasticity 450 GPa	
Mahendra Boopathi *et.al.*	Alumin um alloy 2024	Silicon Carbide And Fly Ash	Stir Casting Method	Al(100%)gm Mg(1.5%)gm Sic(5%0gm Flyash(5%)gm	276	262	88.2
				Al(100%)gm Mg(1.5%)gm Sic(5%0gm Flyash(10%)gm	278	269	89.7
				Al(100%)gm Mg(1.5%)gm Sic(10%0gm Flyash(10%)gm	293	287	95.7
Ajitanshu Vedrtnam *et.al.*	Al 2024	silicon carbide and copper	stir casting method				90
Kapil Kumar *et.al.*	2024 Al	Al2O3 Nano-Particles	stir casting process		210		
					Bendin		

K.R. Ramkumar *et.al.*	AA 7075	TiC	stir casting route	Al 0wt%TiC Al 2.5wt%TiC Al5.5.0t%TiC	**g strength** 126 365 510		
Alexander E. Steinman *et.al.*	Al	AlN, AlB2 and BN phases	ball milling and spark plasma sintering (SPS)	Al BN 3%wt Al BN 5%wt Al BN 7%wt	250 300 270		
Mulla Ahmet Pekok *et.al*	(AA2024)		selective laser melting	150W /80µ/ 98mm/s	140 MPa		
				200W /80µm / 98mm/s	120 MPa		
				200W /60µm / 98mm/s	122 MPa		
J. Fayomi *et.al*	AA8011	ZrB2-Si3N4	Stir casting	95%AA8011+5 %ZrB2-Si3N4	175	140	52
				90%AA8011+10%ZrB2-Si3N4			
M. Kok *et.al*	2024 Aluminum alloy	Al_2O_3 particle	vortex method	Al_2O_3 particle 10%wt	90		95
				Al_2O_3 particle 20%wt	100		110
				Al_2O_3 particle 30%wt	110		130
Bhargavi Rebba *et.al*	Aluminum Alloy (Al-2024)	Molybdenum Disulphide (MOS2)	stir casting technique	Al+2% MoS2 Al+4% MoS2 Al+5% MoS2	211.15 261.03 208.59	171.23 213.08 162.65	77.0 88.7 81.1

3.1 MECHANICAL PROPERTIES

Hardness

Hardness is the most important parameters describing the tribological characteristics of metal matrix composites. After the observation of numerous research papers it was found that the value of the hardness varies for different metal matrix & reinforced material and also varies for different mode of preparation of composite material. It is shown in fig 1.2 that the minimum value of hardness (52VHN) founded by J Fayomi *et.al.* and the maximum value (160) founded by J W Kaczmar *et.al.* The maximum value of hardness can be achieved with the use appropriate

reinforced material such as TiC, Sic, B4C etc. from fig 1.2 it is shown that the value of the hardness varies for different type of reinforced material, but highest value of hardness achieved with the use of molybdenum disulphide. It can be illustrate from fig. stir casting method is best suited to achieved highest hardness of the material.

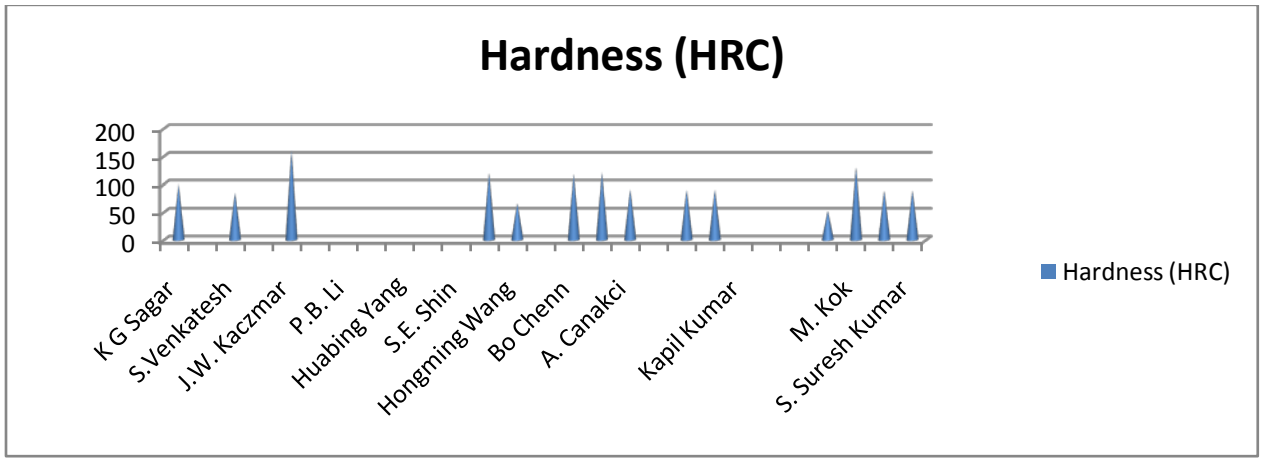

Figure 1.1 Researcher's Vs Hardness

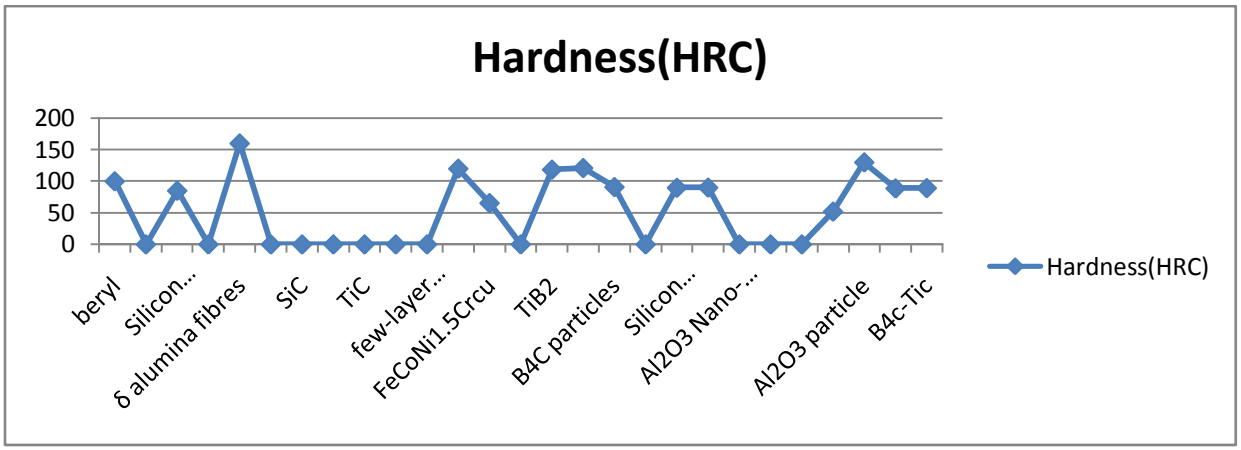

Figure 1.2 Reinforcement material Vs Hardness

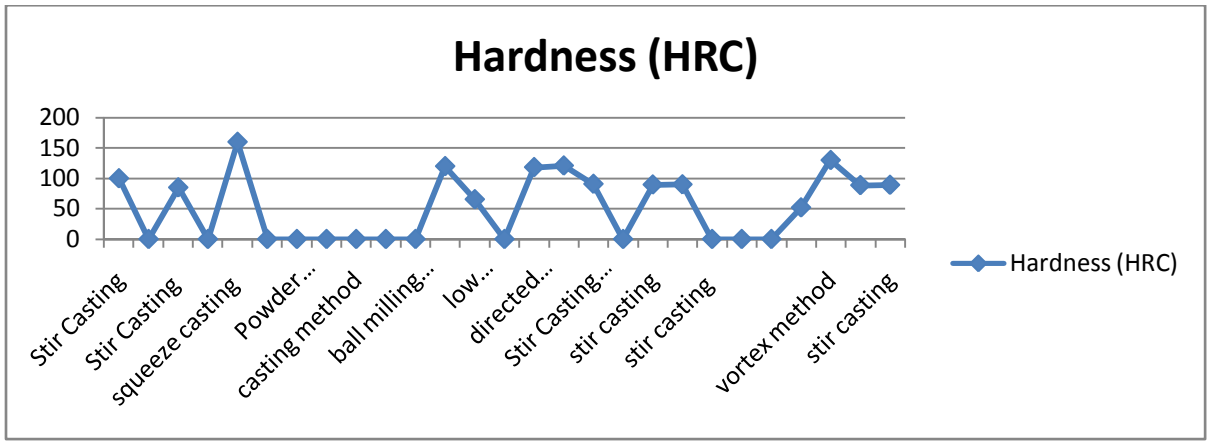

Figure 1.3 Method of fabrication Vs Hardness

Ultimate Tensile Strength

The tensile strength of a material is a prominent measurement ability to perform in any industrial application. From the literature, it can be observed that there are various techniques such as squeeze casting, powder blending and stir casting are available and also it was found that a lot of experiment has been carried out for metal matrix composites using various reinforced material such as SiC, B_4C, Graphite, Al_2O_3, to obtain better ultimate tensile strength. But from the observation of fig. we can say that the maximum UTS was found in case of researcher's S E Sahin *et.al.*as shown in fig 2.1 and best method to achieved maximum UTS is stir casting method as shown in fig 2.3

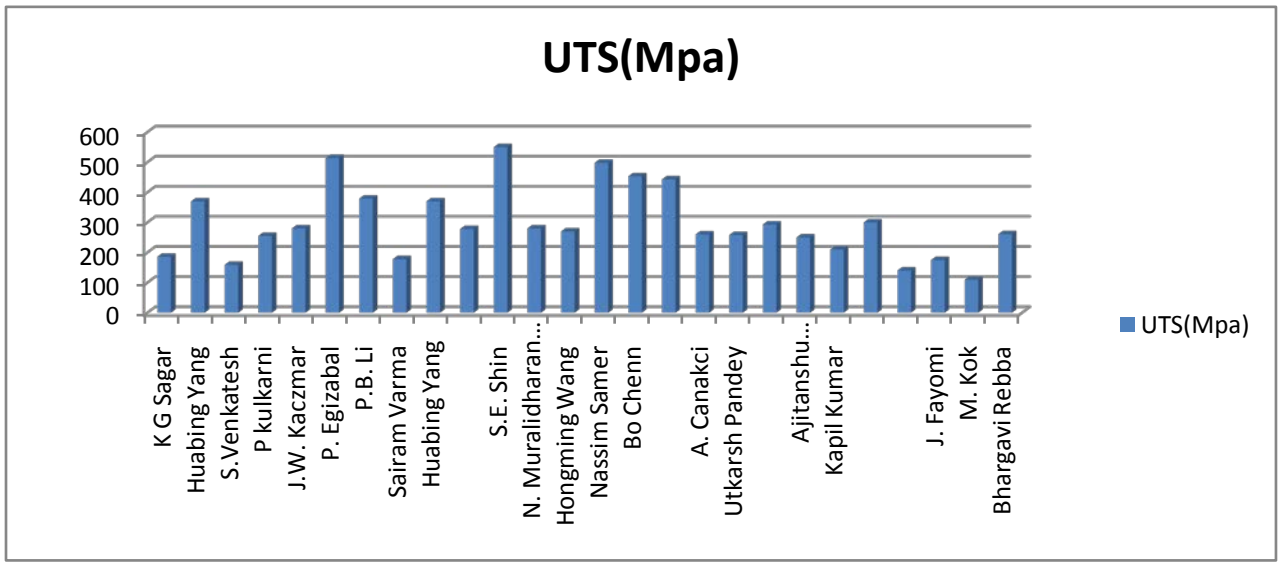

Figure 2.1 Researcher's Vs UTS

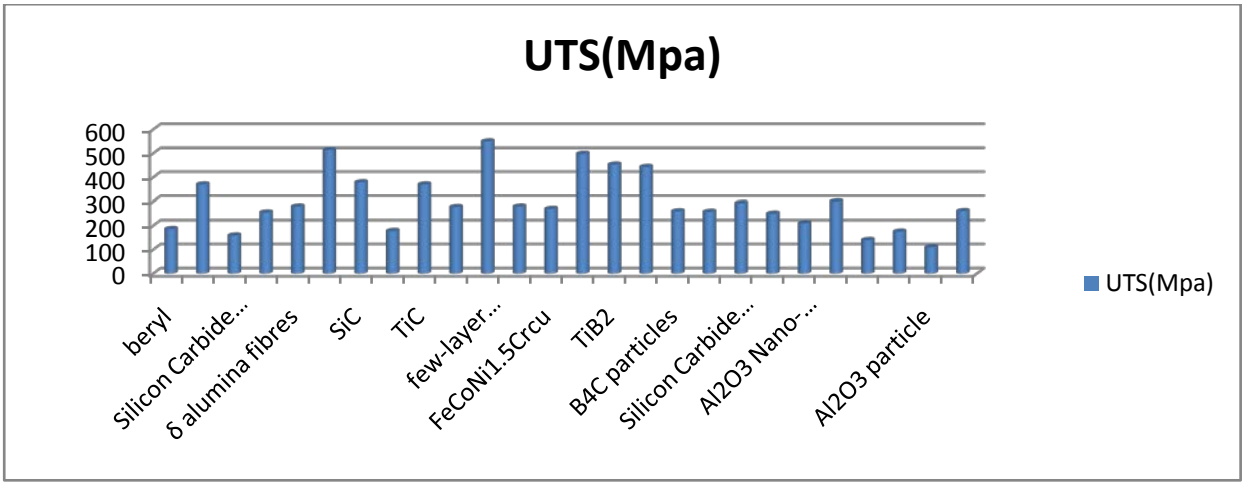

Figure 2.2 Reinforcement material Vs UTS

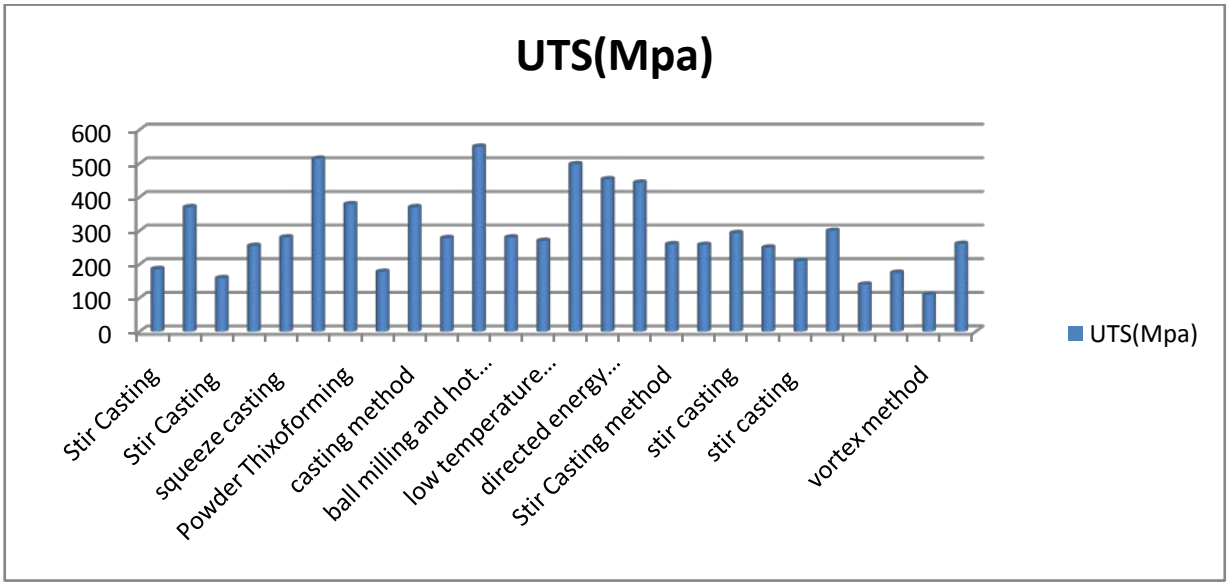

Figure 2.3 Fabrication method Vs UTS

Yield Strength

Yield strength is the most important property of any industrial material and this property can be enhanced through the use of appropriate reinforced material. After the observation of so many research paper it was observed that there are various reinforcement material are used such as alumina particulate, molybdenum disulphide, sic, tic etc. (shown in fig. 1.4) In this review article the maximum value of yield strength was obtained in case where TiC used as a reinforcement material. (Shown in fig 3.2) Titanium carbide, TiC, is an extremely hard refractory ceramic material which is best suited for industrial purpose.

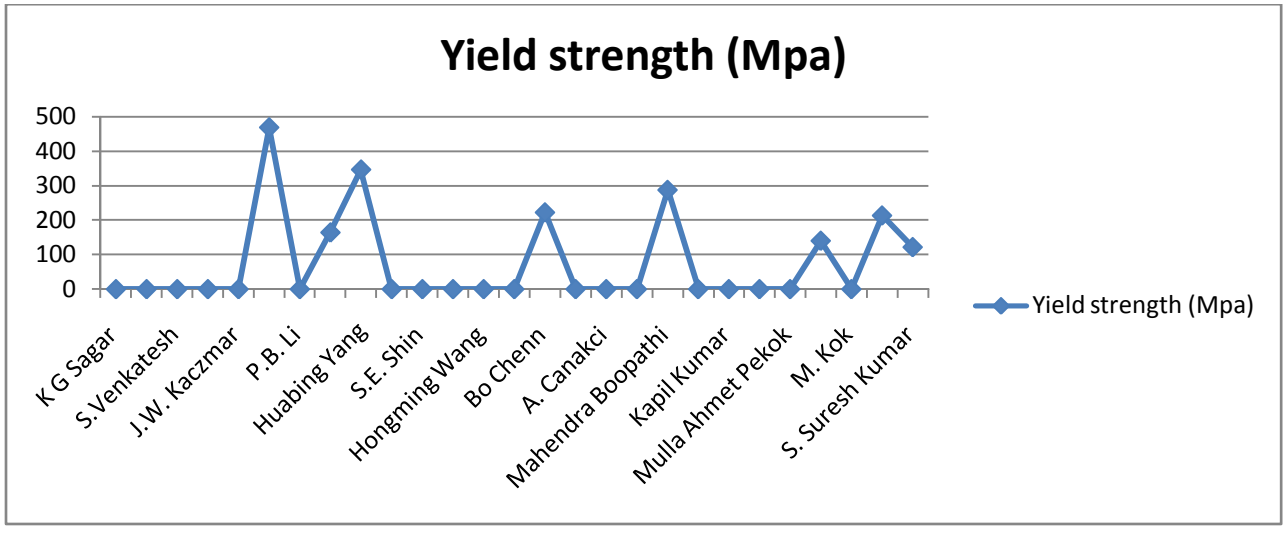

Figure 3.1 Researcher's Vs Yield strength

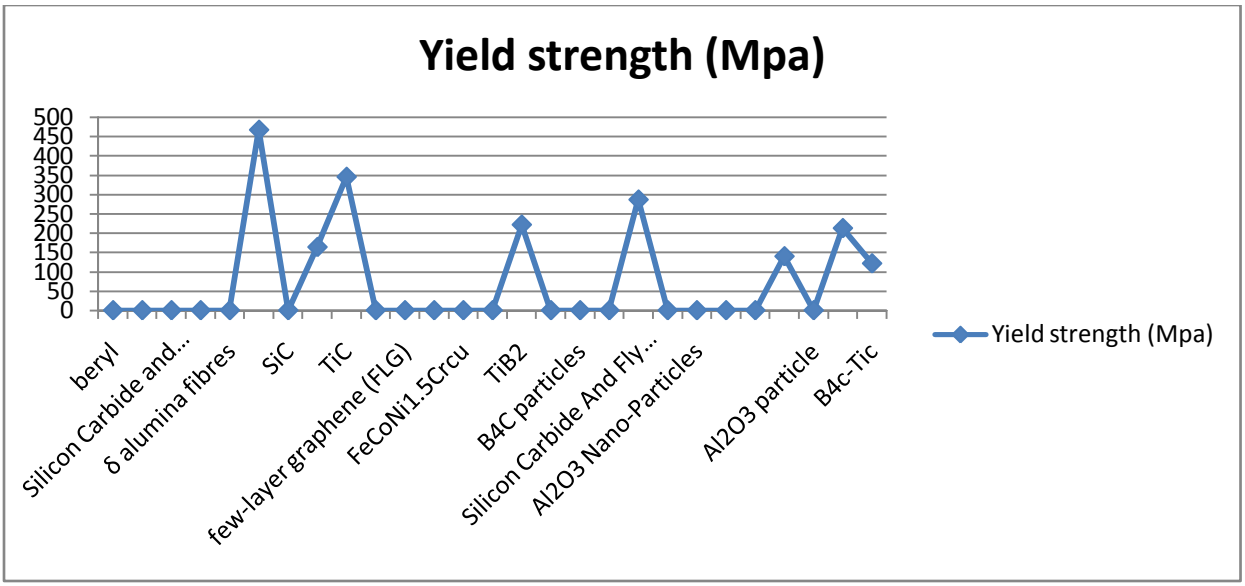

Figure 3.2 Reinforcement material Vs Yield strength

CONCLUSIONS

After the observation of numerous review paper and articles, the mechanical properties of various Aluminum matrix composites have been studied and it was perceived that TiC offers a combination of features such as low density, high hardness and excellent wear resistance which is used as a reinforced material for the preparation of the metal matrix composites. The fallowing observations of this research work can be concluded as follows.

- It was noticed that TiC is successfully using nowadays among the various reinforcement material for the development of various types of composites like metal matrix composites, ceramic matrix composites and polymer composites.
- From the literature review, it is very clear that there are various techniques such as squeeze casting, powder blending and stir casting are available through which the Aluminum matrix can be easily reinforced to obtain better performance. Though in all stir casting are mostly used.
- After the study of review of literature it can be pronounced that AA 2024 reinforced with various percentage of TiC is having the improved mechanical and tribological characteristic such as hardness, ultimate tensile strength and yield strength.
- It was found that a lot of experiment has been carried out for Aluminum alloy 2024 using various reinforced material such as SiC, B_4C,graphite, Al_2O_3, but very few works has been carried out for Alumium alloy 2024 using TiC as a reinforced material.

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