CHAPTER 1
INTRODUCTION

1.1 GENERAL

In the world over for many applications in particular aerospace industries and others, there is heavy demand for advanced light materials. For several decades one such advanced material in use is aluminium and its alloys. Aluminium has the following inherent properties that make it an attractive material for aerospace applications. Some of the characteristics are:

a) Favorable strength to weight ratio.

b) Controlling properties through manufacturing processes and heat treatment methods.

c) Attractive and most corrosive resistance material.

d) Good thermal conductivity.

e) Fairly reliable electrical conductivity, non toxic to human usage or beverage and other food storing applications.

f) Good potential for recycling.

g) As raw materials for thermit welding and other heat generation usage etc.

The current usages of aluminium are produced from the following manufacturing process as shown in Fig 1.1.

The properties of aluminium alloys depend on these processes. Some alloy systems are akin to heat treatment processes and various properties can be enhanced though heat treatment. The main limitation in further enhancing the properties is the inability to enhance through further processing and or heat treatment.
Aluminium Processing

- Casting
  - Sand
  - Permanent moulding
  - Squeeze casting
  - Thixo casting
  - Thixo Squeeze
  - Pressure die
  - Vacuum suction
  - Electro slag refining

- Wrought
  - Forging
  - Sheet metal
  - Forming
  - Roll forming

- Others
  - Welding
  - Friction forming
  - Mechanical alloying

Figure 1.1 Processing of aluminium alloys
Thus new manufacturing processes and aluminium alloy treatment processes are in the process of development. Among the several routes available the promising one's are.

a) Twin roll casting or Direct strip casting (DSC)

b) Aluminum metal matrix composites. These are explained as follows

1.2 TWIN ROLL CASTING

Twin roll casting process [1] is an effective and efficient way of manufacturing aluminum sheets in a most economical way. It also combines economy with quality of aluminum strips or sheets made by using these procedures. Though the process is known for production of steel sheets its usage for making an aluminum sheets is yet to be understood from the point of view of standardization of procedures.

1.2.1 Twin Roll Casting Process

The ability to produce useful solid metal components from the liquid state has been known for thousands of years with several mass production processes developed during industrial revolution. Over the past five decades a number of industrial processes involving dynamic casting techniques have been developed. These are termed continuous casting processes and generally involve pouring of molten metal into some type of mould where a steady state is eventually reached and the material, in billet, plate, strip or rod form, is withdrawn at a given exit velocity with out disruption to the process. The continuous casting process involving aluminum into slabs, billets, and blooms first appeared in the 1950’s and gained ascended quickly over ingot casting. These continuous casting routes have now developed into a mature industrial technology and a very high percentage of the world’s aluminum production is obtained through continuous casting.
Continuously cast slabs and billets are generally produced in thickness of at least 300 mm and subsequently hot rolled to make products such as plate, strips and sheets. The interest of Direct Strip Casting (DSC) [2] lies in their potential for near-net-shape casting (NNSC) products that effectively reduces a number of secondary processing steps. Overall NNSC processes have the capability of producing low-cost products, but there are various key issues that need to be met in order to displace the more conventional casting or wrought processes.

The alloys produced by conventional continuous casting and thin slab casting must undergo a number of secondary processing stages such as reheating, multiple-pass hot rolling and cold rolling and annealing to obtain the desired final thickness. In contrast, the processing route to produce thin-gauge sheet by DSC is vastly simplified as it is often allows strip to be cast and coiled in a single, continuous process. The simple setup of a strip caster makes small plants and a low overall investment in capital possible. The DSC process is also capable of quickly changing the casting conditions to generate a particular combination of properties in the finished product.

The process which we have adopted is the vertical DSC process; where in liquid metal is poured from a tundish between the two counter-rotating rolls with liquid pool usually contained by side dams (see Fig. 1.2). The rolls are made up of conducting metal or a combination of metals and are rotated at a constant speed and in some cases may be cooled internally by water or air. The rolls provide the cooling needed for the solidification of liquid aluminium and, depending on alloy type, may contribute to a small reduction in thickness of the strip. The molten metal and the emerging hot strip are usually protected from oxidation by inert gas shroud. The entire casting process is fully automated in terms of roll separation.
Figure 1.2 Vertical direct strip casting process set up
forces, temperature, cooling water, casting speed with feedback control loops optimizing the process. An important point to note is the micron level roll gap control required in DSC process of aluminum to ensure the desired thickness accuracy in the cast product.

1.2.2 Advantages and Disadvantages of Direct Strip Casting of Aluminum

Advantages [3]

- Lower investment costs.
- Lower operating costs.
- Lower energy consumption.
- Less land.
- Avoids or greatly reduces hot rolling.
- Continuous operation is carried out.
- Generates less re-melt scrap.
- Higher tensile strength with good elongation.
- Can produce some alloys not otherwise available.
- More uniform properties, including earing, over length and breadth of coil.

Disadvantages

- Cost penalties of line failure.
- Higher work hardening rate. May involve more roll process.
- Lack of flexibility for frequent alloy changes.
- Inability to handle strong alloys or the more highly alloyed Al-Mg alloy.
- Inability to produce products with decorative anodizing.
- Homogenization or anneal required to obtain satisfactory deep-drawing properties.
- Not suitable for production of thick aircraft plate.
- Not suitable for clad products.
In light of foregoing discussion there are number of notable advantages of DSC. compared with conventional casting technologies, viz. [4, 5, 6]

- Drastically reduces capital investment cost.
- Uses much smaller continuous caster.
- Eliminates almost all of rolling.
- Offers huge process simplification.
- Minimizes scale losses to improve yield.
- Uses recycled scrap or direct reduced iron processes that are more earth friendly than conventional process.

1.2.3 Economic viability of strip casting

Conventional casting into slabs or ingots and subsequent secondary processing requires an expensive capital investment but an operational plant is usually highly efficient. To achieve the full economic benefits of DSC and hence, compete with other continuous casting processes, it is necessary to take into account;

1) Initial investment cost.
2) Running costs.
3) Maintenance of desired productivity.
4) Energy consumption.

There is a real challenge of producing a wider range of commercially competitive alloys by direct strip casting. For example, DSC of aluminium alloys is currently very limited to foil stock and building applications since the number of alloys is restricted by productivity and quality concerns. The design of new alloys and exploitation of existing alloys in conjunction with new strip casting technology is an important metallurgical challenge for broadening the scope of near-net-shape continuous casting.
1.2.4 Energy and environmental considerations

A very significant benefit of DSC over conventional casting processes is the saving in energy. The consumption of energy associated with various manufacturing processes clearly shows the massive decrease in energy consumption for DSC and thick slab casting (TSC) compared with conventional casting. In fact it has now come to know that strip casting will use up to 90% less energy to process molten metal into sheet form and will reduce greenhouse gas emissions by up to 80% over conventional continuous casting and secondary processing. This represents an environmentally friendly process.

A further notable benefit of DSC is the scale of the operating plant. It is evident that a significant reduction in land will minimize both environmental impact and capital costs for a new casting facility. An additional environmental impact associated with DSC is the ability to make better use of scrap and recycled products. DSC produces high solidification rates which will reduce problems associated with segregation of residual elements in materials such as low carbon steel strip. Hence alloy cleanliness requirements may not be so restrictive and lower quality scrap, normally unsuitable for conventional strip production, may be used in DSC process.

1.3 METAL MATRIX COMPOSITES (MMCs)

Composite material may be defined as a macroscopic combination of two or more distinct materials with a recognizable interface between them. The application of composites is not only limited to improving structural properties, but also for improving electrical, thermal, and environmental properties. Composite materials contain a continuous matrix constituent that binds together and provides to form an array of a stronger, stiffer reinforcement constituent. By means of doing this, the resulting composite material has structural properties superior to either of its constituent materials.
Having more than one material in the matrix, the load is shared and thus improves the load carrying capacity. Composites can be formed by various constituents. The fiber in the Composites is stiffer and stronger than continuous matrix phase. Many types of reinforcements often have good thermal and electrical conductivity, a good coefficient of thermal expansion (CTE) and good wear resistance.

1.3.1 History of Composites

The development of MMCs first originated in 1950’s and early 1960’s. The need for the requirement of MMCs in industrial application was due to dramatically extend the structural efficiency of metallic materials while retaining their advantages, including high chemical inertness, high shear strength, and good property retention at high temperatures. Early work included the usage of sintered aluminium powder as a precursor in discontinuously reinforced MMCs. In 1960’s and 1970’s, the major breakthrough was the development of high strength monofilaments-first Boron and silicon carbide (SiC). During late 1970’s efforts were renewed in the field of discontinuously reinforced whisker reinforcements. The concept of particulate reinforcements came due to the high cost of whiskers and difficulty in controlling damage during consolidation. During 1980’s major efforts included particle reinforced, whisker reinforced, and tow based (An untwisted bundle of continuous fibers) MMCs of aluminum, magnesium, iron, and copper for applications in automotive, thermal management, tribological and aeronautical industries. Significant improvements in performance and material quality were achieved by increasing number of mostly small businesses that specialized in production of MMC components for target markets. The full impact of MMC technology was not widely appreciated due to insufficient publicity given to the advantages of using MMCs though the applications of MMCs increased over a period of time.
1.3.2 Reinforcements

The principal purpose of reinforcement is to provide good strength and stiffness to the composite. In a continuous reinforced composite, the fibers provide virtually majority of strength and stiffness. Fiber tows have been found important applications in MMCs. Fiber monofilaments are being used in MMCs, and they usually consist of a single fiber with a diameter generally greater than 100 micrometers. In MMCs particulates, chopped fibers are the most commonly used reinforcement morphology.

1.4 THESIS PRESENTATION

In this chapter, an introduction to aluminium strip casting process, metal matrix composites and the properties of the aluminium strips is given. Chapter 2 deals with development of the twin roll casting process in the industry as well as in the universities are explained along with various references to the past work. Chapter 3 the objective of the present study is given. In Chapter 4 discussions on development of facilities required for carrying out the research work. Chapter 5 covers the experimental procedure along with some cases for the experiments. Chapter 6 deals with discussion over the results obtained through the experiments conducted. Chapter 7 concludes the current research work along with the scope for the future development.