Investigation of Process Parameters For Diff Case Gear Meter By Comparison Method

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Abstract- *Die casting is a manufacturing process that can produce geometrically complex parts through the use of reusable dies. Accuracy and quality are the first need of customers that must be fulfilled by offering high quality products. The different process parameters like Melt temperature, Holding time, Injection pressure, Rate of cooling, Velocity of flow of molten metal etc., need to be set correctly in order to get desired quality at optimum cycle time. For die casting process, there are various techniques by which we can improve the quality of die cast product. In this work I am going to find out the process parameters for the Diff Case Gear Meter just by comparing the current component with other component by taking mass as their reference. For the same we got work permission from Advent Tool Tech Pvt. Ltd., Pune.*

Keywords- Die casting, Process parameters.

I. INTRODUCTION

Die casting is a quick, reliable and cost-effective manufacturing process for production of high volume; metal components that are net-shaped have tight tolerances. Basically, the pressure die casting process consists of injecting under high pressure a molten metal alloy into a steel mold (or tool). This gets solidified rapidly (from milliseconds to a few seconds) to form a net shaped component. It is then automatically extracted. Depending upon the pressure used, there are two types of pressure die casting namely High Pressure Die Casting and Low Pressure

The die casting process involves the use of a furnace, metal, die casting machine and die. The metal, typically a non-ferrous alloy such as aluminium or zinc, is melted in the furnace and then injected into the dies in the die casting machine. There are two main types of die casting machines - hot chamber machines (used for alloys with low melting temperatures, such as zinc) and cold chamber machines (used for alloys with high melting temperatures, such as aluminium). However, in both machines, after the molten metal is injected into the dies, it rapidly cools and solidifies into the final part, called the casting.[1]

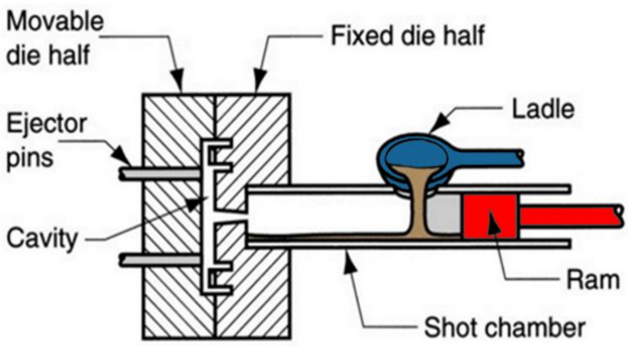

Figure 1. Cold chamber die casting.[2]

II. DEFECTS IN DIE CAST COMPONENTS

Die Casting is a complex process that results in casting defects if configured improperly. The various types of defects which found in die casting are listed below[1],

1. Shrinkage
2. Porosity
3. Mismatch
4. Incomplete cavity

III. LITERATURE REVIEW

The die casting process and its process parameters are studied through various papers related to the same topic. From this study it is come to know that the quality of die cast component depends upon its various process parameters like, temperature of molten metal, injection pressure of molten metal, holding time of molten metal, cooling rate, velocity of flow of liquid metal etc. M.R. Barone, D.A. Caulk studied the analysis of liquid metal flow in die casting process and finally both concluded that the metal flow, if not controlled precisely, can create defects in the die casting. The governing equations are integrated through the cavity thickness, creating an equivalent 2D theory, which describes the motion of the liquid in terms of velocity and pressure. Most flow related casting defects are caused either by trapped gas or premature solidification. Ideally, the liquid metal should displace the cavity gas ahead of the flow front as the cavity fills. As the pressure builds, some of the gas escapes through the vents, but if the advancing metal seals the vents before all the gas escapes or it encircles portions of the gas as it flows, the solidified casting usually contains gas porosity. If the liquid metal cools too rapidly as it flows, it may partially solidify before the cavity fills, which can degrade surface quality or in severe cases reduce structural soundness.[3]

In traditional die casting process the various defects were only because of poor design of runner and gating system. B.H. Hu, K.K. Tong, X.P. Niu, I. Pinwill designed and optimized the runner and gating systems for the die casting by numerical simulation. A commercial CAE package (MAGMAsoft) was used for numerical simulation and finally in their study it is found that runner and gating systems play a very important role in the die casting of high quality products. Poor gating designs can lead to various defects such as gas porosity, shrinkage porosity, flow lines, cold shuts and poor surface finish etc.[4]

Guilherme Ourique Verran , Rui Patrick Konrad Mendes, Marco Aurelio Rossi in there paper describe the results obtained in a study performed in partnership between Lab Fund/DEM/PGCEM/UDESC and the WEG Motors**,** department of Industrial Engineering for the Quality Control and Aluminum Die Casting. It involves the combination of an experimental DOE(design of experiments) methodology and of a commercial numeric applicative. The influence of the speed injection parameters in the first and second phases and of the upset pressure over the die casting parts quality, in 305 aluminum alloys is investigated. Initially, an experiment planning was performed, where several combinations of the three injection parameters were used, in order to enable the evaluation of their influence on the occurrence of foundry defects, such as porosities and cold shuts. The obtained castings sanity evaluation was performed by visual inspections and quantitative metal graph analyses, as well as by density measurements in a significant casting region, in which great quantities of porosities appear after surface machining. In view of the obtained results, analyses were performed through numeric simulations of the die casting process, using the injection parameters for which the best and the worst results were obtained concerning the presence of porosities and cold shuts. The comparison between experimental results and the information obtained through the analyses of the performed simulations shows a good convergence, regarding the trend to porosity and cold shuts occurrence in function of the variations in the injection parameters.[5]

One more factor which is responsible for the quality of the die casting is the proper design of die, D.H. Lee, P.K. Seo, C.G. Kang, studied the die filling and solidification phenomenon in semi-solid injection forging process were simulated by MAGMAsoft/thixo module. The effect of designed gate dimension on filling phenomenon was estimated by filling simulation. The calculated results were compared with experimental data. The free surface phenomenon obtained by experiment has good agreement with computer simulation results. The solidification affects much as porosity and shrinkage for designed semi-solid forging die had been predicted by computer simulation. However, recently, the same method which is used to die design of die casting and squeeze casting.[6]

High Pressure Die Casting (HPDC) is a complex process that results in casting defects if configured improperly. However, finding out the optimal configuration is a non-trivial task as eliminating one of the casting defects (for example, porosity) can result in occurrence of other casting defects. The industry generally tries to eliminate the defects by trial and error which is an expensive and error -prone process. M. Imad Khan,Yakov Frayman and Saeid Nahavandi in their paper aim to improve current modelling and understanding of defects formation in HPDC machines. They conducted conventional die casting tests with a neural network model of HPDC machine and compared the obtained results with the current understanding of formation of porosity.[7]

Although die casting enables high productivity, pore defects in the die castings are unavoidable. These pore defects influence the mechanical properties or air leakage efficiency of the products. To reduce the number of pore defects, Yoshihiko Hangai, Soichiro Kitahara and Shigeyasu Amada, performed compression tests on the front housings of car air conditioners made by ADC12 aluminum alloy die casting at room temperature. Because of plastic deformation, the porosity rate of the die castings decreases as the compression strain of the specimen increases, particularly in the middle of the specimens where the porosity rate is high. However, the efficiency of the reduction in the porosity rate and damage of the products differs depending on the compression load.[8]

Faura et al. proposed a solution based on commercial software, in order to determine the optimum plunger acceleration. The numerical analysis was carried using the Wrafts code, which is based on a linear isoparametric finite-element method to solve momentum and mass conservation equations.[9]

Baker et al., using the same software (WRAFTS), proposed a mould filling simulation that is capable of accurately predicting the amount and location of entrapped gas at the end of fill.[10]

In the work of Wang et al., a typical industrial case was analyzed. A 3D coupled fluid flow and heat transfer simulation was presented, in order to predict the flow pattern and temperature profile during metal pouring into the shot sleeve and the subsequent plunger movement. The authors show that the first metal is splashed within the shot sleeve and quickly looses its temperature. A wave reflection is created, as the plunger advances, and it causes a metal splash at the sleeve exit. From the result of the flow prediction, an optimum plunger operation was recommended. The thermal analysis predicts that a solid layer forms on the bottom face of the shot sleeve, in areas close to the die.[11]

Mahesh N Adke et al.reports on an optimization of Pressure die-casting process parameters to identify optimized level for improving the cycle time using Taguchi method for DOE.[12]

IV. RESEARCH GAP

After studying all above related papers, in this work we are going to find out the process parameters and simultaneously check the impact of process parameters on the quality of die casting by comparing mass and their process parameters of similar components.

V. SCOPE OF PRESENT WORK

The different process parameters like Melt temperature, Holding time, Injection pressure, Rate of cooling, Velocity of flow of molten metal etc., need to be set correctly in order to get desired quality at optimum cycle time and hence in this way we can achieve the desired production rate. For die casting process, there are various techniques by which we can improve the quality of die cast product. But in this study major concentration will be on process parameters.

VI. METHODOLOGY

Initially similar parts of same material, size and shapes, which are produced on the same machine are observed and their process parameters studied in detail. From the group of observed parts, two parts found that, which have small difference in their masses i.e.- Magneto cover-1=310gm and Magneto cover-2=425 gm, then their process parameters observed and studied carefully. Their actual readings of process parameters were recorded after certain interval of time (10 min.) during their actual production and found in the following range which are shown in the tables 1 and 2.

Table 1: Input process parameters for Magneto cover-1.

Melting temp. in °C.	Injection pressure in bar.	Plunger velocity in m/sec.	Cooling time in sec.
685	201	2.2	7

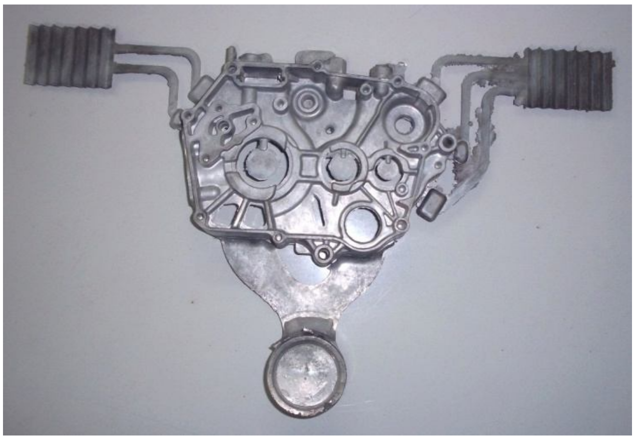

Figure 2. Magneto cover-1.

Table 2: Input process parameters Magneto cover-2.

Melting temp. in °C.	Injection pressure in bar.	Plunger velocity in m/sec.	Cooling time in sec.
686	209	2.1	8

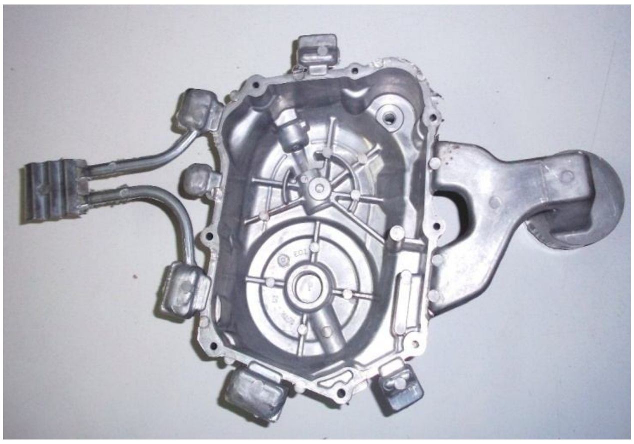

Figure 3. Magneto cover-2.

By referring their mean readings for both parts, simultaneously by considering their masses, it is found that there is little difference between their process parameters, which is shown in the below table.

Table 3: Comparison of process parameters for both Magneto covers.

Name of component and its mass	Melting temp. in °C.	Injection pressure in bar.	Plunger velocity in m/sec.	Cooling time in sec.
Magneto cover-2-425 gm	686	209	2.1	8
Magneto cover-1-310 gm	685	201	2.2	7
Difference	1(↓)	8(↓)	0.1((↑)	1(↓)

Based on the above readings range for process parameters can be decided by comparing mass of Magneto cover-1 with diff case gear meter, which is having mass 205 gm. For that whatever range of process parameters would be available for diff case gear meter would lie below the readings of Magneto cover-1. For the same range for each parameter is decided which is shown in below table,

Table 4: Input process parameters for case gear meter.

Melt temperature in °C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.
680	160	2	4

At initial stage of trial with given set of parameters the actual component produced, but it did not give the desired quality because its dimensions got oversized due to minute expansion of dies because of excess pressure and surface of casting found with small pin holes due to excess plunger speed or velocity. Then the parameters which are responsible for formation of such defects have been randomly changed by using our past experience and again trial conducted for second time and finally we got Ok component. The randomly changed parameters cannot be assumed to be optimum. So all parameters which affect the quality are varied from set value to its minimum / maximum value by keeping other parameters to its constant value. Minimum / Maximum or optimum value is the second last value at which we get defect free casting. While doing so casting is also checked for quality. In this way optimum reading for each parameter is found out, which is shown in the following tables,

Table 5: Optimum temperature reading.

Melt temperature in °C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Remark.	Defect.
683	120	1.5	6	-----	Ok
681	120	1.5	6	-----	Ok
680	120	1.5	6	-----	Ok
679	120	1.5	6	-----	Ok
678	120	1.5	6	-----	Ok
677	120	1.5	6	Misrun	Not ok
676	120	1.5	6	Misrun	Not ok

From the above table we can say that **679°C** is the optimum value for melt temperature.

Table 6: Optimum injection pressure reading.

Melt temperature in °C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Remark.	Defect.
679	120	1.5	6	-----	Ok
679	130	1.5	6	-----	Ok
679	140	1.5	6	-----	Ok
679	150	1.5	6	-----	Ok
679	160	1.5	6	Flash	Not ok
679	157.5	1.5	6	Flash	Not ok
679	**155**	1.5	6	-----	Ok

From the above table we can say that **155 bar** is the optimum value for injection pressure.

Table 7: Optimum plunger velocity reading.

Melt temperature in °C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Remark.	Defect.
679	155	1.5	6	-----	Ok
679	155	1.55	6	-----	Ok
679	155	1.6	6	-----	Ok
679	155	1.7	6	-----	Ok
679	155	**1.8**	6	-----	Ok
679	155	1.85	6	Porosity	Not ok
679	155	1.9	6	Porosity	Not ok

From the above table we can say that **1.8 m/sec** is the optimum value for plunger velocity.

Table 8: Optimum cooling time reading.

Melt temperature in °C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Remark.	Defect.
679	155	1.8	6	-----	Ok
679	155	1.8	**5**	-----	Ok
679	155	1.8	4.5	Hot tears	Not ok
679	155	1.8	4	Hot tears	Not ok
679	155	1.8	4	Hot tears	Not ok
679	155	1.8	4	Hot tears	Not ok
679	155	1.8	4	Hot tears	Not ok

From the above table we can say that **5 sec** is the optimum value for cooling time.

After getting optimum reading for each parameter, then again trial is conducted by using the same values, which is shown in the next tables. Twenty no. of trials have been conducted in first two hours and simultaneously the cycle time is recorded with stop watch. While doing so observation is done for quality and other imperfections.

Table 9: Optimum process parameters for case gear meter.

Melt temperature in ⁰C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Cycle time in sec.	Defect.	Remark.
679	155	1.8	5	**35.34**	-----	Ok
679	155	1.8	5	**35.90**	-----	Ok
679	155	1.8	5	**36.16**	-----	Ok
679	155	1.8	5	**35.42**	-----	Ok
679	155	1.8	5	**38.50**	-----	Ok
679	155	1.8	5	**35.35**	-----	Ok
679	155	1.8	5	**35.71**	-----	Ok
679	155	1.8	5	**35.56**	-----	Ok
679	155	1.8	5	**36.22**	-----	Ok
679	155	1.8	5	**37.10**	-----	Ok
679	155	1.8	5	**35.46**	-----	Ok
679	155	1.8	5	**35.56**	-----	Ok
679	155	1.8	5	**36.72**	-----	Ok
679	155	1.8	5	**35.40**	-----	Ok
679	155	1.8	5	**35.31**	-----	Ok
679	155	1.8	5	**35.70**	-----	Ok
679	155	1.8	5	**35.52**	-----	Ok
679	155	1.8	5	**36.10**	-----	Ok
679	155	1.8	5	**35.90**	-----	Ok
679	155	1.8	5	**35.96**	-----	Ok
	Mean cycle time=35.94					

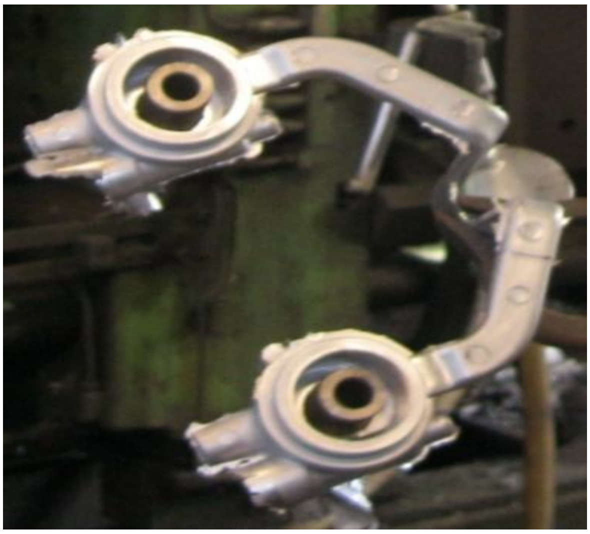

Figure 4. Diff case gear meter.

VII. RESULTS AND DISCUSSIONS

After getting optimum reading for each parameter, then again these values are compared with the values obtained by DOE method and it shows that both values are in agreement with each other within small deviation. It also shows that whatever historical study was done that was correct. In the graph, it shows that there is little difference between the values which are obtained by DOE and comparison methods.

Table 10: DOE and Comparison results.

	Melt temperature in ⁰C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Cycle time in Sec.
DOE	680	160	2	4	32
Comparison	679	155	1.8	5	35.94
Difference	1(↓)	5(↓)	0.2(↓)	1(↑)	3.94(↑)

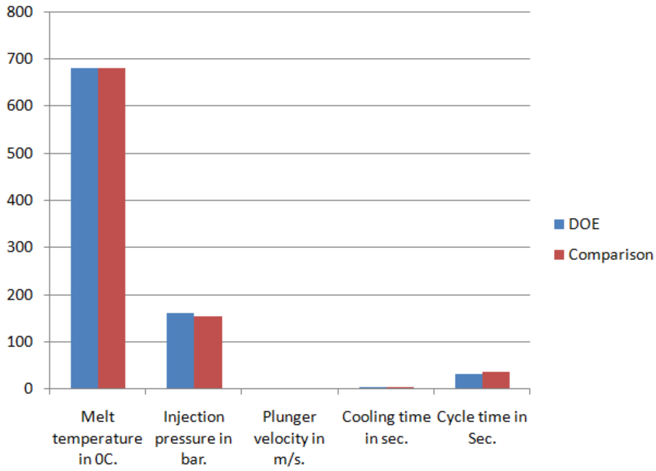

Figure 5. Graphical presentation of DOE and Comparison results.

VIII. CONCLUSION

The conclusions drawn from the work carried out are as follows,

- Basically the quality of die casting depends upon its process parameters, which need to be determined and adjusted if needed, for getting better quality.
- The optimum cycle time in terms of the good quality of the die casting part were obtained by using the following optimum process parameters with Temperature (T)= 679 ^{0}C, Injection pressure(p)=155 bar, Plunger velocity(v)= 1.8 m/sec and cooling time(t_c)= 5 sec.
- The four different criteria used to evaluate the optimum cycle time presented a good correlation among themselves.
- The results obtained by DOE are in agreement with the comparison results within small deviation without affecting the quality of the die casting part.

- Comparison of the results of the two methods proved that the deviations are acceptable

IX. ACKNOWLEDGMENT

We would like to express our gratitude to **Mr. Shailesh Bhadad**e , Managing director, Advent tool Tech Pvt. Ltd., Pune, for his consistent guidance and inspiration throughout the project work, which we are sure, will go a long way in our life. We express our sincere thanks to our principal **Dr. M. A. Chougule** and vice principal **Prof. J. M. Jaketia.** We express sincere thanks towards **Mr. S. K. Mohite**, our Head of Mechanical Engineering department, as all the success is the result of his affectionate encouragement. We express our sincere thanks to all our staffs and colleagues who have helped us directly or indirectly in completing this work.

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