Faculty of Engineering

Parametric Study for Runner Modification of Die Casted Part with Venting Systems

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

High pressure die casting (HPDC) creates complex components by injecting the molten metal inside the cavity at high pressure. Failure in die casting may reduce product mechanical properties, surface quality, and life cycle. This research aimed to investigate the die-casting process of an inspection instrument–test piece using parametric study and computational fluid dynamics (CFD) analysis. Parameters used in the die-casting process are important since they affect the quality of molten flow inside the cavity. Thus, a parametric study is conducted to investigate the optimum parameter used in the die-casting process of the test piece. Based on the parametric analysis, the higher the velocity, the higher the pressure of molten metal inside the cavity, which means low air entrapment, hence, high volume of molten metal leads to high temperature. Cavity pressure lower than atmospheric pressure also could help to suck the air out from the molten metal, however, too low cavity pressure also could lead to backflow that could trap more air. In this analysis, the optimized parameters are cavity pressure of 10,000 Pa and inlet velocity of 3.00 m/s. This research also investigated the effect of runner gating system design optimization in reducing gas porosity. This research proposed a new runner design named outward curvature runner with air vents that have improved the velocity and temperature distributions in reducing air entrapment and thermal differences according to CFD analysis results. This research also aims to give die-casting manufacturers ideas for reducing manufacturing costs and improving productivity.

Keywords: Design, air vents, parameter, velocity, temperature

Parametrik terhadap Reka Bentuk Acuan Produk Penuangan Beracuan yang Diubahsuai berserta dengan Rongga Udara

ABSTRAK

Penuangan beracuan bertekanan tinggi (HPDC) menghasilkan produk kompleks dengan memasukkan logam lebur ke rongga acuan dengan tekanan yang tinggi. Kecuaian semasa penuangan beracuan akan mengurangkan kriteria mekanikal, kualiti permukaan produk, dan hayat produk. Dalam kajian ini, proses penuangan beracuan alat pemeriksaan ukuran iaitu alat pengkaji dianalisa melalui kaedah parametrik dan dinamik bendalir komputeran (CFD). Parameter digunakan dalam proses penuangan beracuan penting dalam mempengaruhi sifat bendalir. Oleh itu, kajian parametrik telah dijalankan bagi mengenal pasti parameter optimum dalam pembuatan alat pengkaji. Berdasarkan kajian parametrik yang dijalankan, semakin tinggi halaju logam lebur, semakin tinggi tekanan dalam acuan, bermakna semakin kurang udara terperangkap dan ketumpatan yang tinggi telah menyebabkan suhu juga tinggi. Tekanan acuan yang rendah dari tekanan atmosfera mampu menyedut keluar udara dari logam lebur, tetapi, tekanan acuan yang terlalu rendah juga mengakibatkan aliran balik yang memerangkap banyak udara. Dalam kajian ini, parameter optimum ialah tekanan acuan 10,000 Pa dan halaju pemula 3.00 m/s. Pembaharuan reka bentuk sistem laluan gating bagi mengurangkan udara terperangkap turut terdapat dalam kajian ini. Pengubaharuan reka bentuk acuan yang bernama laluan melengkung keluar berserta rongga udara, telah menoptimakan halaju dan suhu logam dimana udara terperangkap dan jurang suhu telah dikurangkan menurut kajian CFD. Pengilang bermanfaat dari kajian ini bagi meningkatkan produktiviti dan mengurangkan kos.

Kata kunci: *Reka bentuk, rongga udara, parameter, halaju, suhu*

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CAD	Computer-aided design
CFD	Computational fluid dynamics
ET	Total energy (J)
HPDC	High-pressure die casting
K	Kelvin
MPa	Mega Pascal
P	Pressure (Pa)
T	Time (s)
Re	Reynolds Number
Pr	Prandtl Number
Q	Volume Flow Rate (m3/s)
e	Specific Energy (J/kg)
k	Specific Kinetic Energy (J/kg)
pv	Specific Flow Energy (J/kg)
q	Specific Heat (J/kgK)
u	Specific Velocity (m/kgs)
w	Specific Work Done (J/s)
ρ	Density (kg/m3)
τ	Stress (N/m2)
μ	Dynamic Viscosity (kg/ms)

CHAPTER 1

INTRODUCTION

1.1 Study Background

Metal injection molding (MIM) process market demand has been growing over the years. Demand for this process increased from 2014 and is expected to continue growing till 2025 as shown in Figure 1.1. The metal injection molding of medical and industrial parts is increasing due to the ability of the process to produce high-precision products. The increasing demand for automotive parts through this process is due to its capability to produce lightweight and sustainable parts (Grand View Research, 2016).

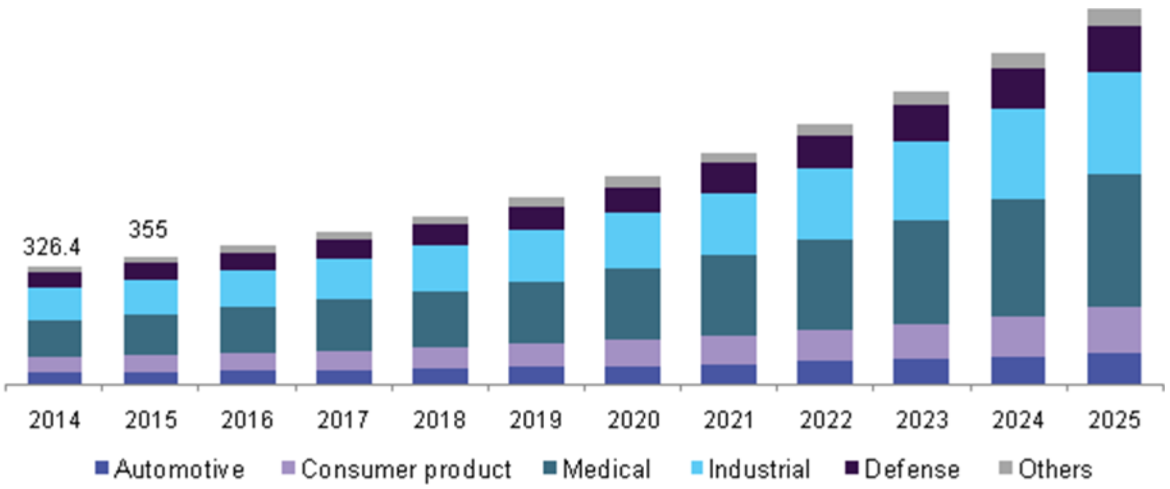

Figure 1.1: The United States MIM Market by End-user (Grand View Research, 2016)

The demand for metal injection molding in Asia Pacific is shown in Figure 1.2. Advancement of technology and the industrial revolution led to increasing demand for metal injection molding products.

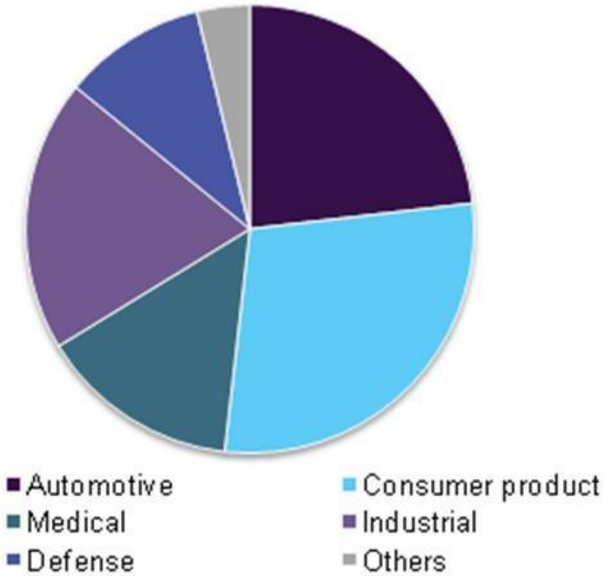

Figure 1.2: MIM Market by End-user in the Year 2015 (Grand View Research, 2016)

The goal for any manufacturing industry is to minimize waste and the total manufacturing cost. The die-casting process frequently leads to significant savings in cost as compared to other manufacturing processes. This is because of the ability of the die-casting process to produce high-precision products in mass production while waste is minimized. The mold design used in the die-casting process could produce complex products which helps to minimize secondary operations such as grinding and milling. In the die-casting process, molten metal is injected into a mold cavity at high pressure by a plunger through a horizontal shot tube. The molten metal will then be solidified before being ejected from the cavity as die cast part (Nikroo et al., 2008). Die-casting processes can produce a high variety of non-ferrous products (Ravi, 2011).

Three categories of die-casting processes that are widely used among die-casting consumers are low-pressure die-casting, gravity die-casting, and High-pressure die-casting (HPDC). Limitations of low-pressure die-casting and gravity die-casting are the difficulties of this process to produce complex products such as automobile cylinder head with internal structure (Jeong et al., 2015). Die casting industries have recommended HPDC and high vacuum die-casting process as an effective cost process in manufacturing die-cast parts at high production rates. The ability of HPDC to follow a variety of products' mold thickness precisely is one of the reasons why HPDC is widely adopted in die-casting industries. The product will also have good mechanical characteristics (Sadeghi, 2015). HPDC also serves as a plastics products manufacturing process (Moscovitch et al., 2006). Figure 1.3 gives the full picture of the HPDC process. In the first phase, the plunger is pulled out to allow the molten metal to flow into the sleeve from the ladle. In the second phase, the die-cast product filled the cavity. Lastly, in the third phase, the plunger will be pressed under high pressure till the die-cast product solidifies.

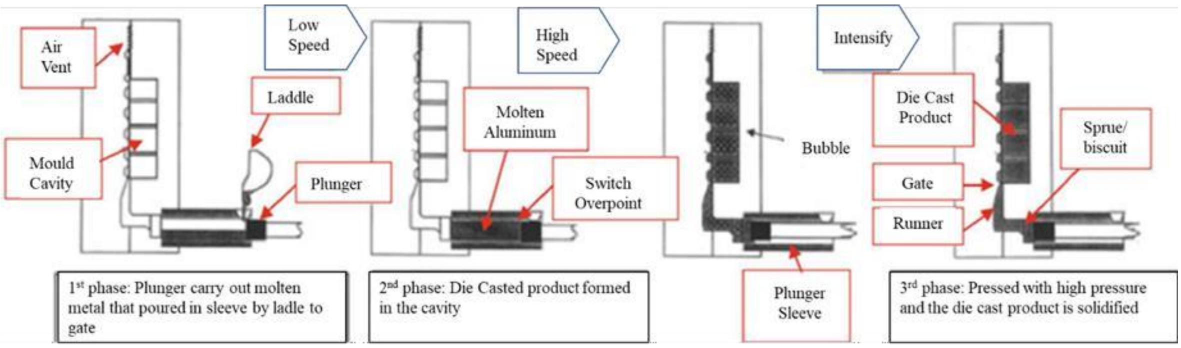

Figure 1.3: Phases of High-Pressure Die Casting Process (Ibrahim et al., 2019)

Molten metal was initially obtained from metal granules that had been loaded inside the feeder, then moved into a cylinder using screws that transferred the granules toward the nozzle for injection. Then, granules will be heated and turned into molten metal. For better fluidity behavior the molten metal will be injected at high pressure and temperature. The parameters of molten metals are crucial to enhancing the fluid solidification process

(Lohmuller et al., 2006). According to Rosof (1989), the metal granules must undergo a mixing process before being injected into two half-mold clamps together. In the mixing process, the metal granules will be mixed with a binder in a ratio of 1;1.

According to Energy Efficiency and Renewable (EERE), (n.d.), the thixomolding method is an advanced method in die casting replacing the traditional die casting method. The thixomolding method could help to increase the productivity of the die-cast manufacturing process. Thixomolding also could help minimize waste and provide a better workplace for material handling. Figure 1.4 shows the schematic drawing of the thixomolding machine retrieved from Kainer (2003).

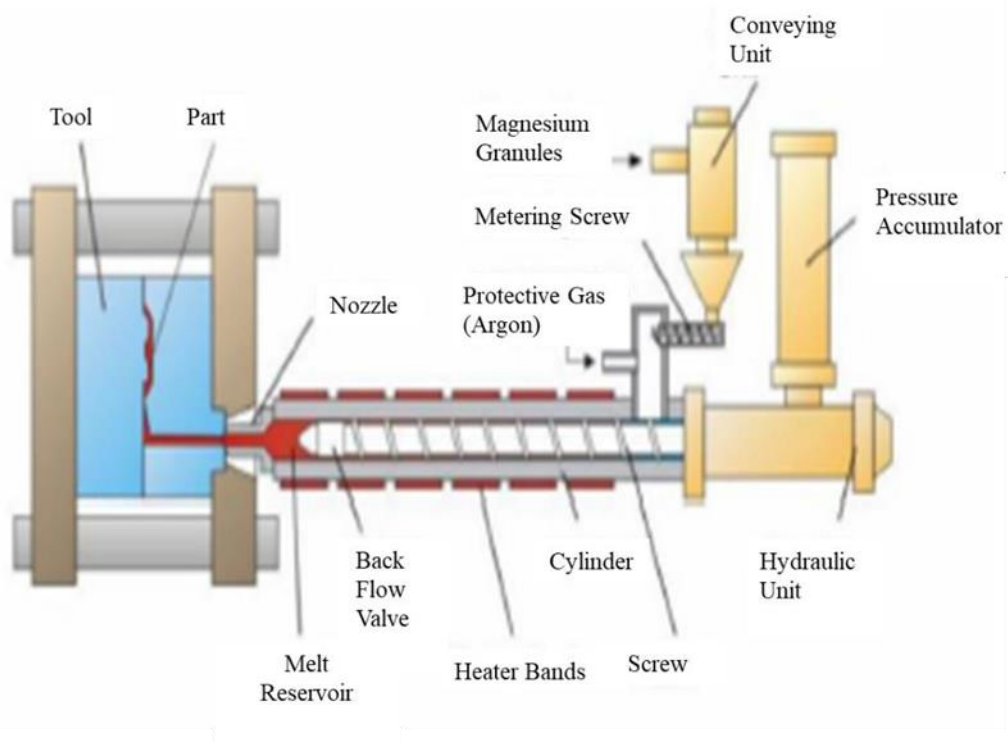

Figure 1.4: Schematic Drawing of Thixomolding Machine (Kainer, 2003)

Table 1.1 shows the thixomolding machine components and their function:

Table 1.1: Example of a Table Main Components and Function of Thixomolding Machine

Component	Function
Feeder	- Load metal granules - Transfer granules to the cylinder
Screw	- Transfer the granule to the nozzle at the cylinder front - Valves to prevent backflow
Cylinder	- Heat metal granules to molten metal
Nozzle	- Inject the molten metal into the mold cavity

There are two primary processes inside die-casting machines: the hot chamber process and the cold chamber process. Figure 1.5 shows the schematic diagram of the hot chamber process. The hot chamber process is mainly used in the die-casting process of magnesium, lead, tin, and zinc. In this process, the hydraulic actuator is submerged in the molten metal. This helps to prevent molten metal from being exposed to air which can lead to oxidation, turbulence, and loss (Sully, 1988). However, lengthy contact between the hydraulic actuator and molten metal can lead to major setbacks for materials with high melting points (Guerra, 1997).

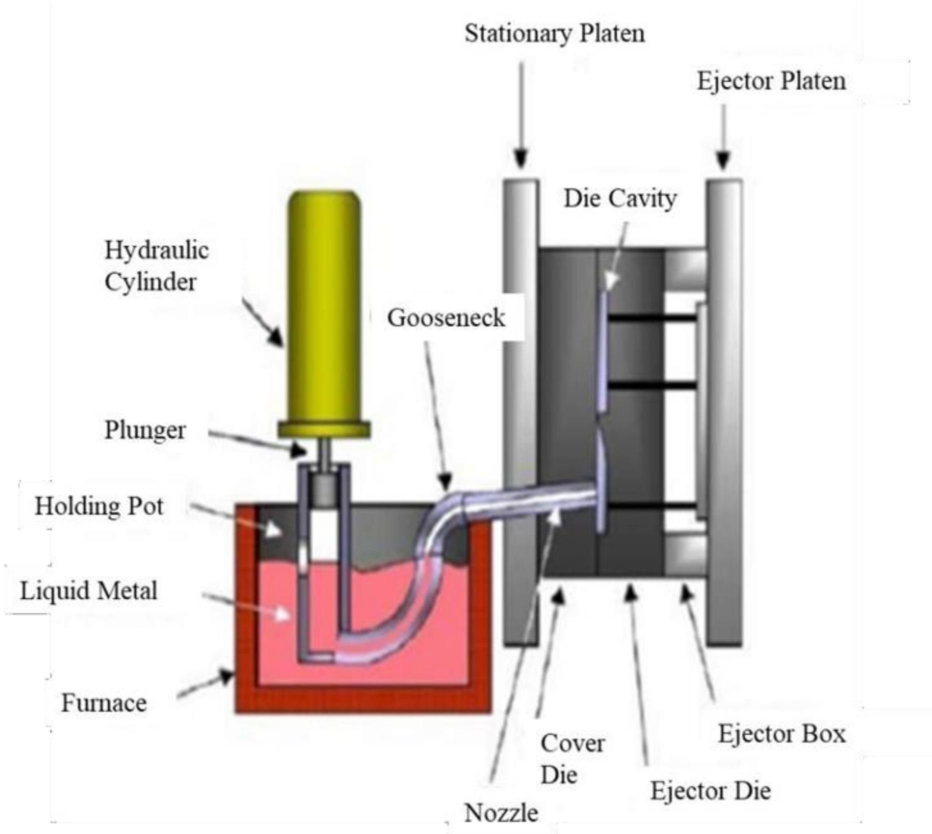

Figure 1.5: Schematic of Hot Chamber Die Casting Machine (Singh, 2016)

Meanwhile, the invention of the cold chamber process can resolve the setback in the hot chamber process. Figure 1.6 shows the schematic diagram of the cold chamber process. In the cold chamber process, the hydraulic piston shot is placed horizontally to the chamber's pouring hold to facilitate the molten metal. The cold chamber process only lasts for a very short time and slight exposure of piston and molten metal. Cold chamber processes are usually used in die-casting processes of high-temperature molten metal such as aluminum and copper alloys.

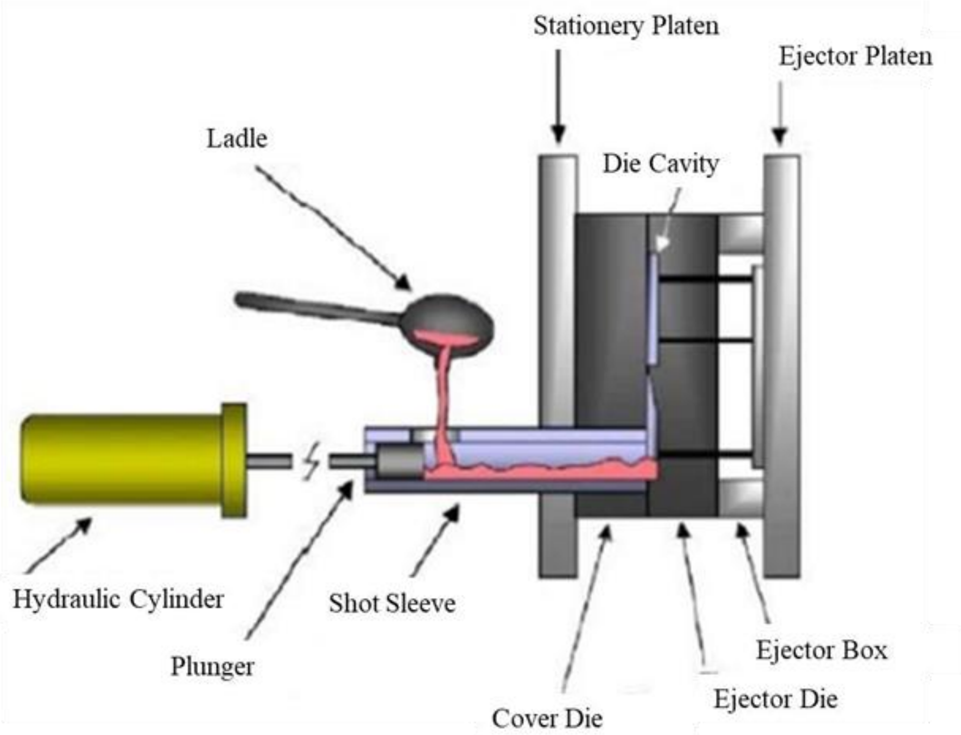

Figure 1.6: Schematic of Cold Chamber Die Casting Machine (Singh, 2016)

1.1.1 Magnesium Metal and Alloy

According to Avedesian and Baker (1999), casting was the dominant magnesium element manufacturing process for about 98% of magnesium structural applications. A mixture of aluminum, iron, and manganese produces magnesium alloy. One of the most common magnesium alloys is manganese. Manganese has a positive effect on the properties of magnesium alloys such as improving damping capacity, resistance to corrosion, creep behavior, and fatigue (Yu et al., 2017). Due to their low density, magnesium and magnesium alloys have superior basic strength and rigidity relative to other engineering materials. Magnesium also provides several alluring properties such as dimensional stability, better machining ability, capability to be recycled, better dissipation of heat, good electromagnetic shield damping, and sound damping. Thus, magnesium fulfills the demand for cast saving and reduction of weight in modern industries particularly in computer and communication products, the industry of automotive, and power equipment. Research studies and applications of magnesium alloys have been expanding around the world to gain an understanding of the magnesium properties differences against aluminum alloys (Nakase et al., 2017).

The growing demand in the usage of magnesium alloy among manufacturers is due to its excellent fluidity behaviors, which has better resistance towards hydrogen peroxide, resulting in low casting defects compared to aluminum and copper (Luo, 2013). The increased utilization of magnesium and magnesium alloys requires a further understanding of solidification behavior to develop advanced casting technologies for magnesium alloy castings with fine grain size, minimum porosity or cracks, and further improved metallurgical quality. Magnesium and magnesium alloys need more understanding of solidification behavior to establish advanced magnesium alloy casting technologies for fine grain casting, reduced porosity or cracks, and further metallurgical quality improvement. (Fallis, 2013).

1.1.2 Test Piece

Figure 1.7 shows the side view of the final product of the test piece. Meanwhile, Figure 1.8 shows the test piece and its venting system provided by Kyokuto Die Casting. This research will focus on the casting of the test piece. The test piece is laddering type, multiple thicknesses measuring equipment used to detect thickness and 90° angle product. It is important for small tolerance products to assure the product conforms to the quality standard, and to avoid any component failure due to failing design dimensions and tolerance.

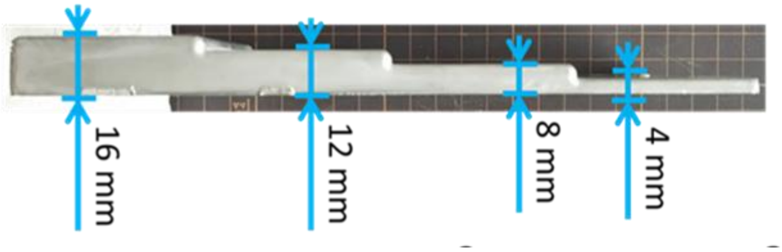

Figure 1.7: Side View of Test Piece

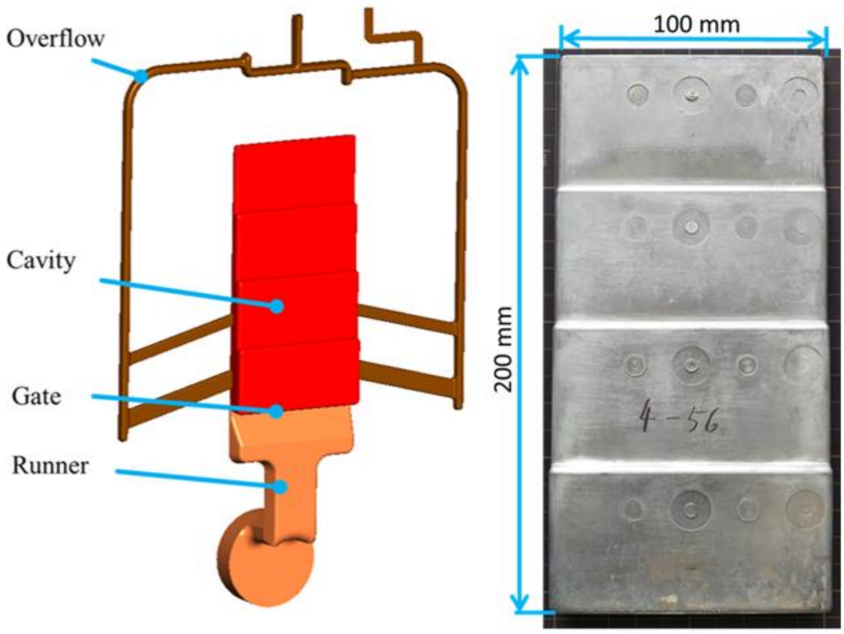

Figure 1.8: Front View of Test Piece with the Venting System

1.2 Problem Statement

Tesla has been making significant investments in alloy casting technologies over the past few years to enable the production of larger cast parts that have the potential to significantly simplify the manufacturing process. Elon Musk has confirmed that Tesla will use the Giga Press, the largest casting machine in the world, to create the body of the Cybertruck. Cybertruck is going to be built in 2023 using a full-body stainless-steel exoskeleton that requires advanced casting capability. The Giga Press casting machine has