EFFECT OF THE PROCESSING PARAMETERS ON HIGH-PRESSURE DIE-CASTING PROCESS

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Abstract:

HPDC is one of the important sector in manufacturing industries, majorly in production of complicated geometries commonly used in automobile, aerospace and other service industries. The contribution from the optimal parameters, the temperature, showed more influence on the casting quality than the other parameters. In this study, the processing parameter of high speed in the range of 3.97 to 4.97 m/s and that of fast start point in the range of 293 to 333 mm were calculated and then the HBC samples of using the Al alloy of ADC12 were produced through the HPDC process. The shrinkage defects on HBC were characterized by visual inspection, radiography testing and microstructure examination. The result showed that the best parameters for reducing shrinkage defect of HBC by the HPDC process are 4.97 m/s of high speed and 313 mm of fast start point. The optimum parameters of high speed and fast start point were verified to contribute to producing a high quality of the HBC for the applications in automotive engine.

1.0 INTRODUCTION

Quality of the casting product is an important factor in producing a superior manufacture product, due its competitiveness in the market. This has motivated the manufacture world doers to compete in innovating and to strive for various ways to achieve this goal. One of the ways to increase productivity of the production line is to increase the good quality products and reduce the ratio of not good quality products (NG In-Process). The casting technology has been developed to optimize the parameter of the casting process. High Pressure Die Casting (HPDC) is a shape manufacturing process and has been used to produce many automotive components. The molten metal is injected into metal mold at high speed and solidified under high pressure [1-2]. The HPDC products have high dimensional precision and elevated production efficiency, also significant financial profit for automotive industries [3]. However, components manufactured by HPDC contain defects, such as shrinkage defects, that could decrease their mechanical properties Shrinkage defect is the existence of cavity or trapped air inside a product produced from cast in HPDC production line. The mechanical properties is influenced by filling process and solidification conditions, particularly depends on HPDC parameters such as the condition as pressure applied and the gate velocity [4] Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The mold cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mold during the process. Most die castings are from nonferrous metals, specifically zinc, copper, aluminum, magnesium, lead, alloys. Depending on the type of metal being cast, a hot- or cold-chamber machine is used. [5] The Taguchi method is a well-known technique that provides a systematic and efficient methodology for process optimization and this is a powerful tool for the design of high-quality systems. Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community.

Problem of the statement:

The sponsoring Company whose associate concern is primarily engaged in production of Die Casting is keen to investigate the levels for the factors responsible for arriving at the best quality for the cast components. Pressure die casting is primarily affected by the process parameters such as solidification time, molten temperature, Filling time, injection pressure and plunger velocity. It is therefore essential that the optimum casting technique with minimum defects be adopted to reduce the manufacturing cost of die casting component during mass production. The optimization of the process parameters poses a challenge for defects since the interplay among the parameters needs to be captured for setting the process for each component. In manufacturing processes, there are various parameters with different adjustment levels, which may influence the final characteristics of the product. To optimize a manufacturing process, the trial-and-error method is used to identify the best parameters to manufacture a quality product

2.0 LITERATURE REVIEW

[6] Wenlong Xiao, 2012, studied the casting defects in Mg-ZnAl-RE alloys with different combinations of Al and Zn. It was noticed that the defects vary as combination changes and the hot tearing susceptibility changes as Zn increases up to sometime and then decreases. The yield strength was increased due presence of Al and Zn. The tensile strength and ductility depend on casting defect. It was concluded that the mechanical properties were increased by adding Al and Zn.

[7] Yasushi Iwata, 2012, investigated effects gas porosity in HPDC. The author indicated that the defects were minimized by optimizing compression behavior even though the entrap air or gas was opaque by high casting pressure during pressurization, finally remain in the castings as defects after solidification

[8] Rajesh Rajkolhe, J. G. Khan (2014), conducted an organized study on casting defects and its remedies. It was observed that even in totally controlled procedure defects were observed in casting. The study gave root cause for casting defects which could help in analysing the defects.

[9] R. Vinayagamoorthy 2015, conducted experiments on reduction of defects in ring blank casting. The author studied the design parameter that affects the cold metal fault in the ring blank casting sand. The main three parameters are choke thickness, pouring basin and runner diameter for reducing cold metal defect. It was observed that the higher levels sand inclusion, sand mismatch of pattern and increased in pouring base was difficult so it was only used in lower levels and cold metal defect which would reduce the cold metal defect.

[10] Liu Cao,2017 summarized on oxide inclusion defects in casting on walls. The paper highlighted that the oxide inclusion was common defect in casting they were difficult to observe in experimentally to accurately predict. The calculations were to be done the density of liquid metal temperature and the density of oxide inclusion

3.0 RESEARCH METHODOLOGY

The block compressor was produced using aluminum alloys of ADC12. The steps of processing and research are described in two steps. First, re-calculation of casting aspects so that beginning parameter can be identified, which will be used to prove the formulation. Gating system on the cast in HPDC process consists of 3 cast cavities, as seen in Figure 2 and 3. To achieve an optimum parameter determination, a calculation of high-speed value and fast start point is conducted. Furthermore, a method to determine HPDC parameter in order to obtain optimum parameter will be discussed.

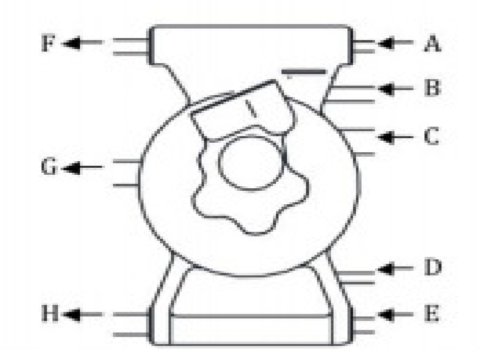


Figure: Input and output gating systems of Al alloy on the Cavity produced by block compressor

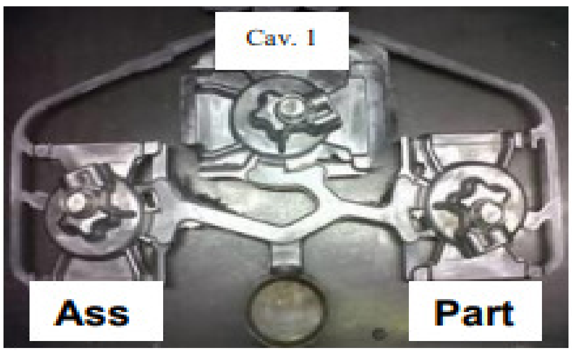


Figure. Number of Cavity

Second step is conducting an experiment on production process of casting RH 10SRE11 with injection systems as shown as Fig. that is by using the beginning parameter re-calculation result, particularly high speed and fast starts point. High-speed effect is presented in Figure showing a schematic picture of a plunger tips movement of injecting the liquid Al material into the die cast. Fast start point (FSP) is the beginning of high-speed point application during the process of pushing the molten aluminium into the cast. Fast start point will be trialed on 3 positions; of which before gate, on the gate, and after the gate.

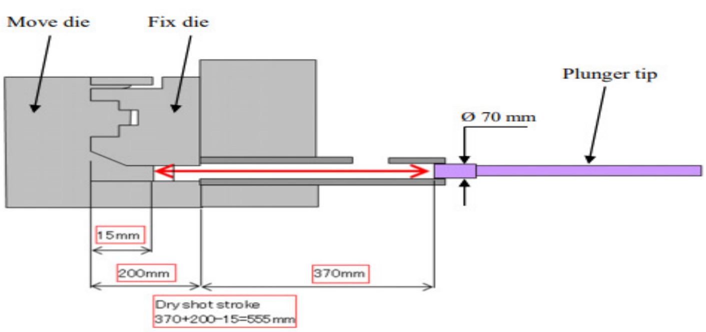


Figure: Injection system of molten Al alloy into metal mold using HPDC process

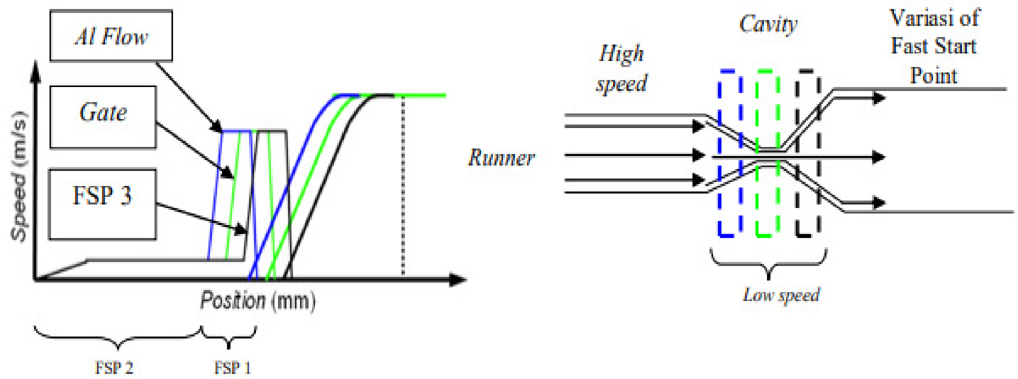


Figure: Fast start point on the gate of HPDC process on compressor product.

The parameters of HPDC process are cross section area of gate of 91 mm2 / cavity; over flow (O/F) of 43.5 mm2 /cavity; diameter of plunger tip of 70 mm, cross section area of plunger tip of 3846.5 mm2, product weight of 1600 gr (3 cavity); over flow weight of 450 gr; ρ (density melt Al) of 2.4 gr/cm3 and charging volume of. 284.7 cm3. Based on these parameters, charging time can be calculated as shown in equation (1).

$$= k \cdot \left(\frac{T_i - T_f + S \times Z}{T_f - T_d} \right) \cdot X$$ **........................ (1)**

t = Charging time (s) k = > 0.0346 s/mm

Ti = Melting temperature on Gate (^oC) = 632 ^oC

Tf = Pouring Temperature = 570 ^oC

Td = Dies Temperature = 150 ^oC

S = Solid rate = 20 %

Z = Coefficient of Conversion Unit = 4.8 oC / %

X = Thickness of product = 4 mm

Vp (lower limit speed injection value) =

$$= \frac{V \times W}{A_{tip} \times t} = 4.27 \text{ m/s}$$ .... (2)

Setting lower limit = - 0.2 m/s

In this section, the result of the experiment of the research will be addressed by comparing the result of inspection process (visual inspection, radiographic inspection, and microstructure inspection), so that the best result shall be obtained.

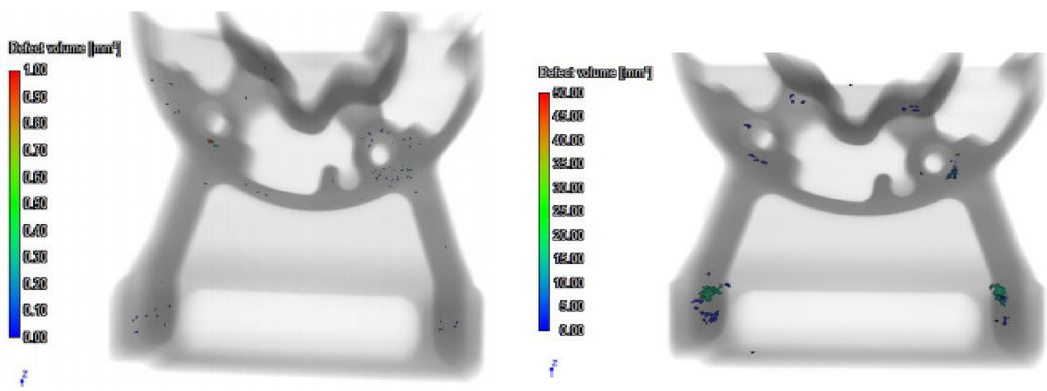
4.0 RESULTS AND DISCUSSION

In high pressure die casting of ADC12 aluminium alloys, Porosity is the most common defect caused due to entrapment of air/gas and oxides due to the turbulent flow of metal during the cavity filling [8]. This defect is classified as gas porosity (caused due to air trapped air in sleeve), shrinkage porosity (due to solidification of the metal in the gate before solidification in other areas of the casting) and flow porosity (caused due to insufficient pressure towards the end of cavity filling). The mechanical properties and pressure tightness are affected due to presence of porosity in castings. Porosity in a high pressure die casting varies both with part geometry of component and casting parameters of the process Effects of the processing parameters of a high-pressure die-casting (HPDC) process on the shrinkage defect of housing block compressor (HBC) were examined in this research. Because of the reduction of defect can increase the productivity of HBC that representing a good quality product, the processing parameters determining the quality of product must be optimized Below is a summary table of result of visual inspection. Figure shows an example of visual checking result under a condition where a defect is present (O) and no defect (X). From the above observation, it can be seen that speed value with the most no defect condition (O) is (high speed, fast start point) parameter, respectively.

Table: Summary of visual inspection examinations

Fast Start Point		293 mm			313 mm			333 mm		
Cavity No.	.	1	2	3	1	2	3	1	2	3
High speed	3.97 m/s	X	X	O	X	X	X	X	X	O
	4.47m/s	X	X	O	X	X	X	X	X	X
	4.97m/s	X	X	O	X	O	X	X	O	X

The following, radiographic examination will be explained. On this radiographic examination, a comparison of void sizes resulting from each measurement is conducted. The standard used is the values below 15 mm^3 by using reference from the standard of the housing block compressor manufacturer.



(a) (b)

Figure: Radiographic observation image: (a) minor defect, (b) major defect.

In the following, the result of structure micro-observation will be explained. From the result, morphology shapes of a microstructure of each parameter will be compared. Figure shows the sample position on which a microstructure observation will be conducted. Each of the samples is observed using 2 types of magnification, which are 100x and 500x. Figure is resulted from 100x magnification. From this figure, it can be seen that the structure on figure (b) is more uniform and homogenous than the structure in figure (b). This explains that figure (b) has an evenly distributed Si Eutectic structure than figure (a). Also, from figure (a), it can be seen that a micro shrinkage, which is spread almost every location in figure (b). the present of dendritic sizes between figure (a) and figure (b) are almost similar. Moreover, micro porosity is also can be seen, which explains that micro porosity is still formed in each of the parameters. Therefore, it can be concluded that this parameter has effect on porosity and shrinkage, which occurred on the sample.

Figure: Sample position to examine the microstructure.

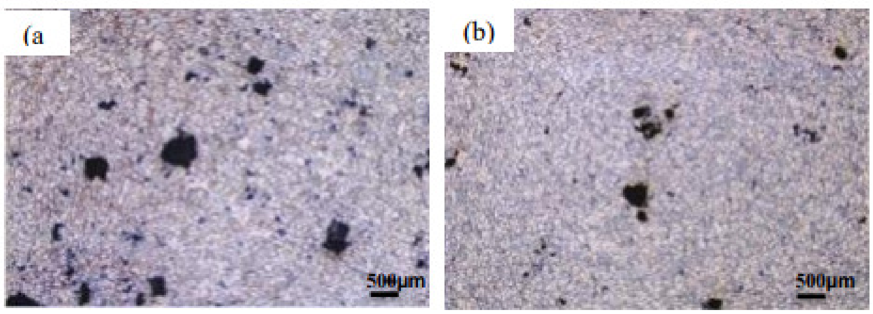


Figure: Microstructure of block compressor with HPDC parameters of: (a) 3.97 m/s with 293 mm, (b) 4.97 m/s with 313 mm

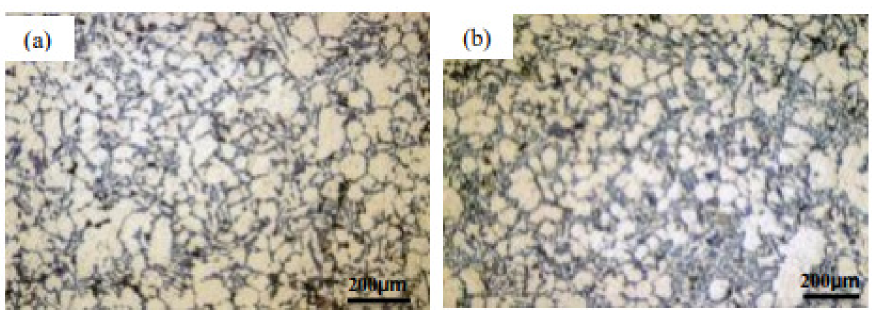


Figure: Microstructure of block compressor with HPDC parameters of: (a) 3.97 m/s with 293 mm, (b) 4.97 m/s with 313 mm

Conclusion:

Casting simulation nowadays has become a dominant tool to imagine mould filling, cooling and solidification to expect the location of inner defects such as shrinkage porosity, sand inclusions, and cold shuts in the components. From the research it can be concluded that the result of visual inspection is the parameter with minor defect is 4.97 m/s high speed and 293 mm, 313 mm, and 333 mm fast start point. Radiographic analysis result is the parameter with the small void volume (under 15mm3) is high-speed 4.97 m/s with 293 mm and 313 mm fast start point. The result of microstructure analysis is the parameter with distributed eutectic silicon grain size is 4.97 m/s with 313 fast start point. Generally, the dendritic size is not much different from each of the parameters. The best parameter for manufacturing block compressor is the parameter of 4.97 m/s high speed with 313 mm fast start point.

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