MANUFACTURING OF 10CC VOLUMETRIC DISPLACEMENT FOUR STROKE PETROL MODEL ENGINE CYLINDER BLOCK USING METAL CASTING PROCESS

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ABSTRACT

This thesis is proposed to develop a 10 cc volumetric displacement four stroke petrol engine cylinder block using metal casting process. Since the development of the engine design getting advanced and complex, casting process also need to keep pace with those development. Thus, to enhance the casting process, control of molten metal flow, pattern design and analysis process play an important role. Therefore, this project will result in the development of casting technology using lead metal and bondcrete to simulate the alternative way of low cost casting method. As for the component to be cast, a small displacement model engine is chosen because it is more likely the same with the internal combustion for commercial vehicles but slightly different path in comparison to bigger displacement engine and easy to manufacture using modest equipment. In a small scale, the development of the complex engine is also reduce and provide important significance platform of application of casting technology for engine block development. Bondcrete casting shows a potential for an alternatives casting process but a lot of tuning needed. While lead is chosen to simulate the bondcrete casting as a molten metal due to its low melting point. It is found that melting point of lead is about 327.46 degree Celsius which is lower than aluminum. Even though there are some defect that usually experienced by other casting such as porosity, inclusion and short casting, but overall process is successfully done using low tooling cost. Based on the final product, it can be concluded that bondcrete casting can be used as an alternatives of other casting process.

ABSTRAK

Tesis ini dihasilkan bertujuan untuk membangunkan proses pembuatan 10 cc sesaran volumetrik 4 strok enjin petrol menggunakan proses tuangan. Sejajar dengan pembangunan enjin yang semakin maju dan kompleks, proses tuangan juga perlu bergerak seiring. Dalam rangka meningkatkan proses tuangan, kawalan aliran logam cair, pola reka bentuk dan analisis proses memainkan peranan penting. Namun, kos dan peralatan sering menjadi penghalang dalam proses pembuatan. Oleh itu, projek ini menghasilkan pembangunan teknologi dengan menggunakan ‘bondcrete’ dan plumbum sebagai cara alternatif yang lebih jimat dan mudah. Model enjin yang bersesaran kecil digunakan dalam projek ini kerana proses pembakaran dalamannya yang sama dengan enjin kenderaan komersial yang lebih besar. Dalam skala kecil, pembangunan yang rumit dapat dikurangkan dan memberi platform yang sama signifikan dalam aplikasi pembangunan proses tuangan. Tuangan bondcrete menunjukkan bahawa ianya sesuai untuk dijadikan alternatif dalam proses tuangan tetapi masih banyak yang perlu dibaiki. Sementara plumbum dipilih untuk mensimulasikan proses tuangan bondcrete sebagai logam cair kerana takat leburnya yang rendah iaitu sekitar 327.42 darjah Celcius iaitu lebih rendah berbanding aluminium. Walaupun terdapat beberapa kecacatan yang biasa dialami oleh proses tuangan yang lain seperti ‘porocity’. ‘inclusion’ dan ‘short casting’, tetapi proses keseluruhan berjaya dilakukan dengan menggunakan alat kos rendah. Berdasarkan produk akhir, dapat disimpulkan bahawa proses tuangan bondcrete boleh digunakan sebagai alternatif kepada proses tuangan.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Sand casting is the most economical method of manufacturing a tanned casting. Casting of a few pounds can also be economically made from the process. However, other casting method, including permanent mould and die-casting are less expensive for large production runs. Sand castings are typically chunky in shape, have a rough surface texture, and have a relatively low-dimensional accuracy relative to other casting methods. The process is variable to a wide variety of nonreactive alloys. Heat treatment, finish machining and inspection are needed to acquire desirable mechanical properties and ensure accuracy of critical dimensions to get desired properties and shape.

1.2 PROBLEM STATEMENT

Engine design and development able to provide a complicated shape of geometry to achieve maximum efficiency but due to constraint in manufacturing technology, development of engine technology is limited to heavy output is always way from the designer expectation since long time ago.

For commercial purpose, the manufacturing of the vehicle of at an engine will not be fully done by conventional lathe and milling process. It consume time and not efficient. Casting technology provides a solution the shape of engine components in economic way, save time, and production cost.

As the enhancement in manufacturing process such as CNC, the development of the engine design move parallel with the manufacturing process. During the product development, manufacturing process will determine the final dimension.

In order to produce a correct casting cylinder block model, control of molten metal flow, pattern design and analysis process play an important roles. Therefore, this project will result in the development of casting technology using lead alloy and bondcrete to simulate the alternative way of low cost casting method.

As for the component to be cast, a small displacement model engine is chosen because it is more likely the same with the internal combustion for commercial vehicles but slightly different path in comparison to bigger displacement engine and easy to manufacture using modest equipment. In a small scale, the development of the complex engine cylinder block parameters is reduce and also provide an important significance platform for application of casting technology for engine block study.

1.3 OBJECTIVES

- To reverse engineering a 10cc volumetric displacement four stroke petrol model engine cylinder block.
- To design and analyze the casting mold and pattern of cylinder block engine using computer aided design tools.
- To prototype the cylinders block using metal casting process.

1.4 WORK SCOPES

The scope of work in development of 10cc four stroke engines will be as follow:

i. Reverse engineering of small displacement engine
ii. Development of pattern and mould of 10 cc volumetric displacement four stroke petrol model engine cylinder block

iii. Manufacture a 10 cc volumetric displacement four stroke petrol model engine cylinder block using bondcrete casting method.

iv. Using lead as a molten metal in bondcrete casting method.

1.5 FLOW CHART

There are several stages involved in making this project. The flow chart in Figure 1.1 shows the overall flow of project in step by step process. Details procedure in completing this project will be described further in other chapters.

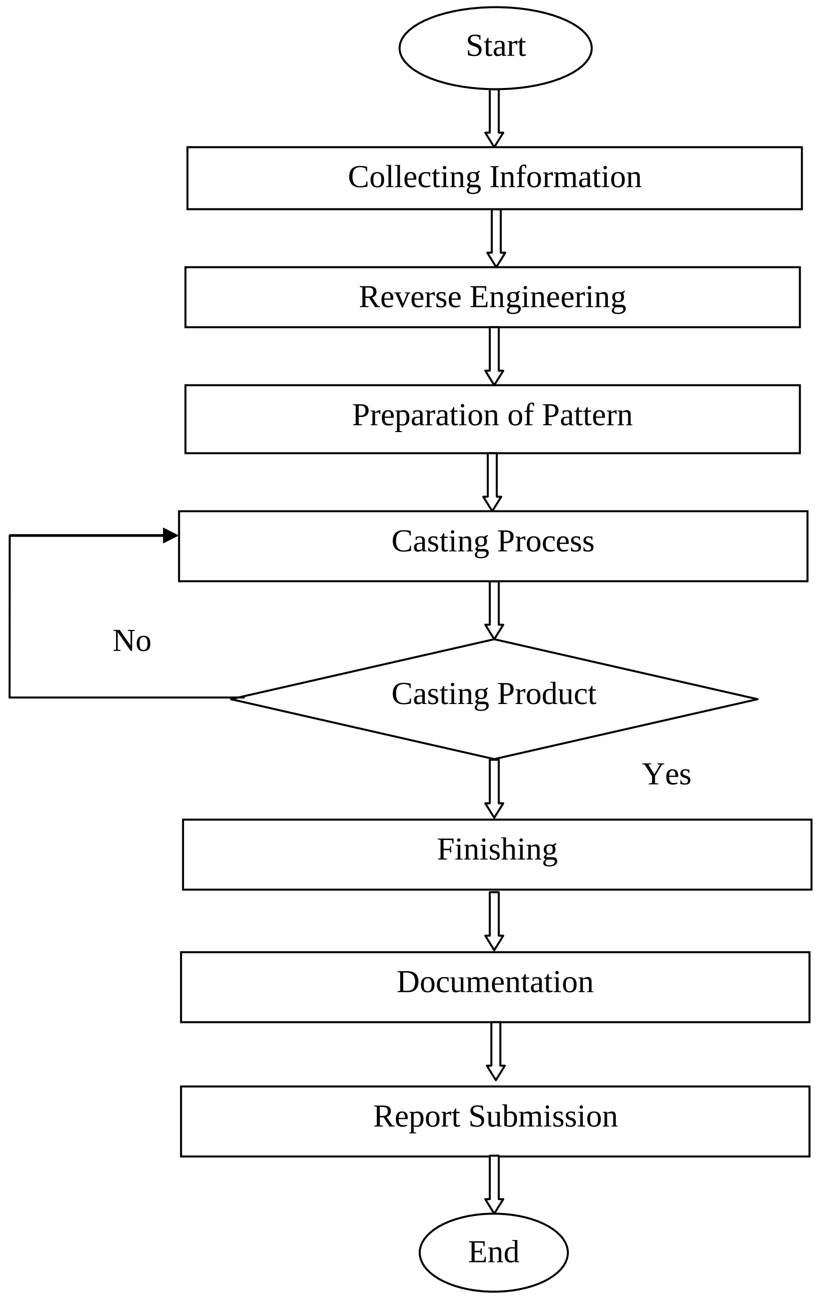


Figure 1.1: Flow Chart of Project.

CHAPTER 2

LITERATURE REVIEW

2.1 METAL CASTING

Casting is a manufacturing process by which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods (Degarmo, 2003).

2.1.1 Types of Metal Casting

Although casting is one of the oldest known manufacturing techniques, modern advances in casting technology have led to a broad array of specialized casting methods. The major classification of casting practices is related to mould materials, moulding processes, and methods of feeding the mould with molten metal. Table 2.1 shows the major categories of metal casting:

Table 2.1: Major categories of metal casting.

Categories	Descriptions
Expandable moulds	• Typically made of sand, plaster, ceramics, and similar materials. Generally mixed with various binders. • Typical sand moulds consist of 90% sand, 7% clay, and 3% water. • These materials are capable of withstanding the high temperature of molten metals. • After the casting is solidified, the mould is broken up to remove the casting.
Permanent moulds	• Made of metals that maintain their strength at high temperatures. • They are used repeatedly and the casting is easily removed so that the mould can be used for the next casting. • Solidifying casting is subjected to a higher rate of cooling.
Composite moulds	• Made of two or more different materials such as sand, graphite, and metal which combining the advantages of each materials. • These moulds have permanent and an expandable portion. • Used in various casting processes to improve mould strength, control the cooling rates, and optimize the overall economics of the casting process.

Source: Kalpakjin and Schmid (2006)

2.2 EXPANDABLE MOULD CASTING PROCESSES

Expendable mould is a process that refers to temporary, non-reusable moulds that have to be broken to remove the materials cast. Usually this process does not imply the use of inexpensive materials.

Expendable casting use a variety of materials for the mold such as plaster, concrete, resins, even wax. This process include sand, shell mould, plaster mould, ceramic mould, evaporative pattern, and investment casting. The method to be used is depends upon the nature of the products to be cast. Table 2.2 shows the general characteristic of casting process to help in selecting the method best-suited for a given production run.

Table 2.2: General Characteristic of Casting Processes

	Sand	Shell	Evaporate pattern	Plaster	Investment	Permanent mould	Die	Centrifugal
Typical materials cast	All	All	All	Non-ferrous (Al, Mg, Zn, Cu)	All	All	Non-ferrous (Al, Mg, Zn, Cu)	All
Weight (kg):								
Minimum	0.01	0.01	0.01	0.01	0.001	0.1	<0.01	0.01
Maximum	No limit	100+	100+	50	100+	300	50	5000+
Type of surface finish (μm R_a)	5-25	1-3	5-25	1-2	0.3-2	2-6	1-2	2-10
Porosity[1]	3-5	4-5	3-5	4-5	5	2-3	1-3	1-2
Shape complexity[1]	1-2	2-3	1-2	1-2	1	2-3	3-4	3-4
Dimensional accuracy[1]	3	2	3	2	1	1	1	3
Section thickness (mm):								
Minimum	3	2	2	1	1	2	0.5	2
Maximum	No limit	-	-	-	75	50	12	100
Type dimensional tolerance (mm/mm)	1.6-4 mm (0.25 mm for small)	±0.003		±0.005-0.010	±0.005	±0.015	±0.001-0.005	0.015
Cost[1,2]								
Equipment	3-5	3	2-3	3-5	3-5	2	1	1
Pattern/Die	3-5	2-3	2-3	3-5	2-3	2	1	1
Labor	1-3	3	3	1-2	1-2	3	5	5
Typical lead time[2,3]	Days	Weeks	Weeks	Days	Weeks	Weeks	Weeks-months	Months
Typical production rate[2,3] (part/mould-hour)	1-20	5-50	1-20	1-10	1-1000	5-50	2-2--	1-1000
Minimum quantity[2,3]	1	100	500	10	10	1000	10,000	10-10,000

Notes: 1. Relative rating, 1 best, 5 worst. For example, die casting has relatively low porosity, mid-to low shape complexity, high dimensional accuracy, high equipment and die costs and low labor costs. These ratings are only general; significant variation can occur depending on the manufacturing methods used.

2. Data taken from Schey, J.A., Introduction to Manufacturing Processes, 3rd ed., 2000.

3. Approximate values without the use of rapid prototyping technologies.

Source: Kalpakjin and Schmid (2006)

Among the most common and oldest examples of the expendable mold technique is plaster casting other than sand casting. Plaster casting makes use of an original to make mould. Table 2.3 shows the comparative advantages of plaster casting and other casting processes.

Table 2.3: Comparative advantages, disadvantages and applications for various casting method.

Sand Casting		
Advantages	**Disadvantages**	**Recommended Application**
Least expensive in small quantities (less than 100) Ferrous and non - ferrous metals may be cast Possible to cast very large parts. Least expensive tooling	Dimensional accuracy inferior to other processes, requires larger tolerances Castings usually exceed calculated weight Surface finish of ferrous castings usually exceeds 125 RMS	Use when strength/weight ratio permits Tolerances, surface finish and low machining cost does not warrant a more expensive process
Permanent and Semi-permanent Mold Casting		
Less expensive than Investment and Die Casting Dimensional Tolerances closer than Sand Castings Castings are dense and pressure tight	Only non-ferrous metals may be cast by this process Less competitive with Sand Cast process when three or more sand cores are required Higher tooling cost than Sand Cast	Use when process recommended for parts subjected to hydrostatic pressure Ideal for parts having low profile, no cores and quantities in excess of 300
Plaster Cast		
Smooth "As Cast" finish (25 RMS) Closer dimensional tolerance than Sand Cast Intricate shapes and fine details including thinner "As Cast" walls are possible Large parts cost less to	More costly than Sand or Permanent Mold-Casting Limited number of sources Requires minimum of 1 deg. Draft	Use when parts require smooth "As Cast" surface finish and closer tolerances than possible with Sand or Permanent Mold Processes

cast than by Investment process		
Investment Cast		
Close dimensional tolerance Complex shape, fine detail, intricate core sections and thin walls are possible Ferrous and non-ferrous metals may be cast As-Cast" finish (64 - 125 RMS)	Costs are higher than Sand, Permanent Mold or Plaster process Castings	Use when Complexity precludes use of Sand or Permanent Mold Castings The process cost is justified through savings in machining or brazing Weight savings justifies increased cost
Die Casting		
Good dimensional tolerances are possible Excellent part-part dimensional consistency Parts require a minimal post machining	Economical only in very large quantities due to high tool cost Not recommended for hydrostatic pressure applications For Castings where penetrate (die) or radiographic inspection are not required. Difficult to guarantee minimum mechanical properties	Use when quantity of parts justifies the high tooling cost Parts are not structural and are subjected to hydrostatic pressure

Source: http://www.yarbis.yildiz.edu.tr (2010)

2.3 BONDCRETE CASTING

Bondcrete casting is a modification of a traditional method of metal casting which combine sand casting method and plaster casting method. Most sand casting operation use silica sand (SiO_2) as mold material. The advantages of sand casting are capable to cast all types of metal which is regardless to the shape; size, weight, and low tooling cost are used. (P.L Jain, 2003). The basic steps in performing sand casting are making and placing a pattern in sand to make an imprint, incorporating a gating system, removing the pattern and filling the mold cavity with molten metal, allowing the metal to cool and solidified, breaking away the sand mould and removing the casting (Kalpakjin and Schmid, 2006).

While plaster casting is applied to the original to create mould or cast of the original. This mould is then removed and fresh plaster is poured into it, creating a copy in plaster of the original. Usually, this casting method is used to cast the more difficult undercut sculpture.

For bondcrete casting, a pattern made of wax is applying plaster casting while the rest of processes are more likely to sand casting but using bondcrete as a mould material.

2.3.1 Bondcrete

Bondcrete is a versatile sealing and bonding agent. Usually, bondcrete is widely used in building and renovating industries for topping, plastering, sealing, decorative finishes, general craftwork and so on. Bondcrete contains an exclusive resin additive that ensures maximum bonding strength for casting both ferrous and non-ferrous metals.

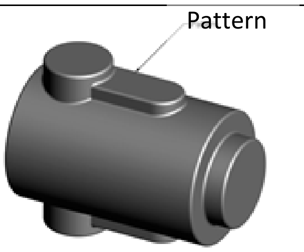
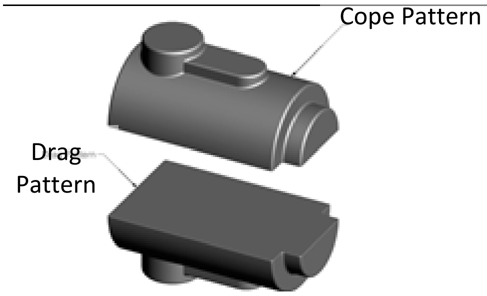
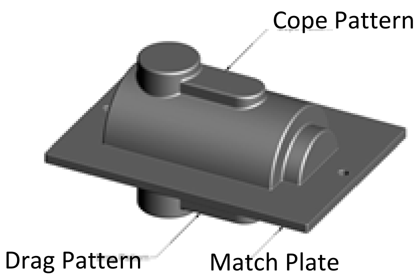
Bondcrete is chosen as a mould material because of its mechanical strength that can hold high temperature. Bondcrete also have excellent properties in surface finishing and treatment.

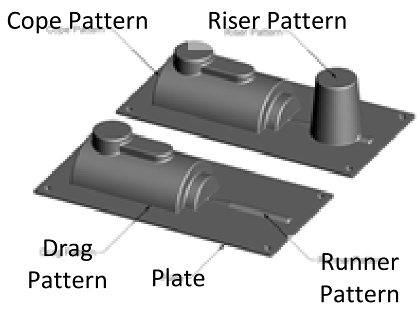
Since bondcrete is a high concentrated solid product, it need high dilution ratio. The suitable proportion to prepare bondcrete with water is 1:2. Molten metal is poured into the bondcrete within 12 to 24 hours after bondcrete mould preparation to keep away from moisture evaporation that may results surface drying and friable mould surfaces (Totten, Funatani, and Xie, 2004). Once casting is solidified, it can be remove immediately by breaking the moulds.

2.3.2 Pattern

Pattern is a replica of the object to be cast, used to prepare the cavity into which molten material will be poured during the casting process (Bawa H.S., 2004). Patterns can be of different types depending on the shape and size of the part to be manufactured. Below are some of the commonly used pattern types.

Table 2.4: Types of pattern

Types of pattern	Description
	• A solid pattern - the most simple of all and is used to make simple shapes. As the name itself suggests, a solid pattern is a single solid piece without any subparts or joints.
	• A split pattern - used for shapes which are more intricate are manufactured using patterns which are made out of 2 or more pieces. These pieces are aligned together with the help of dowel pins.
	• A match-plate pattern - Similar to a split pattern, except that each half of the pattern is attached to opposite sides of a single plate. This pattern design ensures proper alignment of the mold cavities in the cope and drag and the runner system can be included on the match plate.

	• Cope and drag pattern – Similar to a match plate pattern, except that each half of the pattern is attached to a separate plate and the mold halves are made independently. Just as with a match plate pattern, the plates ensure proper alignment of the mold cavities in the cope and drag and the runner system can be included on the plates.

Source: http://www.custompartnet.com (2009)

The pattern's material is selected based on the size and shape of the casting, quantity of casting production, dimensional accuracy and molding process. After the material selection, the pattern design becomes the critical portion in foundry process.]]

As for this project, pattern is made using two difference materials which are wood and wax. Wood is a common material used for making pattern because of it is very cheaper, easy of availability, easy to shape and fabricated into many forms. Types of woods that usually used for pattern making are mahogany, teak wood and deodar.

For wax pattern, it is used because to avoid mould cavity getting damaged while removing the pattern. The mould is inverted and heated to melt the wax out of the mould. Wax pattern provide high degree of surface finish and dimensional accuracy to casting.

The pattern dimensions are totally different from the final dimension due to shrinkage and further processing. Thus, some allowances are added during the stage of pattern design, such as metal shrinkage and machining allowance. The shrinkage allowance and machining allowance can be summarized as Table 2.5 and Table 2.6.

Table 2.5: Shrinkage allowance

Material	Pattern dimension, mm	Shrinkage allowance, mm/m
Lead	Up to 12	12.9
	12 to 18	11.9
	Above 18	10.4

Source: Rao (1998)

Table 2.6: Machining allowance for lead

Dimension, mm	Allowance, mm		
	Bore	**Surface**	**Cope Side**
Up to 300	3.0	3.0	5.5
301 to 500	5.0	4.0	6.0
501 to 900	6.0	5.0	6.0

Source: Rao (1998)

2.3.3 Elements of Gating System

The major elements of a gating system include pouring basin, sprue, well, runner and ingate, in the sequence of flow of molten metal from the ladle to the mould cavity (Figure 2.1). The main objective of a gating system is to lead clean molten metal poured from ladle to the casting cavity, ensuring smooth, uniform and complete filling. Clean metal implies preventing the entry of slag and inclusions into the mould cavity, and minimizing surface turbulence.

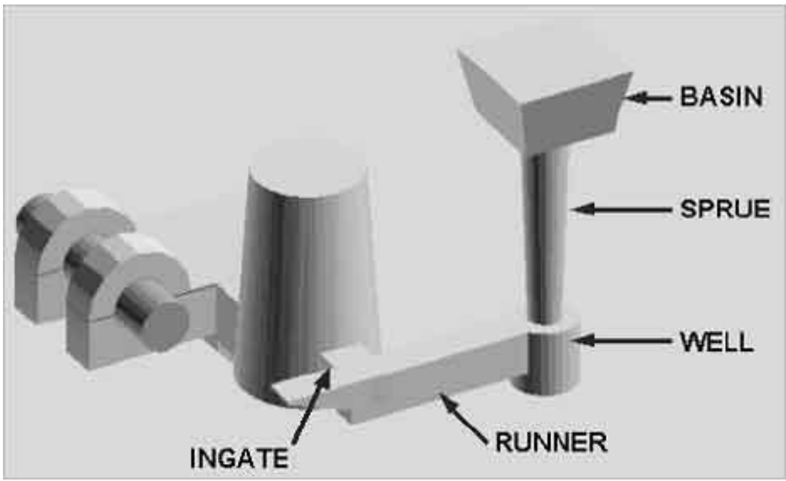


Figure 2.1: Major elements of gating system

For pouring basin, it acts as a reservoir that accepts the molten metal from the ladle. It is also capable to filter the slag and dirt from entering the mould cavity (Rao, 1988). For sprue, it is the channel that connected to runner and gates before reaches to the mould cavity. Two types of sprue are commonly used, straight sprue and tapered sprue. The straight cylindrical sprue will result a narrow metal flow at the bottom. This is due to the permeability of sand mould which tends to capture atmospheric air into the low pressure area of mould. Tapered sprue is designed to eliminate the obstacle of air aspiration.

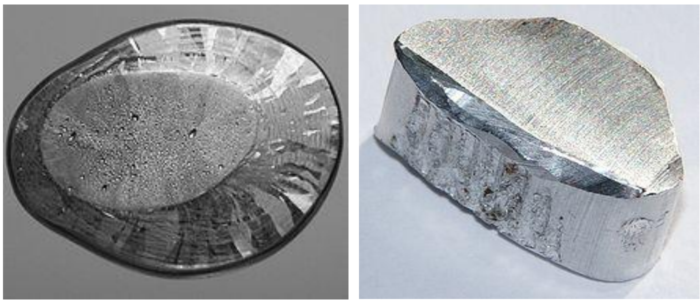
Runner is a horizontal channel that placed in between of sprue and ingates and allows molten metal flow into the mould cavity. The importance of fully filled of runner is effectively trapping the slag and yield a clean molten metal to enter the mould cavity. Gates or ingates are the entrance of mould cavity and it is designed in easily broken off after solidification of casting. During solidification of casting, volumetric shrinkage may occur to various metals. Thus, risers are built and act as reservoir to supply molten metal readily. The design of riser must be concerned on the riser volume which must be sufficient for compensating the shrinkage of casting and solidified at the end of casting process. Generally, cylindrical or hollow cylindrical shape is preferred.

There are three types of riser design. There are open or top riser, blind riser and internal riser. Top riser is placed on top of the compacted sand mould but loses heat to the ambiance by radiation and convection. This can be improved by cover the exposed area with insulator such as plaster of Paris or asbestos sheet. Blind riser is built and surrounded by sand mould. Thus, it will lose heat slowly compared to top riser. The internal riser is placed on all sides by the casting and absorbed heat from casting to retain its melt in longer time.

2.3.4 Raw Material for Molten Metal

In casting, all types of metals can be melted. Types of metal that is often used are aluminum, cast iron, and tin depending on the application and the required properties.

Lead is used in this project to replace the aluminum (Figure 2.2), because have the physical properties almost the same as aluminum. As for lead, it is much heavier but more soft than aluminum. Due to its low melting point and more cheaply than aluminum, lead is chosen in this project. The characteristic and physical properties of them are shown in Table 2.7 and Table 2.8.



(a) (b)

Figure 2.2: (a) Solidified lead. (b) Spectral line of aluminum

Source: en.wikepedia.com (2010)

Table 2.7: Characteristic of Lead and Aluminum

Material	Lead	Aluminum
Characteristics	• Highly resistant to corrosion. • Ductile, very malleable, poor electrical conductivity. • Very soft but can be toughened by addition of small amounts of antimony.	• Easily formed, machined and cast. • Strong, depending on its purity. • Low density, corrosion resistant, electrical conductive. • High reflective, malleable.

Source: Shariman (2009)

Table 2.8: Physical Properties of Lead and Aluminum

Material	Lead	Aluminum
Properties	• Density (near room temperature): 11.34 $g \cdot cm^{-3}$ • Melting points: 327.46^{0}C • Boiling points: 1749 °C • Thermal conductivity at (300 K): 35.3 $W \cdot m^{-1} \cdot K^{-1}$	• Density (near room temperature): 2.70 $g \cdot cm^{-3}$ • Melting points: 660^{0}C • Boiling points: 2497 °C • Thermal conductivity at (300 K): 64.94 $W \cdot m^{-1} \cdot K^{-1}$

Source: Valery (2007)

2.4 CASTING DEFECT

A casting defect is an irregularity in the metal casting process that is undesired. Some defects can be tolerated while others can be repaired otherwise they must be eliminated. Defects can be corrected or removed, or the casting must be rejected. There are many types of defects which result from many different causes. Some of the solutions to certain defects can be the cause for another type of defect (Rao, 1999).

The following defects can occur in castings:

Table 2.9: Types of defect occurred in casting process.

Types of pattern	Description
	• Flash - This is where the mold somehow separated enough to allow metal between the halves, along the parting line. • Causes include letting the mold dry out; the clay in the sand shrinks resulting in a gap between the halves. • Another cause is much more serious: if sprue is very tall and the casting covers a wide area of the mold face, it's possible for the mold to actually be forced up by the hydrostatic pressure of the metal. • The seriousness of this depends on the density of the metal and the weight of the mold.
	• Mold Shift – It is due to not aligning the mold correctly. • Most flasks have alignment pins to prevent this.
	• Porosity - It may occur because of gas from the mold.

	• Inclusion – Caused by the broken piece of pattern or because of loose sand. • For sand molds, the solution is to fastidiously blow out all loose sand, and make sure the sprue and gate areas are strong, since the metal will erode sand and wash it deeper into the mold.
	• Short casting – the mold didn't fill all the way. • Usually caused by the metal solidifying before it fills the cavity. • It could also be a restriction: too small a sprue, gate, or not enough venting keeping the metal from going in or the aluminum cooling too quickly.

Source: Stefanescu (2008)

2.5 CYLINDER BLOCK

Cylinder block is the linchpin of vehicles which run on internal combustion, providing the powerhouse for the vehicle. The cylinder block usually a solid cast car part, housing the cylinders and their components such as cylinder head, valves, pistons, camshafts and others inside a cooled and lubricated crankcase (Pulkrabek, 1997).

In the basic terms of machine elements, the various main parts of an engine such as cylinder, cylinder head, coolant passages, intake and exhaust passages, and crankcase are conceptually distinct, and these concepts are instantiated as discrete pieces that are bolted together. Such construction was very widespread in the early decades of the commercialization of internal combustion engines, and it is still sometimes used in certain applications where it remains advantageous especially very large engines, but also some small engines. However, it is no longer the normal way of building most petrol engines and diesel engines, because for any given engine configuration, there are more efficient ways of designing for manufacture. These generally involve integrating multiple machine elements into one discrete part, and doing the making such as casting, stamping, and machining for multiple elements in one setup with one machine coordinate system This yields lower unit cost not only for production but also for maintenance and repair.

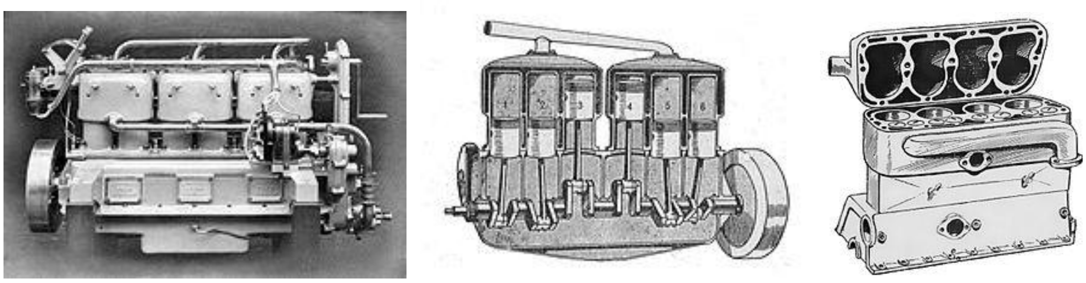
2.5.1 Development of Cylinder Block and Integrated Cylinders

The move from extensive use of discrete elements (via separate castings) to extensive integration of elements such as in most modern engine blocks was a gradual progression that passed through various phases of mono block engine development, where in certain elements were integrated while others remained discrete. This evolution has occurred throughout the history of reciprocating engines, with various instances of every conceptual variation coexisting here and there. The increase in prevalence of ever-more-integrated designs relied on the gradual development of foundry and machining practice for mass production. For example, a practical low-cost V8 engine was not feasible until Ford developed the techniques used to build the Ford flathead V8 engine, which soon also disseminated to the larger society. Today the foundry and machining processes for manufacturing engines are usually highly automated, with a few skilled workers to manage the making of thousands of parts.

In the earliest decades of internal combustion engine development, mono block cylinder construction was rare; cylinders were usually cast individually. Combining their castings into pairs or triples was an early win of mono block design. Each cylinder bank of a V engine typically comprised one or several cylinder blocks until the 1930s, when mass production methods were developed that allowed the modern form factor of having both banks plus the crankcase entirely integrated.

Casting technology at the dawn of the internal combustion engine could reliably cast either large castings, or castings with complex internal cores to allow for water jackets, but not both simultaneously. Most early engines, particularly those with more than four cylinders, had their cylinders cast as pairs or triplets of cylinders, then bolted to a single crankcase.

As casting techniques improved, an entire cylinder block of 4, 6, or 8 cylinders could be cast as one. This was a simpler construction, thus less expensive to make. For straight engines, this meant that one engine block could now comprise all the cylinders plus the crankcase. Mono block straight fours, uncommon when the Ford Model T was introduced with one in 1908, became common during the next decade, and mono block straight sixes followed soon after. By the mid-1920s, both were common, and the straight sixes of General Motors were Ford. During that decade, V engines retained a separate block casting for each cylinder bank, with both bolted onto a common crankcase. For economic, some engines were designed to use identical castings for each bank, left and right (Ludvigsen,1956). The complex ducting required for intake and exhaust was too complicated to allow the integration of the banks, except on a few rare engines, such as the Lancia 22½ narrow-angle V12 of 1919, which did manage to use a single block casting for both banks (Ludvigsen, 1956). The hurdles of integrating the banks of the V for common, affordable cars were first overcome by the Ford Motor Company with its Ford flathead V-8, introduced in 1932, which was the first V-8 with a single engine block casting, putting an affordable V-8 into an affordable car for the first time (Sorensen, 1956).



(a) (b) (c)

Figure 2.3: (a) Cylinders are cast in three pairs. (b) Cylinders are cast in two blocks of three. (c) A flathead engine with integral cylinders.

2.5.2 Small Displacement Engine Block

A small displacement engine are a broad classification of internal combustion engines that are range from engines for radio controlled vehicles to those used in go carts, lawn mowers, chain saws, or other power equipment.

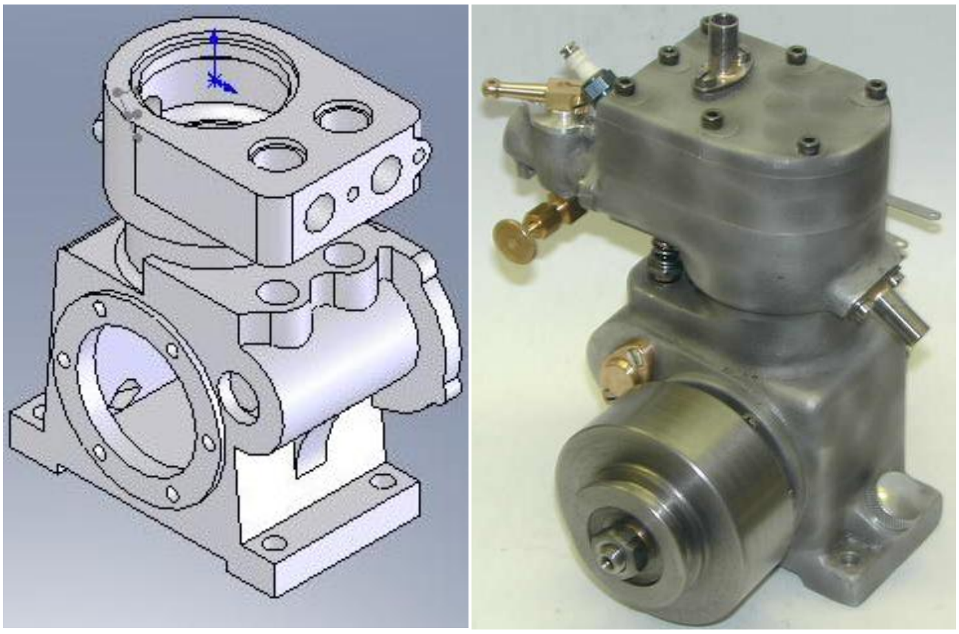
Method of making the engine block varies according to manufacturer fundamental and the design of engine block itself. The common fabrication processes to make the engine block is using casting or machining process. An advantage of using sand casting is also not much raw material to be cut compared to fabrication process using machining methods. Thus, the raw material can be saved. Sand casting is among the cheapest and simplest fabrication process to make the engine block compared to other metal casting methods and machining process. As for machining process, high milling and lathe skill is involved. Although the advance machining process can be done using computer numerated control (CNC) machine, but it is not compatible for large scale production and time consuming.

In this project, the study is focusing on making the main block of 10 cc volumetric cylinder block of an engine using bondcrete casting, alternatives to sand casting process. Small displacement engine is used in this project as it plays a large role in engine technology same as bigger displacement engine. It is also become easier to analyze and fabricate the small displacement engine compatible with the existing equipment in the laboratory.

2.6 REFERENCE DESIGN

2.6.1 Design Criteria

As mentioned earlier, a small displacement engine of 10cc volumetric cylinder block is used in this project. The engine block criteria used is stated as below:



(a) (b)

Figure 2.4: Reference design. (a) 3D Solid Modeling of Whippet Engine Cylinder Block. (b) Original Model of Whippet Engine Cylinder Block.

Source: Whippet for the water, The Model Engineer (1963)

Table 2.10: Description about Whippet Engine Cylinder Block

Description	
Inventor:	Edgar T. Westbury
Engine type:	Four stroke engine
Engine of volumetric displacement:	10 cc
Number of cycle:	1 cylinder
Fuel type:	Petrol
Volume:	150.48 cm^3
Weight:	1.3 kg

This engine is developed by Edgar T. Westbury in 1963 (Edgar T.W., 1963). The Whippet conveys an air of having been well thought out to meet its design objectives, unhindered by any pretension towards style. The engine has four stroke engines and is developed as simple as possible in construction and not unduely heavy.

The engine's design contains a single cylinder, four cycles, spark ignition, side-valve, plain bearing, and petrol engine of 10 cc displacement. It features a wet sump with splash lubrication that can be cooled by a siphon system- no oil or water pump are required. The crankshaft is designed simple over hung with a follower that engages the crankpin to drive the timing gears. The use of a simple conrod with solid ends, further simplifying construction and assembly. While crankcase boring operations is simplified thus mesh attained is corrected by the subsequent placement of the idler pinion.

According to Westbury, compression ratio has been restricted by the choice of the side valve arrangement, and is not generally conducive to high performance; however, it does reduce both the component cunt, complexity and the overall height while facilitating effective water cooling of the head which provides flexible and quiet operation.

The mono-block crankcase can be considered as bulky and complex but it actually simplifies construction and provides a very practical mounting base for an engine intended for marine operation. This is a medium performance petrol engine that can be used in model power boats or for other application such as lawn mowers, chain saws, model aero planes and other power equipments.

Considering all the design and construction features combined with the size, the Whippet engine can easily fabricate using modest equipment since all the components can be cast or machined. But in this project, only cylinder block engine is to be considered for casting process.