CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Extensive survey of available literature on Al MMC’s was carried out and a summary of the literature is presented under the following headings:

1. Stir casting techniques
2. Wear behaviour of composites
3. Artificial Neural Networks
4. Drilling characteristics of composites
5. Machining characteristics of composites
6. Corrosion behaviour of composites

2.2 STIR CASTING TECHNIQUES

Aluminium Matrix Composites (AMCs) are used as materials in aerospace and automotive industries owing to their superior strength-to-weight ratio and high stiffness. Several research works have been carried out for the production of composites. They have applied various methods to fabricate the composites.

Among various processing techniques, stir casting appears to be most promising route for production of aluminium matrix composites because of simplicity and capability to produce composites on industrial scale.
Stir casting method is favoured for the production of large number of complex shaped components in cost effective manner when compared to powder metallurgy process which has its own limitation such as processing cost and size limitation on the components.

A major difficulty in stir casting is in obtaining sufficient wetting of reinforcement particle with the liquid metal in order to get a homogeneous dispersion and is influenced by

a) Wettability between the matrix and the reinforcement particles.

b) Porosity in the cast metal matrix composites.

c) Chemical reactions between the reinforcement material and the matrix alloy.

Achieving a uniform distribution of reinforcement within the matrix is yet another challenge in the stir casting process, which directly affects on the properties and quality of composites.

Interfacial strength between the matrix and reinforcement plays a significant role in determining the properties of MMCs. These aspects have been discussed by many researchers. Fly ash particles incorporated into molten Al were observed to be floating on the molten Al surface due to the high surface tension which leads poor wettability.

Wettability can be defined as the ability of a liquid to spread on a solid surface, and represents the extent of intimate contact between a liquid and a solid. Gas layers at the surfaces of the particles can cause the buoyant migration, mechanical stirring can be done in a semi solid state rather than in the completely liquid state to breakdown the gas layers, thereby reducing
surface tension. Wettability can be improved by increasing the surface energies of the solids, decreasing the surface tension of the liquid matrix alloy and decreasing the solid/liquid interfacial energy at the reinforcement matrix interface.

Addition of reactive elements such as Li, Mg, Ca, Ti, Zr and P increases the wettability of metal-ceramic systems by inducing a chemical reaction at the interface and also by decreasing the surface tension of the molten Al and the solid-liquid interfacial energy of the melt.

Addition of elements having high affinity for oxygen increases the wettability of certain ceramic particles. Magnesium, which acts as a powerful surfactant as well as a reactive element, in the aluminium alloy matrix seems to fulfill all the above requirements. Important role played by the magnesium during the composite synthesis is the scavenging of the oxygen from the dispersoid surface, thus thinning the gas layer and improving wetting action with the surface of the dispersoids. Conclusions from previous research studies have confirmed the strengthening of aluminium alloys with a dispersion of particulates, thereby strongly enhancing their potential in tribological and structural applications.

In order to achieve the optimum properties of the metal matrix composite, several factors that have to be considered, including achieving a uniform distribution of the reinforcement material in molten matrix, improving the wettability or bonding between the matrix and reinforcement, enhancing the solid solution strengthening mechanism by interfacial chemical reactions as well as minimizing the porosity. This requires the sound theoretical and practical knowledge on the part of composite material engineers.
Mandal et al (2004) fabricated aluminium matrix composites using stir casting method. Preheated reinforcements at 475K were added to the center of the vortex formed during stirring.

Chaudhury et al (2004) produced Al-2Mg-11 TiO$_2$ (rutile) composite using vortex method. The melt was stirred with a stirrer at a rotational speed of 200rpm. It was observed that, the addition of rutile particles tend to increase the hardness of composites.

Ipek (2005) fabricated SiC reinforced 4147 Al matrix composites using liquid metallurgy route. Melt was heated up to 910K and stirring was carried out approximately 400 rpm speed for 30min under CO$_2$ gas atmosphere to avoid oxidation.

Sarkar et al (2008) have employed impeller mixing technique to fabricate Al– fly ash composites and concluded that up to 17 wt. % fly ash could be incorporated in the matrix by liquid metallurgy route. Addition of magnesium increased the wettability which enhanced the wear resistance and mechanical properties.

Although a larger number of investigations have been carried out on mixing in solid– liquid suspensions by applying chemical engineering principles, the number of studies reported on mixing phenomena in metallurgical systems is relatively few.

Rohatgi et al (1998) have conducted a study on the mixing quality of two phase slurries using SiC– water system to determine the influence of impeller geometry and baffles on the uniformity of distribution of SiC in the mixture. It was found that variation of SiC concentration during stirring in the
absence of baffles was 7.5 vol % compared to 2 vol% in the presence of four baffles.

In order to achieve a good homogeneous distribution of fly ash particles in Al matrix, the impeller must be designed such that it creates vortex in the composite slurry. Hence, a proper understanding of the impeller parameters is essential.

Inherent difficulties associated with stir casting method are non-wettability of the reinforcement particles by liquid Al, segregation of particles, higher porosity and extensive interfacial reaction due to higher processing temperature. Porosity in stir castings occurs as a result of gases entrapped during melting as well as during stirring/mixing, which form gas bubbles, leading to large scale porosity (Hashim et al 1999, 2003).

The amount of porosity depends on the processing parameters, type of matrix and reinforcement, weight fraction of reinforcement and interfacial reaction. The distribution of the reinforcement particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added (Girot et al 1987). Non-uniform distribution of reinforcements could lead slip of dislocations and initiation of micro cracks which causes premature failures in the composite

As the reinforcement content in the melt increases, the inter particle distance is lowered and clusters formation occurs which leads to the entrapment of gas layers between the particles. These layers drag the reinforcement particles together leading to spontaneous rejection from the Al melt. In order to distribute the lumps into small aggregates, it is important to increase the shear force in the composite slurry.
In the present study a modified two stage stir casting technique has been implemented to produce the Al- fly ash particulate composites with an objective to obtain homogenous dispersion of fly ash material in the pure commercial Al.

2.3 WEAR BEHAVIOUR OF MATERIALS

2.3.1 Introduction

Wear is material removal from one surface of the component to another during relative motion between them. Adhesive wear occurs when two solid surfaces slide over one another under pressure whereas abrasive wear may involve gouging, grooving, as well as plastic deformation caused by the penetration of hard abrasive reinforcement particles (Prasad et al 1986). Materials with a high hardness, strength and toughness are most resistant to abrasive wear (Askeland and Phule 2002).

Presence of a particulate reinforcement in metal matrix enhances the tribological characteristics along with higher specific strength and stiffness making them good candidate materials for many engineering situations where sliding contact is expected (Ibrahim et al 1991, Sinclair and Gregson 1997). Several investigations have been carried out experiments for analyzing the wear behaviour of aluminium matrix composites.

The most commonly employed metal matrix composite system consists of aluminium alloy reinforced with hard ceramic particles such as SiC, Al₂O₃, (Ma et al 2003, Muratoglu and Aksoy 2000) or soft particles such as Graphite and Talc (Zhang et al 1994). Recently low-cost and low-density fly ash particulate reinforcements are being investigated as replacements for the relatively more expensive conventional reinforcements such as SiC, B₄C and Al₂O₃.
2.3.2 Wear Behaviour of Composites

Various researchers have carried out experiments for evaluating the wear behaviour of aluminium matrix composites.

Ramachandra and Radhakrishna (2007) have investigated the effect of fly ash content on sliding wear, slurry erosive wear and corrosive behaviour of aluminium matrix composites produced by stir casting method and concluded that Al (12 wt% Si) -15 wt% of fly ash particulate composite showed improved abrasive wear resistance. Increase in normal load and sliding velocity increased the magnitude of wear and frictional force.

Addition of 6% of fly ash particles into A356 Al alloy showed lower wear rates at low loads (10 and 20 N) while 12% of fly ash reinforced composites showed lower wear rates compared to the unreinforced alloy in the load range 20–80 N. At higher load, subsurface delamination is the main mechanism in both the Al alloy as well as in composites (Sudarshan and Surappa 2008).

Gurcan and Baker (1995) investigated the wear resistance of Al 6061 reinforced with SiC composites. The maximum wear resistance was observed in the composite containing 20 wt. % of SiC particles.

Seah et al (1996) reported an increase in the wear resistance of cast ZA-27- Gr composites with the increase in graphite reinforcement up to 1 wt. %. Further addition of graphite results only in marginal improvement in the wear resistance. It also lowers the hardness of the material.

Zhan and Zhang (2006) reported that inclusion of graphite with copper - SiCp composite retards severe wear at higher temperatures and delays the start of seizure due to the prevention of metal-to-metal contact.
Tedguo and Tsao (2000) studied the wear behaviour of self-lubricating Al hybrid composites reinforced with SiC and graphite particles. They reported that as the incorporation of graphite particles decreased friction coefficient and wear rate considerably.


Vencl et al (2010) studied the tribological behaviour of heat treated Al356 composites reinforced with Al2O3 / SiC and graphite particles fabricated by compo casting process. The results revealed that the wear resistance and coefficient of friction were better at the SiC particulate composites compared to Al2O3 particulate composite, while the incorporation of graphite particles enhanced the wear resistance further.

Mondal et al (1998) studied abrasive wear behaviour of Al alloy–Al2O3 composites as a function of applied load, size and volume fraction of reinforcement. It was observed that the wear rate of composite decreases linearly with increase in Al2O3 content and the wear resistance of composite varied inversely with square of the reinforcement size.

2.4 ARTIFICIAL NEURAL NETWORK

2.4.1 Introduction

An artificial neural network concept has been developed from the artificial intelligence and is inspired by the biological nervous system. The artificial neural networks, as a versatile numerical modeling tool, are
frequently used for solving the practical problems in so different areas as medicine, economy, physics or engineering applications.

Artificial Neural Network can be used to simulate the complex engineering problems which cannot be solved by the existing analytical model or a low order empirical polynomial is unsuitable. ANN models have the ability to undertake the problem of complicated relationships among the process variables and predict an output, even if the interactions among the variables are not completely known.

Various studies on the prediction of mechanical properties, machinability and tribological characteristics of Al MMCs employing ANN have been carried out.

### 2.4.2 Development and Applications of ANN

Rashed and Mahmoud (2009) have applied ANN model to analyze the influence of size and weight percentage of SiC particulates, applied pressure and temperature on the wear resistance of SiC reinforced Al 356 and they found that considerable savings in terms of cost and time could be obtained from using ANN models.

Zhang and Friedrich (2003) have reviewed the use of ANN model in predicting the tribological behaviour of polymer matrix composites.

Jain et al (1999) have analyzed modeling of abrasive flow machining process using ANN and reported that the Back Propagation Neural Network model has a mathematically strong learning ability in training and mapping the relations between inputs and outputs.
Cakar and Cil (2004) have used Multi-Layer Perceptron (MLP) using the back propagation algorithm which is an iterative gradient descent algorithm, minimizes the mean square error between the actual outputs of the network and the desired outputs in response to the given inputs.

From the literature review, it can be concluded that the feed forward network with back propagation finds applications in a number of areas of engineering and technology compared with the other types of neural networks.


Singh et al (2006) applied back propagation neural network to predict the flank wear of high speed drills for composite machining. The normalized data sets were used for training the network. They observed that the neural network was able to effectively learn the pattern of wear, and thus applicable to predict drill wear during composite machining.

Altinkok and Koker (2005) predicted mechanical properties such as tensile strength, density and porosity of particle reinforced aluminium composites using back propagation algorithm with one hidden layer. They concluded that the neural network prediction was in good agreement with experimental results.

Review of past research literature suggests that ANN can be applied for the prediction of mechanical and wear behaviour of composite materials. Since the tribological behaviour of composites is a complex and non linear
which causes difficulty in understanding, Artificial Neural Network can be used to predict the wear behaviour of composites more accurately.

The accuracy of network result depends on chosen ANN architecture which can be described by their topology, weight vectors, and transfer (activation) function. Neural network has the ability of adoption, learning, generalization, implementation and self-organization.

2.5 DRILLING CHARACTERISTICS OF COMPOSITES

2.5.1 Introduction

Machinability of composites depends upon a number of material factors like particle size, shape and type of reinforcement, distribution of reinforcement material as well as machining parameters. Various investigators have carried out studies on the machining characteristics of composites using different machines like CNC, EDM and ECM (Mujahid and Friska 2005, Ciftci et al 2004). A brief summary on machinability studies of aluminium composites in the past is discussed below.

2.5.2 Burr Formation during Drilling

In view of the growing engineering applications of metal matrix composites, a need for detailed and systematic study of their machining characteristics and machinability is very relevant.

Burr is an undesirable projection of material as a result of plastic deformation during drilling operation. Burrs can pose many problems during assembling and inspection of precision components. It deteriorates the surface quality and degrades the performance in precision parts. Burrs may cause
blockage of critical passages in pneumatic, hydraulic and electronic circuits, which might cause serious problems during service.

During drilling, almost reaches the exit surface of the work piece, a layer is formed between the exit surface and the drill’s cutting edge. This thin layer does not have enough stiffness to be cut by the drill and plastic bending deformation occurs leading to formation of a burr. During the drilling of each hole, entrance and exit burrs are produced. The entrance burr, which is usually smaller than the exit burr, can be removed easily by chamfering the hole. On the other hand the exit burr is of prime importance due to the difficulty in removing it. If the burr is formed inside a hole, special tools could be employed for deburring. The deburring process is usually done manually because of the difficulties in automation. Moreover deburring operation which increases the total production cost by 20 – 30 % and requires a significant amount of time. Hence a major emphasis on burr minimization becomes necessary.

2.5.3 Drilling of Composites

Various researchers have analyzed the drilling parameters such as drill’s geometry, feed rate and cutting speed on the formation of exit burrs and have proposed burr formation mechanisms.

Pande and Relekar (1986) have analyzed burr formation in terms of burr height and thickness by varying the cutting speed and feed rate.

Gaitonde et al (2007) employed the Taguchi methodology for minimization of burr height and burr thickness with reference to drill’s geometries and cutting parameters.
Burr formation is an important aspect in drilling of MMCs. During drilling of MMCs, the cutting tool undergoes severe abrasive wear due to the presence of hard ceramic particles.

Gul and Mehtap (2004) reported that drilling of MMCs causes several problems in manufacturing such as high drilling force, tool wear and burr.

Akhlaghi and Bidaki (2009) have reported that during dry sliding wear, Al alloy – graphite composite forms a layer of graphite with solid lubricant between the contacting surfaces and this improves resistance to wear and machinability.

2.5.4 Drilling of Hybrid Composites

Brown and Surappa (1988) reported that the machining forces for Al- Si alloy-Graphite composite are lower than those for a similar material without graphite, because of lower tool-chip friction and lower shear flow stress.

Sharma et al (1996) reported that during drilling of ZA-27-Graphite reinforced composites, the torque and thrust force required for drilling increases with the increase in feed rate for composites of all compositions and decreases with an increase in graphite content. Limited attempts have been made on investigating of the formation of burr height during drilling of hybrid MMCs.

Songmene and Balazinski (1999) worked on drilling and milling of Al- SiCp, Al- SiC- Gr and Al-/Al2O3- Gr composites and concluded that the addition of graphite particles improves the machinability of the composite.
2.5.5 **Statistical Analysis in Drilling of Composites**

Various researchers have employed Taguchi design of experiments and analysis of variance to access the influence of the various factors and their interactions which influence the machinability of the materials in machining process.

Davim (2003) studied the influence of cutting parameters on tool wear and surface roughness using Taguchi Design of Experiments and analysis of variance during drilling of composites.

Ramulu et al (2003) conducted drilling experiments using PCD drills to drill Al$_2$O$_3$ particulate reinforced aluminium composites. Machining parameters were analyzed using ANOVA, Response Surface Methodology and regression models were developed. They concluded that drilling forces and average surface roughness values are significantly influenced by the feed rate than the cutting speed.

Tosun (2006) carried out the analysis in determination of optimum parameters for attaining the best surface roughness and the minimum burr height in drilling by using Grey Rational Analysis. Experimental results have shown that the surface roughness and the burr height in the drilling process can be reduced effectively through the new approach.

Talib et al (2004) performed the Scanning Electron Microscopy (SEM) observation on wear mechanism of TiN-Coated, High Speed Steel (HSS) twist drill while drilling mild steel. Results showed that the TiN coated HSS twist drill had given a drill life twice that of uncoated twist drill.

Tsao (2007) employed Taguchi method to analyze of drilling quality associated with core drill while drilling carbon fibre reinforced plastic
(CFRP) laminate composite material. The thrust force and surface roughness of core drill with drill parameters (grit size of diamond, thickness, feed rate and spindle speed) were experimentally investigated in this study. Confirmation tests demonstrated that Taguchi technique is a feasible and an effective method for the evaluation of drilling-induced thrust force and surface roughness (errors within 10%) in drilling composite material.

In the present work, a step drill was employed to minimize the burr size. Unlike twist drill, two cutting stages have to be completed in step drilling. At first, front cutting edge drills the work piece and subsequently second cutting process starts at the step edge. During the second cutting process, the hole is enlarged to its final size through step edge. Hence burr formation in the second cutting stage is determined by the step angle and step size of the drill. Therefore, designing a step drill requires an optimal step angle and step size to minimize the burr.

As part of this study, trial drilling tests were conducted using HSS and solid carbide drills on composite specimens under dry condition. Unlike carbide drill, HSS drill bit became blunt after few trials. It also generated noise and heat during the drilling process. Carbide tools have higher stiffness and superior wear resistance than HSS and hence suitable for drilling of composite materials and cutting conditions where higher feeds and speeds are required. Hence, carbide step drill bit was selected for this study.

2.6 MACHINING CHARACTERISTICS OF COMPOSITES

2.6.1 Introduction

Aluminum matrix composites have emerged as a potential material due to their excellent engineering properties, particularly in aerospace, automotive and electronic industries. The surface quality of the machined
component plays a vital role due to the increasing demand of precision machining for functional attributes such as fitness, fatigue, creep strength, heat transfer, corrosion and wear behaviour.

Machining parameters with respect to tool and work piece have to be optimized in order to attain minimum cutting forces, increased tooling life and better surface texture of the machined components. Moreover the selection of optimal machining parameters has great impact on the economics of machining operations. The influence of turning parameters on surface finish of MMC’s is shown in Figure 2.1.

![Figure 2.1 Influence of turning parameters on surface finish of MMCs](image)

### 2.6.2 Turning of Composites

Manna and Bhattacharyya (2003) reported that a higher cutting speed with low feed rate and low depth of cut enhances the surface finish while turning Al -10 % SiC<sub>p</sub> composites. They recommended that the range of
depth of cut that can be used is 0.25 to 1mm for SiCp reinforced aluminium matrix composites.

Wang et al (2003) reported that the main concern during machining of MMCs is the high tool wear and poor surface finish due to the abrasive action of the ceramic reinforcing particles compared to monolithic alloys.

According to Davim and Baptista (2001), the hard-reinforced ceramic particles in the matrix will not be sheared off by cutting and creates voids during removal of particles from the matrix.

When the reinforcement particles slide over the cutting tool edge during machining of Al- SiC composites, it forms a new surface at the cutting edge and forms built up edge due to higher friction (Lin et al 1995).

It can be observed from the literature, machining conditions such as cutting speed, feed rate and depth of cut influences the machining characteristics of composites significantly.

Medium cutting speeds are recommended for the machining of metal matrix composites. Higher cutting speeds are not useful in all the cases except when PCD tools are used (Lane 1995).

Tooling system influences the effective machining of MMCs, Tooling includes the cutting tools, tool material, geometry, shape and work holding devices.

Material properties are one of the important parameters which influence the machining characteristics of materials. The material properties, which influence machinability, are reinforcement size, reinforcement volume fraction and type of reinforcement material (Hung et al 1998).
Seeman et al (2010) studied tool wear and surface roughness evaluation through the response surface methodology in machining of Al reinforced with 20% SiCp composite. It was reported that the surface roughness is low at higher speed and lower feed rate ranges. Surface roughness was found to increase with increase in depth of cut.

Hoecheng et al (1997) have investigated the influence of speed, feed, depth of cut, tool rake angle and cutting fluid on the surface roughness aluminum alloy/ graphite composites during turning operation.

Yuan and Dong (1993) have analyzed the effect of reinforcement, cutting angle, feed rate and speed on the surface finish in ultra precision diamond turning of Al – SiC composites.

Ciftci et al (2004) have analyzed the influence of different particle size of SiC and cutting speed on tool wear and surface roughness during machining of Al-SiC composites using cubic boron nitride cutting tool. The results revealed that the tool wear was mainly observed on flank side and was strongly influenced by abrasive reinforcement.

2.6.3 Statistical Analysis in Turning of Composites

Muthukrishnan and Davim (2009) have employed ANOVA and ANN modeling techniques to predict the surface roughness and found that the feed rate has major significant factor followed by depth of cut and cutting speed during machining of Al- SiC composite.

According to the metal cutting theory, the feed rate and tool-nose radius decides the pitch and amplitude of the surface profile of the machined component respectively.

Basheer et al (2008) have analyzed the influence of the size of reinforcement, machining parameters on the surface roughness for the Al-SiC composites. They reported that the best surface quality was obtained at the lower feed rate, the smaller SiC particle size and the largest tool-nose radius.

Reinforcement particles used in the manufacturing of metal matrix composites are harder than most of the cutting tool materials which results in high tool wear due to the abrasive action. Most of the researchers have concluded diamond to be the most preferred tool material for machining of MMCs.

Tomac et al (1992) suggested that the cemented carbide and PCD tools are preferred for rough and finish machining respectively based on their investigations on particulate aluminium matrix composites.

Heat (1991) reported that sub-surface damage was greater with cemented carbide compared to PCD tools while machining MMCs containing aluminum oxide fiber reinforcement. This was attributed to the higher hardness of the PCD than that of reinforcement.

Li and Seah (2001) have recommended that the PCD tool for machining the MMCs in comparison to coated carbide tool, since the hardness of the coated tool was less than that of reinforcing particles.

Use of PCD tools in machining of composites increases the cost of machining, hence it is necessary to perform the machinability analysis in order to find optimum cutting parameters using coated carbide tools, to increase
productivity and minimize the tooling cost without compromising the surface finish.

Sahin and Sur (2004) reported that coated carbide tools have higher wear resistance, lower heat generation and lower cutting forces compared to carbide tools during machining. It was found that the flank wear of the coated carbide tools at all cutting conditions were lower compared to carbide tools.

From the literature review, it is clear that the machining of metal matrix composites is an important area of research, but limited studies have been carried out on surface roughness while machining of hybrid metal matrix composites. The study on machinability of Al-fly ash composite acquires more importance due to the presence of fly ash particles which is reported to increase the tensile strength and hardness of the Al matrix.

An attempt has been made to minimize the surface roughness by optimizing the three machining parameters such as cutting speed, feed rate and depth of cut through the Taguchi and ANOVA techniques in turning Al, Al – 15wt. % fly ash and Al – 15wt. % fly ash -1.5 wt. % graphite composites.

From the available literature, coated carbide cutting tool maintains high hardness and resistance to oxidation at high operating temperatures. Hence TiAlN /AlCrN coated tool with 0.8 mm nose radius was selected as cutting tool in order to optimize surface roughness subject to machining constraints.

2.7 CORROSION BEHAVIOUR OF METAL MATRIX COMPOSITES

Metal Matrix Composites (MMCs), particularly aluminium matrix composites have emerged as a potential material for automotive and aerospace
industries due to higher strength to weight as well as strength to cost ratio in comparison to equivalent monolithic alloys. One of the main problems is the use of composite is the role of reinforcement on corrosion resistance.

Corrosion behaviour of the composites depends on the number of variables, such as type, composition of the matrix and reinforcement materials, grit size, weight percentage of the reinforcement particles and its distribution in the matrix, the processing method adapted for manufacturing composites.

The corrosion behaviour is also highly influenced by porosity, high dislocation densities at the matrix-reinforcement interfaces, alloying segregation, the presence of intermetallic compounds and reaction products, residual stress around reinforced particles in the matrix and the electrical conductivity of the reinforcing phases.

Although there is a considerable amount of research on the corrosion behaviour of Al alloys and its composites, limited work has been reported in understanding of corrosion behaviour of Al reinforced with fly ash- Gr particles. Jones (1996) reported that the pure Al is instantaneously covered with a surface oxide film which resists corrosion attack when exposed to corrosive media with pH between 4 and 9, indicating passivity. However, the passivation film gets easily destroyed in the solution containing active anions, such as Cl\(^-\), which leads to localized corrosion, especially pitting corrosion.

Kiourtsidis and Skolianos (1998) studied the corrosion behaviour of AA 2024 –SiC composites in 3.5 wt. % NaCl solution and they reported that the intermetallic phases surrounding the particles initiated pitting attack of the composites.
Aylor and Moran (1985) reported that the pits occurred at the Al-SiC interface in marine environment.

Particulate Al - Gr composites have been developed for potential use in tribological applications such as bearings, bushings, cylinder liners and pistons due to good resistance to wear and seizure. Addition of graphite a well known solid lubricant makes the aluminium alloy self-lubricating.

The strength of commercially pure aluminum is enhanced by the addition of alloying elements. While alloying elements increase its strength, hardness, and Young’s modulus, they can adversely affect its corrosion resistance. Many authors have studied the effect of alloying elements on the corrosion resistance of aluminum.

The corrosion behaviour of Al- fly ash - Gr composite in NaCl solution has been studied as significant interest is being shown to employ in automotive applications.

The present investigation involves the study of corrosion behaviour of unreinforced Al, Al- fly ash and Al-fly ash-Gr reinforced composites in 3.5 % NaCl solution to analyze the effect of fly ash and graphite concentration on corrosion resistance employing potentiodynamic polarization technique. Scanning Electron Microscopy (SEM) investigation of the corroded specimen surface was also carried out.

Summarizing the literature, it can be stated that a good volume of research have been carried out on the mechanical, wear, machining and corrosion characteristics of aluminium metal matrix composites by taking different reinforcement materials.
In the case of hybrid Al matrix composites reinforced with fly ash and graphite particles, limited amount of literature is available encompassing various aspects such as microstructure, mechanical properties, wear, machining and corrosion behaviour in as cast condition. In addition, modeling with Design of Experiments and Artificial Neural Network is also carried out. Based on the literature review, in the present investigation, an attempt was made to study the mechanical properties, wear, machining and corrosion characteristics of pure Al, Al – fly ash and Al – fly ash - graphite composites.