بسم الله الرحمن الرحيم

Experimental Investigations of the Effect of Various Gating Systems in Aluminum Casting Process

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CANDIDATES DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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To commence by the name of Allah, who is the most merciful and compassionate and who gave us the chance to complete this project successfully.

Developing this project gave us the courage to explore our talents and further gave us a clear idea of the “Casting process, various molding materials, Effect of temperature during Casting, Temperature control device and Simulation work”.

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Abstract

This paper presents a systemic study of the effect of different cross section of gate in permanent mold casting of aluminium alloy. To ensure best quality of the product they would cavity must be filled with clean metal in a controlled manner to ensure smooth, uniform and complete filling. A gating system controls smooth, uniform and complete filling of the cavity by the molten metal. In this paper, CFD models illustrating the effect of rectangular and trapezium cross sections of gating on cooling of Aluminium alloy in a permanent mold casting were investigated. Same hydraulic diameter was assigned for each of the cross section of gating systems. Bottom gating system is used for its low gas entrapment and less surface defect characteristics. By analyzing it has been observed that in rectangular cross section the cooling is more rapid than trapezium cross sections considered in the investigation.

Besides that aluminum castings have played an integral role in the growth of the aluminum industry since its inception in the late 19th century. The first commercial aluminum products were castings, such as cooking utensils and decorative parts, which exploited the novelty and utility of the new metal. Those early applications rapidly expanded to address the requirements of a wide range of engineering specifications. Alloy development and characterization of physical and mechanical characteristics provided the basis for new product development through the decades that followed. Casting processes were developed to extend the capabilities of foundries in new commercial and technical applications. The technology of molten metal processing, solidification, and property development has been advanced to assist the foundry man with the means of economical and reliable production of parts that consistently meet specified requirements.

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CHAPTER 1

Casting Process

1.1 Introduction

Typically cast iron is used as the mold material and the cores are made from metal or sand. The molds are preheated up to 200 ºC (392 ºF) before the metal is poured into the cavity for ensuring discontinuities, solid inclusion and voids the molten metal must be poured in a controlled manner. This can be achieved by a well-designed gating system. The most critical design decision is the ideal filling time, based on which the gating channels are required to be designed. Uniform filling implies that all portions of the casting fill in a controlled manner, usually at the same time. It was observed that the surface defects for bottom gating system are very less compared to other gating systems. The casting defect locations are affected by the gating system as it controls the melt entrance into the mold. 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. At present there exist theories which, more or less precisely, describe the behavior of the composite in the casting process. The description presented by them is often incomplete and refers only to some chosen elements of the process. In this study a CFD simulation were calculated based on two different cross sections (rectangular and trapezium) of gating systems.

Sand casting, the most widely used casting process, utilizes expandable sand molds to form complex metal pars that can be made of nearly any alloy. Because the sand mold must be destroyed in order to remove the part, called the casting, sand casting typically has a low production rate. The sand casting process involves the use of a furnace, metal pattern and mold. The metal is melted in the furnace and then ladled and poured into the cavity of the sand mold. This is formed by the pattern. The sand mold separates along a parting line and the solidified casting can be removed. The steps in this process are described in greater detail in the next section. Sand casting is used to produce a wide verity of metal components with complex geometries. These parts can vary greatly in size and weight, ranging from a couple ounces to several tons. Some smaller sand cast parts include components as gears, pulleys, crank shafts, connecting rods and propellers. Larger applications include housing for large equipment and heavy machine bases. Sand casting is also common in producing automobile components such as engine blocks, engine manifolds, cylinder heads, and transmission cases. Besides that the many other textile, navel, railways, machine tools, hardwire spare parts are made by the sand casting process.

1.2 History

In 1924, the Ford automobile company set a record by producing 1 million cars, in the process consuming one-third of the total casting production in the U.S. As the automobile industry grew the need for increased casting efficiency grew. The increasing demand for castings in the growing car and machine building industry during and after World War I and World War II, stimulated new inventions in mechanization and later automation of the sand casting process technology.

There was not one bottleneck to faster casting production but rather several. Improvements were made in molding speed, molding sand preparation, sand mixing, core manufacturing processes, and the slow metal melting rate in cupola furnaces. In 1912, the sand slinger was invented by the American company Beardsley & Piper. In 1912, the first sand mixer with individually mounted revolving plows was marketed by the Simpson Company. In 1915, the first experiments started with Bentonite clay instead of simple fire clay as the bonding additive to the molding sand. This increased tremendously the green and dry strength of the molds. In 1918, the first fully automated foundry for fabricating hand grenades for the U.S. Army went into production. In the 1930s the first high-frequency coreless electric furnace was installed in the U.S. In 1943, ductile iron was invented by adding magnesium to the widely used grey iron. In 1940, thermal sand reclamation was applied for molding and core sands. In 1952, the "D-process" was developed for making shell molds with fine, pre-coated sand. In 1953, the hotbox core sand process in which the cores are thermally cured was invented. In 1954, a new core binder - water glass (sodium silicate) hardened with CO_2 from the ambient air, came into use.

1.3 Sand casting

Sand casting is known as *sand molded casting*, is a metal casting process characterized by using sand as the mold material. The term "sand casting" can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories called foundries. Over 70% of all metal castings are produced via a sand casting process.

Sand casting is relatively cheap and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened with water to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The sand is typically contained in a system of frames or mold boxes known a flask.

The mold cavities and gate system are created by compacting the sand around models, or patterns, and or carved directly into the sand.

1.3.1 Basic process

There are six steps in this process:

1. Place a pattern in sand to create a mold.
2. Incorporate the pattern and sand in a gating system.
3. Remove the pattern.
4. Fill the mold cavity with molten metal.
5. Allow the metal to cool.
6. Break away the sand mold and remove the casting.

1.3.2 Mold materials

There are four main components for making a sand casting mold:

» Base sand

»Binder

» Additives

» Parting compound.

1.3.3 Molding sands

Molding sands, also known as foundry sands, are defined by eight characteristics:

» Refractoriness

» Chemical inertness

» Permeability

» Surface finish

» Cohesiveness

» Flow ability

» Collapsibility

» Availability/ Low cost.

1.3.4 Properties of Molding Sands

Refractoriness — this refers to the sand's ability to withstand the temperature of the liquid metal being cast without breaking down. For example some sands only need to withstand 650 °C (1,202 °F) if casting aluminum alloys, whereas steel needs sand that will withstand 1,500 °C (2,730 °F). Sand with too low a refractoriness will melt and fuse to the casting.

Chemical inertness — the sand must not react with the metal being cast. This is especially important with highly reactive metals, such as magnesium and titanium.

Permeability — this refers to the sand's ability to exhaust gases. This is important because during the pouring process many gases are produced, such as hydrogen, nitrogen, carbon dioxide, and steam, which must leave the mold otherwise casting defects, such as blow holes and gas holes, occur in the casting. Note that for each cubic centimeter (cc) of water added to the mold 16,000 cc of steam is produced.

Surface finish — the size and shape of the sand particles defines the best surface finish achievable, with finer particles producing a better finish. However, as the particles become finer (and surface finish improves) the permeability becomes worse.

Cohesiveness (or **bond**) — this is the ability of the sand to retain a given shape after the pattern is removed.

Flow ability – The ability for the sand to flow into intricate details and tight corners without special processes or equipment.

Collapsibility — this is the ability of the sand to be easily stripped off the casting after it has solidified. Sands with poor collapsibility will adhere strongly to the casting. When casting metals that contract a lot during cooling or with long freezing temperature ranges sand with poor collapsibility will cause cracking and hot tears in the casting. Special additives can be used to improve collapsibility.

Availability/cost — the availability and cost of the sand is very important because for every ton of metal poured, three to six tons of sand is required. Although sand can be screened and reused, the particles eventually become too fine and require periodic replacement with fresh sand.

In large castings it is economical to use two different sands, because the majority of the sand will not be in contact with the casting, so it does not need any special properties. The sand that is in contact with the casting is called *facing sand*, and is designed for the casting on hand. This sand will be built up around the pattern to a thickness of 30 to 100 mm (1.2 to 3.9 in). The sand that fills in around the facing sand is called *backing sand*. This sand is simply silica sand with only a small amount of binder and no special additives.

1.4 Types of base sands

Base sand is the type used to make the mold or core without any binder. Because it does not have a binder it will not bond together and is not usable in this state.

1.4.1 Silica sand

Silica (SiO_2) sand is the sand found on a beach and is also the most commonly used sand. It is made by either crushing sandstone or taken from natural occurring locations, such as beaches and river beds. The fusion point of pure silica is

1,760 °C (3,200 °F); however the sands used have a lower melting point due to impurities. For high melting point casting, such as steels, a minimum of 98% pure silica sand must be used; however for lower melting point metals, such as cast iron and non-ferrous metals, a lower purity sand can be used (between 94 and 98% pure).

Silica sand is the most commonly used sand because of its great abundance, and, thus, low cost (therein being its greatest advantage). Its disadvantages are high thermal expansion, which can cause casting defects with high melting point metals, and low thermal conductivity, which can lead to unsound casting. It also cannot be used with certain basic metal because it will chemically interact with the metal forming surface defect. Finally, it causes silicosis in foundry workers.

1.4.2 Olivine sand

Olivine is a mixture of orthosilicates of iron and magnesium from the mineral dunite. Its main advantage is that it is free from silica; therefore it can be used with basic metals, such as manganese steels. Other advantages include a low thermal expansion, high thermal conductivity, and high fusion point. Finally, it is safer to use than silica; therefore it is popular in Europe.

1.4.3 Chromite sand

Chromite sand is a solid solution of spinels. Its advantages are a low percentage of silica, a very high fusion point (1,850 °C (3,360 °F)), and a very high thermal conductivity. Its disadvantage is its costliness; therefore it's only used with expensive alloy steel casting and to make cores.

1.4.4 Zircon sand

Zircon sand is a compound of approximately two-thirds zircon oxide (Zr_2O) and one-third silica. It has the highest fusion point of all the base sands at 2,600 °C (4,710 °F), a very low thermal expansion, and a high thermal conductivity. Because of these good properties it is commonly used when casting alloy steels and other expensive alloys. It is also used as a mold wash (a coating applied to the molding cavity) to improve surface finish. However, it is expensive and not readily available.

1.4.5 Chamotte sand

Chamotte is made by calcining fire clay (Al_2O_3-SiO_2) above 1,100 °C (2,010 °F). Its fusion point is 1,750 °C (3,180 °F) and has low thermal expansion. It is the second cheapest sand; however it is still twice as expensive as silica. Its disadvantages are very coarse grains, which result in a poor surface finish, and it is limited to dry sand molding. Mold washes are used to overcome the surface finish problem. This sand is usually used when casting large steel work pieces.

1.5 Other materials

Modern casting production methods can manufacture thin and accurate molds—of a material superficially resembling papier-mâché, such as is used in egg cartons, but that is refractory in nature—that are then supported by some means, such as dry sand surrounded by a box, during the casting process. Due to the higher accuracy it is possible to make thinner and hence lighter castings, because extra metal need not be present to allow for variations in the molds. These thin-mold casting methods have been used since the 1960s in the manufacture of cast-iron engine blocks and cylinder heads for automotive applications.

1.6 Binders

Binders are added to base sand to bond the sand particles together (i.e. it is the glue that holds the mold together).

1.6.1 Clay and water

A mixture of clay and water is the most commonly used binder. There are two types of clay commonly used: bentonite and kaolinite, with the former being the most common.

1.6.2 Oil

Oils, such as linseed oil, other vegetable oils and marine oils, used to be used as a binder, however due to their increasing cost; they have been mostly phased out. The oil also required careful baking at 100 to 200 °C (212 to 392 °F) to cure (if overheated the oil becomes brittle, wasting the mold).

1.6.3 Resin

Resin binders are natural or synthetic high melting point gums. The two common types used are urea formaldehyde (UF) and phenol formaldehyde (PF) resins. PF resins have a higher heat resistance than UF resins and cost less. There are also cold-set resins, which use a catalyst instead of a heat to cure the binder. Resin binders are quite popular because different properties can be achieved by mixing with various additives. Other advantages include good collapsibility, low gassing, and they leave a good surface finish on the casting. MDI (methylene biphenyl disocyanate) is also a commonly used binder resin in the molding sand

1.6.4 Sodium silicate:

Sodium silicate [Na_2SiO_3 or (Na_2O) (SiO_2)] is a high strength binder used with silica molding sand. To cure the binder carbon dioxide gas is used, which creates the following reaction: $\boldsymbol{Na_2O(SiO_2) + +CO_2 = Na_2CO_{3+}2SiO_2 + Heat}$

The advantage to this binder is that it occurs at room temperature and quickly. The disadvantage is that its high strength leads to shakeout difficulties and possibly hot tears in the casting.

CHAPTER 2

Design Experimental Setup

2.1 Design Considerations

In the models generated in AutoCAD, different parts of the mold i.e. sprue, basin, riser etc. were designed by maintaining same hydraulic diameter to ensure the flow characteristics to be same at corresponding points of each model.

2.2 Temperature Meter Design

- ✓ The temperature controller used for conducting our experiment was bought from the market.
- ✓ It basically can measure the temperature range of 0-999 degree Celsius.
- ✓ Furthermore, the K-type thermocouple was used in our experiment, and also rest of the arrangements were well assembled to take the reading easily.
- ✓ The temperature meter design used in our experiment is shown in the figure below.

Fig 2.1 Multi Temperature Meter

2.3 Temperature Meter specification:

Model: CD-XMTA-1001

Range: 0-999°Celcius

Input: K type thermocouple

Power: AC-220V

YANGMING, XINXIN AUTOMATION INSTRUMENT FACTORY, KOREA

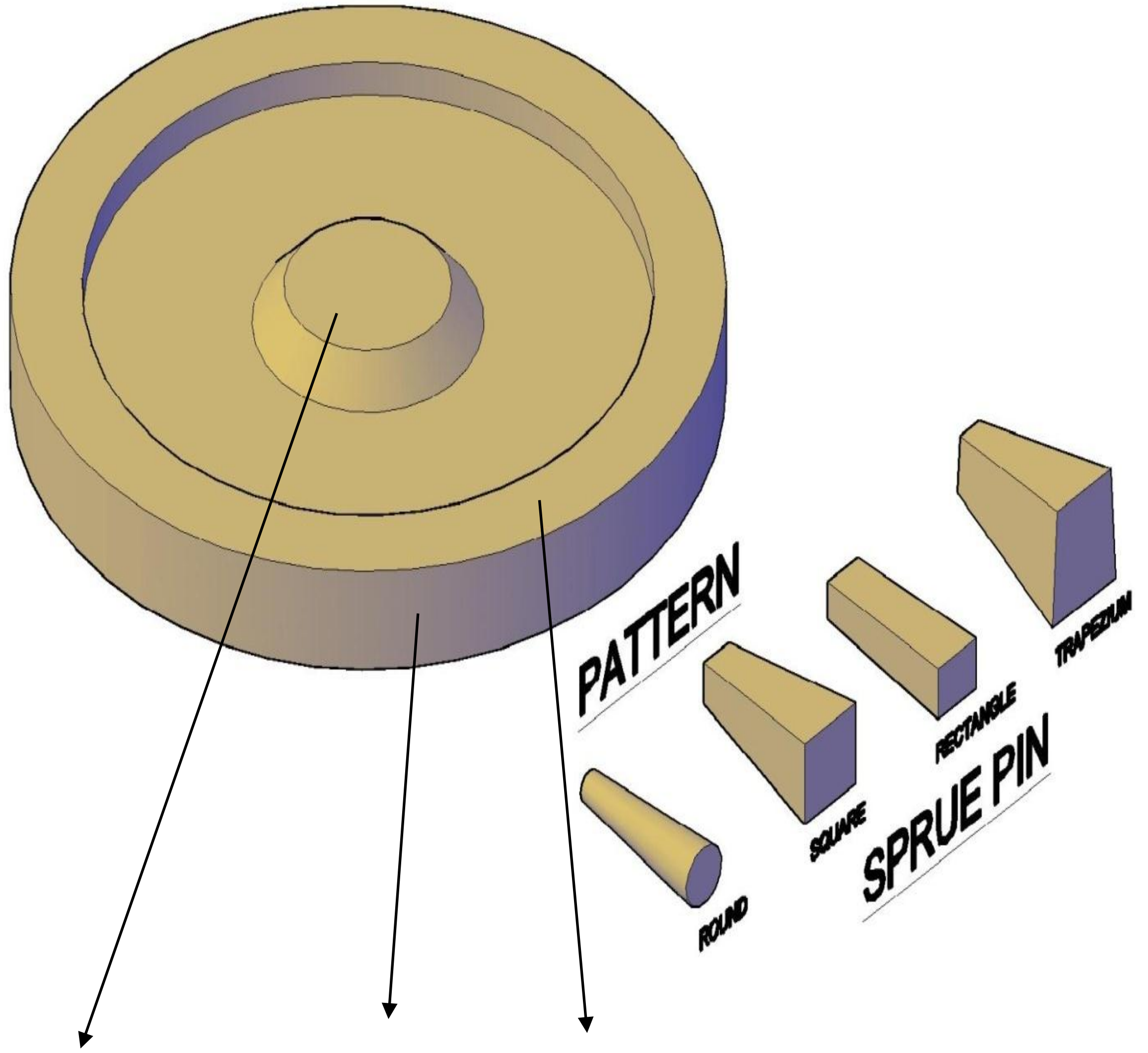
2.3.1 K Type Thermocouple

Type K chromel (90 percent nickel and 10 percent chromium) and alumel (95% nickel, 2% manganese, 2% aluminium and 1% silicon) is the most common general purpose thermocouple with a sensitivity of approximately 41 µV/°C, chromel positive relative to alumel. It is inexpensive and a wide variety of probes are available in its −200 °C to +1350 °C (-328 °F to +2462 °F) range. Type K was specified at a time when metallurgy was less advanced than it is today, and consequently characteristics may vary considerably between samples. One of the constituent metals, nickel, is magnetic; a characteristic of thermocouples made with magnetic material is that they undergo a deviation in output when the material reaches its Curie point; this occurs for type K thermocouples at around 350 °C

Type = K
Temperature range °C (continuous) = 0 to +1100
Temperature range °C (short term) = −180 to +1300
Tolerance class one (°C) = ±1.5 between −40 °C and 375 °C ±0.004×T between 375 °C and 1000 °C

2.4 Pattern Design

The Pattern is designed in Auto CAD. As shown in the figure 2.2, the Sprue Pin Is designed in various shapes such as square, round, rectangular and trapezium.



Point 1 **Point 2** **Point 3**

Fig 2.2 Pattern with various zone point and various types Sprue

2.5 Pattern Making

Wooden pattern is made in our experiment and also the other sprue spins were used so that the mold can be conveniently made by this pattern.

Fig 2.3 Wooden Pattern and Various sprues

2.6 Sprue Design

A sprue is the passage through which liquid material is introduced into a mold. During casting or molding, the material in the sprue will solidify and need to be removed from the finished part.

In casting, a sprue is the passage through which a molten material is introduced into a mold, and the term also refers to the excess material which solidifies in the sprue passage. In sand casting, the sprue is formed by a dowel which is removed from the sand to make the hole into which the metal is poured.

2.7 Function of Sprue

Sprue can serve as filters, heat sinks, and as feeders. Bronze in particular has a high shrinkage rate as it is cooling; a sprue can continue to provide molten metal to the casting, provided it is large enough to retain its heat and stay liquid, as metal in the main casting cools and shrinks. The design of the sprue and runner system can be also utilized to trap unwanted dross and sand from continuing into the main cavity; this may include adding porous material to the runners, or designing the sprue to eject the dross to the side of the sprue using cyclonic separation.

The design of gating and runner is also essential for casting. The design can be done by using vertical and bottom gating.

For bottom gating

$$t_f = \frac{2A_m(\sqrt{h_t} - \sqrt{h_t - h_m})}{A_g\sqrt{2g}}$$

Where:

t_f= Time for filling
A_m= Area of mold
A_g= Area of gate
g= Acceleration due to gravity
h_t= Total height
h_m = Height of mold cavity

This equation may change if the height of gating is equal to height of casting material.

Then the equation will be:

$$t_f = \frac{2A_m\sqrt{h_t - (h_t - h_m)}}{A_g\sqrt{2g}}$$

Or, simplified,

$$t_f = \frac{2A_m\sqrt{h_m}}{A_g\sqrt{2g}}$$

Where:

t_f= Time for filling
A_m= Area of mold
A_g= Area of gate
g= Acceleration due to gravity
h_t= Total height (Height of gating + height of mold cavity)
h_m = Height of mold cavity

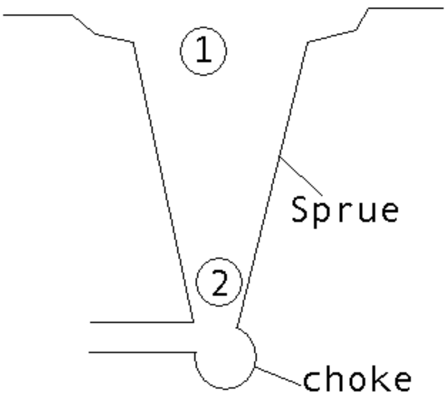
For top gating

A_1=area at the sprue entrance

A_2=area at the sprue exit

h_1=the level of liquid metal above the sprue entrance

h_2=the level of liquid metal above the sprue exit



$$\frac{A_1}{A_2} = \frac{\sqrt{h_2}}{\sqrt{h_1}}$$

Fig 2.4 Sprue and Choke

2.8 Choke Area Design

Sprue Area = M.T/t .d (2.g.H) $^{0.5.Cd}$

The terms are described in more detail in the explanatory notes

M = cast weight, casting and feeders, kg;

T = bottom pour correction factor: average filling rate/initial filling rate at start of pour;

t = measured or required filling time of casting including feeders, seconds;

d = liquid metal density, kg/m^3;

g = gravity constant; 9.81ms^2

H = metal head: in the case of the sprue exit this will be the total head above it including the pouring basin; for the sprue entrance this will be the head in the pouring basin.

Cd = discharge coefficient to allow for variations in mass distribution in the mold and friction losses; when T is based on experimental measurement this is equal to 1

2.9 Riser Design

Risers are reservoirs of molten material. They feed this material to sections of the casting to compensate for shrinkage as the casting solidifies. There are different classifications for risers. Riser design criterion considering the cooling of the casting:

(volume/area) riser= (volume/area) casting (3)

Higher V/A indicates towards increased solidification time.

❖ **Risering**

✓ Risering is a process designed to prevent shrinkage voids that occur during solidification contractions

✓ Aluminum – 6.6%

✓ Steel – 2.5 to 4%

❖ **Criteria for Riser design**

- Riser must remain molten until casting is completely solidified
- Riser should have enough liquid metal to feed casting
- Riser should be kept at proper distance from the casting

2.10 Gates and runners

Some mold makers make a distinction between three separate entities: the gate, the runner, and the sprue. Certainly in the plastics injection molding industry, the gate is the location at which the molten plastic enters the mold cavity and is often seen as a small nub or projection (the "gate mark") on the molded piece. The sprue is large-diameter channels through which plastic flows, usually around the edges of the part or along straight lines. Finally, in this naming scheme, the runner represents only the smaller channels that divert from the sprue to the individual part. An analogy to the sprue/runner system might represent the sprue with city water mains, and runners with the smaller pipes leading to individual houses.

Many scale model kits are made from injection-molded plastic. Hobbyists, such as builders of scale models, typically remove the parts of a model kit from the runner using a sharp craft knife or razor saw. They may also use the sprue or runner as a raw material to fabricate additional parts, such as railings on model ships, or antenna wires on airplanes. Sprue in model kits often includes engravings to identify the parts by number.

2.11 Optimum condition

The knowledge of melting temperature of metals and alloys is necessary to estimate their corresponding pouring temperature. Aluminum alloy casting has melting temperature of 660°C with its corresponding pouring temperature range between 700°C-750°C. In order to avoid rapid solidification, intercepted directional solidification and shrinkage of casting and mold warping, it is necessary to maintain an optimum temperature. The pouring temperature of 700°C for inlet temperature with a tolerance of 10°C has been taken.

2.12 Flow Characteristics

- Important characteristics in fluid flow is *Turbulence* as opposed to *Laminar Flow*
- Reynolds number

Re = vDr/η

v: velocity

D: diameter

r: density

η: viscosity

- Re is usually between 2000 and 20000

❖ **For Re above 20000**

- ‘dross’ formations occur caused by air and gases
- Scum on top can get mixed with alloys

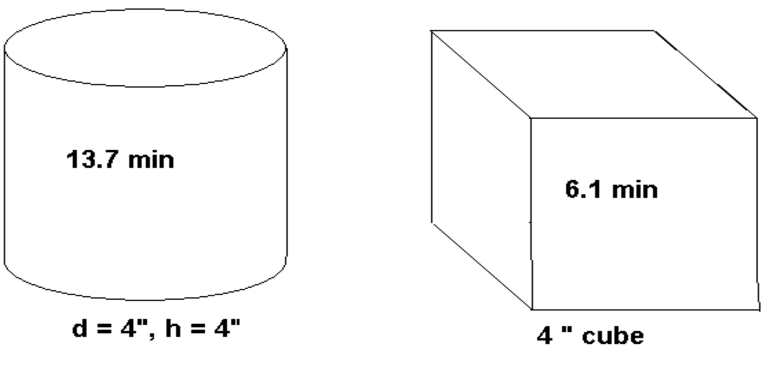
❖ **Elimination techniques**

- Avoid sudden changes in fluid flow
- Avoid sudden changes in cross section
- ‘dross’ can be reduced by filters (ceramic, mica)
- Also with proper pouring basin and gating system

❖ **Heat Transfer: Chvorinovs Rule**

- Solidification time is proportional to volume of casting and its surface area
- C: constant reflects mold metal properties

$$time = C\left(\frac{volume}{surfacearea}\right)^2$$



Example

Three pieces being cast have the same volume but different shapes. One is a sphere, one a cube and the other a cylinder (Height = Diameter). Which piece will solidify the fastest and which the slowest?

- Solidification time a $1/(\text{surface area})^2$
- Assume volume to be unity
- Sphere $V = (4/3)\ pr^3$, $r=(3/4p)^{1/3}$ and $A = 4pr^2 = 4p(3/4p)^{2/3} = 4.84$
- Cube $V = a^3$, $a=1$, $A= 6a^2 = 6$
- Cylinder $V = pr^2h = 2pr^3$, $r=(1/2p)^{1/3}$, $A = 2pr^2 + 2prh = 6pr^2 = 6p(1/2p)_{2/3}$ $= 5.54$

Thus respective solidification times are

- $T_{(sphere)} = 0.043\ C$
- $T_{(cube)} = 0.028\ C$
- $T_{(cylinder)} = 0.033\ C$

C is a constant

2.13 Gating System

- Pouring basin, Sprue, choke, runner, ingate

❖ **Function**

- Trap contaminants
- Regulate flow of molten metal
- Control turbulence
- To establish directional solidification

❖ **Design of gating system**

Pouring cup

- Cut into cope
- Large enough to keep the sprue full
- Skim core to provide clean metal

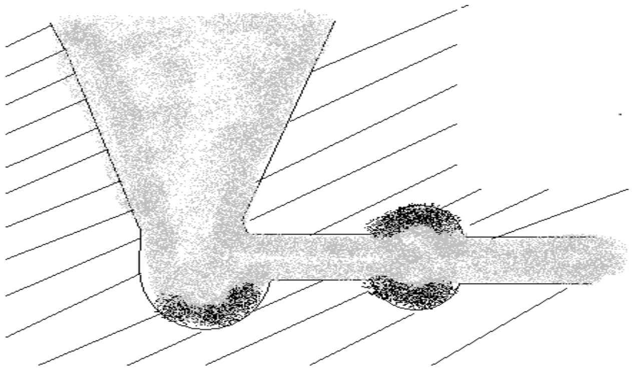


Fig 2.5 Pouring cup

CHAPTER 3

Working procedure

3.1 Experimental Work

Throughout the experiment, we have worked with various types of gating systems and used sodium silicate as sand binder.

3.1.1 Molding Materials with Sodium silicate Binder

Sodium silicate [Na_2SiO_3 or (Na_2O) (SiO_2)] is a high strength binder used with silica molding sand. To cure the binder carbon dioxide gas is used, which creates the following reaction: $\boldsymbol{Na_2O(SiO_2) + +CO_2 = Na_2CO_{3+}2SiO_2 + Heat}$

- The advantage to this binder is that it occurs at room temperature and quickly.
- The disadvantage is that its high strength leads to shakeout difficulties and possibly hot tears in the casting.

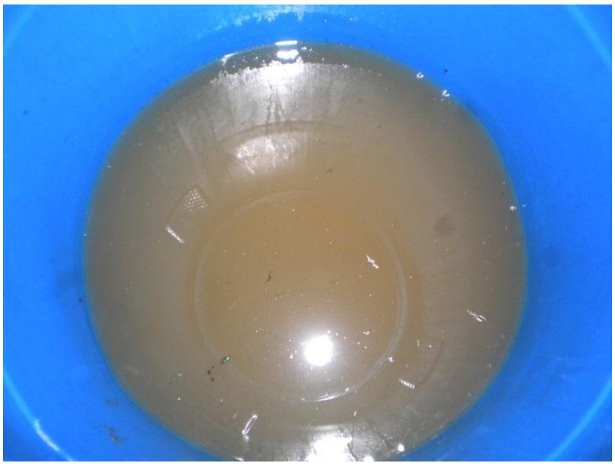


Fig: 3.1 Sodium silicate Binder

3.1.2 Sodium silicate -Bonded Sand

In this process sodium silicate (water glass) acts as binder. This is essentially a quick process of mold preparation. The mold is prepared with a mixture of sodium silicate and sand and then treated with carbon dioxide for two to three minutes such that a dry compressive strength of over 1.4 MPa is arrived at. 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 carbon dioxide gas starts the reaction by forming hydrated sodium carbonate 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.

3.1.3 Composition of Sodium silicate bonded Molding Sand

Molding Sand constituent	Weight percentage
Silica Sand	84
Sodium Silicate	14
Wood flower	0.5
Parting Materials	Chalk Powder 1.5
Carbon di Oxide gas flow	Pressure 5 to 10 PSI

Table: 3.1 Composition of Sodium silicates bonded Molding Sand

Fig: 3.2 Mold where using Sodium silicate mixing sand

Fig: 3.3 Mold with thermocouple

3.2 Composition of Aluminum

The table below clearly shows the typical composition of Aluminum.

DIN	Cu	Mg	Si	Fe	Mn	Zn	Ti	Cr	
Al 99.0	0.1	-	0.5	0.6	0.1	-	-	-	Aluminum 99% Min.

Table 3.2 Composition of Aluminum

3.3 Pouring parameter

Para meters	Value
Pouring temperature	700°C-750°C
Inlet temperature	710°C
pouring speed	2.6 cm/s
Pressure	1 atm

Table 3.3 pouring parameter

3.4 Metal Melting Furnace

Crucible furnace, as shown in the figure below, was used in our experiment for melting the metal. The maximum temperature required for melting the metal was approximately 800°C.

Fig: 3.4 Crucible Furnace used in our experiment

Fig: 3.5 Temperature meter during taking the temperature

Fig: 3.6 casted Aluminum

As can be seen in figure 3.4, the Temperature meter used for conducting our experiment ranged from 0-999°C and figure 3.5 indicates the casted aluminum.

3.5 Result

Three points in each model were considered for analyzing the result. Point 1 is located at the middle portion of the mold while point 2 & 3 are located at the narrowest sections of the cavity in opposite sides. These Points are considered for result analysis. From the data stored in the simulation, cooling curves were drawn for each of the corresponding point showing change of temperature at the specific points with respect to time for each model. The melting temperature of aluminium is 660°C and pouring temperature is almost 700°C - 750°C. Due to molding materials some temperature are absorbed, so finally we got maximum 780°C of square sprue at the position of point number 3. We took the temperature data by video up to 12 minutes. The initial temperature varied for various sprue and various point but it came equilibrium after a few minutes.

3.6 Temperature (◦C) Table for Point 1

Time (Minute)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Rectangle	593	569	532	511	474	441	413	389	369	350	336	320
Trapezium	99	543	509	454	411	378	356	333	313	295		
Square	751	600	598	578	548	524	483	448	416	390	367	347
Round	617	576	554	518	493	458	422	392	368	347	329	315

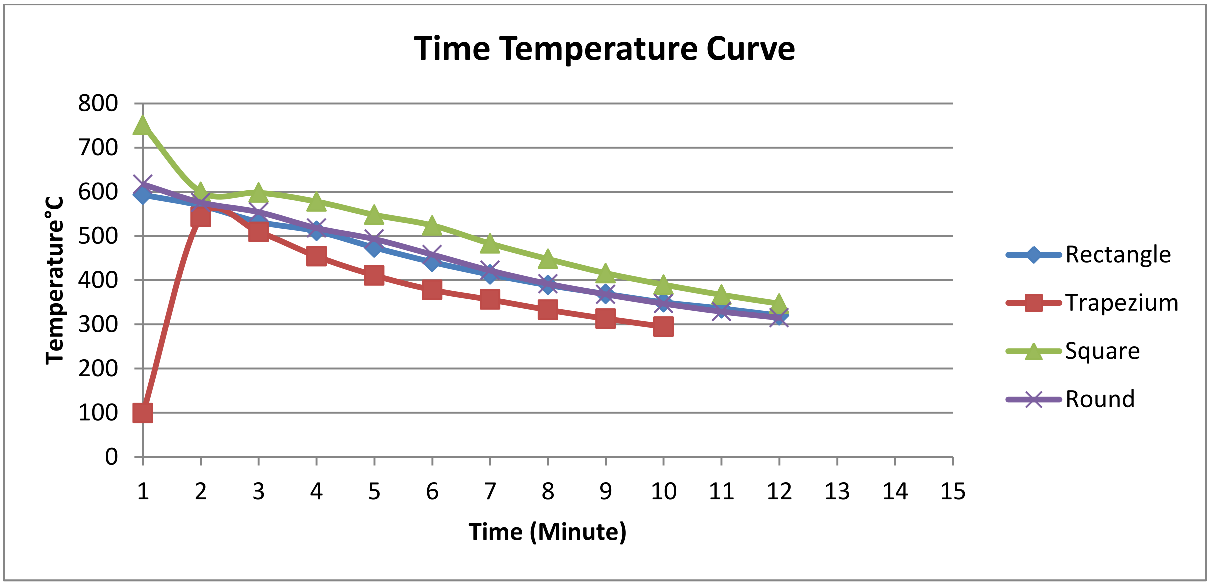


Fig: 3.7 Time vs Temperature Curve of point -1

3.7 Temperature (◦C) Table for Point 2

Time (Minute)	1	2	3	4	5	6	7	8	9	10	11	12
Rectangle	554	539	519	493	460	431	405	382	363	328	310	310
Trapezium	132	529	492	449	410	379	358	337	317	300		
Square	618	596	580	563	438	514	479	445	417	391	369	350
Round	536	570	551	528	496	459	426	398	375	355	337	321

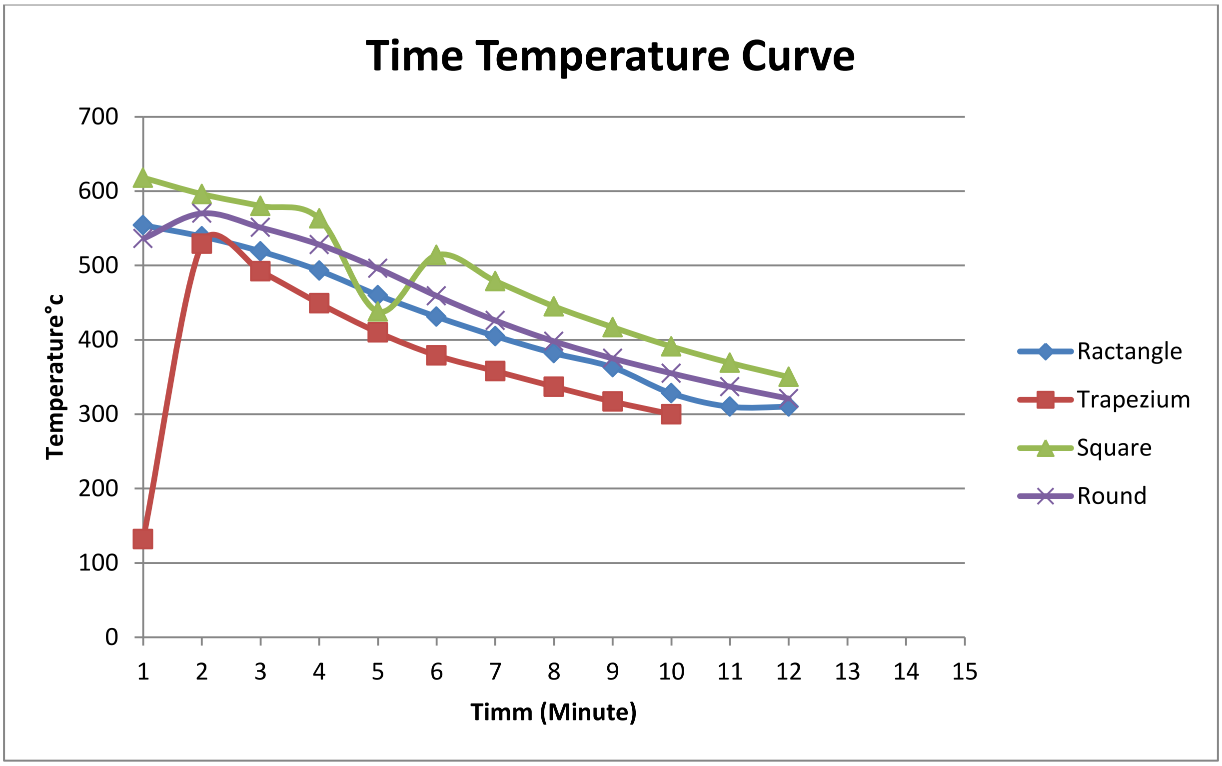


Fig: 3.8 Time vs Temperature Curve of point -2

3.8 Temperature (◦C) Table for Point 3

Time (Minute)	1	2	3	4	5	6	7	8	9	10	11	12
Rectangle	606	569	542	509	476	444	417	392	372	353	339	325
Trapezium	527	526	482	449	409	378	358	337	317	300		
Square	780	614	598	573	546	518	481	449	419	393	371	351
Round	598	596	559	535	498	462	429	400	377	357	339	323

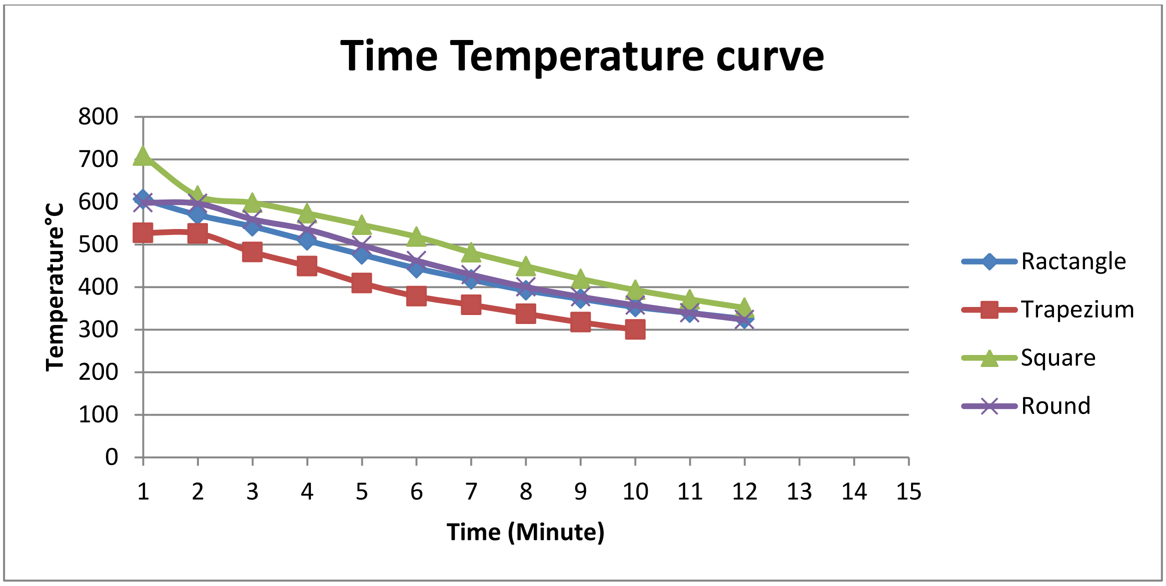


Fig: 3.9 Time vs Temperature Curve of point -3

CHAPTER 4
Previous Simulation work

4.1 Simulation (Previous Work)

We have seen the simulation work "Investigation of the effect of Rectangle and Trapezium crass section of getting system by CFD simulation in cooling of aluminum alloy in a permanent mold casting." The data and graph are given below.

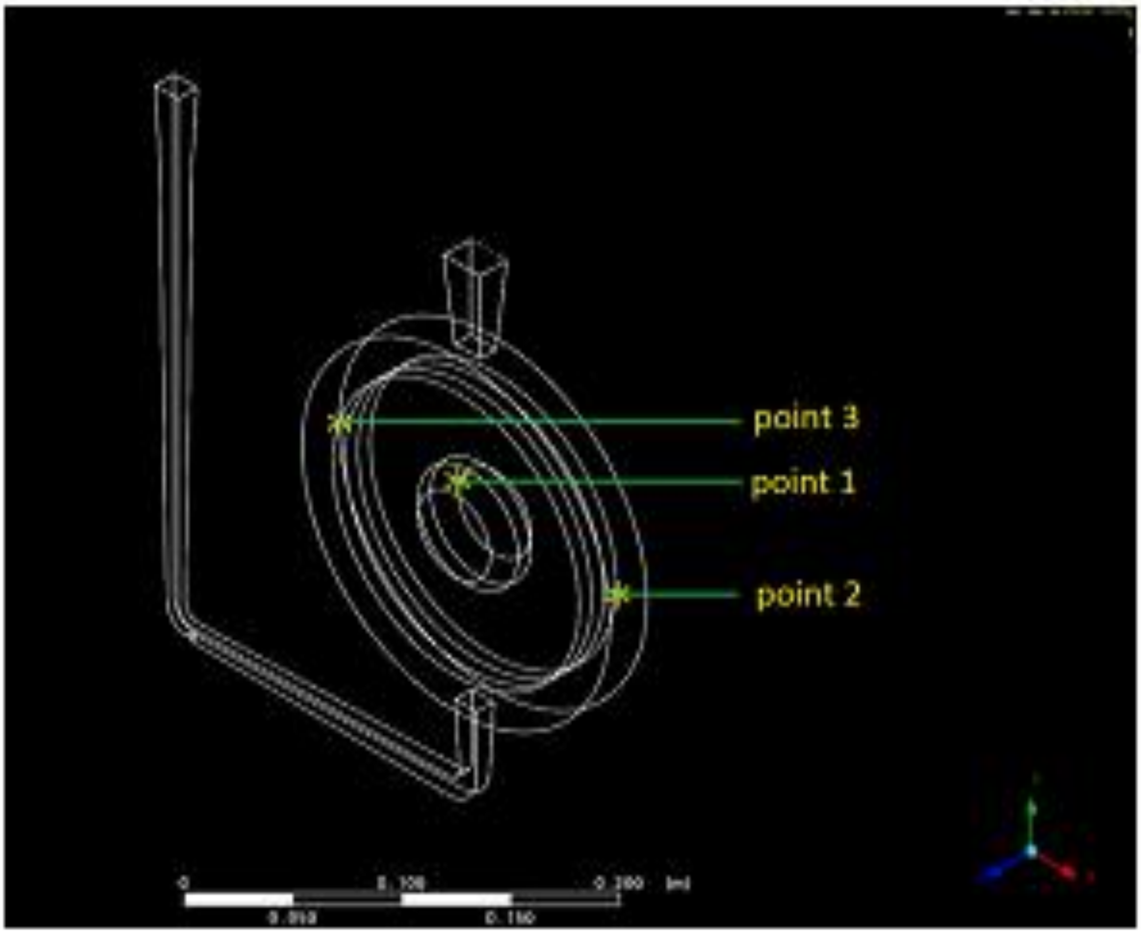


Fig 4.1 point consideration for result analysis

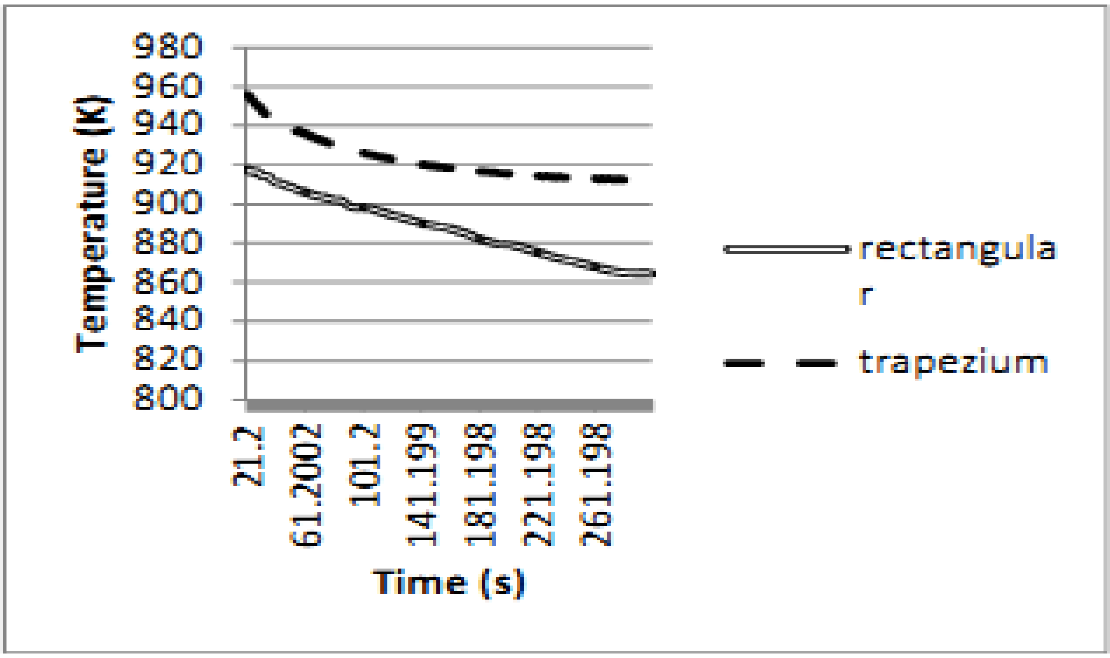


Fig 4.2 cooling curve at point 1

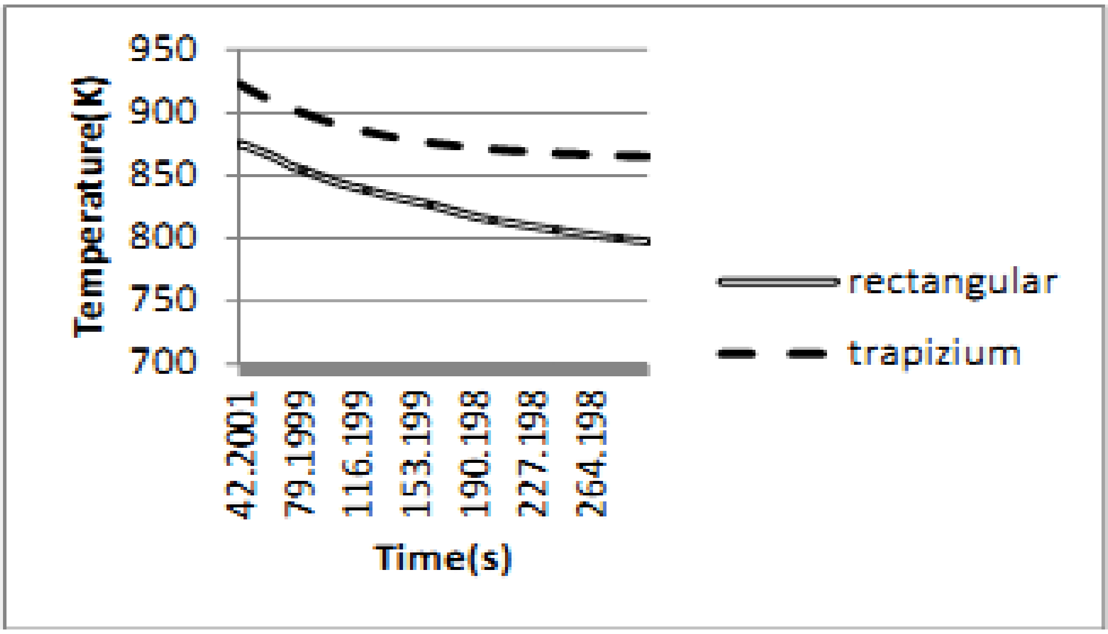


Fig. 4.3 cooling curve at point 2

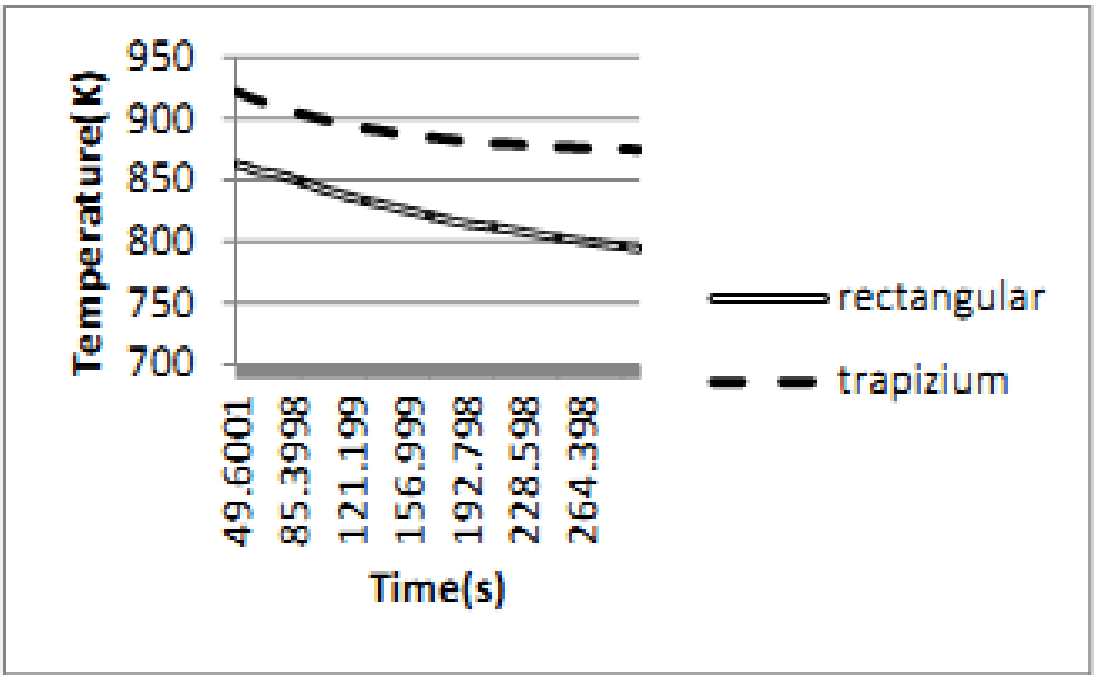


Fig 4.4 Cooling curve at point 3

4.2 Observation of Experimental work and Simulation work

By analyzing the result it can be concluded that for rectangular cross sectional model the cooling is more rapid than trapezium cross section model. Due to limitation of the resources, time step of 1500 with 0.2 second per step were taken. It is expected that more accurate results can be obtained by assigning higher time steps.

4.3 Comparison of Experimental work and Simulation work:

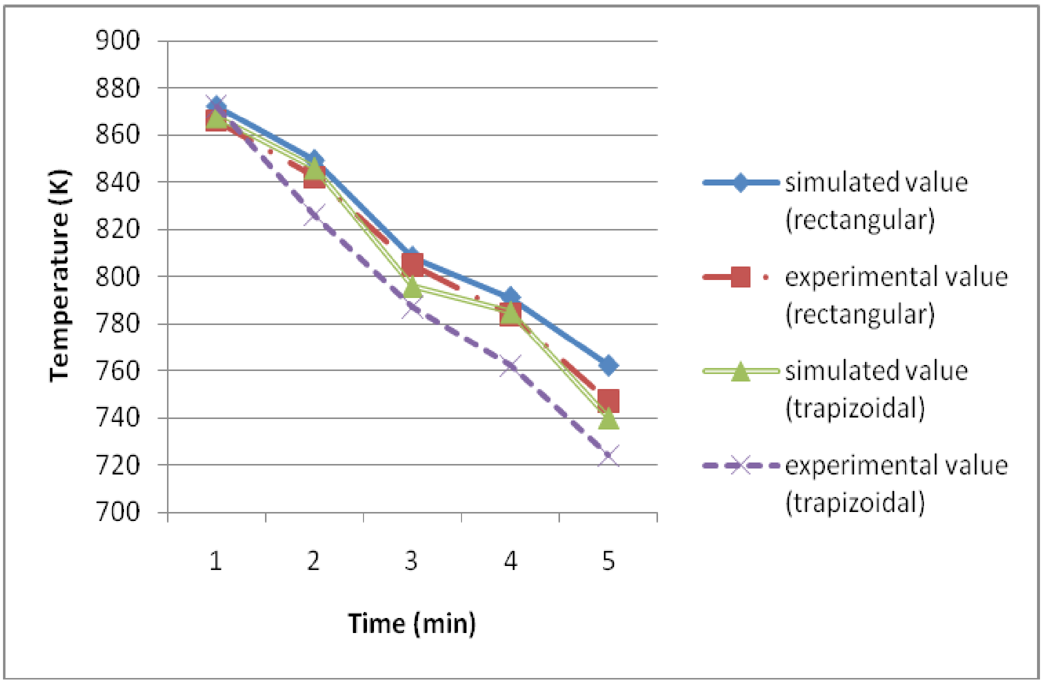


Fig. 4.5 cooling curve of different models at point 1

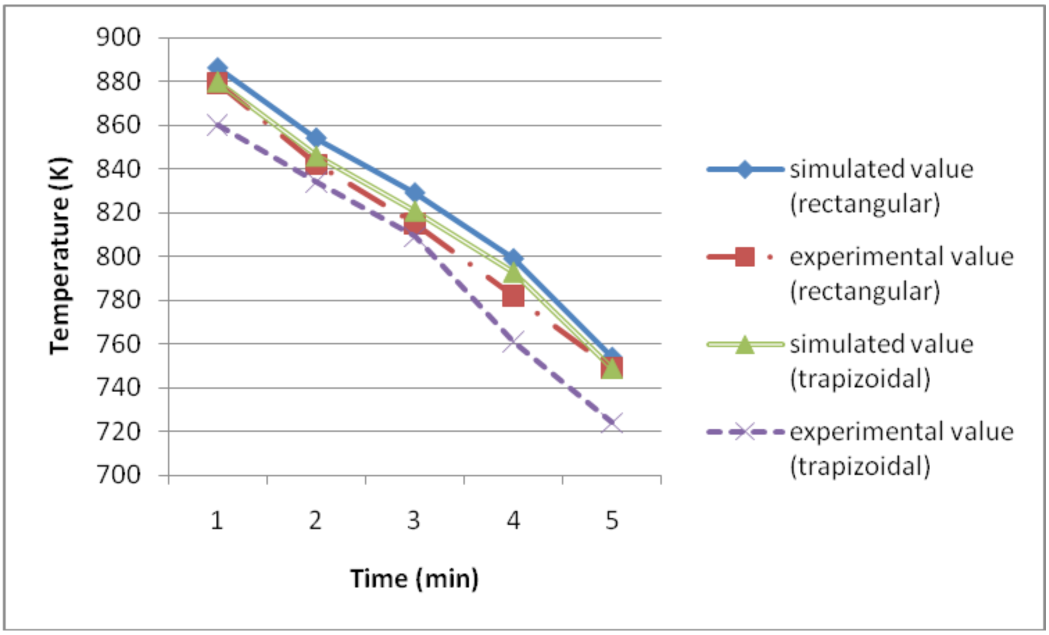


Fig 4.6 cooling curve of different models at point 2

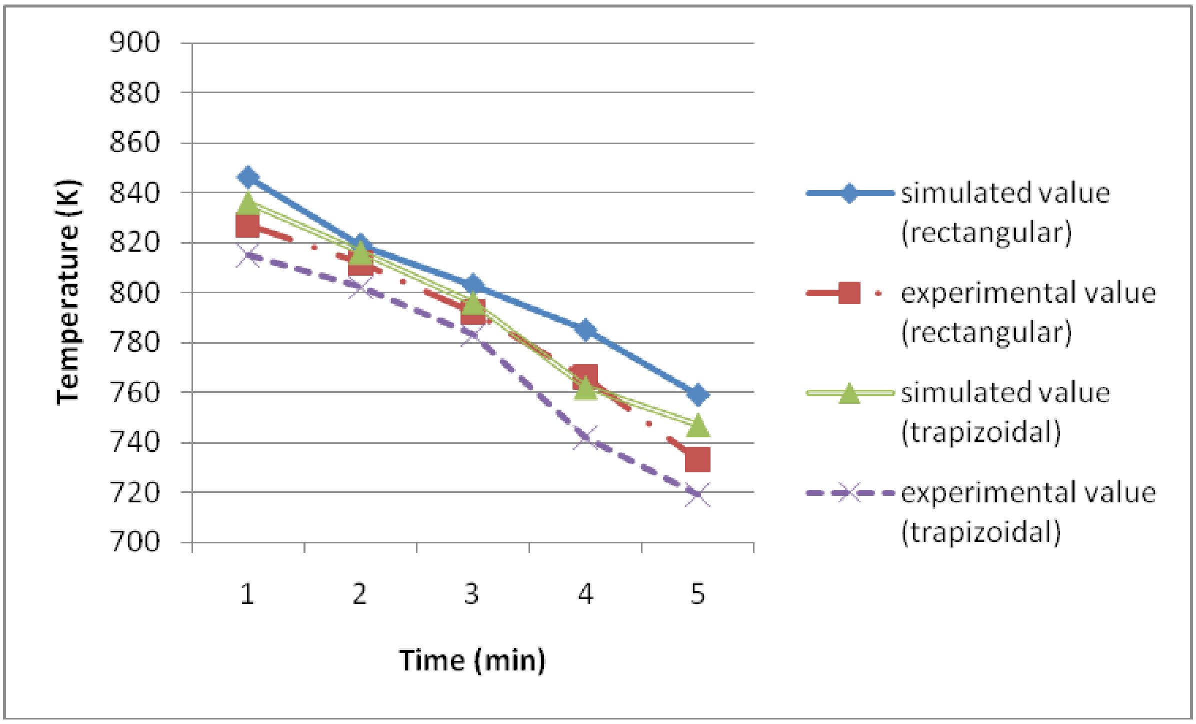


Fig. 4.7 cooling curve of different models at point 3

4.4 Discussions

The simulation work was permanent mold casting and the molding materials were Cast Iron. But our experimental work was Temporary mold casting and molding materials were silica sand. For this reason, when we compare between simulation work and experimental work some variation in the graph can be observed.

CHAPTER 5

Working with different Binders

5.1 Changing the Binder with Molding Material

In a casting process many kind of binders are used. Out of them sodium silicate, clay, molasses, oil are very widely used in sand molding system. We have already worked with sodium silicate binder. We have worked with the rest of the binders discussed in this chapter.

5.1.1 Clay binders

Clay binders are most commonly used binding agents mixed with the molding sands to provide the strength. The most popular clay types are:

- Kaolinite or fire clay (Al_2O_3 2 SiO_2 2 H_2O) and
- Bentonite (Al_2O_3 4 SiO_2 H_2O)

5.2 Moisture

Clay acquires its bonding action only in the presence of the required amount of moisture. When water is added to clay, it penetrates the mixture and forms a microfilm, which coats the surface of each flake of the clay. The amount of water used should be properly controlled. This is because a part of the water, which coats the surface of the clay flakes, helps in bonding, while the remainder helps in improving the plasticity. A typical composition of molding sand is given in table 5.1

5.3 Clay-Bonded Sand

Molding sands may contain about 2 to 50 per cent of clay. With suitable water content, it is the principal source of the strength and plasticity of the molding sand. Clay is thus the bond or binder of molding sands. In some mineral deposits, clay and sand occur in mixed proportions, so that the sand can be mined and used directly for molding. Clays are defined as "essentially aggregates of extremely minute crystalline, usually flaked shaped particles that can be classified on the basis of their structure and composition into a few groups which are known as clay minerals. Some clay is composed of particles of a single mineral, whereas others are mixtures of clay minerals or contain admixtures of quartz, pyrite, organic matter, etc."

5.4 Types of Clay

1. Fire clays or Kaolinites
2. Bentonite
3. Special clays(halloysite, illite, attapulgite)

Kaolinite has a melting point of 1750° to 1787° C and Bentonite has a melting temperature range of 1250° to1300° C. Of the two, Bentonite can absorb more water which increases its bonding power. There are two types of Bentonite available, one with sodium as adsorbed ion which is often called western Bentonite volume increases some 10 to 20 times, high dry strength which lowers the risk of erosion, better tolerance of variations in water content, low green strength, high resistance to burn out, which reduces consumption) and the other with calcium ion called southern Bentonite (low dry strength, high green strength). The clay chosen for molding sand should give it the requisite strength for the given application taking into consideration the metal being cast and thickness of the casting.

5.5 Water

Water, present in amounts of about 1.5 to 8 percent, activates the clay in the sand, causing the aggregate to develop plasticity and strength. Water in molding sand often refers to as tempering water. The water is absorbed by the clay up to a limiting amount. Only that water rigidly held by the clay appears to be effective in developing strength. Additional water, however, can act as a lubricant, and makes the sand more plastic and more moldable, though the strength may be lowered. Thus control of water percentage in the aggregate is very important. Water may engage in ion exchanges with the clay if dissolved minerals are present.

Molding Sand constituent	**Weight percentage**
Silica Sand	76
Clay (Sodium Bentonite)	15
Wood flower	1
Coal dust	1
Water	6
Parting materials	Graphite 1

Table 5.1 Composition of Clay bonded Molding Sand

Fig. 5.1 typical clay used in our experiment

Fig. 5.2 molding sand with clay

Fig: 5.3 Aluminium products by casting.

5.6 Temperature Table for clay

Time	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Point-1	668	650	570	559	536	503	460	420	390	363	339	318	300	284
Point-2	284	561	442	422	401	433	420	398	365	353	343	323	306	291
Point-3	515	657	598	579	542	513	469	430	397	369	345	325	307	288

5.7 Molasses-Bonded Sand

Molasses is mainly the byproduct of sugar mills**.** Cane molasses, unrefined and containing 60 to 70 per cent sugar solids, may be used for increases dry strength of the sand and edge hardness of molds. Dextrin may be used for the same purpose.

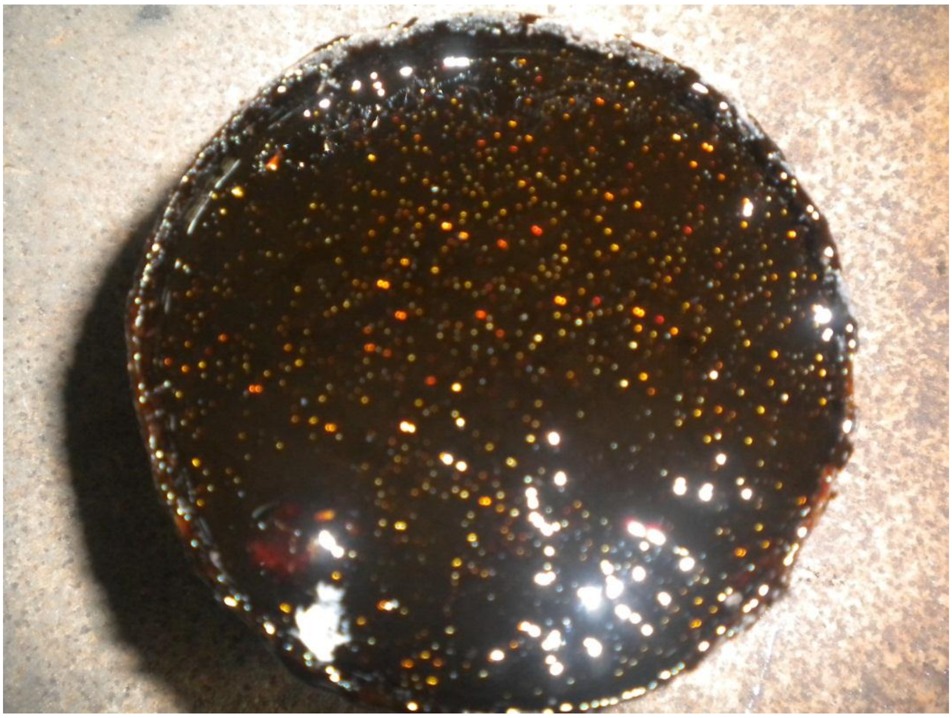


Fig. 5.4 Molasses Binder

Fig. 5.5 Molasses Bonded Sand

5.8 Temperature Table for Molasses

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Point-1	52	43	38	38	39	42	46	50	54	58	27	27	28	32
Point-2	51	59	85	95	99	102	113	120	127	133	137	107	107	73
Point-3	517	513	495	480	458	443	411	390	373	357	340	327	263	260

5.9 Oil-Bonded Sand

Oil-bonded sand is foundry sand that uses oil instead of water as a bonding agent. Hobbyists like oil-bonded sand because it's easier to use, it doesn't steam like water-bonded sand and it produces a finer finish. Because of the sand, this type of casting doesn't produce clean surfaces. The sand is too porous to get a smooth finish. Oil has more of a gluey character than water. It can fill in the pores between the sand particles and that's why oil-bonded sand will give a slightly finer surface texture.

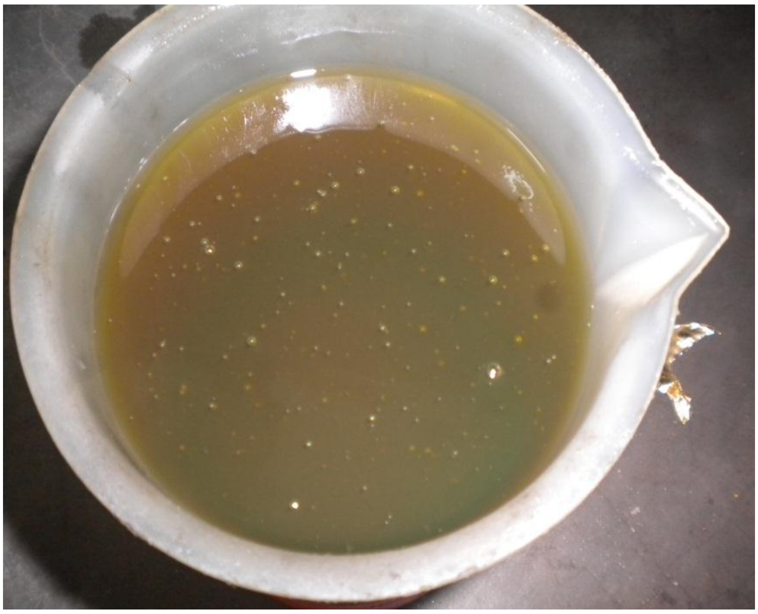


Fig. 5.6 Oil Binder

5.10 Temperature Table for Oil

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Point-1	564	545	537	531	526	514	502	488	479	470	464	444	435	423
Point-2	358	558	556	557	549	544	533	521	510	503	488	474	462	454
Point-3	635	617	606	595	584	570	558	548	540	528	518	505	492	480

Table-2: Temperature of each point during cooling.

5.11Cooling Curve of various Point Comparison with Sand Binder

Temperature at Point - 1

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Clay	668	650	570	559	536	503	460	420	390	363	339	318	300	284
Molasses	52	43	38	38	39	42	46	50	54	58	27	27	28	32
Oil	564	545	537	531	526	514	502	488	479	470	464	444	435	423

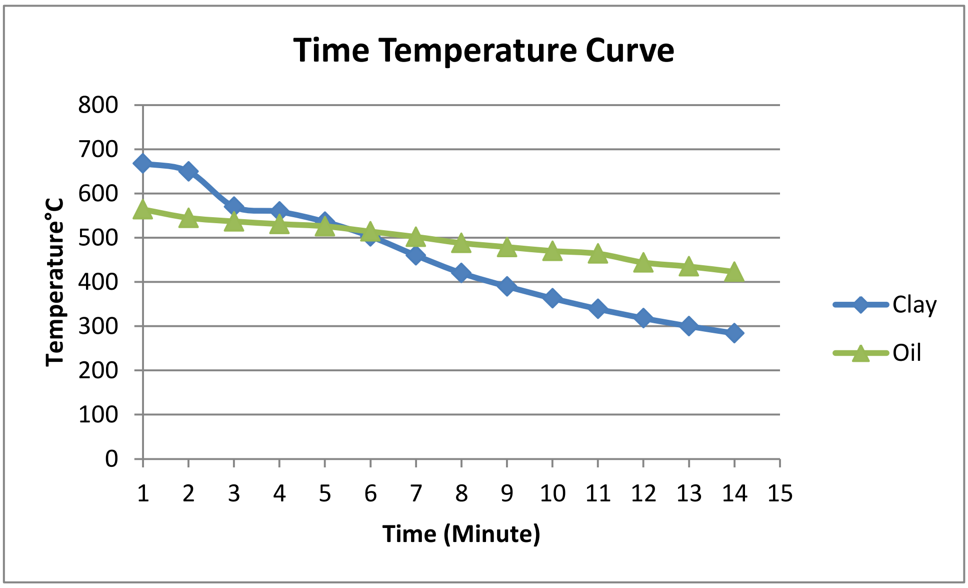


Fig 5.7 Time – Temperature Curve of various sand Binder at point 1

Temperature at Point - 2

Time	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Clay	284	561	442	422	401	433	420	398	365	353	343	323	306	291
Molasses	51	59	85	95	99	102	113	120	127	133	137	107	107	73
Oil	358	558	556	557	549	544	533	521	510	503	488	474	462	454

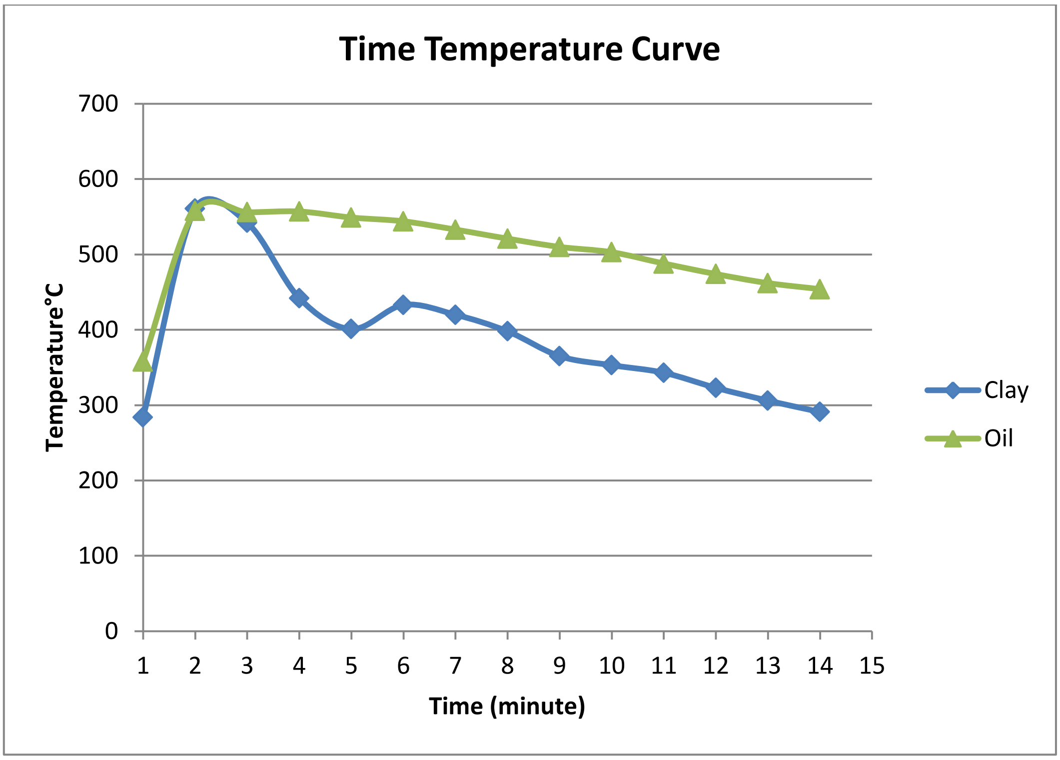


Fig 5.8 Time – Temperature Curve of various sand Binders at point 2

Temperature at Point – 3

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Clay	515	657	598	579	542	513	469	430	397	369	345	325	307	288
Molasses	517	513	495	480	458	443	411	390	373	357	340	327	263	260
Oil	635	617	606	595	584	570	558	548	540	528	518	505	492	480

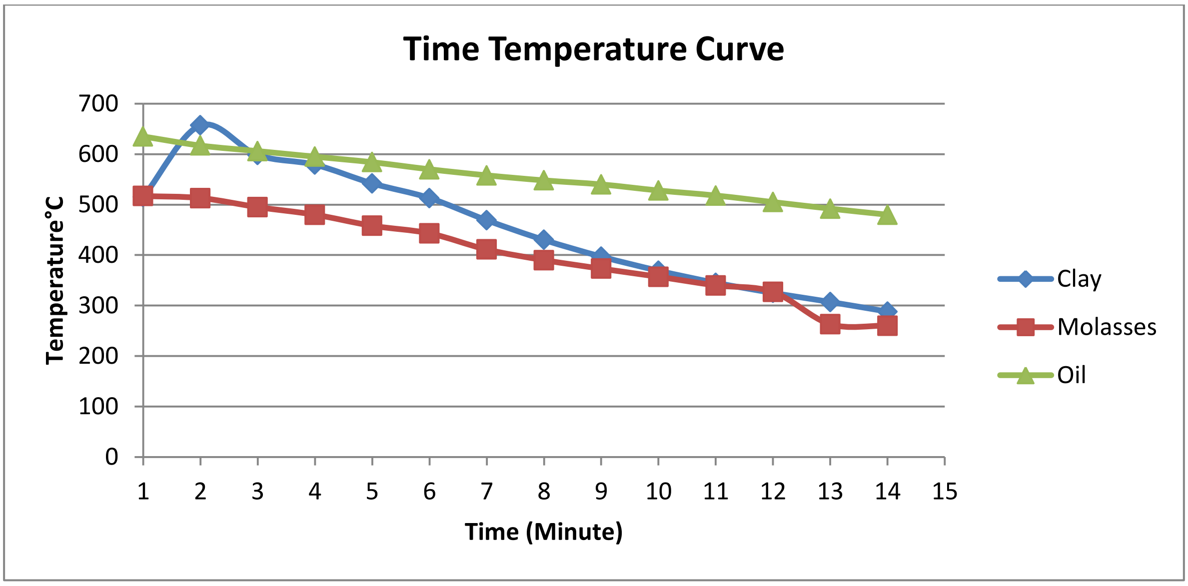


Fig 5.9 Time – Temperature Curve of various sand Binder at point 3

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