IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Analysis design of the gating system on high-pressure die casting process for production effectiveness

To cite this article: Lukas Dwi Purnomo *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **508** 012058

View the article online for updates and enhancements.

IOP ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

This content was downloaded from IP address 120.234.63.196 on 18/09/2019 at 15:25

IOP Conf. Series: Materials Science and Engineering **508** (2019) 012058 doi:10.1088/1757-899X/508/1/012058

Analysis design of the gating system on high-pressure die casting process for production effectiveness

Lukas Dwi Purnomo, Dwi Rahmalina, A. Suwandi*

Mechanical Engineering Department, Faculty of Engineering
Universitas Pancasila

*agrisuwandi@univpancasila.ac.id

Abstract. The purpose of this study is to improve the efficiency of production time for the manufacture of radiator components by performing gating system design optimization. The production data obtained is used as data to examine cases that occur on the production floor. The method of analysis is used to perform simulations on the design of the gating system that already exists, and then compare the results with the new design. The existing gating system design has two cavities while the new design has one cavity. Based on the simulation results, the two cavity gating system has a cooling time of 5 seconds longer than gating one cavity. As a result of longer cooling time, the product can be attached to the mould so difficult removable and can lead to defective products. The percentage of air trapped in the new design is 3.12%, whereas, from the previous design 19.29%, this can cause a reduction in potential defects in porosity in the product.

1. Introduction

The manufacturing industry has a very broad coverage. Almost all sectors need a manufacturing industry to support their activities. These sectors include agriculture, transportation, economy, trade, and many other sectors. In the transportation sector, the easy to find manufacturing industry is the automotive field that produces vehicles with a variety of shapes and uses. Vehicles produced include motorcycles, cars and trucks [1]. One of them is a component made of aluminium material. This material was chosen because of its low price and lightweight. Besides, that aluminium can be easily obtained, and the production process that is often found is casting. Casting is the formation of a product by melting the main material into molten then put into die. The casting process for aluminium material usually uses a high-pressure die casting, sand casting and gravity casting process.

The design of a casting product in high pressure die casting has several parts including biscuit, runners, sub-runners, gates, products, overflow, gas vent and chill event. A well-designed runner and gating system is very important to produce good quality die castings by providing a homogenous mould filling pattern. Flow analysis of the component is done in order to analyse the cavity filling process visibly [2]. One of the key elements to make a metal casting of high quality is the design of a good gating system. The gating system refers to those channels through which the metal flows from the ladle to the mould cavity [3]. For the optimum design of the gating system, the study of the filling process is of great significance since it directly affects casting quality. The goal of proper mould filing cannot be achieved without proper gating design which influences the flow pattern, further affects the temperature distribution and modifies the progression of solidification [4]. Beside that when manufacturing HPDC mould, generally, the casting layout design should be considered based on the relation among injection

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

system, casting condition, gate system, and cooling system [5]. Gating system design must be very effective in actual manufacturing facilities to avoid the occurrence of such defects [6]. Based on the research, the gating system has an important role not only in the smooth production but also in the manufacturing process.

This study aims to improve the efficiency of the radiator component production time by changing the gating system. The part production uses high pressure die casting method. Data is obtained based on the actual results of production during 2017 to provide an explanation of the condition of the part's production. The data is obtained from a gating system that uses two cavities in a single production process. The focus of this research is to design the gating system of one cavity due to the use of the existing gating system, production efficiency is not achieved and the waste in terms of molten material used in the casting process. In addition, the construction of dies also plays a role in contributing problems during production. This is evidenced by the percentage of downtime, the type of problem indies and the production capacity that does not reach the target. Calculated based on existing conditions, the same as producing with the number of cavity one.

2. Method and Materials

Investigate that die casting is a versatile manufacturing technique where liquid metal is poured into die. The tie consists of core and cavity is the main challenge in die casting design and manufacture of dies. Design and analysis integration results in better results [7]. Perform computer simulations to analyze liquid metal flow and analyze effective die designs. Optimal conditions are calculated through simple equations that are examined using experimental output [8]. Focusing research on the design phase of dying for car components made of aluminium alloy (ADC12). The design phase for die casting involves the selection of discrete design parameters namely, the gate area, gate speed, gas vent position and also the defect properties of the casting [9]. Investigate gating systems that are very important for die casting, but designing a gating system is an iterative process that can be very time to consume and expensive. The aim is to develop a design system that helps realize the automatic generation of geometry gating systems by applying parametric designs. With such capabilities, die designers can combine their expertise into the design process at an early stage and make the initial gating system design more like their final design [10].

2.1. Modelling of Case Comp Thermo

Case comp thermo (see Figure 1) is the part used as a radiator component in the car. This part will be assembled with a Thermo Cover which has several other parts in electrical terms. The initial design of Case Comp Thermo uses Solidworks. The parting line is made to separate parts from the fixed and movable die. Then, the appropriate draft angle is given on both sides of the parting line to ensure the part easy removal from the die.

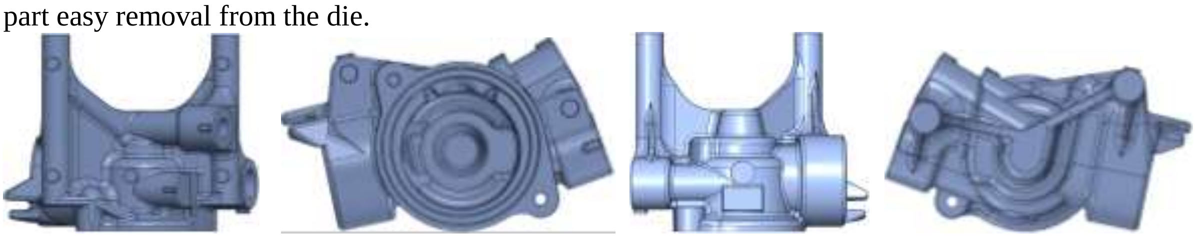

Figure 1. Model of Case comp thermo

2.2. Die Design Calculations

There are several things that must be calculated to design the gating system for simulation, among others part projected area, overflow area, runner area. Beside that calculate the filling ratio for injection and also machine tonnage [9].

- Total Part Projected Area = (Part Projected area) + (Overflow Projected Area) + (Slide Projected Area)

- Runner Projected Area = (Part Projected Area) + (30-40% More)
- Total Projected Area = (Total Part Projected area) + (Runner Projected Area)
- Tonnage of Machine = (Total Projected Area) + (Casting Pressure) + (Die Locking Force)
- Shot Weight = (Weight Per Cavity) + (Runner + Biscuits)
- Filling ratio = $\frac{\text{Shotweight}}{(\text{Plunger Area})(\text{Active Length})(\text{Density})}$
- Cavity Fill Time (t) = $KT\frac{Ti-Tf+Sz}{Tf-Td}$

Where K is Empirical constant; T is casting thickness (mm) ; Ti is a temperature of moulted metal as it enters the die (^{o}C); Tf is Minimum flow temperature (^{o}C); Td is temperature of die cavity surface (^{o}C); S is allowable % solid fraction (%), its selection depends upon casting thickness, and Z is units conversion factor.

2.3. Data preparation

Data is taken from the production during 2017 which is related to production downtime and the types of problems that exist in the die and compared with the calculation of capacity made in planning the production of the part. Table 1 is downtime data which has obtained.

Table 1. Case comp thermo die downtime

NO	Month	TYPE OF DOWNTIME				
		Break Down Machine	Dies Problem	Process Problem	Molten Problem	Another Problem
1	January	795	960	1085	675	0
2	February	135	1160	590	30	0
3	March	130	1575	1410	10	0
4	April	40	1025	605	0	0
5	May	385	1000	1690	155	70
6	June	215	1200	1165	375	70
7	July	240	1700	1670	235	0
8	August	480	930	275	895	0
9	September	400	860	1900	55	130
10	October	200	1905	1640	80	0
11	November	270	5170	1110	15	0
12	December	470	2730	1075	565	20
	Total	3760	20215	14215	3090	290

In Table 1, the highest downtime type is dying problem which reaches 20,215 minutes a year or around 55.4 minutes per day. Almost every month, die problems become the highest problem experienced by Cases Comp Thermo die and the biggest in November is 5,170 minutes. Below will be explained about the type of problem die that often occur. In table 2, the highest problem is that the core problem reaches 5,430 minutes. Casting product design will determine the construction of dies to be made. To find out whether the design has been maximized it can be simulated in advance so that it can minimize the problems that will occur during production.

From the production capacity on table 3, there are 254 units of production per day. Total downtime per day is 80.22 minutes or 4,813 seconds. Cycle time for casting 47 seconds. Because in one casting cycle there are 2 parts, the cycle time is considered 94 seconds. Part wasted due to 4,813 production downtime: 94 = 51.2 or 51 pieces. So that the parts produced were 254 - 51 = 203 pieces. In other words, the achievement of production is only 79.9% of the needs. So that to meet production targets, companies need additional time to produce part casting by increasing working hours or shifting production schedules of other parts that can disrupt its production schedule and pay for overtime manpower and the use of supporting resources such as casting machines, melting machines, electricity, etc. Besides that the next process will be disturbed, such as machining, painting and assembling, not to mention the defects that will be generated from the process that can reduce achievement and disrupt delivery to customers.

Table 2. Type of case comp thermo die problem

NO	MONTH	TYPE OF DIE PROBLEM										
		Over Heat	Part Sticky at Cavity	Cavity surface not flat	*Cooling Dies*	*Core Problem*	*Flash*	Adaptor	Chipped	Insert Pin	Thick Scraps	*Under cut*
1	January	155	70	0	10	145	105	41	170	180	50	75
2	February	120	15	390	0	180	0	31	290	0	0	165
3	March	260	330	0	20	425	0	40	10	430	0	100
4	April	115	0	0	10	160	30	25	235	370	0	30
5	May	205	40	0	30	180	0	35	30	355	0	160
6	June	130	315	0	135	110	120	26	100	200	0	0
7	July	145	185	0	10	170	0	34	360	500	270	60
8	August	185	420	0	30	0	0	24	0	220	0	25
9	September	55	205	0	35	235	0	31	50	125	155	0
10	October	15	230	0	0	880	30	37	85	210	375	75
11	November	150	785	0	65	2350	30	46	380	780	80	540
12	December	135	655	170	0	595	40	43	345	600	20	110
	Total	1670	3250	560	345	5430	355	413	2055	3970	950	1340

Table 3. Calculation of case comp thermo production capacity

No	Part Name	Type	Depreciation setting		Rejection rate internal	1.Basic Calculation Capacity (Depreciation Setting Base)						Production Capacity vs Depreciation Setting (%)	Initial MAX Production Unit per Day	HPM delivery / day
			(/3th)	(/month)		CT (s)	Working Time (H)	Daily Production Capacity (unit)	Working Days Normal	Working Days Holiday	Monthly Production Capacity (unit)			
1	CASE COMP THERMO	2AG	91,350	2,538	15%	115	21.25	254	21	8	5334	52.43%	203.2	181
2	CASE COMP THERMO	2CF	103,950	2,888	15%	115	21.25	254	21	8	5334	45.87%	254	206
3		2MD	239,481	6,652	15%	115	21.25	593	21	8	12453	46.58%	593	475
4	C.C. WATER OULTET	2AG	91,350	2,538	15%	55	21.25	236	21	8	4956	48.80%	188.8	181
5		2CF	103,950	2,888	15%	55	21.25	236	21	8	4956	41.74%	236	206
6		2MD	239,481	6,652	15%	55	21.25	532	21	8	11172	40.46%	532	475
7	C.C. WATER OULTET	2MD	239,481	6,652	15%	55	21.25	650	21	8	13650	51.27%	520	475
8	SLIDER COMP TENSIONER	2CF	103,950	2,888	15%	65	21.25	280	21	8	5880	50.89%	224	206
9	COVER THERMO	2AG	91,350	2,538	15%	32	21.25	304	21	8	6384	60.25%	243.2	181
10		2CF	103,950	2,888	15%	32	21.25	304	21	8	6384	54.77%	304	206
11	COVER THERMO	2MD	239,481	6,652	15%	32	21.25	609	21	8	12789	47.98%	487.2	475

Note: Rejection rate of 15% is the total process from beginning to end

3. Results and Discussion

3.1 Draft Angle Analysis

Draft angle analysis is done to ensure that sufficient drafts are provided when designing casting parts (see Figure 2). The minimum draft angle from 1 to 1.5 degrees is given in the parts on both sides of the parting line.

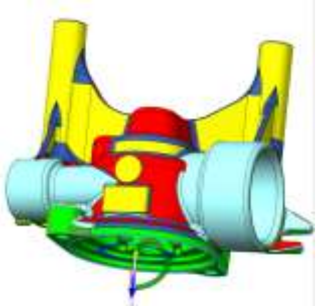

Figure 2. Draft angle analysis of case comp thermo

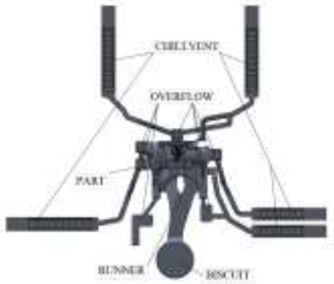

Figure 3. Shot weight

3.2 Die Calculations

Table 4 shows the results of calculations from equation 2.4 calculation results are used as input from the magma simulation parameters.

Table 4. Calculation Result

No	Item	Value	No	Item	Value
1	Weight Part	0.704 kg	6	Sleeve length	380 cm
2	Total Projection Area	266,273 cm^2	7	Volume Sleeve	14624.11 cm^3
3	Shot weight	1408 gr	8	Filling ratio	40%
4	Ø Plunger tip	70 mm	9	Metal Pressure	700 Kgf
5	Area Tip	36.32 cm^2	10	Machine Tonnage	233.34 Ton

Figure 3 as shown the gating system for 1 cavity or the shot weight. The runner is the path or groove through which the metal liquid from the distributor reaches the product area which has the role of giving direction to the metal liquid to fill the entire cavity area. Biscuit is the formation of liquid metal that will change solid or freeze in the area between the die sleeve and the distributor. The chill vent is a part to efficiently remove the remaining air or gas from the inside out of the cavity.

3.3 Simulation Analysis

The simulation results of the two cavity gating system and one cavity describe on Figure 4 and 5. This simulation uses Magmasoft which is used for mould filling and solidification analysis [11]. From the simulation results of the gating system (see figure 4 and 5) , it was found that in two cavities, the molten flow at the end of the shot, the product has several areas that are potentially hot and other areas are already cold.

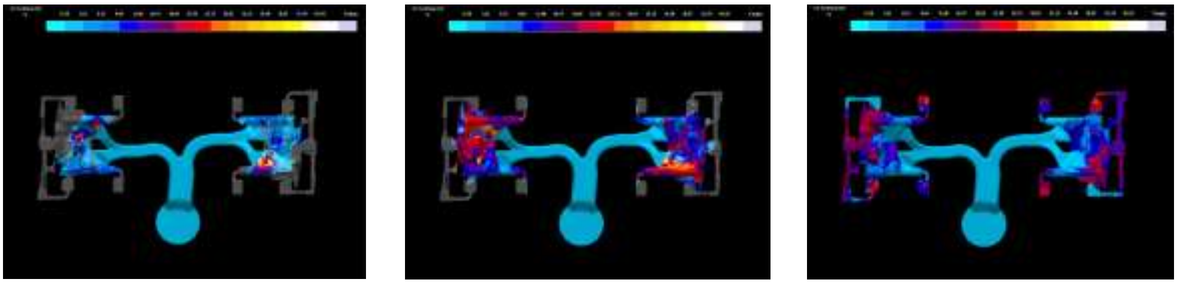

Figure 4. Simulation of two cavity design

This can also affect the quality of the product that will be made. The solidification process that occurs in the two cavity gating system takes longer to occur; this can be seen in the colour of the simulation results due to the runner's longer distance compared to one cavity in passing the product part. So that potential defects in the product can occur. Whereas when viewed from the results of the simulation of one cavity, the results tend to be better which is shown from a fairly stable colour.

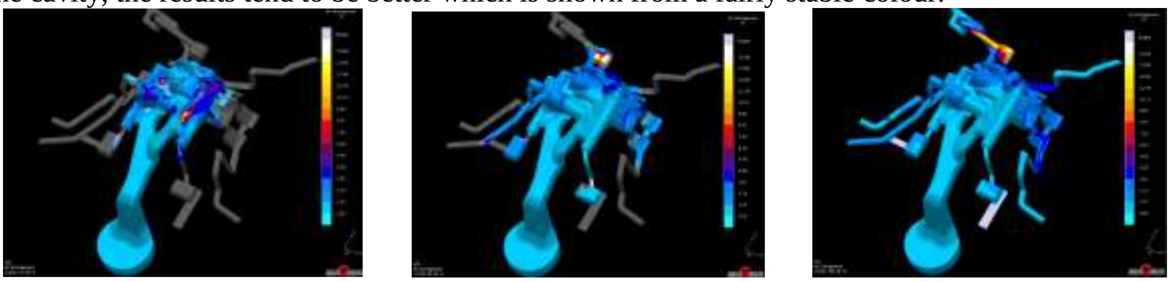

Figure 5. Simulation of one cavity design

Solidification is an integral part of the casting process. During compaction, the casting structure is generated. Because many castings are used in as-cast conditions (that is, without further thermal or mechanical processing), the structure resulting from solidification, the as-cast structure, is often also the final structure of the casting. It also follows that the mechanical properties of casting, which are a direct consequence of microstructure, are controlled through a process of solidification [10].

4. Conclusion

Research and simulations have been carried out to obtain the results of a new gating system design that will be used to improve the production efficiency of radiator component products with simulation results on a one-cavity gating system that is better than the current design for production. This can be seen from the colours produced by the simulation. In two cavities the simulation results have many colours that explain instability during the casting process where cycle time and solidification are not concurrent so that the potential problems in the product are more numerous. The results in one coloured cavity are more stable, so there is less potential for problems in the production.

5. References

[1] Information at https://www.astra.co.id/Business/Automotive, 2018.
[2] Ramnath, B. V., et al., Analysis and Optimization of Gating System for Commutator End Bracket, 2014. pp: 1312 – 1328.
[3] Ezparza, C. E., et al., Optimal design of gating systems by gradient search methods, 2006. pp: 457-467.
[4] Ingle, P. D., Narkhede, B. E., A Literature Survey Of Methods To Study and Analyze The Gating System Design for Its Effect on Casting Quality, pp : 5421-5429, 2017.
[5] K.K. Seo , H.K. Kwon , Simulation study and application on HPDC process with automobile part, Adv. Mater. Res. 658 (2013) 281–286 .
[6] Lee, B. D., et al., Optimization of Gating System Design for Die Casting of Thin Magnesium Allot Based Multi Cavity LCD Housings, 2011.

[7] M. R. Bodhayana, N. Ramesha. Tool design for pressure dies casting of Housing Component. Int J Theor and Appl Res in MechEngg, 3:(2), pp. 30-33, 2014.
[8] B.S. Sung, I.S. Kim.The moulding analysis of automobile parts using the die-casting system. JMateriprocetech, 20-I , pp: 635–639, 2008.
[9] Vispute P. R., et al., Utilizing flow simulation in the design phase of a die casting die to optimize design parameters while validating through experimentation during trials, 2017. Volume 1 Issue 8, pp: 263-269.
[10] Stefanescu, Doru Michael, Science and Engineering of Casting Solidification, Second Edition, Ohio, Springer, 2009.
[11] Dabade, Uday A., Bhedasgaonkar, Rahul C., Casting Defect Analysis using Design of Experiments (DoE) and Computer Aided Casting Simulation Technique, pp: 616-621, 2013