MME 346 - LAB REPORT

Exp - 03

EFFECT OF CASTING SHAPE & SIZE ON SOLIDIFICATION TIME

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OBJECTIVE

The objective of this experiment is to

1. Understand the variables affecting solidification and
2. Understand the importance and limitations of Chvorinov's rule for predicting the solidification time of casting.

INTRODUCTION

The amount of heat that must be removed from a casting to cause it to solidify is directly proportional to the amount of superheat and the amount of metal in the casting, or the casting volume. Conversely, the ability to remove heat from a casting is directly related to the amount of exposed surface area through which the heat can be extracted and the insulating value of the mould. These observations are reflected in Chvorinov's Rule, which states that tf, the total solidification time, can be computed by-

$$t_f = C\left(\frac{V}{A}\right)^n$$

where V is the volume of the casting; A is the surface area; and C is the mould constant, and n is a constant, which varies from 1.5 to 2.0 (2 in Chvorinov's work). The total solidification time is the time from pouring to the completion of solidification and mould constant C depends on the characteristics of the metal being cast (its density, heat capacity, and heat of fusion), the mould material (its density, thermal conductivity, and heat capacity), the mould thickness, and the amount of superheat.

EQUIPMENTS

- Greensand Mould
- Commercial Grade Pure Aluminium
- Furnace
- Crucible
- Thermocouple
- Stopwatch

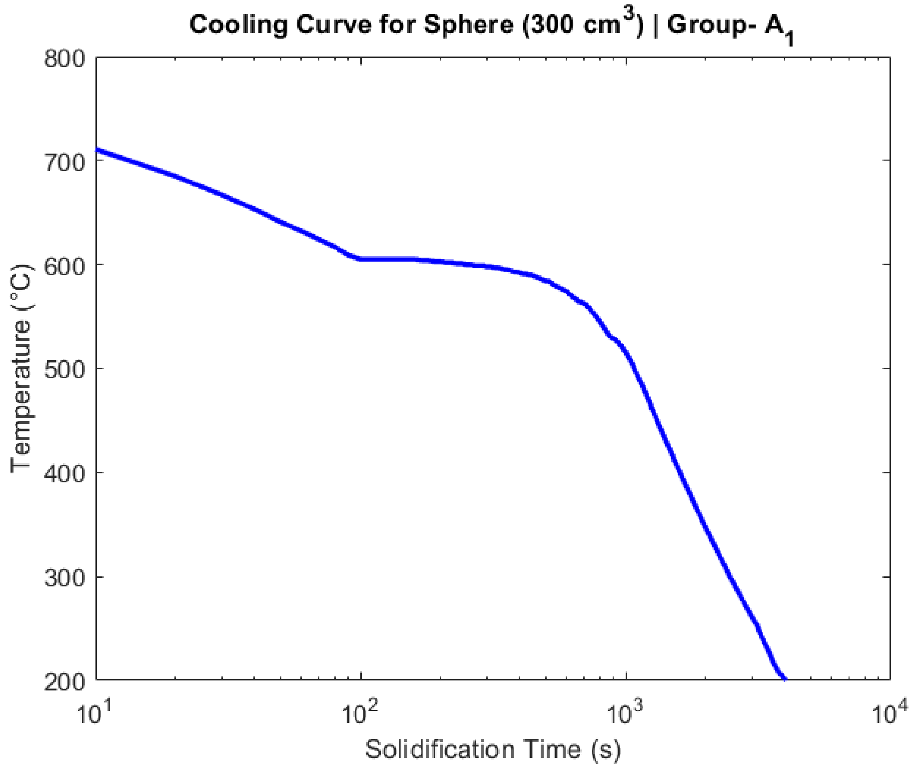
EXPERIMENTAL PROCEDURE

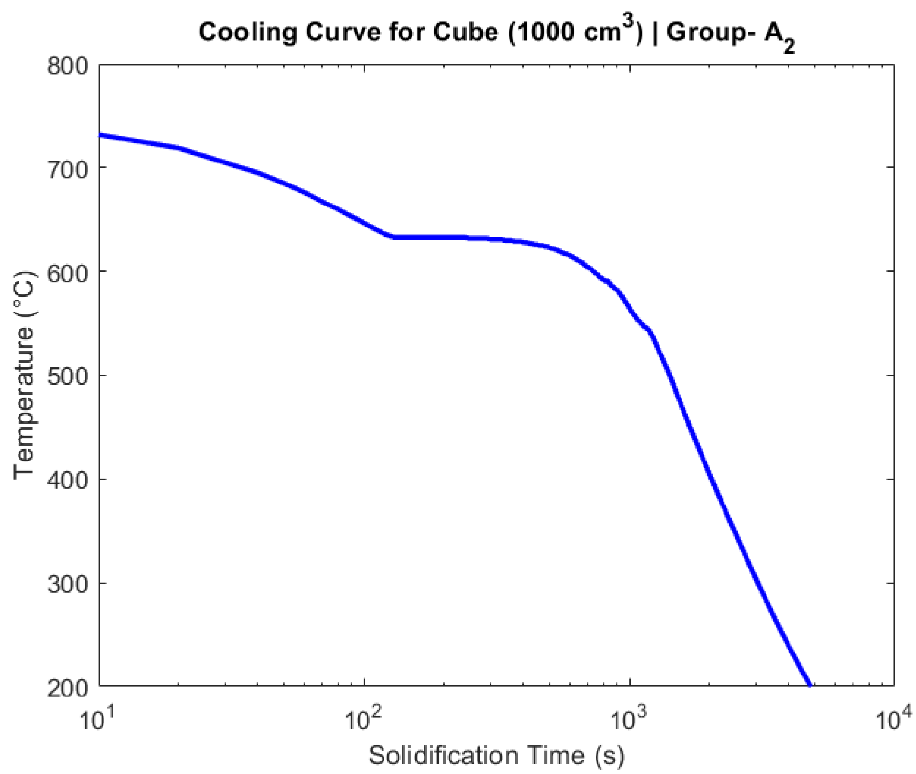
1. The moulds were prepared using greensand moulding process days in advance.
2. One K-type thermocouple tip was inserted at the centre of the mould cavity to record the temperature of the solidifying casting.
3. Required amount of materials was melt using crucible/induction furnace and the liquid was poured into the mould at about 1200 °C.
4. A Temperature VS Time chart was used to record the temperature of the solidifying casting at an interval of 10 second until the temperature of the casting decreased to 200°C.

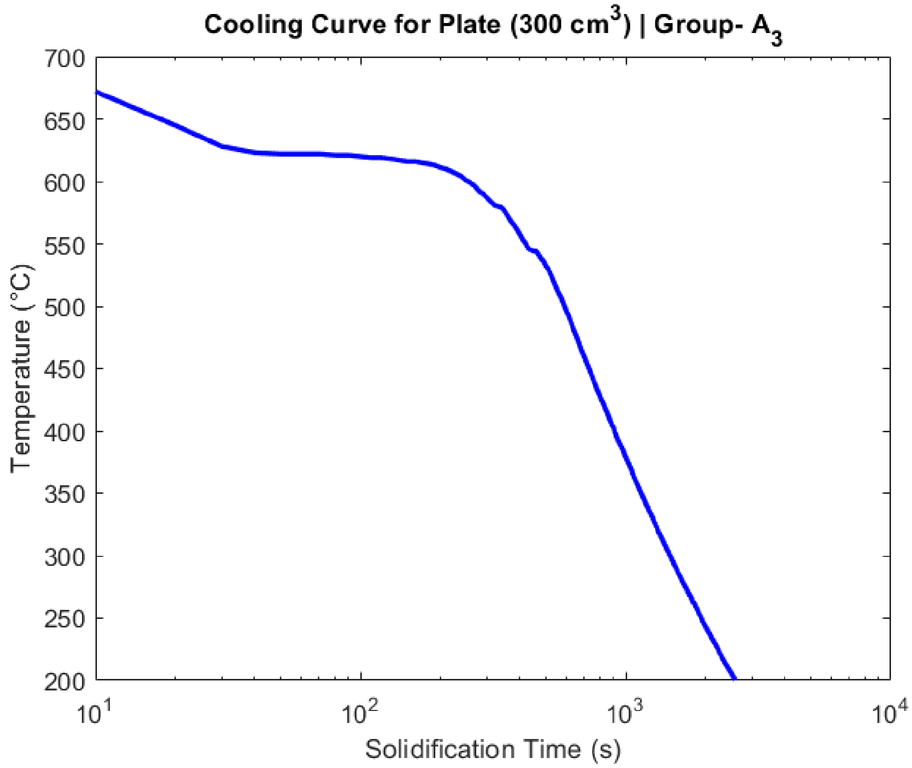
RESULTS & DISCUSSION

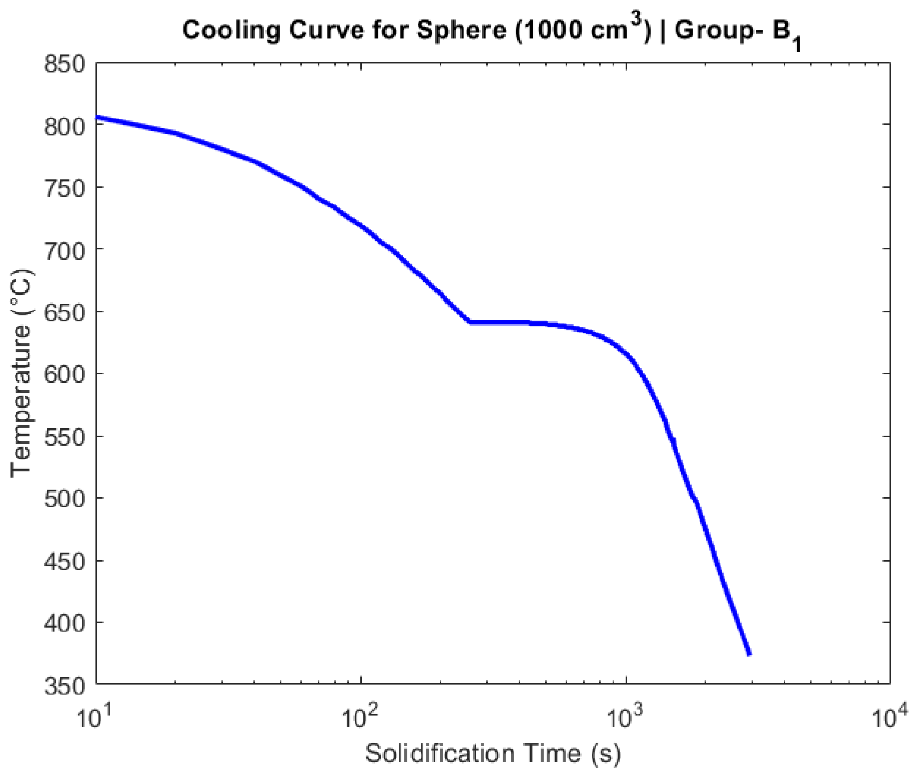
Figure showing final cast product

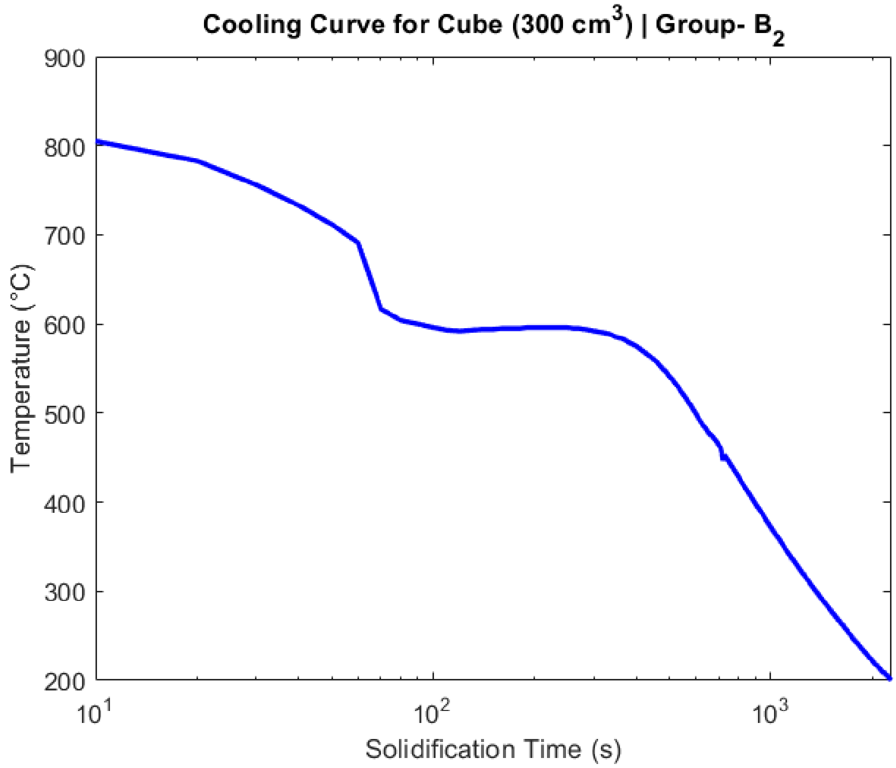
Cooling curves generated from experimental data and plotted in semilog graph is shown below-

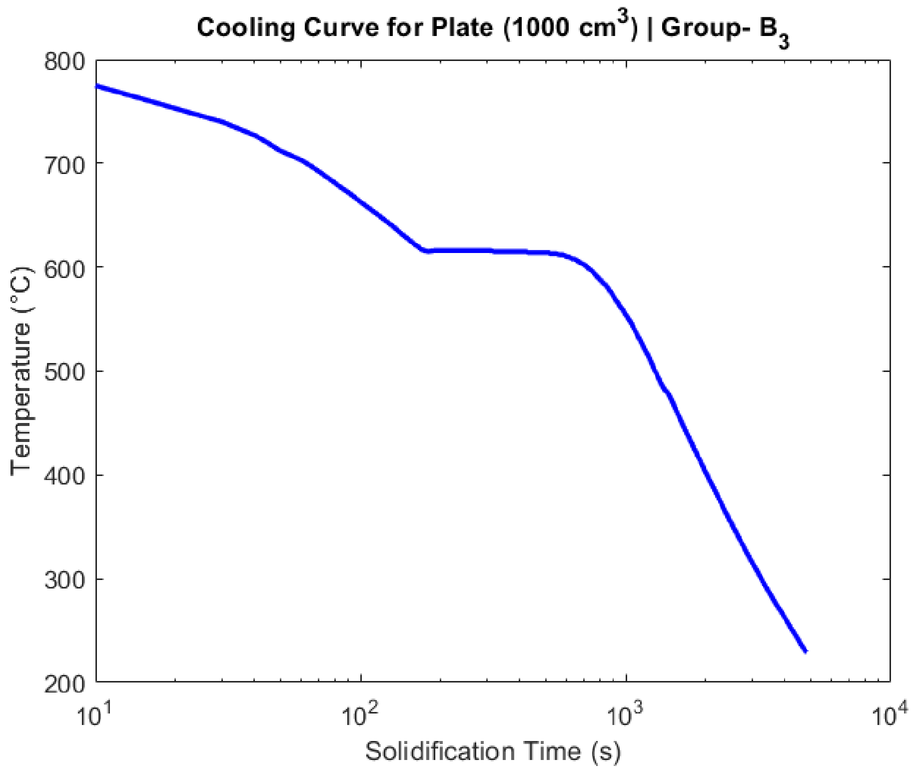

Cooling Curve for Sphere (300 cm³) | Group- A1
Temperature (°C)
Solidification Time (s)
800
700
600
500
400
300
200
10^1
10^2
10^3
10^4


Cooling Curve for Cube (1000 cm³) | Group- A2
Temperature (°C)
Solidification Time (s)
800
700
600
500
400
300
200
10^1
10^2
10^3
10^4


Cooling Curve for Plate (300 cm^3) | Group- A_3
700
650
600
550
500
450
400
350
300
250
200
Temperature (°C)
10^1
10^2
10^3
10^4
Solidification Time (s)


Cooling Curve for Sphere (1000 cm^3) | Group- B_1
850
800
750
700
650
600
550
500
450
400
350
Temperature (°C)
10^1
10^2
10^3
10^4
Solidification Time (s)

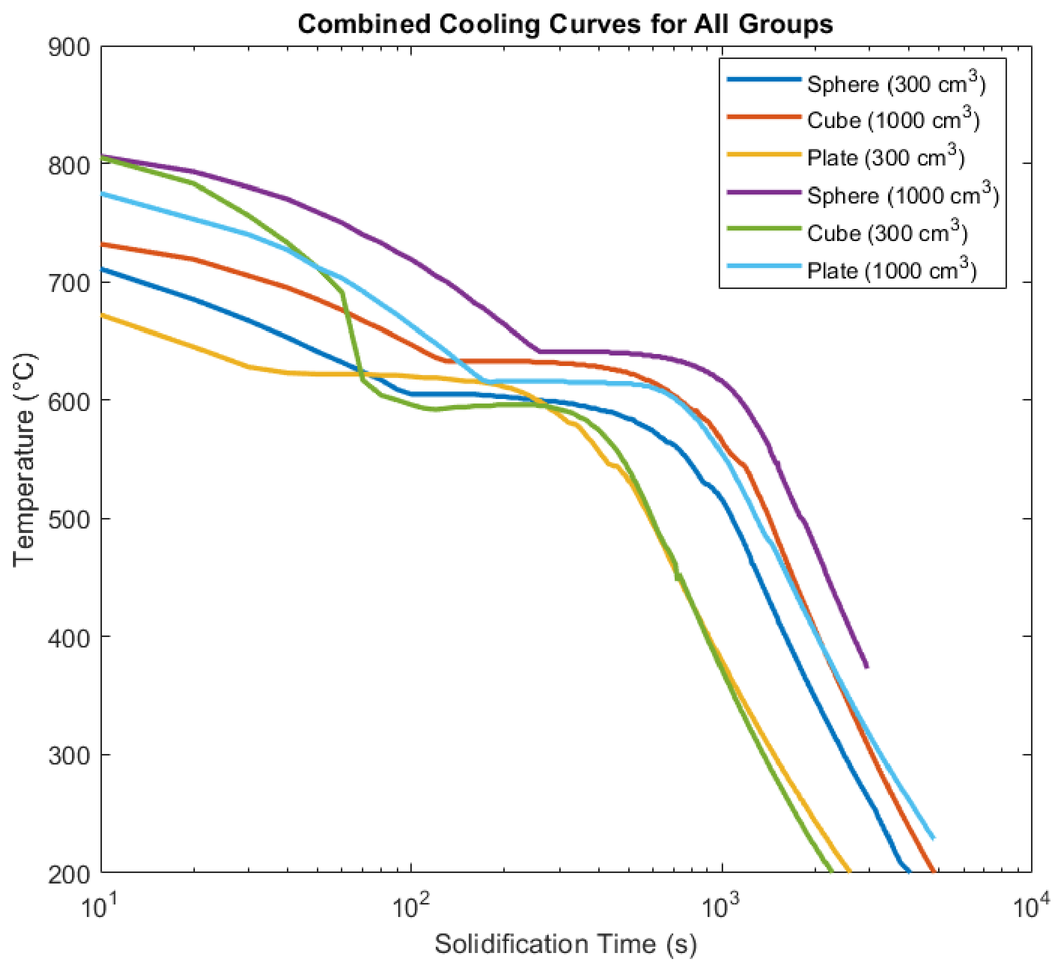

Cooling Curve for Cube (300 cm^3) | Group- B$_2$
Temperature (°C)
Solidification Time (s)
900
800
700
600
500
400
300
200
10^1
10^2
10^3


Cooling Curve for Plate (1000 cm^3) | Group- B$_3$
Temperature (°C)
Solidification Time (s)
800
700
600
500
400
300
200
10^1
10^2
10^3
10^4

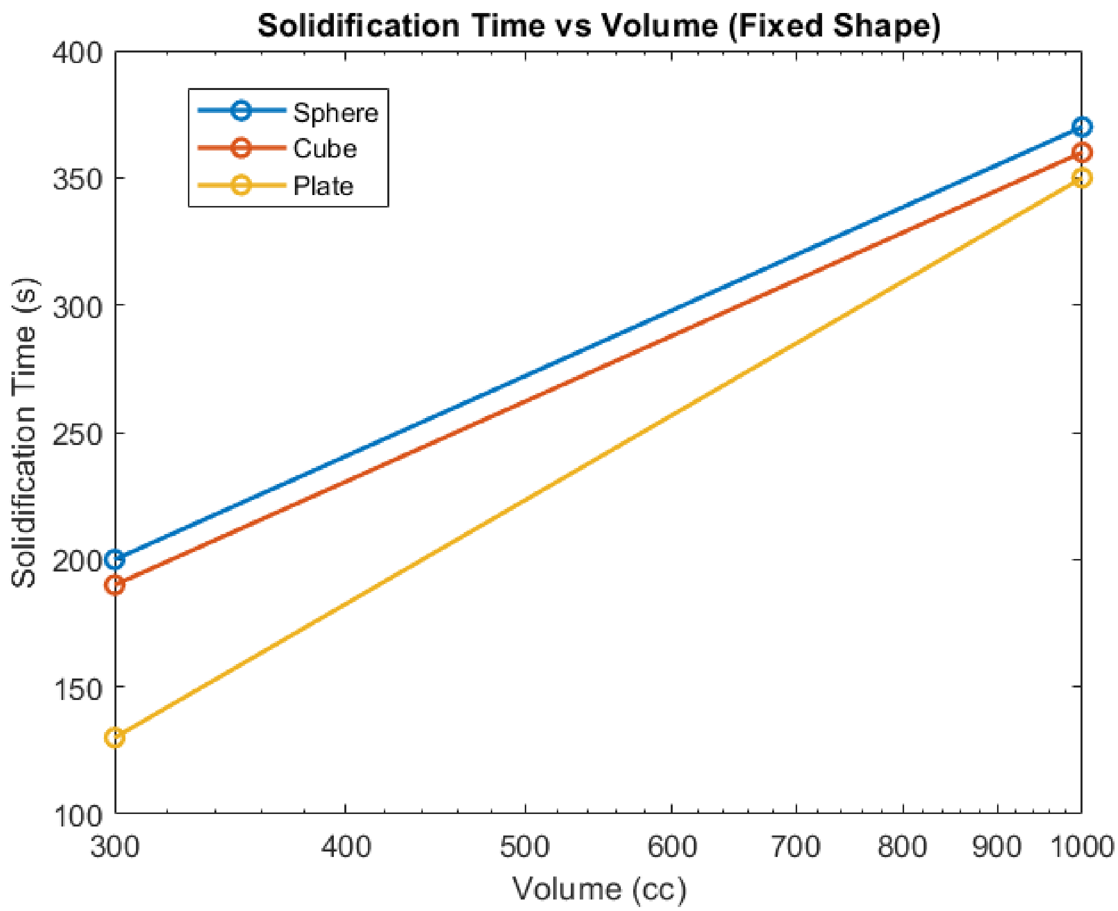
The solidification time for different shapes and volumes retrieved from the cooling curves are tabulated below-

Shape	***300 cm³***		***1000 cm³***	
	Start Time	***End Time***	***Start Time***	***End Time***
Sphere	110	310	260	630
Cube	100	290	130	490
Plate	40	170	170	520

Volume of casting (cm³)	***Solidification time (s)***		
	Sphere	**Cube**	**Plate**
300	200	190	130
1000	370	360	350



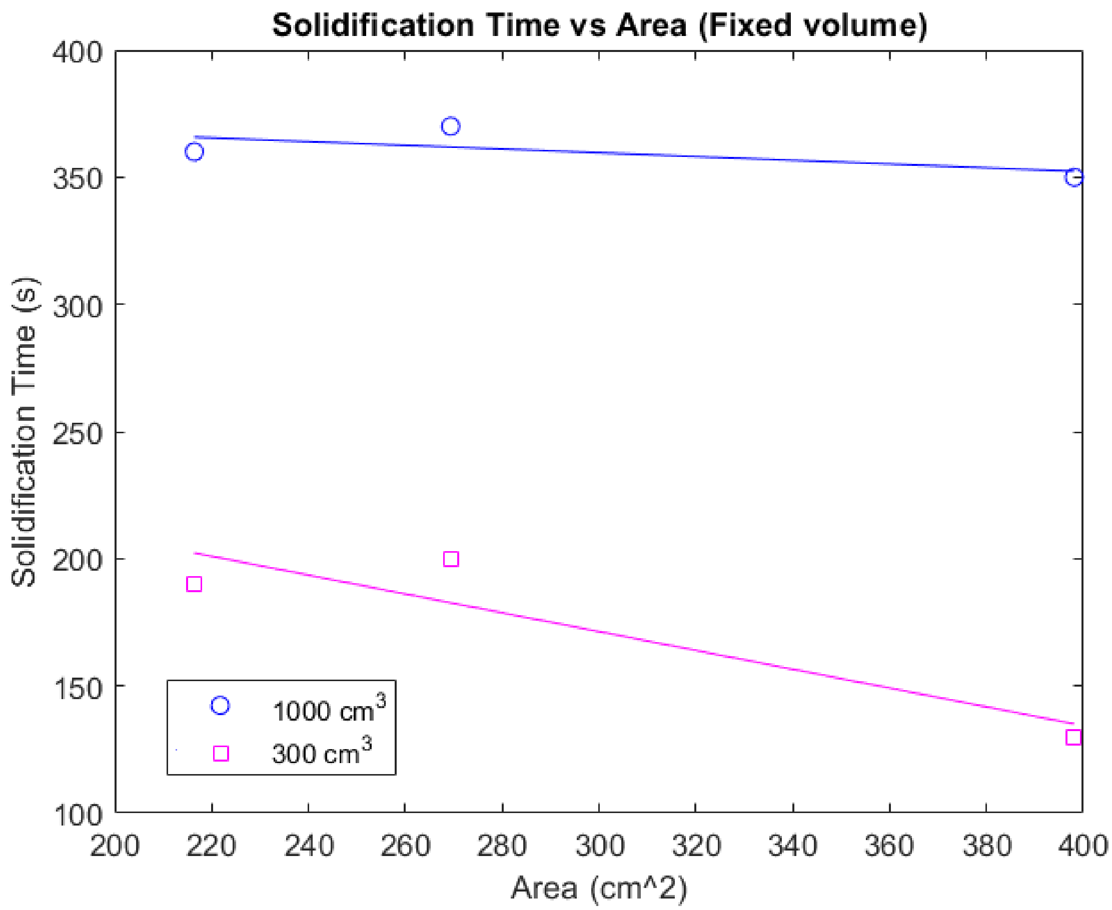
i) EFFECT OF CASTING VOLUME ON THE SOLIDIFICATION TIME OF ALUMINIUM CASTINGS HAVING SAME SHAPE:



Shape	*Equation*
Sphere	$t = 0.229V + 131.43$
Cube	$t = 0.242V + 117.14$
Plate	$t = 0.314V + 35.71$

From the graph it can be seen that solidification time increases with increasing volume for a fixed shape. This happens because the amount of heat to be eliminated becomes larger when volume increases. It can also be seen that the solidification time is maximum for the sphere and minimum for the cube.

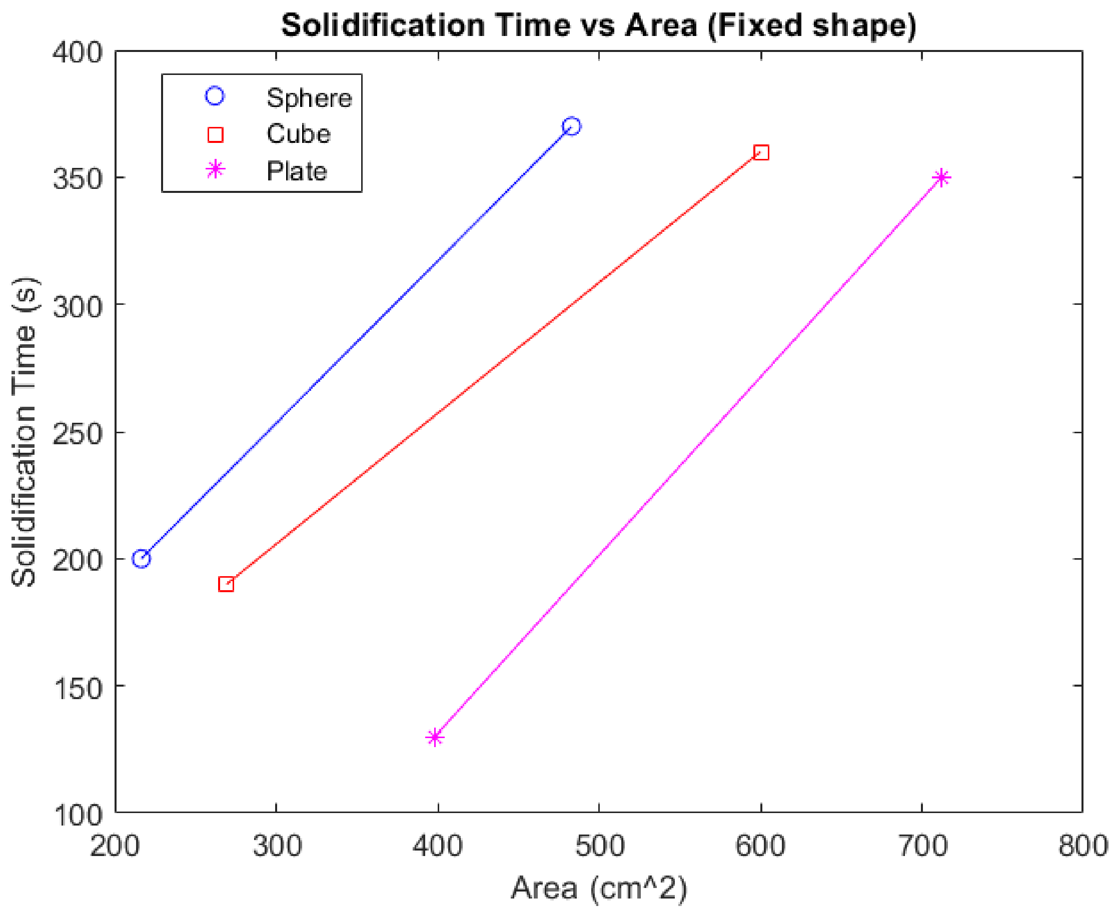
ii) A) EFFECT OF SURFACE AREA OF CASTING ON SOLIDIFICATION TIME OF ALUMINIUM CASTINGS HAVING SAME VOLUME:



Volume (cm^3)	***Equation***
300	$t = 0.37A + 282.3$
1000	$t = -0.07373A + 381.7$

The solidification time is seen to decrease with increasing surface area of the casting. This is because, with increasing surface area the heat is dissipation becomes faster. Also, it should be noted that the solidification time is greater for castings with higher volume.

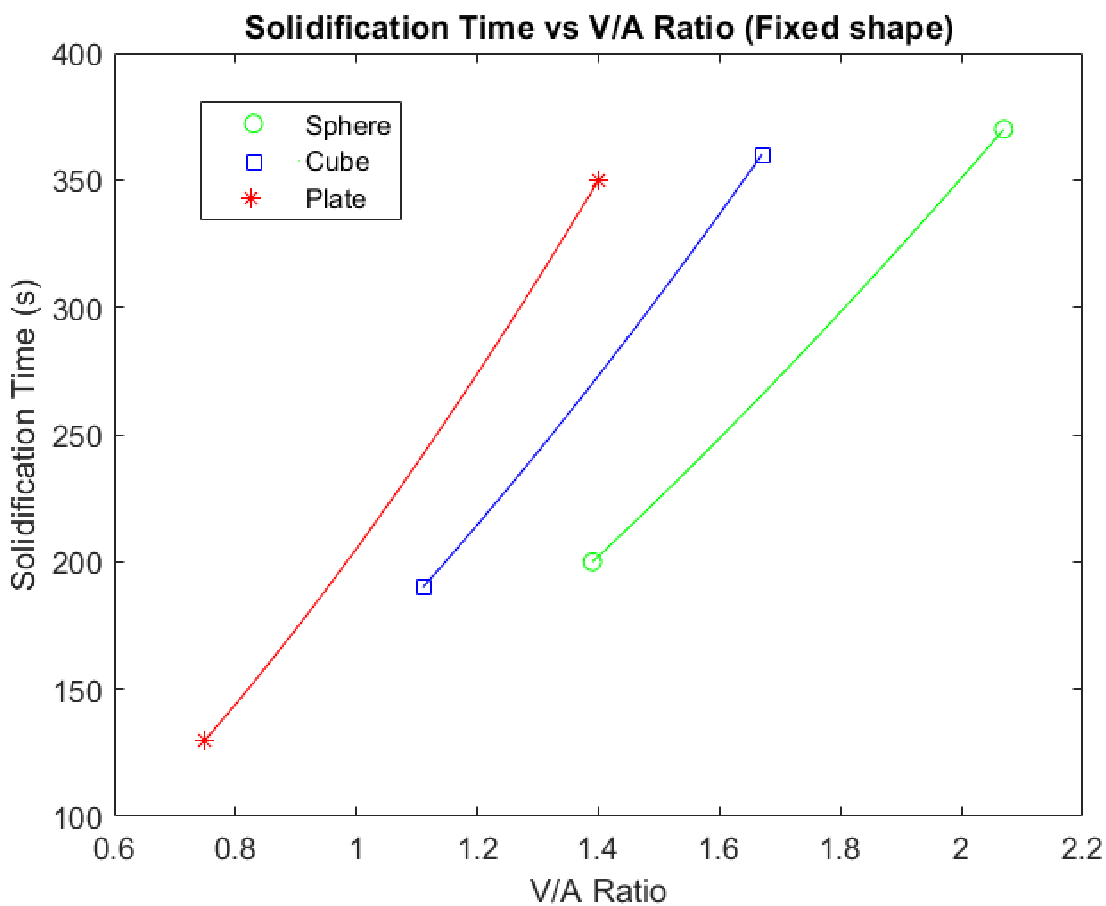
ii) B) EFFECT OF SURFACE AREA OF CASTING ON SOLIDIFICATION TIME OF ALUMINIUM CASTINGS HAVING SAME SHAPE:



Shape	*Equation*
Sphere	$t = 0.6376A + 62.01$
Cube	$t = 0.5141A + 51.53$
Plate	$t = 0.7004A - 148.9$

When the shape is fixed, with increasing surface area the solidification time increases. This might seem counterintuitive but actually V increases with increasing surface area, thus V/A ratio increases, which results in higher solidification temperature. From the graph it can be also seen that the solidification time at higher volume for all three shapes is very close. But the plate with 300 cm^3 shows minimum solidification time.

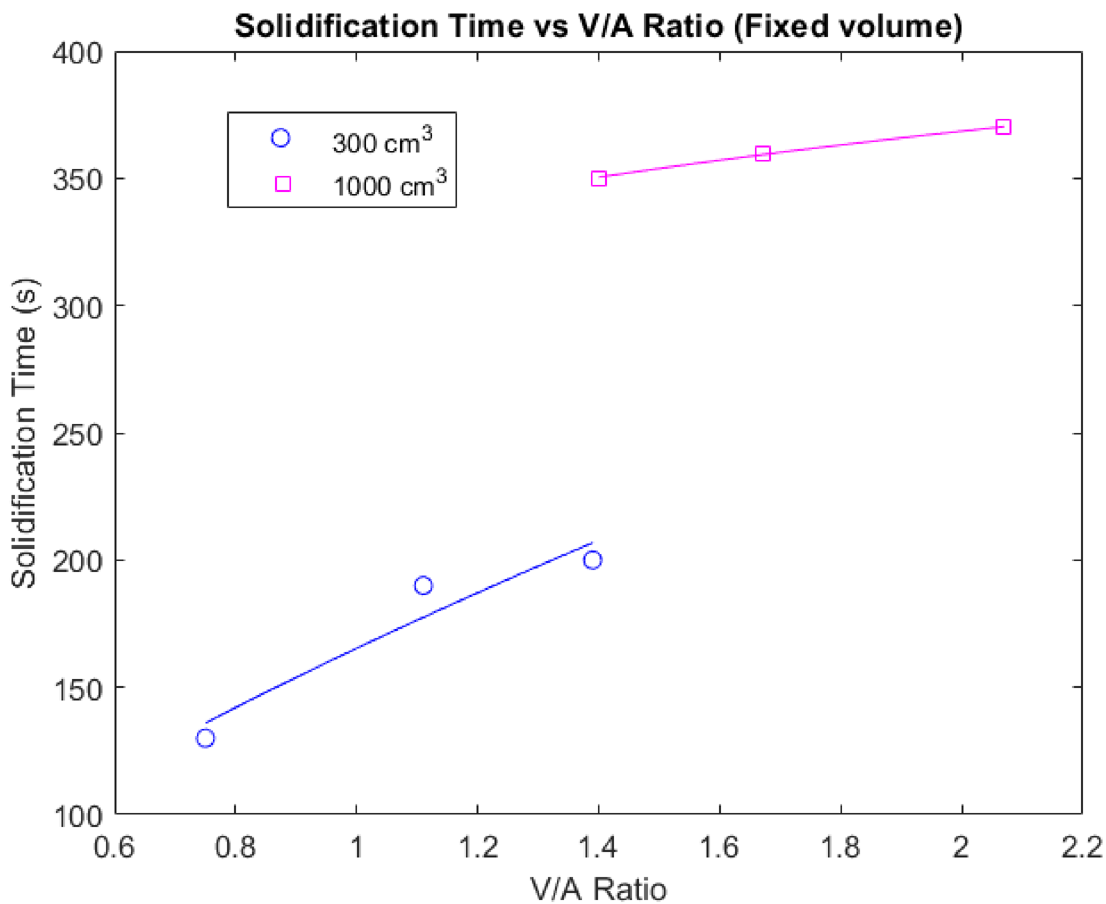
iii) A) EFFECT OF V/A RATIO ON SOLIDIFICATION TIME OF ALUMINIUM CASTINGS HAVING SAME SHAPE:



Shape	***Equation***
Sphere	$t = 120.3\left(\frac{V}{A}\right)^{1.545}$
Cube	$t = 161.4\left(\frac{V}{A}\right)^{1.565}$
Plate	$t = 205.2\left(\frac{V}{A}\right)^{1.587}$

Solidification time increases exponentially with increasing V/A ratio when shape is kept constant. The exponent is seen to vary between 1.5 to 1.6. The sphere has largest V/A ratio where this ratio for the plate is smallest. The exponent is maximum for plate and minimum for sphere.

iii) B) EFFECT V/A RATIO ON SOLIDIFICATION OF ALUMINIUM CASTINGS HAVING SAME VOLUME



Volume (cm³)	*Equation*
300	$t = 165.3\left(\frac{V}{A}\right)^{0.68}$
1000	$t = 334.1\left(\frac{V}{A}\right)^{0.1413}$

With increasing V/A ratio solidification time increases when volume is kept constant. Solidification time is much greater for castings with 1000 cm^3 . But the exponent is maximum for castings with 300 cm^3 volume.

iv) COMBINED EXPRESSION FOR CHVORINOV'S RULE

Chvorinov's rule states that-

$$t_f = C\left(\frac{V}{A}\right)^n$$

$$\ln(t_f) = \ln(C) + n\ln(\frac{V}{A})$$

Sphere:

Volume	*Solidification Time*	*V/A Ratio*
300	200	1.39
1000	370	2.07

$$\ln(370) = \ln(C) + n\ln(2.07) - (i)$$

$$\ln(200) = \ln(C) + n\ln(1.39) - (ii)$$

Solving (i) $and\ (ii)\ we\ get -$

$\mathbf{n = 1.54}$ and $\mathbf{C = 120.26}$

$\therefore$ Combined expression for Chvorinov's Rule for sphere is $-$

$$t_f = 120.26\left(\frac{V}{A}\right)^{1.54}$$

Cube:

Volume	*Solidification Time*	*V/A Ratio*
300	190	1.11
1000	360	1.67

$$\ln(360) = \ln(C) + n\ln(1.67) - (i)$$

$$\ln(190) = \ln(C) + n\ln(1.11) - (ii)$$

Solving (i) $and\ (ii)\ we\ get -$

$\mathbf{n = 1.56}$ and $\mathbf{C = 161.38}$

$\therefore$ Combined expression for Chvorinov's Rule for cube is $-$

$$t_f = 161.38\left(\frac{V}{A}\right)^{1.56}$$

Plate:

Volume	***Solidification Time***	***V/A Ratio***
300	130	0.75
1000	350	1.4

$\ln(350) = \ln(C) + n ln(1.4) - (i)$

$\ln(130) = \ln(C) + n ln(0.75) - (ii)$

Solving (i) and (ii) $we\ get$ $-$

$\mathbf{n = 1.58}$ and $\mathbf{C = 205.21}$

$\therefore$ Combined expression for Chvorinov's Rule for plate is $-$

$$t_f = 205.21\left(\frac{V}{A}\right)^{1.58}$$