LITERATURE REVIEW

Y. Bar-Cohen et al., 1986[147], is examined the structures of aircraft one of the techniques widely is NDT. Bar-Cohen conducted an experimental work on fibre-reinforced composite utilised material as a part research work to detect internal flaws in the material by ultrasonic test. This test given results not only surface roughness, coupling system internal reflection etc. but also given detect gross flaws in the fiber-reinforced composite materials. For finding the flaw size by means of ultrasonic test, the ultrasonic wavelength should be equal or smaller to the flaw size, if wave length is greater than the flaw size the wavelength will be scattered by the large number of fibers contained in the fiber-reinforced composite materials.

Kupperman et, al., 1990 [149], conducted experimental test to measure the strain in the metal matrix composite made up of SiC fiber reinforced in titanium matrix, fiber orientation is in one direction. Because neutrons can penetrate more deeply than x-rays, this approach offers the potential to provide bulk measurements. Due to the difference in thermal coefficients of expansion of matrix and reinforced material, internal strains were produced.

Chen et, al., 1996[146], used a photo thermal microscope to examine the interface between the matrix and reinforcement materials. In his experimental work the material used as a metal matrix composite made up of zirconia particles reinforced in a zinc alloy matrix. And the images can be taken by photo thermal microscope at high magnification than microscope.

Buchanan et al., 1997[148], NDT techniques were used to find the damage accumulation in the metal matrix composite while carrying out mechanical test. The investigation reveals the peak to peak amplitude of transmitted ultrasound was found to be good indicator of impending failure of material.

Feng et al.,[121] examined in the year 2000, the microstructure of metal matrix composite as a part of research work. The metal matrix composite made up of TiB2 reinforcement material in an Al matrix, prepared by one of the casting route is in-situ. The examination reveals that the TiB2 particles distributed homogeneously by adding Si into the matrix more than the 5wt% of the matrix. The microstructure images study reveals that less than 5wt% of Si added into the matrix TiB2 particles does not distributed evenly in the matrix.
Particle reinforced MMCs are attractive due to their enhanced properties like higher strength, stiffness and specific weight, isentropic properties and ability to be processed easily compared to conventional monolithic materials. The main emphasised,

Nikhilesh Chawla et al, 2001[7], was on tensile, creep, and fatigue behaviour of the wrought particulate reinforced light alloy metal matrix composites. Metal matrix composites provide significantly enhanced properties like higher strength, stiffness and weight savings in comparison to conventional monolithic materials. Particle reinforced MMCs are attractive due to their cost-effectiveness, isotropic properties, and their ability to be processed using similar technology used for monolithic materials. This review captures the salient features of experimental as well as analytical and computational characterization of the mechanical behaviour of MMCs. The main focus is on wrought particulate reinforced light alloy matrix systems, with a particular emphasis on tensile, creep, and fatigue behaviour.

Aluminium metal matrix composites refers to the class of aerospace application materials due to light weight and high performance. The reinforcement in AMC’s could be in the form of continuous/discontinuous fibers, whiskers or particulates, in volume factions ranging from a few percentage to 70%. Properties of AMCs can be tailored to the demands of different industrial applications by suitable volume fractions of reinforcement and processing methods. The past two decades of research have provided intrinsic & extrinsic effects of ceramic reinforcement and the physical, thermo-mechanical and tribological properties of AMCs. AMCs had been in use in the high-tech structural and functional applications including aerospace, defence, automotive, and thermal management areas, as well as in sports.

S. Balasivanandha Prabu, et al, 2006[114], research work was focused on mainly high silicon content aluminium alloy–silicon carbide metal matrix composite material, with 10%SiC were successfully synthesized, using different stirring speeds and stirring times. The microstructure of the produced composites was examined by optical microscope and scanning electron microscope. The Brinell hardness test was performed on the composite specimens from base of the cast to top. The results revealed that stirring speed and stirring time influenced the microstructure and the hardness of composite. Microstructure analysis revealed that at lower stirring speed with lower stirring time, the particle clustering was more. Increase in stirring speed and stirring time resulted in better distribution of particles. The hardness test results also revealed
that stirring speed and stirring time have their effect on the hardness of the composite. The uniform hardness values were achieved at 600rpm with 10min stirring. But beyond certain stir speed the properties degraded again. An attempt is made in this study to establish the trend between processing parameters such as stirring speed and stirring time.

N Chawala et al, 2006[131], Modelling and prediction of the overall elastic–plastic behaviour and fracture mechanisms in particle-reinforced composites materials. Analysis of such materials are very complex in nature, because of its microstructural aspects i.e. reinforcement particle size, shape, and distribution. In this paper author described a serial sectioning process, followed by finite element method simulation, to reproduce a model of the 3D microstructure of particle-reinforced metal matrix composites. The model of 3D microstructure accurately represents the alignment, aspect ratio, and distribution of the particles in comparison with single-particle and multiparticle models of simple shape (spherical and ellipsoidal).

By the study of 3D microstructure based on modelling the author concluded that:-

Analytical models are unable to predict accurately the properties of particle-reinforced composite material since these models do not account for the microstructural factors that influence the mechanical behaviour of the material.

FEM simulation of the uniaxial loading behaviour of particle-reinforced aluminium composites was conducted on 3D multiparticle models with simple shape (spherical and ellipsoidal particles) and the 3D microstructure obtained from serial sectioning. From the results it is concluded that the 3D microstructure models were most accurate in predicting the uniaxial deformation of the composite.

A. Ahmed et al, 2007 [140] was studied on the effect of ceramic reinforcements on the mechanical properties of 7xxx series aluminium matrix composites (AMCs). Initially it was expected to improve the tensile strength by reinforcing of an Al 7xxx alloy with ceramic particulates but in practically it has produces diverse results. Many of the researches have been concluded significant, increase in tensile strength of particulate reinforced 7xxx Al matrices. The main study on this experimental work is to predict the role of ceramic particulates on the tensile and fracture behaviour.
Manufacturing variables have to be controlled to avoid any contamination and aggregation of reinforcement particulates in the matrix which are believed to be one of the possible causes of premature-failure of the composite. Further work is required to build Al 7xxx matrix composites reinforced with nano-scale particulates as they have the potential to greatly enhance the strength. This work is also desired to improve the ductility and fracture toughness of the reinforced alloy without sacrificing its improved stiffness and strength.

E. Bayraktar et al, 2008[138] was research work revealed that mechanical properties of metal matrix composites (MMCs) are essentially parameters of the manufacturing processes. Practically the mechanical behaviour of the MMCs depends on type of matrix reinforcement and heat treatment. The factors such as the porosity of the matrix, volume fraction of the reinforcement and their distribution, sedimentation of particles and particle size, dross and porosities also influence the behaviour of the MMC. The static and cyclic deformation behaviour of these two metal matrix composites has been investigated at room temperature; 2124/Al-Si-Cu fabricated by powder metallurgy and AS7G/Al-Si-Mg fabricated by foundry.

The microstructure for optical images was made by Olympus optical microscope (OM). The failed specimens are observed by using of scanning electron microscope (SEM) and also the variation of volume fraction depending on the tomography density (TD) was evaluated by means of X-rays computed tomography.

AS7G composite showed considerable lower mechanical properties compared to the Al2124 composite. Because of the crack generally initiated at the interface (SiC/matrix) with many interface de-bonding between the SiC particles and the matrix.

A detailed study of damage mechanism was performed using smooth specimens as received and heat treated conditions of the SiCp/2124 and AS7G composites with different production methods and different volume fraction of particles. The AS7G composite showed considerable lower mechanical properties (tensile, fatigue strength, etc.) regarding to the 2124 composite. In the AS7G composite, the crack generally initiated at the interface (SiC/matrix) with many interface debonding between the SiC particles and the matrix. This was the principal cause of the reduced fatigue strength.
The 2124 composite showed the smooth crack paths, while the crack path in the AS7G composite were more twisted with branching in high stress levels. This is attributed to the hard SiC particles in bigger size, which can be a barrier to the growth of small cracks and then leading to crack branching. As a summary, the mechanical behaviour of these composites is related to the particle geometry (shape), the distribution and also the size of the particles in the matrix. Applications of F-rays CT on the composite materials are more efficient and skilful. F-rays CT well characterise the particle size and the distribution of the reinforcements-volume fraction as 3D at the macroscopic scale as a possible way to study this aspect.

K. Dragan et al, 2009[141], was used the modern approach to the detection of various types of defects in composite structures used in aerospace. In such structures, including glass reinforced plastics and carbon reinforced plastics, different failure modes could occur at a manufacturing stage and during service life. Defects are connected with inadequate technology, poor workmanship, cycling fatigue loads, impact damage and environmental conditions. The main types of defects are delaminations, disbonds, foreign object inclusions and porosity. To detect such defects, several non-destructive evaluation techniques can be applied, merely to mention ultrasonic, low frequency acoustics, infrared thermography and shearography. The use of multimode non-destructive evaluation techniques enables characterization of defects which cannot be detected by using single non-destructive evaluation methods. Demonstrated the necessity of using non-destructive evaluation methods for the implementation of quality control and maintenance procedures while servicing aerospace composite elements.

Christian Carey et al, 2009[144], since the first powered flight at Kitty Hawk, there has been a constant development, for a variety of reasons, in the materials used in aviation applications. Apart from two periods in the 50’s and 60’s, where fatigue properties and supersonic applications drove material development, the main aim has been an overall weight reduction. These developments have continued to the present day with the current driving force being the challenges facing aviation on reducing its impact on climate change. Improving a materials properties, mechanical or otherwise, allows designers to produce lighter and simpler parts thus reducing the weight of the aircraft, and likewise the fuel burn, reducing the emissions. This has been achieved by a number of different methods, from improving incumbent materials by new production method sand processing, producing new improved materials to replace the incumbent
or latterly by utilising novel structures and hybrid combinations. This paper sets out a review of current aviation materials, future developments and future applications.

**M.A. Baghchesara et al, 2010 [142]**, discontinuously reinforced aluminium composites are being recognized as an important class of engineering materials that are making significant progress. The reasons for their success are related to their desirable properties including low density, high hardness, and high compressive strength, wear resistance, etc. Casting and powder metallurgy are the two major fabrication methods of aluminium matrix composites, though powder metallurgy is more complicated than casting, but it yields to a better interface between reinforcement and matrix alloy, improving mechanical properties of Al-nano MgO composite. Pure atomized aluminium powder with an average particle size of 1 µm and MgO particulate with an average particle size between 60-80 nm were used. Composites containing 1.5, 2.5 and 5.0% of volume fraction of MgO were prepared by powder metallurgy method. The specimens were pressurized by cold isostatic pressure machine. The consolidation temperatures were 575, 600 and 625 °C. After sintering and preparing the samples, mechanical properties were measured. The results of microstructure, compression and hardness tests showed that addition of MgO particulates to aluminium matrix composites improve the mechanical properties.

A356.1 aluminium alloy reinforced with nano-sized MgO was successfully fabricated via powder metallurgy method. SEM micrographs indicate that reinforcement particles were homogeneously distributed in the matrix of composites. However, partial agglomeration was observed in composites with high content of MgO. Therefore, powder metallurgy was found as a suitable method for fabrication of this kind of composites. Mechanical properties such as hardness and compressive strength improved. Composites containing 2.5 and 5.0 vol % MgO fabricated at 625 °C showed maximum compressive strength and hardness, respectively, in comparison with other specimens and they can be selected as optimum samples. However, composite containing 2.5 vol % MgO would be more reliable, since it has maximum density. Furthermore, mechanical properties of composites, generally decreased by increasing the large content of MgO.

**In year 2011, N. B. Dhokey et al., [112]** Aluminium-based TiB₂ reinforced composite is a promising material to be used as brake drum material, and it may emerge as substitute for conventional gray cast iron. Aluminium-based composites containing 2% by wt copper
reinforced with 2.5 and 5wt% TiB$_2$ composites were made in induction furnace by in situ synthesis process using simultaneous addition of halide fluxes (K$_2$TiF$_6$ and KBF$_4$). These cast composites were evaluated for microstructures, hardness, flow curve properties, and tensile properties. It was observed that overall wear behaviour gave reasonably good correlation with mechanical properties of composites as compared to gray cast iron.

Metal matrix composites (especially aluminium and titanium based) are used in aerospace and automobile industries due to their enhanced properties such as modulus, hardness, tensile strength, and wear resistance combined with significant weight saving.

Aluminium with ceramic reinforcements such as Al$_2$O$_3$, SiC, TiC, and TiB$_2$ are used for structural applications, for their good toughness and wear resistance.

Modulus of composite increases with TiC- and TiB$_2$-particle additions and it is greater than that for composite with Al$_2$O$_3$ and SiC. Also, interfacial bonding is enhanced in the TiC- and TiB$_2$-added composites.

There are different techniques of forming TiB$_2$ in the matrix such as powder metallurgy method, spray, deposition and several casting methods such as rheocasting, squeeze casting, stir-casting and compo casting.

Different systems are used for synthesis of this composite such as TiO$_2$-Al-B, TiO$_2$-Al-B-CuO, TiO$_2$Al-B$_2$O$_3$, NaBH$_4$, and TiCl$_4$ and Ti-containing and B-containing salts are added to the melt resulting in a series of chemical reactions which produce submicron TiB$_2$ particles within the melt.

The addition of reinforcement produces increase in strength and stiffness over the base alloy at the expense of ductility as compared to cast aluminium.

The wear rate of the composites improves significantly with the TiB$_2$ content. The friction coefficient also decreased with increasing TiB$_2$ content, which indicates decrease in wear rate and hence the improvement in the wear resistance of the composite.

Based on the foregoing discussion of Al-MMC sand its relative comparison with gray cast iron, the following conclusions can be drawn.
Mechanical properties are strongly affected by the content of TiB$_2$ in Al-MMCs.

Wear behavior gives a reasonable correlation with hardness, ultimate tensile strength, fracture strength, and strain hardening exponent of Al-MMCs. The relationship between wear rate and mechanical properties validates Archard’s equation. Wear rate decreases with increasing TiB$_2$ content.

A. Sreenivasan, et al, 2011[113], dealt with the study of microstructure and wear characteristics of TiB$_2$-reinforced aluminium metal matrix composites (MMCs). Matrix alloys with 5, 10 and 15% of TiB$_2$ were made using stir casting technique. Effect of sliding velocity on the wear behaviour and tribo-chemistry of the worn surfaces of both matrix and composites sliding against a EN24 steel disc has been investigated under dry conditions. A pin-on-disc wear testing machine was used to find the wear rate, in which EN24 steel disc was used as the counter face, loads of 10-60N in steps of 10N and speeds of 100, 200, 300, 400 and 500 rpm were employed. The results showed that the wear rate was increased with an increase in load and sliding speed for both the materials. However, a lower wear rate was obtained for MMCs when compared to the matrix alloys. The wear transition from slight to severe was presented at the critical applied loads. The transition loads for the MMCs were much higher than that of the matrix alloy. The transition loads were increased with increase in TiB$_2$ and the same was decreased with the increase of sliding speeds. The SEM and EDS analyses were undertaken to demonstrate the effect of TiB$_2$ particles on the wear mechanism for each conditions.

Wear rate was higher for the unreinforced aluminium alloy when compared to the Al/ TiB$_2$ reinforced composites. Wear rate was decreased with increasing TiB$_2$ content in the MMC composites. The wear rate of the MMCs as well as the matrix alloy was increased with the increase in applied load. However, it was decreased with increase in speed. The MMC specimens were demonstrated abrasion wear at low loads, whereas, in the case of higher applied loads, delamination wear was dominant. The wear rate increased abruptly just above the critical load. The transition to high wear rate regime was induced by massive surface damage and material transfer to the counter-face. The presence of TiB$_2$ particles would help in delaying of the transition wear from mild to severe.
Dumitru-Valentin Dragut, et al, 2011[116], main objective of work was the characterization of a metal matrix composite material based on a deformable aluminium alloy AA 6060 reinforced with AlB₂ particles. An alumina-thermic reaction between the aluminium AA 6060 alloy and KBF₄ was used for the synthesis of the composite. Analyses were performed by optical microscopy, electron microscopy (SEM + EDS) and X-ray diffraction. The composite contains particles with the characteristic morphology of the aluminium diboride.

The Al/AlB₂ in situ composite was produced via exothermic chemical reaction between KBF₄ and liquid AA6060 aluminium alloy at 850°C.

The thermodynamics and the mechanisms of the interaction between Al and KBF₄ in the presence of cryolite (as activator and solvent for Al₂O₃) was investigated. The XRD analysis revealed the formation of AlB₂ poliedric compounds dispersed in the matrix and an interface Al/AlB₂ very clean and with a high adhesion energy generally observed.

The microstructures (Optical Microscopy, SEM/EDS) confirms the presence of AlB₂ compounds in the condition of high cooling rate of the composite material.

A. R. K. Swamy, 2011[119], compared the mechanical properties of Al6061-Tungsten carbide composites containing Tungsten carbide (WC) particulate, and Al6061-graphite particulate composites containing graphite particles. The reinforcing particulates in the MMCs vary from 0% to 4% by weight. The 'vortex method' of production was employed to fabricate the composites, in which the reinforcements were poured into the vortex created by stirring the molten metal by means of a mechanical agitator. The composites so produced were subjected to a series of tests.

The results of this study revealed that as the Tungsten carbide particle content was increased, there were significant increases in the ultimate tensile strength, hardness and Young's modulus, accompanied by a reduction in its ductility. There was, however, only a very marginal increase in the compressive strength, where as in graphite reinforced composites as the graphite content was increased, there were significant reduction in hardness and monotonic increases in the ductility, ultimate tensile strength (UTS), compressive strength and Young's modulus of the composite, An attempt is made in the paper to provide explanations for these phenomena.
The significant conclusions of the studies on Al6061-WC and Al6061-Gr metal matrix composites are as follows.

Al6061-WC and Al6061-graphite composites were prepared successfully using liquid metallurgy techniques by incorporating the reinforcing particulates up to 4 wt%.

It was found that increasing the graphite content within the aluminum matrix results in significant increases in the ductility, UTS, compressive strength and Young’s modulus, but a decrease in the hardness.

A compromise is necessary when deciding how much graphite should be added to enhance the mechanical properties of the composite without sacrificing too much of its hardness and hence its wear resistance.

The properties of the cast Al6061-WC composites are significantly improved by varying the amount of WC. It was found that increasing the WC content within the matrix material, resulted in significant improvement in mechanical properties like hardness, tensile strength, and compressive strength at the cost of reduced ductility.

Highest values of mechanical properties like hardness, tensile strength and compressive strength were found at 3 wt% WC.

R. Hariharan et al, 2012[104], aluminum based metal matrix composites (MMCS) are advanced materials having the properties of high specific strength and modulus, greater resistance, high elevated temperature and low thermal expansion coefficient. These composites are widely used industries like aerospace, defence, automobile, biomaterials as well as sports etc.

In present work aluminium alloy reinforced with TiB₂ MMCs materials are prepared by using stir casting technique have cost advantages over the composites made by other. Four different volume fractions (2%, 4%, 6% and 8%) of particulate TiB₂ are used in production of aluminium matrix composite at 750°C. An X-ray diffract meter is used to confirm the presence of TiB₂ as well as to estimate quantitatively the weight percentage of TiB₂ particles in the composite for the various reaction holding times. Microstructures of the composites are studied by Scanning Electron Microscopy (SEM). The wear and frictional properties of the metal matrix composites
was studied by performing dry sliding wear test using a pin-on-disc wear tester. The addition of TiB₂ particles results in increased mechanical properties, such as tensile and hardness.

Aluminium based metal matrix composites (MMC’s) reinforced with ceramic particles have been the subject of numerous research workers. Owing to the low density, low melting point, high specific strength and thermal conductivity of aluminium alloys, a wide variety of ceramics such as SiC, Al₂O₃, TiC and graphite have been reinforced into it. Among these particles, TiB₂ has emerged as an outstanding reinforcement. This is due to the fact that TiB₂ is stiff hard and more importantly it does not react with aluminium to form any reaction product at the interface between the reinforcement and the matrix.

Due to the unique combination properties of Al- TiB₂ composites such as low density and thermal expansion, high modulus, strength and wear resistance, good ductility and thermal conductivity; they have been used in many important Industries such as aerospace and military industries.

The addition of the TiB₂ particles into Al-6061 is a good route to improve the mechanical properties of materials.

The resulting composite showed the increase in tensile strength when compared to the unreinforced alloy.

SEM and XRD analysis of the composite confirms the presence of TiB₂ particle and its volume fraction.

The increased volume fraction of the TiB₂ particles contributed to increase the strength of composites.

The dry sliding at room temperature shows that there is a definite increase in the wear resistance of Al6061 alloy by the addition of TiB₂ particles

**M. Karbalaei Akbari et.al 2013[111]**, fabricated nanometric alumina particle – reinforced A356 composites. The nano alumina particles, which was separately milled using planetary ball mill having ball to powder ratio 20:1 for 24 hours, were wrapped in aluminium foils and added into molten aluminium. It was followed by stirring at a constant speed of 450 rpm at durations of
4, 8, 12 and 16 min at a casting temperature of 850°C. The composite slurry was poured into cast iron mold. The cast specimens were heat treated to the following schedule i.e., 8hours at 495°C, followed by 2H at 520°C, followed by water quenching (40°C) and artificially aged for 8h at 180°C. The hardness and tensile properties were improved by addition of Nano-alumina particles. The maximum hardness was achieved at 4 min of stirring time. By means of increasing the stirring time, there will be a reduction in the tensile performance of composite.

**Lokhan Rothod, et al, 2013[122].** Aluminium alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The excellent mechanical properties of these materials and relatively low production cost make them a very attractive candidate for a variety of applications both from scientific and technological viewpoints. The aim involved in designing metal matrix composite materials is to combine the desirable attributes of metals and Ceramics. Present work is focused on the study of behaviour of Aluminium Cast Alloy (LM6) with and Al₂O₃ composite produced by the stir casting technique. Different % age of reinforcement is used. Tensile test, Impact test and wear test performed on the samples obtained by the stir casting process. Optical microscope was performed to know the presence of the phases of reinforced material.