INVESTIGATION MECHANICAL PROPERTIES AND MICROSTRUCTURE OF ALUMINIUM SILICON ALLOY USING SAND CASTING

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SUPERVISOR’S DECLARATION

I hereby declare that I have checked this project report and in my opinion, this project is adequate in terms of scopes and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing.

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Date : 6 DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This project is to investigate mechanical properties and microstructure of aluminium silicon alloy using sand casting. In this project there were separated into two parts which are foundry laboratory and inspection parameter. In foundry laboratory, a sand casting process was performed by using a diesel furnace to melt the raw material. Then, determinate an optimization of mass degassing agent added in the casting aluminium silicon alloy is to remove the hydrogen element in the casting product. After the casting process, an inspection parameter was performed to investigate the mechanical properties (tensile strength and hardness) and microstructure changed of the aluminium silicon alloys. From the observation of the result, a modified alloys exits slightly higher hardness values than non-modified. Since the coarseness of porosity is proportional to grain size, porosity in fine grained casting is finer and less harmful in fine-grained casting. In additional, shrinkage and hot cracking are usually associated with coarse-grained structure. So, a finer grain size minimizes shrinkage and the mechanical properties, such as tensile is better for fine grained casting than coarse-grained casting. The modified of the casting product by adding the degassing agent inside the casting will give better result mechanical properties in hardness test and tensile strength until an optimization point achieved where there is improvement of mechanical properties.

ABSTRAK

Projek ini menerangkan kajian sifat-sifat mekanikal and perubahan mikrostruktur bagi aloi aluminium silikon. Projek ini dibahagikan kepada dua bahagian iaitu proses tuangan logam dan penyelidikan parameter. Dalam proses tuangan logam, tungku diesel telah dipilih untuk mencairkan logam. Kemudian, nilai optimum degassing agen yang ditambah ke dalam produk ditentukan supaya dapat mengeluarkan semua hydrogen gas dalam produk tuangan. Selepas proses tuangan logam, kerja-kerja uji kaji parameter bagi produk dijalankan bagi menyiasat sifat-sifat mekanikal (kekuatan tegangan dan kekerasan) dan perubahan mikrostrukur selepas proses tuangan logam bagi aloi aluminum silikon. Daripada pemerhatian eksperimen yang dijalankan, hasil daripada pertambahan degassing agen dalam prosess tuangan aloi aluminium silikon mempunyai nilai kekerasan yang lebih tinggi daripada produk yang tiada penambahan degassing agen. Ini disebabkan oleh hubugan berat degassing agen yang ditambah dalam tuangan proses adalah berkadar terus dengan bilangan porositi, perimeter saiz porositi, jarak antara butiran dalam mikrostruktur. Selain daripada itu, penyusutan dan retak panas biasanya berkaitan dengan butiran kasar. Oleh itu, saiz butiran lebih halus and licin dapat meminimumkan penyusutan dan secara tidak langsung meningkatkan sifat mekanik, seperti tegangan yang lebih baik. Kesimpulannya, produk tuangan yang ditambah degassing agen akan memberikan hasil yang lebih baik dalam ujian sifat mekanik seperti kekerasan dan kekuatan tegangan sehingga satu optimum titik degassing agen tercapai.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Aluminium is one of non ferrous metal that widely in used and it was first produced in 1825. It has a white or white gray appearance because it oxidized (Bruce et al, 1987). In the most of abundant metallic element, making up about 8% of the earth's crust and it was produced in quantity second only to that of iron (Lingberg, 2008). The principle ore for aluminium is bauxite which is a hydrous (water-containing) aluminium oxide and includes various others oxides. The production process from bauxite to aluminium consumes a great deal of electricity which contributes significantly to the cost of aluminium (Lindberg, 2008). There were elements such as copper, magnesium, silicon and zinc added into the aluminium to become aluminium alloy to improve the strength, hardness and fluidity (Ravi, 2006).

In recently years, aluminium alloy become one of the most important engineering material in views of machinability, formability, weldablity and castablity (Lindberg, 2008). Aluminium alloy is classified into wrought alloys or cast alloy. One of the cast alloys is aluminium silicon alloy which show excellent castability and good pressure tightness (Ravi, 2006). It is good flow characteristics and has a typically ultimate tensile strength of 140 – 270 MPa (Ravi, 2006).

Today industries, there are a lot of method to improve the strength of the ingot aluminium alloy such as heat treatment, degassing agent, grain refinement and others. One of the easiest methods to improve the mechanical properties of aluminium alloy is by adding the degassing agent in the casting product (Campbell, 2008). The additional of degassing agent were removing the unwanted hydrogen elements from the casting product. This can help reducing the porosity of the casting product and thus the grain size of the aluminium alloy was less harmful (Campbell, 2008). As the result, the microstructure of the aluminium alloy is changed because reduction of the porosity of casting by additional of degassing agent.

1.2 IMPORTANT OF RESEARCH

This research will deepen the knowledge of investigate the suitable sand mould for alloy aluminium silicon by using metal casting process. Besides that, this project is to investigate the effect additional amount degassing agent though the mechanical properties and microstructure changed for 10 kg of aluminium silicon.

1.3 PROBLEM STATEMENT

Basically, there are not fix amount of the addition degassing agent in casting process of aluminium silicon alloy. The additional of degassing agent roughly around 0.01 percent which is not according a correct standard rate of casting size (Campbell, 2004). Besides that, there were no others similar research on using the same degassing agent, Alugus 202 in order to control the casting defect in porosity. So, the purpose of this project is to get a clear understand the effect mass of degassing agent, Alugus 202 to be added which can influence the mechanical properties and the microstructure of the aluminium silicon alloy.

1.4 PROJECT OBJECTIVE

a) Identify the impact of degassing agent on casting product.
b) Investigation microstructure changed and mechanical properties consists of hardness and tension strength with different mass of degassing agent
c) Determine the optimization of degassing agent on casting product.

1.5 SCOPE OF PROJECT

a) CO_2 sand was used as mould.

b) The raw material that used is aluminium silicon alloy.

c) The microstructure and mechanical properties investigation consists of hardness and tensile strength of material with different mass of degassing agent after sand casting process.

d) Alugus 202 as the degassing agent in controlling the porosity defect of sand casting process.

e) Casting size was up to 10kg in mass.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, it had done review on metal casting process and properties of alloy aluminium silicon. By reviewing on others author review, determined the impact of degassing agent on casting product and investigation of properties change in alloy aluminium silicon before and after undergoes metal casting process.

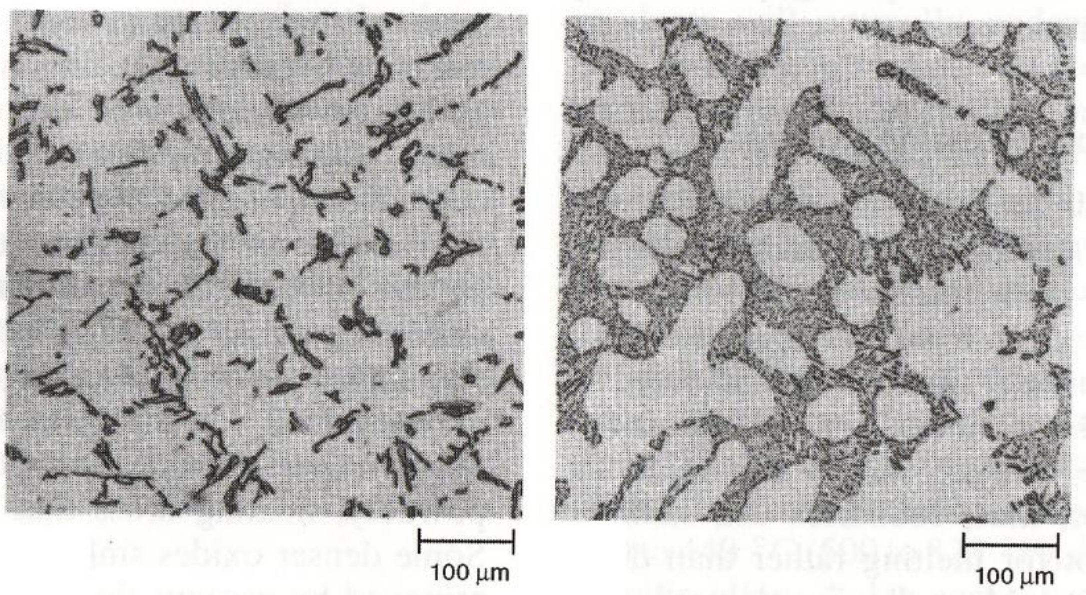
2.2 ALUMINIUM SILICON ALLOY

Aluminium silicon alloy or silumin are widely used for air-compressors, automobile transmission components, aircraft pump parts, automotive and compressor pistons, escalator steps, thin-walled and intricate instrument casting and air craft supercharger covers (Ravi, 2005). The tensile strength of aluminium silicon alloy ranges between 140-270MPa (Ravi, 2005) and the Vickers hardness test is 29HV5 (Ravi, 2005). Because of the relatively high silicon content, the aluminium silicon alloys (4xxx) has excellent flow characteristic, excellent castability and good pressure tightness.

The American metallurgist Paxz discovered in 1920 that addition of small amounts of sodium (a couple of hundredths of a percent) to aluminium silicon alloy melt before solidification changed the flaky, plate-like and branched microstructure of normal aluminium silicon alloys into a much finer, more regular and fibrous microstructure (Fredriksson and Akerlind, 2006).

The structure consists of relatively coarse plates of Si imbedded in a matrix of Al phase as show in Figure 2.1. These plates often have a broom-like shape. The disc- and flake-shaped Si crystals easily break at the solidification front which result the crystal multiplication (Fredriksson and Akerlind, 2006). Crystal multiplication means that parts of dendrite skeleton are carried into the melt and serve as nuclei for new crystals. The broken crystal fragments often turn before they grow. The result that silicon plates have diverging direction and a fan-shaped structure is formed.

A lamella structure is formed when both precipitated phases grow side by side. The unmodified eutectic structure in Al-Si flakes which grow in a fan shaped morphology in cooperation with Al (FCC) (Fredriksson and Akerlind, 2006).



(a) (b)

Figure 2.1: Modification of aluminium silicon casting alloys for unmodified (a) and modified (b) with an original magnification: 100x.

(Source: Campbell, 2008)

2.3 PHASE DIAGRAM OF ALUMINUM SILICON ALLOY

Based on the phase diagram for Al-Si system as show in Figure 2.3 below, it contains a eutectic point at 12.6 wt- % Si. The eutectic temperature is 577 ℃ is very low and the Al dissolves a maximum 1.65 wt-% Si while the solubility if aluminium in silicon is very low and can be neglected. The slow cooling of Al-Si alloys, starting from the liquid phase, leads to different microstructure being formed depending on whether the silicon content is lower than the eutectic composition (hypoeutectic alloys) or higher than the eutectic composition (hypereutectic) as show in Figure 2.2.

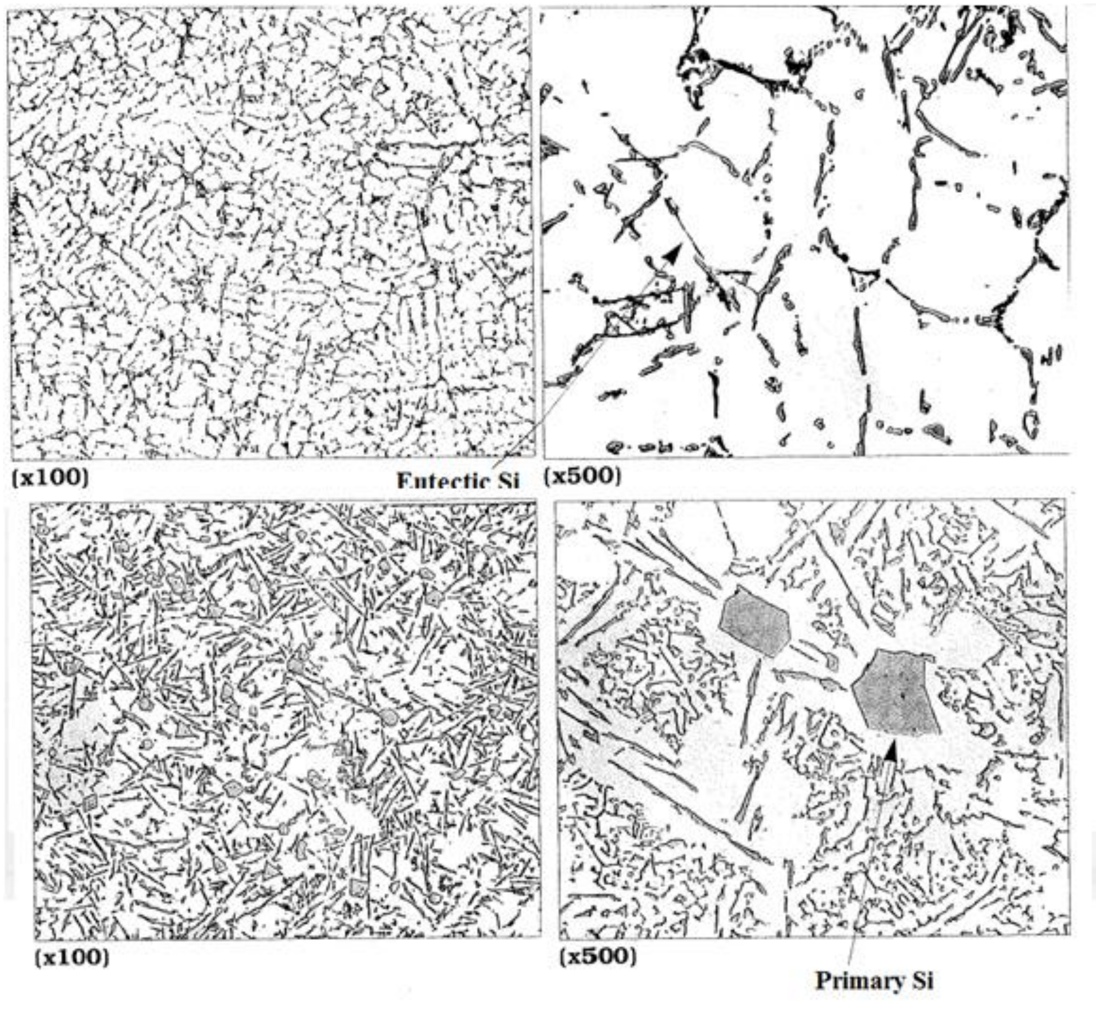


Figure 2.2: Hypeeutetic of Al-Si

(Source: NCMTT, SIRIM BERHAD)

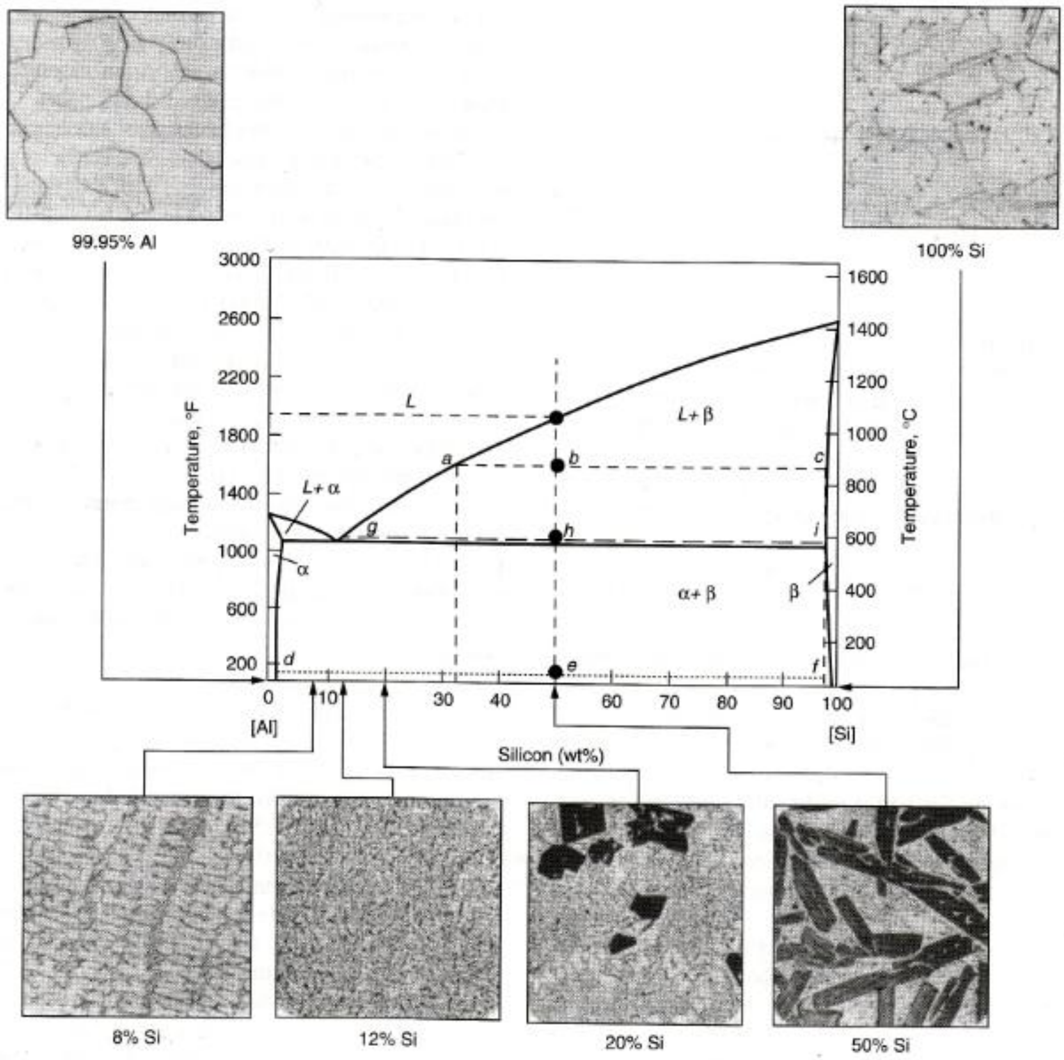


Figure 2.3: Aluminium silicon phase diagram in Fahrenheit and Celsius

(Source: Campbell, 2008)

2.4 METAL CASTING PROCESS

Casting is a 6000 year young process which is mentioned in several Sanskrit works such as Shilpashastra derived from Sthapatyaveda containing the principles of realizing all kinds of man-made structures (Ravi, 2005). Earliest castings include the 11 cm high bronze dancing girl found at Mohenjo-do in between the range dated 3000-3500 BC (Ravi, 2005). Besides that, there was remain of Harappan civilization contain kilns for smelting copper ingots, casting tools, stone moulds, cast ornaments, figurines and others items of copper, gold, silver and lead (Ravi, 2005).

Sand casting is the oldest and still the most widely used casting process. In this process which can be describe as produced by forming a mould from a sand mixture and then pouring molten liquid metal into the cavity in the mould. The mould is then cooled until the metal has solidified. In the last stage, the casting is separated from the mould. The advantages of the sand casting is almost any metal can be cast which is no limit to part size, shape, weight and it is low tooling cost to do this laboratory (Kalpakjian and Schmid, 2006). Basically, the common method of proceed in sand casting process must included pattern making, mould making, melting and pouring of metal, cooling and solidification and lastly is the cleaning process and the inspection.

2.4.1 Pattern

Patterns are the foundry man’s mould forming tool. Pattern is used to form mould cavity in which molten metal is poured. A pattern is a replica of the part or component to be made by the casting process. Pattern replicates the mould cavity and allows the molten metal to solidify inside the mould.

Wood is the most common used of pattern material because it is easy availability, low weight and low cost (Parashar and Mittal, 2006). It is easily to shape, join, work and relatively cheap compare to others pattern material like metal. 90% of the castings are produced by using wood pattern (Parashar and Mittal, 2006). The limitation for the wood pattern is lower life and economical for small quantity production.

Shrinkage allowance is the amount that a pattern is made over size to compensate for the contraction of the casting metal (Parashar and Mittal, 2006). It is the contraction during cooling to room temperature. All metal shrink when cooling except perhaps bismuth because of inter-atomic vibrations which are amplified by an increase in temperature as shown in Table 2.1 below (Rao, 1998). Therefore, the pattern is made bigger in size than the required casting size.

Table 2.1: Shrinkage Allowance

Material	**Shrinkage allowance, mm/m**
Aluminium Alloy	13.0
Aluminium Bronze	20.0 to 30.0

(Source: Rao, 1998)

Draft allowance is the taper provided on the vertical faces of the removable pattern so that the pattern can withdrawn from the rammed sand without causing the damage to the vertical side without the need for excessive rapping (Parashar and Mittal, 2006). All the faces of the part that are parallel to the draw direction are provided a draft angle to facilitate withdrawal. Draft allowance three degrees or more for large internal faces in manual moulding for sand casting process (Ravi, 2006).

Table 2.2: Suggested draft values for wood patterns

Height of the given surface, mm	**Draft angle of surfaces, degrees**	
	External surface	**Internal surface**
20	3.00	3.00
21 to 50	1.50	2.50
51 to 100	1.00	1.50
101 to 200	0.75	1.00
201 to 300	0.50	1.00
301 to 800	0.50	0.75
801 to 2000	0.35	0.50
Over 2000	-	0.25

(Source: Rao, 1998)

2.4.2 Gating System

Gating systems is defined earlier as all those elements which are connected with the flow of molten metal from the ladle to mould cavity (Rao, 1998). There are various elements that are connected with a gating system which is included pouring basin, sprue, sprue base, runner, gate and riser (Parashar and Mittal, 2006).

Nowadays, gating system mainly included parts such as pouring basin, sprue, sprue base, runner, riser, choke, ingate (Rao, 1998). The objective of gating system is to ensure the pouring, cleaning apparatus and economic of casting design (Rao, 1998). For the fast pouring will minimize the temperature loss during mould cavity filling. This can reduce the metallurgical fade and rate of oxidation. The typical pouring rates for aluminium silicon alloy in sand casting process for mass up to 10kg, the pouring rate is around 0.25-0.3 kg/s (Rao, 1998).

Pouring basin is a small funnel shaped cavity at the top of the mould into which the molten metal is poured, which act as a reservoir from which it flow smoothly into the sprue (Rao, 1998). Proper design of pouring basin will reduce splashing at start of pour (Parashar and Mittal, 2006). Sprue is a vertical channel through which the molten metal from the pouring basin reaches the mould cavity. The sprue may have two types which is straight or taper shape. In straight sprue, the metal contract inwards and is pulled away from the sprue walls. In taped sprue, the liquid metal flows down firmly in contact with walls and this can help in reduces turbulence and eliminates aspiration or sucking of gas or air from the mould. Sprue base is a reservoir for the metal at the bottom of the sprue to reduce the momentum of the falling molten metal. The molten metal as it moves down the sprue, gains in velocity, some which lost in the sprue base well, and the mould erosion is reduced (Parashar and Mittal, 2006).

Runner is a horizontal plane which connects the sprue base and the mould cavity letting the molten metal enter the mould cavity (Rao, 1998). It exists to reduce flow velocity of metal stream thus allowing slag particles to float out of metal stream. Gates or ingate is the openings through which the molten metal enters the mould cavity (Rao, 1998). The shape and cross section of the ingate should be such that it can be readily to be broken off after casting solidification and also allow the metal to enter quietly into the mould cavity. Choke is defined as a cross sectional area in gating system which determines mould filling time (Rao, 1998). It happened to be at the bottom of the sprue and hence the first element to design in the gating system is the sprue size and proportions. The main advantages in having the sprue base as the choke area is that proper flow characteristics are established early in the mould.

Riser is a hole cut or moulded in the cope to permit the molten metal to rise above the highest point in the casting. The riser facilities escaping to stream, gas and air from the mould cavity as the mould is filled with the molten metal (Parashar and Mittal, 2006). There are three types of riser is available which is top riser, blind riser and internal riser (Rao, 1998). The top riser is opened loses of heat to atmosphere by radiation and convection. Thus, plaster of paris, asbestos sheet is applied to reduce the loss of heat to atmosphere. The heat of loss for blind riser is slower compare to top riser because all sand moulding is covered the riser. Thus, it is more effective than top riser. The internal riser is the best which is surrounded on all sides by the casting such that heat from the casting keeps the metal in the riser for longer time.

The gating ratio refers to the proportion of the cross-sectional area between the sprue, runner and ingates and is generally denoted as sprue area: runner area: ingates is 1:4:4 (Rao, 1998).

2.4.3 CO_2 Sand Mould

The CO_2 sand process used rammed moist sand that is bound together with sodium silicate which is hardened on the pattern by blowing CO_2 gas through the mould (Lindberg, 1990). This method gives a good surface finish and high accuracy which reduce the machine allowance and versatile easier for small, medium and large foundries for light and heavy casting for ferrous and non-ferrous foundries alike (Jain, 1995).

Basically, this procedure is more accurate mould than either green sand and it avoids baking (Lindberg, 1990). It is better withstanding handling and high metal head pressure such that a dry compressive strength of over 1.4 MPa is arrived. The carbon dioxide is expected to form a weak acid which hydrolyses the sodium silicate resulting in amorphous silica which forms the bond. The introduction of CO_2 gas starts the reaction by forming hydrated sodium carbonate (Na_2CO_3 + H_2O). This gelling reaction increases the viscosity of the binder till it becomes solid. The compressive strength of the bond increases with standing time due to dehydration. The gassing of carbon dioxide pressure should be maintained around 0.14 to 0.28 MPa depending largely on the section to be gassed (Rao, 1998).

2.5 CRUCIBLE FURNACE

A crucible furnace is very convenient for small foundries where the operation is intermittent and a variety of alloys are handled in small quantities. The crucible is made melted is put in a heated crucible which acts as a melting pot. It is made of clay and graphite by moulding the material into standard shape and produced in sizes from 1 to 400 (Jain, 1995). The different metal will have a different capacity of crucible which the crucible capacity is multiplying with the ration of density of the metal. Normally, fuel used to heating the metal may be coke, oil, diesel or gas.

Diesel furnace is a type of Oil-and Gas-fired Furnace which use the fuel for heating the crucible. The furnace is in cylindrical shape and the flame produced by combination of diesel with air is allowed to sweep around crucible and uniformly heating on it. The advantages of the diesel furnace are zero wasted of diesel because no sooner is the metal ready than the supply of diesel can be stopped and less pollution of metal is taking place (Jain, 1995). Besides this, there are others advantages like the output of the times is greater due to higher efficiency, better temperature control can be maintained and saving spacing and labour cost (Jain, 1995).

Generally, there are two types of diesel furnace which are tilting and bale out type. For the tilting type is the furnace type raised above of floor level, mounted on