

# Optimising ceramic shell thickness to enhance its permeability for investment casting

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**ABSTRACT** –The quality of casting is a common issue in manufacturing industries as it affects the manufacturing cost and the mechanical properties of the product. Thus, the casting parameters are required to be analysed, design and control in order to produce a better quality of the casting. Permeability is one of the parameters that can cause defects such as blowholes, pinholes and gas porosity. This paper aims to find the optimised ceramic shell thickness to enhance its permeability. A test specimen with thickness range of 4 mm to 8 mm was designed and produced. The comparative study between manual calculation and simulation results was conducted. The manual calculation was applied using Java programming while the casting simulation was carried out using AnyCasting software. It is concluded that to optimise the ceramic shell thickness to enhance its permeability can be achieved by minimising the thickness of the ceramic shell to 4 mm. Results from this study can be used to analyse further the mechanical properties and quality of casting parts in actual experimentations.

## 1. INTRODUCTION

Casting is a popular process used in industry [1]. Metal casting mould usually uses ceramic as raw materials. Thus, the casting parameters are required to be analysed, design and control to produce a better quality of the casting. Different parameters can cause various casting defects. This paper studies the effect of the ceramic shell thickness on the investment casting and to investigate its permeability of the casting operations. The permeability is a measure of ceramic material's porosity, which is referred to as the passage of air through a given thickness of material [2]. The manipulation of ceramic's permeability is important to avoid air trapped in the shell cavity during casting.

This paper will focus on the design of the casting section by using different thickness range 4 mm to 8 mm, which is the thickness for many casting applications [3], with constant parameters such as temperature and pressure to find out the best thickness of material to magnify the permeability ability. Less than 4mm is not suitable for casting application thus, was not considered in this research. Then, the result is shown in anyPOST to check the melt flow and solidification, and to identify the casting

defects.

## 2. METHODOLOGY

### 2.1 Modeling

The investment casting design is shown in Figure 1. The sprue is 40 mm X 40 mm in cross-section. The cup has a 60mm lower diameter and a 75 mm upper diameter with a height of 50mm. The distance between the sprue and the casting is 40mm.

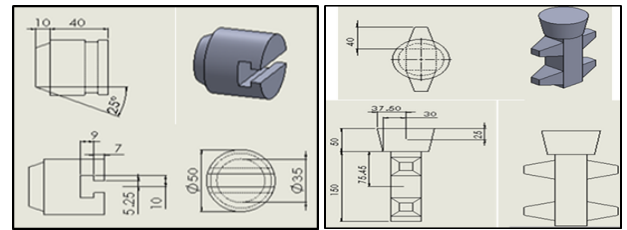


Figure 1 The Casting Model

### 2.2 Casting simulation

The casting simulation was done using AnyCasting software. Input data for the AnyCasting Simulation are shown in Table 1.

Table 1 Input data for casting simulation

Input	Value
Thermal condition during filling	1550 °C
Thermal condition after filling	Normal
Temperature of preheat for shell mould	800 °C
Initial temperature	25 °C
Heat transfer coefficient for the air	0.01 cal/cm <sup>2</sup> *s*C
Heat transfer coefficient for the shell mould	0.6 cal/cm <sup>2</sup> *s*C
Gravity	980 cm/s <sup>2</sup>
Ceramic shell thickness	4, 5, 6, 7, 8mm
Air velocity	20 cm/s
Direct pouring radius	15 mm

2.3 Manual calculation

The next study is the manual calculations by developing a JAVA programming to allow simple calculation of permeability. The defects such as blowholes, pinholes and the gas porosity can be eliminated when the sand base of casting has high permeability, which allows the gas pass through smoothly without trapped inside the body of casting [4]. The gas permeability was calculated by using the Darcy’s Law with the formula shown below.

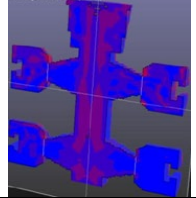
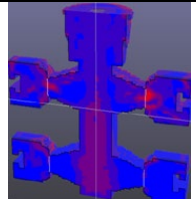
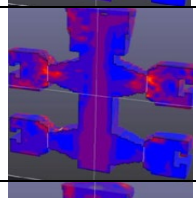
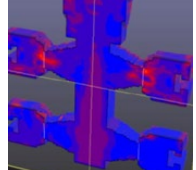
$$K = MQd / (\delta P \cdot A) \quad (1)$$

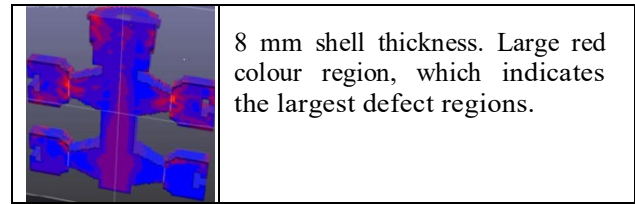
The permeability constant, K is equivalent to the product of viscosity of gas, M (dyne sec/cm<sup>2</sup>), the gas flow rate, Q (cm<sup>3</sup>/sec) and sample thickness, d (mm) divided the pressure differential,  $\delta P$  (dyne/cm<sup>2</sup>) and the surface area, A (mm<sup>2</sup>).

3. RESULT AND DISCUSSION

By using the casting simulation in AnyCasting, the results are listed in Table 2. The result based on the combined defect parameters was observed and compared visually.

Table 2 4 to 8 mm shell thickness casting defect

	4 mm shell thickness. The red colour region is rarely identified visually which indicates there is no defect.
	5 mm shell thickness. Small red colour region, which indicates small defect, occurred.
	6 mm shell thickness. Increased red colour regions, which indicates more defect.
	7 mm shell thickness. More red colour regions which indicate increased defect regions.



Next, the Darcy’s Law formula was inserted into the JAVA program. The results were shown in Table 3. It clearly shows that the lower the ceramic shell thickness will have the better gas permeability [4]. The shell of 4 mm shows permeability of 0.0051

Table 3 List of results obtained from Darcy’s Law

Test No	Thickness, d (mm)	Max Flow Velocity, v (m/s)	Permeability, G (darcy)
1	4	185.905	0.00509952
2	5	185.807	0.00509683
3	6	183.644	0.00503750
4	7	183.145	0.00502381
5	8	183.313	0.00502834

4. CONCLUSION

The result has shown that the 4 mm shell mould thickness has the best casting quality compared to other thickness. By using 4 mm thickness, casting defects such as blowholes, pinholes can be avoided. By inserting the Darcy’s Law formula into the JAVA program developed, it shows that lower ceramic shell thickness will have better gas permeability. Both casting simulation and the Java calculation program developed results have shown that the lower ceramic shell thickness has a better gas permeability value. However, the simulation and the calculations may not be 100% reflect on the real casting process, so it is needed to be proved by the results obtained from the experiments.

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