# Optimization of Process Parameters For Magneto Cover By Using Taguchi Methods For DOE

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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 we are going to find out the optimum process parameters for the Magneto cover by using Taguchi method. For statistical analysis minitab software is used. The results obtained by using software is used as input for physical experimentation. 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. This gets solidified rapidly 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 Die casting.

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 aluminum 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 which are used for alloys with low melting temperatures, such as zinc and cold chamber machines which are used for alloys with high melting temperatures , such as aluminum. 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]

## 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

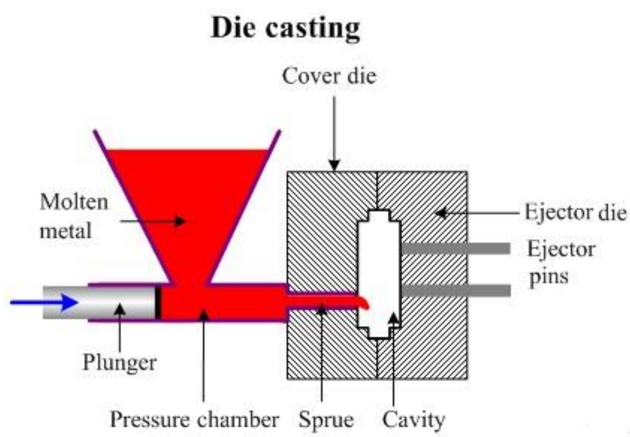



Figure 1- Die casting process.[2]

## 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.[1]

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 playa 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.[2]

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.[3]

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 MAGMA soft/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.[4]

High Pressure Die Casting (HPDC) is a complex process that results in casting defects if configured improperly. However, finding out the optimal configuration is anon-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 Nahav and in their paper aim to improve current modeling 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.[5]

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.[6]
Faura etal. 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.[7]

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.[8]

## IV. DEFINITION OF PROBLEM

The sponsoring company whose associate concern is primarily engaged in production of Die Casting is keen to investigate the optimum levels for the process parameters responsible for arriving at the best quality for the **Magneto cover** die cast component. Pressure die casting is primarily affected by the process parameters such as 'solidification time', 'Molten temperature', 'Filling time', 'Injection pressure' and 'holding time' etc.

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 pose a challenge for defects since the interplay among the parameters need to be captured for setting the process for each component.

**MAGNETO COVER:**

- Material – Cast aluminum.
- Melting temperature- 660℃.
- Composition-

Table 1: Percentage of individual alloying elements.

| Si % | Fe % | Cu % | Mn % | Mg % | Ni % | Zn % | Sn % |
|---|---|---|---|---|---|---|---|
| 9.5 | 2 | 0.6 | 0.35 | 0.5 | 0.5 | 0.5 | 0.15 |

- Type of Die casting machine and its tonnage- Cold chamber die casting machine, 80 ton.

**OBJECTIVES OF WORK:**

- Select the component/s for study.
- Identify the critical parameters for processing the cast components.
- Capture the historical data for process parameters with its levels.
- Perform DOE considering response factor as the cycle time or the quality of the component or any suitable output parameter for the study.
- Trial and testing upon development for experimentation.
- Validate the thesis by comparing with the experimental results.

## V. METHODS FOR SOLVING PROBLEM

**PHYSICAL EXPERIMENTATION-**

In a physical experimentation a suitable machine of required tonnage is selected for carrying out experimentation. The different processing parameters like injection pressure, velocity of molten metal, temperature of molten metal, cooling time etc., are set before carrying out experimentation. After setting all these parameters, one parameter which affects cycle time is varied from set value to its minimum or maximum value and keeping other parameters to its constant value, simultaneously checking the quality of product. In this experimentation the parameter which is considered for getting optimum value is achieved by trial-and-error method. Similarly in the next step second parameter is considered and other parameters kept to its constant value and its optimum value is found. The same procedure is repeated for getting optimum values for each parameter.

**SOFTWARE METHOD:**

A high-performance software for the simulation of casting processes provides opportunities for an interactive or automated evaluation of results e.g.-mold filling and solidification, porosity and flow characteristics etc. Flow modeling software provides a computer simulation of the metal flow within the die-cast die. This is where the molten metal is pushed through the gooseneck and into the die cast i.e.-the mold that holds the shape of the part.

## VI. SELECTION OF METHODS FOR SOLVING PROBLEM

**ANALYTICAL METHOD:**

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, one part is considered which is similar in shape i.e.- Crank case cover, then their process parameters observed and studied carefully. Their process parameters were recorded after certain interval of time (10 min.) during their actual production and found in the following range and finally the mean readings of melting temperature, injection pressure and plunger velocity are calculated for further reference, which are shown in the tables 3 and 4.

**Crank case cover:**

- Material – Cast aluminum.
- Melting temperature- 660℃.
- Composition-

Table 2: Percentage of individual alloying elements.

| Si% | Fe% | Cu% | Mn% | Mg% | Ni% | Zn% | Sn% |
|---|---|---|---|---|---|---|---|
| 9.5 | 2 | 0.6 | 0.35 | 0.5 | 0.5 | 0.5 | 0.15 |

- Type of machine and its tonnage- Cold chamber die casting machine, 80 ton.
- Weight= 1.225 Kg
- Input process parameters for Crank case cover-
-

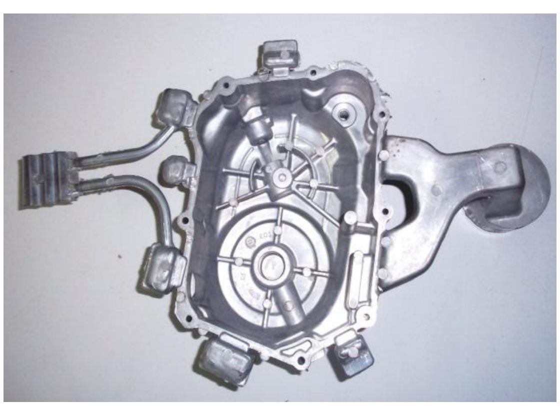
Table 3: Input process parameters.

| Melting temp. in $^0$C. | Injection pressure in bar. | Plunger velocity in m/sec. | Cooling time in sec. | Cycle time in sec. | Remark. |
|---|---|---|---|---|---|
| 685 | 200 | 2.2 | 7 | 44 | Ok |
| 685 | 200 | 2.2 | 7 | 44 | Ok |
| 685 | 200 | 2.2 | 7 | 44 | Ok |
| 685 | 200 | 2.2 | 7 | 45 | Ok |
| 685 | 200 | 2.2 | 7 | 44 | Ok |
| 685 | 200 | 2.2 | 7 | 44 | Ok |

- Mean input process parameters for Crank case cover-

Table 4: Input process parameters.

| **Melting temp. in $^0$C.** | **Injection pressure in bar.** | **Plunger velocity in m/sec.** | **Cooling time in sec.** |
|---|---|---|---|
| 685 | 200 | 2.2 | 7 |



Crank case cover

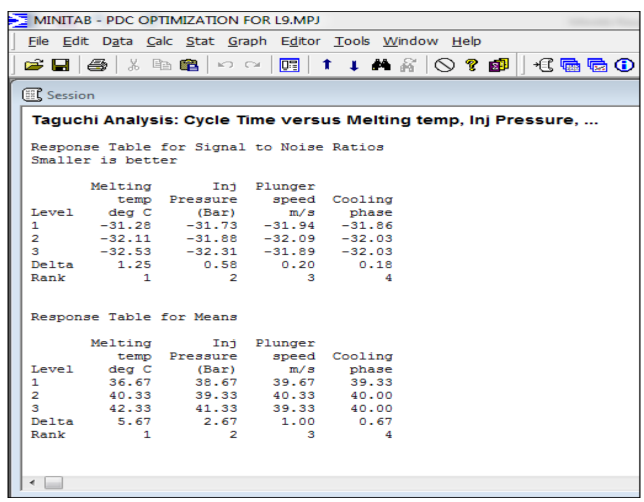
By referring the mean readings, it can be concluded that the range of process parameters available for our case study would lie nearer to these readings. For the same, range for each parameter is decided and Design of experimentation (DOE) performed by using Minitab software.

The following table shows, the optimum solution for given set of parameters is given by value having maximum SN ratio i.e: -30.88.

Table 5: Input process parameters for Magneto cover.

| **Melt temperature in $^0$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** | **SN ratio.** | **Mean.** |
|---|---|---|---|---|---|
| **685** | **200** | **2.2** | **7** | **-30.8** | **35** |
| 684 | 195 | 2.15 | 4.5 | -31.3 | 37 |
| 683 | 190 | 2.1 | 4.5 | -31.5 | 38 |
| 682 | 180 | 2.0 | 5 | -32.0 | 40 |
| 682 | 175 | 1.95 | 4.5 | -31.8 | 39 |

In order to check the effect of individual parameter on cycle time, for the same Taguchi analysis is done. Finally, it shows that melt temperature plays important role in reducing cycle time, then followed by injection pressure, plunger velocity and cooling time parameter.

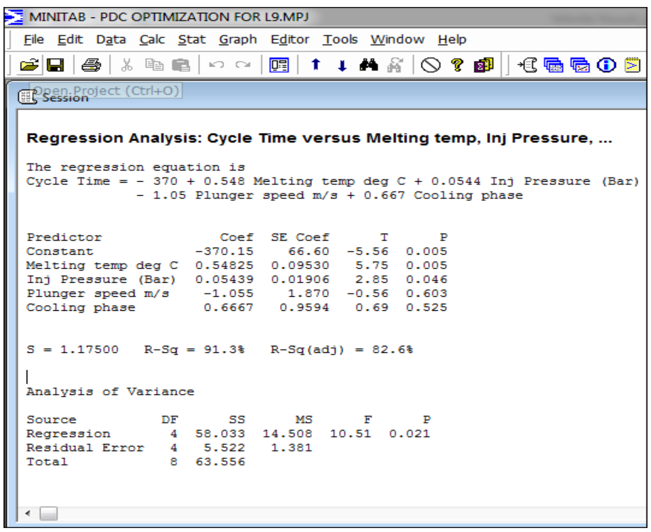



Taguchi analysis

For getting regression equation for given set of parameters for calculating cycle time, regression analysis is done. After carrying out DOE analysis, the software gives best possible values of coefficients for given set of parameters.

From the given set best one selected on the basis of minimum cycle time. After solving four equations by taking related constants from each set, the cycle time for equation no-1 is minimum i.e- 11.9192, as compared to remaining three equations. So, parameters or constant from set can be used for forming regression equation of best fit.

- **-370.15+0.54825×680+0.05439×160-1.055×2+0.6667×4=11.9192 ------ (1).**
- 66.60+0.09530×680+0.01906×160-1.870×2+0.9594×4=142.03 ------ (2).
- -5.56+5.75×680+2.85×160-0.56×2+ 0.69×4=4362.08------ (3).
- 0.005+0.005×680+0.046×160-.603×2+0.525×4=14.071 ------ (4).


MINITAB - PDC OPTIMIZATION FOR L9.MPJ
File Edit Data Calc Stat Graph Editor Tools Window Help
Open Project (Ctrl+O)
Session

**Regression Analysis: Cycle Time versus Melting temp, Inj Pressure, ...**

```
The regression equation is
Cycle Time = - 370 + 0.548 Melting temp deg C + 0.0544 Inj Pressure (Bar)
             - 1.05 Plunger speed m/s + 0.667 Cooling phase


Predictor                 Coef  SE Coef      T      P
Constant               -370.15    66.60  -5.56  0.005
Melting temp deg C     0.54825  0.09530   5.75  0.005
Inj Pressure (Bar)     0.05439  0.01906   2.85  0.046
Plunger speed m/s       -1.055    1.870  -0.56  0.603
Cooling phase           0.6667   0.9594   0.69  0.525


S = 1.17500   R-Sq = 91.3%   R-Sq(adj) = 82.6%


Analysis of Variance

Source          DF      SS      MS      F      P
Regression       4  58.033  14.508  10.51  0.021
Residual Error   4   5.522   1.381
Total            8  63.556
```

Regression analysis.

## VII. GRAPHICAL ANALYSIS

### Process parameters vs SN ratio-

Graph of process parameters Vs SN ratio, which shows that the nature of graph is straight line up to midpoint, but as the line crosses this point, suddenly line changes its slope. The point at which line changes its slope by this we can conclude that, the optimum range for all process parameters lies nearer in between start and end points of that graphs. In order to get optimum level for all parameters then variation is expected to be done in between start and end points, which is shown in the below graph.

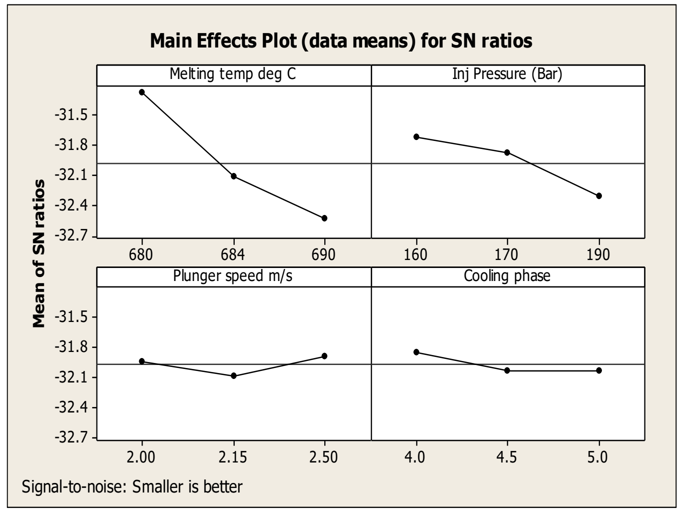



Fig.2: Graph of process parameters Vs SN ratio.

### Process parameters vs Mean-

Similarly graph of process parameters Vs mean, which shows that the nature of graph is straight line up to midpoint, but as the line crosses this point, suddenly line changes its slope. The point at which line changes its slope by this we can conclude that, the optimum range for all process parameters lies nearer in between start and end points of that graphs. In order to get optimum level for all parameters then variation is expected to be done in between start and end points, which is shown in the below graph.

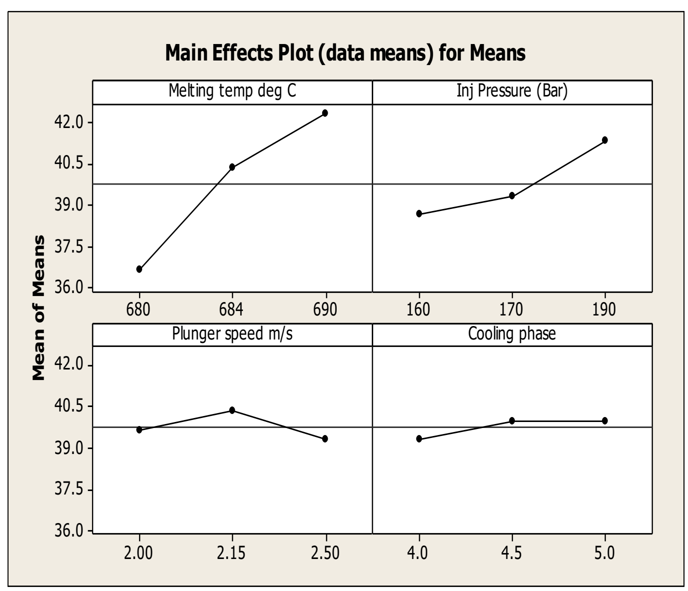



Fig.3: Graph of process parameters Vs mean.

## VIII. ACTUAL PHYSICAL EXPERIMENTATION

After completing the analytical method, the results achieved by design of experiment (DOE) are used as input for experimentation. For the same experimental set up is made ready and a cold chamber machine of 80 ton capacity is selected. On the same machine die for Magneto cover is fitted. Before running the machine, it is necessary to understand the effect of individual parameter on cycle time, for the same Taguchi analysis is referred, which shows that melt temperature can greatly minimize the cycle time, then followed by injection pressure, plunger velocity and cooling time. The optimum parameters obtained by DOE analysis are set as input for machine, which are shown in the following table.

Table 6: Input process parameters for Magneto cover.

| **Melt temperature in $^{0}$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** |
|---|---|---|---|
| 685 | 200 | 2.2 | 7 |

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 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 cycle time 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 it so casting is checked for quality.

According to Taguchi analysis, melt temperature is the major parameter for which greater attention is required to be paid for reducing cycle time. According to graph of melt temperature Vs SN ratios and melt temperature Vs mean, which show that the nature of graph is straight line up to 684 $^{0}$C and suddenly line changes its slope as it crosses this temperature. The point at which line changes its slope by this we can conclude that, the optimum range for melt temperature lies in between 680-690 $^{0}$C. So variation of melt temperature is expected to be done from 680 to 690 $^{0}$C. In both graphs line starts at 680 $^{0}$C and ends at 684 $^{0}$C, but in actual practice while selecting range instead of taking 680 $^{0}$C as a starting range, temperature variation is done from 675 to 684$^{0}$C, because if we take 680 $^{0}$C as a starting point and if casting is produced accordingly and if it found to be ok, then the temperature 680 $^{0}$C may not be assumed to be optimum, there may be chances that optimum level for melt temperature could be 684 $^{0}$C or 690 $^{0}$C. So for this reason 684 $^{0}$C is taken as starting range for variation of melt temperature. The temperature 684 $^{0}$C is the extreme last range, because under this temperature fluidity of metal starts to get affected due to fall in temperature. In this way optimum value for temperature is obtained. Similarly, by referring both graphs for all process parameters, then variation is done in between start and end point and their optimum value is obtained. The following different tables show the optimum readings of different process parameters, which are achieved step by step.

Table 7: Optimum temperature reading.

| **Melt temperature in $^{0}$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** | **Remark.** | **Defect.** |
|---|---|---|---|---|---|
| **684** | 200 | 2.2 | 7 | ----- | Ok |
| 685 | 200 | 2.2 | 7 | ----- | Ok |
| 683 | 200 | 2.2 | 7 | ----- | Ok |
| 683 | 200 | 2.2 | 7 | ----- | Ok |
| 682 | 200 | 2.2 | 7 | ----- | Ok |
| 682 | 200 | 2.2 | 7 | Misrun | Not ok |
| 682 | 200 | 2.2 | 7 | Misrun | Not ok |

From the above table we can say that **684 $^{0}$C** is the optimum value for melt temperature, which needs to be maintained or set before carrying out actual process.

Similarly for injection pressure, according to graph of injection pressure Vs SN ratios and injection pressure Vs mean, which show that the nature of graph is straight line up to 170 bar and suddenly line changes its slope as it crosses this pressure. The point at which line changes its slope by this we can conclude that, the optimum range for injection pressure lies in between 160-190 bar. But in actual practice usually a lower value say 200 is selected for safer side and during experimentation 200 bar is taken as starting range. The optimum value for the same is obtained in the following way.

Table 8: Optimum injection pressure reading.

| **Melt temperature in $^{0}$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** | **Remark.** | **Defect.** |
|---|---|---|---|---|---|
| 684 | 200 | 2.2 | 7 | Flash, i.e- 1mm | Not Ok |

| | | | | | |
|---|---|---|---|---|---|
| 684 | 195 | 2.2 | 7 | Flash, i.e- 1mm | Not Ok |
| 684 | 190 | 2.2 | 7 | ----- | Ok |
| 684 | 190 | 2.2 | 7 | ----- | Ok |
| 684 | 190 | 2.2 | 7 | ----- | Ok |
| 684 | 185 | 2.2 | 7 | ----- | Ok |
| 684 | **185** | 2.2 | 7 | ----- | Ok |

From the above table we can say that **185 bar** is the optimum value for injection pressure, which needs to be maintained or set before carrying out actual process.

Similarly for plunger velocity, according to graph of plunger velocity Vs SN ratios and plunger velocity Vs mean, which show that the nature of graph is straight line up to 2.15 m/sec and suddenly line changes its slope as it crosses this velocity. The point at which line changes its slope by this we can conclude that, the optimum range for plunger velocity lies in between 2.00-2.5 m/sec. But in actual practice usually a lower value say 1.5 m/sec is selected for start of variation during actual experimentation. The optimum value for the same is obtained in the following way.

Table 9: Optimum plunger velocity reading.

| **Melt temperature in $^0$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** | **Remark.** | **Defect.** |
|---|---|---|---|---|---|
| 684 | 185 | 1.5 | 7 | ----- | Ok |
| 684 | 185 | 1.8 | 7 | ----- | Ok |
| 684 | 185 | 2.1 | 7 | ----- | Ok |
| 684 | 185 | 2.4 | 7 | Porosity | Not Ok |
| 684 | 185 | 2.3 | 7 | ----- | Ok |
| 684 | 185 | 2.2 | 7 | ----- | Ok |
| 684 | 185 | **2.2** | 7 | ----- | Ok |

From the above table we can say that **2.2 m/sec** is the optimum value for plunger velocity, which needs to be maintained or set before carrying out actual process.

Similarly for cooling time, according to graph of cooling time Vs SN ratios and cooling time Vs mean, which show that the nature of graph is straight line up to 4.5 sec and suddenly line changes its slope as it crosses this cooling time. The point at which line changes its slope by this we can conclude that, the optimum range for cooling time lies in between 4.0-5.0 sec. But in actual practice usually a higher value say 6 sec is selected for ease of variation and avoiding defects. The optimum value for the same is obtained in the following way.

Table 10: Optimum cooling time reading.

| **Melt temperature in $^0$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** | **Remark.** | **Defect.** |
|---|---|---|---|---|---|
| 684 | 185 | 2.2 | 7 | ----- | Ok |
| 684 | 185 | 2.2 | 6 | ----- | Ok |
| 684 | 185 | 2.2 | 5 | ----- | Ok |
| 684 | 185 | 2.2 | 4.5 | Hot tears | Not ok |
| 684 | 185 | 2.2 | 4.5 | Hot tears | Not ok |
| 684 | 185 | 2.2 | 5 | ----- | Ok |
| 684 | 185 | 2.2 | **6** | ----- | Ok |

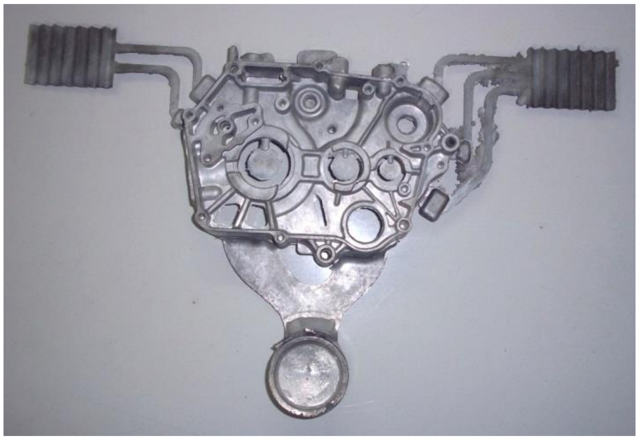
From the above table we can say that **6 sec** is the optimum value for cooling time, which needs to be maintained or set before carrying out actual process.

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 11: Optimum process parameters for Magneto cover.

| **Melt temperature in $^0$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** | **Cycle time in sec.** | **Defect.** | **Remark.** |
|---|---|---|---|---|---|---|
| 684 | 185 | 2.2 | 6 | **35.34** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.90** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **36.16** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.42** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **38.50** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.35** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.71** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.56** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **36.22** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **37.10** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.46** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.56** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **36.72** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.40** | ---- | Ok |

| | | | | | | |
|---|---|---|---|---|---|---|
| 684 | 185 | 2.2 | 6 | **35.31** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.70** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.52** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **36.10** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.90** | ---- | Ok |
| 684 | 185 | 2.2 | 6 | **35.96** | ---- | Ok |



Magneto cover.

## IX. RESULTS AND DISCUSSION

The obtained value of different process parameters from historical study and value obtained by DOE analysis are in agreement with each other within small deviation. It means that invested new process parameters for Magneto cover, approximately matched with the experimental readings. So, whatever the historical study was done that was perfect. Of course, deviation is present between these readings but this deviation is small. After carrying out DOE analysis, the obtained results on the basis of maximum SN ratio are in good agreement with the results obtained by experimental study. From the graphical analysis it was concluded that the optimum range for considered parameters lie nearer in between start and end points of that graphs and during actual experimentation their values have been set differently just for avoiding defects or other mishaps. But when we got their optimum value, the optimum value of almost all parameters lie nearer and in between start and end points of that graphs

Each parameter has its own effect on cycle time as well as on die cast quality. If we referrer the following table we can state that values obtained by both techniques are almost closer to each other and the results of the two applied methods proved that the deviations are acceptable.

Table 12: DOE and Experimental results.

| | **Melt temperature in $^0$C.** | **Injection pressure in bar.** | **Plunger velocity in m/s.** | **Cooling time in sec.** |
|---|---|---|---|---|
| DOE. | 685 | 200 | 2.2 | 7 |
| Experimentation. | 684 | 185 | 2.2 | 6 |
| Difference. | 1(↓) | 15(↓) | 00 | 1(↓) |
| Percentage of increase/decrease. | 0.1459(↓) | 7.5(↓) | 00 | 14.28 (↓) |

## X. 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)= 684 $^0$C, Injection pressure(p)=185 bar, Plunger velocity(v)= 2.2 m/sec and cooling time(tc)= 6 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 experimental results within small deviation without affecting the quality of the die casting part.
- Comparison of the results of the two applied methods proved that the deviations are acceptable.
- The utilization of DOE methodology proved to be very efficient, in the analysis of this problem.

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