Chapter 1

INTRODUCTION

1.1 Background

Aluminium metal is most versatile because of unique combinations of properties which can be achieved through various routes and processing methods. This makes aluminium and its alloys most suitable for various applications from soft and thin wrapping foil to giant machinery parts. Aluminium can resist all types of oxidation compare to ferrous alloys. This is due to spontaneous formation of highly coherent and continuous inert Al_2O_3 thin film (few tens millions of inch) over the surface of the aluminium. Use of aluminium to make aluminium matrix composite is trend now a days either by powder metallurgy route or casting route. Aluminium metal as the matrix metal can serve many useful properties such as improvement in ductility, strength, toughness, hardness, etc.

Composite is the tailor made materials so one can adjust the properties as per the requirements. Making a good interface between the matrix and reinforcements in the composite materials is prime requirement of the composite making industries. The stress which is applied on the composite should be shared across the interface. Making of interface becomes even more difficult when the reinforcement materials are immune to the chemical reactions. Ceramic particles are non reactive to even at higher temperature and hence there will be wettability issue. An in-situ composite is generally having soft matrix materials and hard ceramic particles.

Many researchers have put their efforts in past four decades to make in-situ aluminium matrix composites using various reinforcements such as particulate reinforcements like Al_2O_3 [1–8], SiC [7, 9–11], SiO_2 [5, 12], ZrO_2 [6, 13], graphite [14–19], B_4C [20], Mica [21], TiB_2 [22], MoS_2 [23], TiO_2 [24], TiC [25, 26], Al_3Zr [27], Fe_3O_4 [28], Fe_2O_3 [29], ZnO [30], MnO_2 [31], carbon and boron fiber [32], rice hulk [33], etc. Higher mechanical properties can be achieved in all above cases as compared to the base alloy.

1.2 Problem Formulation

Metal matrix composite materials are known for their superior properties compared to the conventional metals and their alloys. Improved microstructures and mechanical properties of the composite materials are attributed to the type of matrix and reinforcement materials. Various chemical reactions between matrix and reinforcement at processing temperature generate new phases.

In present work, commercially pure aluminium (LM 0 grade) was used as the matrix material. Aluminium metal widely used for varieties of applications because of its -

- low density (2.67 gm/cm^3),
- ease of manufacturing due to low melting point and high ductility,
- high thermal and electrical conductivity,
- excellent corrosion resistance,
- low cost, etc.

MnO_2 powder was used as reinforcing constituent. MnO_2 is economical, easily available and strengthener to the soft matrix like aluminium. MnO_2 is generally immune to various chemical reactions and hence it requires the presence of wetting agents such as transition metals (Li, Mg, Ca, Ti, Zr and P). The purpose of these wetting agents is to improve the wetting characteristics of the immune (generally ceramic) reinforcement particles by reducing the surface tension [6].

Magnesium metal was used in current study as wetting agent for MnO_2 reinforcement. It does not only improve the wetting property but it also enhances the strength of the system by solid solution strengthening. Magnesium metal reacts with the aluminium matrix and reinforcement particles at the processing temperature and generates various in-situ phases. These in-situ phases are so small that they improves the mechanical properties such as strength and hardness. The strength can be increased due to dispersion strengthening effect. Magnesium metal is light in weight compare to the aluminium. Also, it is highly reactive with oxygen at high temperature.

There are many methods to generate in-situ composite materials. Most economical and less time consuming mass production method is the stir casting. Hence in present work, stir casting method was used to produce in-situ aluminium metal matrix composite (AMMC) materials. Four blade stirrer was used in this work with fixed rotational speed. In stir casting method, due to continuous stirring effect, dispersion of generated in-situ phases is good which ultimately reduces the segregation problem. The microstructure and mechanical properties can be increased.

In this technique, attention is needed to avoid gas entrapment while addition of oxides and wetting agents. To decrease the chances of the porosity in the resultant in-situ composite, proper melt treatment has to be carried out before pouring of molten composite bath.

Different parameters and properties studied are listed in following table 1.1.

Table 1.1: Parameters and properties of the research work

Sr. No.		**Description**
1	Parameters	Amount of reinforcement, Sequence of reinforcement addition,
2	Properties	Density, Ductility, Hardness, Tensile strength, Chemical analysis (spectroscopy) XRD and Microstructure.

1.3 Objectives of the work

Followings are the objectives of the research work:

1. To optimise the amount of wetting agent for commerically pure aluminium,
2. To study the variation of reinforcement and its sequence of addition,
3. To study generated in-situ phases after optimised the wetting agent and reinforcement oxides,
4. To study the microstructure and mechanical properties of in-situ composite material and
5. To compare the properties of existing material with new in-situ route.

1.4 Scope of the work

Making an in-situ aluminium matrix composite (AMMC) materials requires extreme care. As mentioned above, many researchers have studied in-situ composite materials through various methods. During the review of the literatures, it was noted that most of all researchers have followed melting and casting route in which the reinforcement materials have been added after the melting of matrix system. In this sequence of addition, different defects were observed in resultant composite materials such as segregation and porosity. Some researchers have tried to use different sequence of addition (in $Al - SiO_2$ system by Rohatgi et. al. [5] and in $Al - MnO_2$ by Hamid et. al. [31]). But in their study, the reinforcement powder particles was added into the molten matrix. At high temperature addition, reinforcement particle surface may pick the gases from an environment. Due to this, poor interface can generate between matrix and reinforcements in later stage during actual processing. Hence the addition of wetting agent is very important so that it can change the surface chemistry of the reinforcement particles. But due to the gas layer, such reactions are also difficult which ultimately make poor interface. To overcome this difficulty, new approach of the reinforcement addition into the matrix has been studied in this research work. Along with above mentioned sequence in which the reinforcement particles were added after the complete melting of the matrix material, the another new sequence of reinforcement particles addition was also studied in present work.

In new sequence, the reinforcement particles were added initially means before the complete melting of the matrix metal. Thus TWO sequences of the addition are like:

1. **Sequence A:** MnO_2 particles are added *after* the melting of the matrix metal (existing approach) and

2. **Sequence B:** MnO_2 particles are added *before* the melting of the matrix metal (new approach).

This comparative study between sequence A and sequence B revealed many interesting facts. Characterisation part of the research work shows the improvements in the properties by adopting new sequence compared to the existing sequence of the addition.

In industries, there is always requirement of the materials which are having improved properties. In this work, matrix metal was commercially pure aluminium (LM 0 grade) and reinforcement particles were MnO_2 powder which are not highly expensive. The manufacturing method adopted was the stir casting method which is again simple and economical method for mass production. This research work in not particular application oriented study but generated in-situ composite materials shows enhanced properties which can help to replace any existing materials.

1.5 Research findings

The present experimental work is divided into THREE phases such as,

1. **Phase I:** Optimization of magnesium content into CPA
2. **Phase II:** Effect of variation of MnO_2 content by changing its addition sequence into CPA and
3. **Phase III:** Effect of variation of MnO_2 by changing its addition sequence along with optimised magnesium metal from phase I into CPA.

After the processing of the aluminium matrix in-situ composites, various characterizations have been performed to investigate mechanical and metallurgical properties. Various mechanical properties such as ductility, density, hardness and strength were analysed.

In phase I analysis of $Al - Mg$ system, magnesium metal was optimized with commercially pure aluminium (CPA) system. It was found that 3 wt % Mg was giving superior mechanical properties. In phase II analysis of $Al - MnO_2$ system, optimisation of MnO_2 powder was carried out with CPA. In this phase, both sequence A and B were followed to check its effect on final composite properties. It was noted that sequence B (MnO_2 powder added before the melting of matrix metal) and 2.5 wt % MnO_2 was giving best results compared to the sequence A (MnO_2 powder added after the melting of matrix metal). Finally in phase III with optimised Mg metal, checked the variation of MnO_2 by changing its addition sequence. It was found that the $Al - 3wt\%Mg - 2.5wt\%MnO_2$ system showed best results. In this study again sequence B was found the best compared to sequence A. It was found that the in-situ phases which are generated in the matrix due to various chemical reactions are more favourable when we follow the sequence B.

1.6 Research methodology

In present work, melting and casting route was followed for fabrication of aluminium matrix composite with MnO_2 reinforcement. Following is the general flow chart of the experimental work presented in figure 1.1.

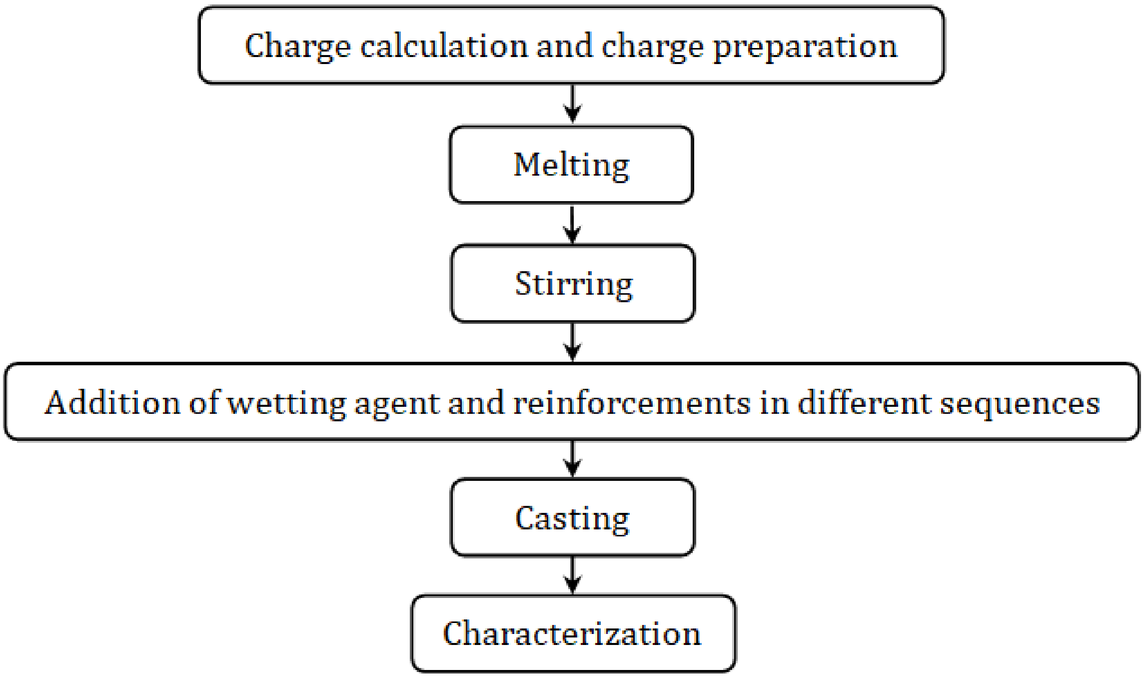

Figure 1.1: Generalised flow sheet of present work methodology.

Detailed methodology of each phase is explained in chapter 3. compassion between the existing addition sequence A with newly adopted addition sequence B.

1.7 Thesis layout

This thesis is containing 07 chapters. The description of each chapter is given below:

1. **Chapter 1:** This is the current chapter describing about background of the work, problem evaluation and novelty, research gap, scope and objective of the work, importance research findings and research methodology used.

2. **Chapter 2:** This chapter contains the detailed literature review starting from the history of the composite materials, classification and manufacturing of composites, solidification behaviours, aluminium matrix composite materials, ex-situ and in-situ composites and applications of the composites in various fields. This chapter also contains the detailed review of most relevant research articles which were published in various books and internationals journals.

3. **Chapter 3:** In this chapter, detailed research methodology (procedure) is explained using simple flow charts. This chapter includes experimental set up details, various difficulties

faced during melting and different characterisation methods.

4. **Chapter 4:** Results and related discussion was explained in this chapter. It starts form the raw materials analysis to final in-situ composite analysis (phase wise) with evidence in form of the tables, graphs and photographs.

5. **Chapter 5:** This is concluding chapter of the research work showing research output in brief.

6. **Chapter 6:** In this chapter, few points were discussed which remained untouch during this work. Also this chapter shows important information on which present work can be carry forward in the future.

7. **Chapter 7:** Total 03 publications from each phase study were presented in this chapter. All these three publications are of international standard from which 02 are published in peer reviews SCOPUS journal whereas 01 paper was presented in international conference and published in its proceeding.