International Journal of Scientific Research and Management Studies (IJSRMS)
ISSN: 23493771 **Volume 1 Issue 10, pg: 317-329**

INVESTIGATING DIE CASTING PROCESS PARAMETERS TO IDENTIFY THE OPTIMIZED LEVELS USING TAGUCHI METHODS FOR DESIGN OF EXPERIMENT (DOE)

[1]U.G.Mulla J.G, [2]V.V.Potadar, [3]S.S. Kulkarni
[1]M E Student, Department of Mechanical Engineering, Univesity of Solapur, India
[2]Vice Principal, A.G. Patil Institute of Technology, Solapur, India
[3]Director, Able Technologies (I) Pvt. Ltd., Pune, India

ABSTRACT

Die casting is a manufacturing process that can produce geometrically complex parts through the use of reusable moulds or 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 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. In my dissertation work I am going to optimize the process parameters by using analytical methods i.e.-Statistical modelling for historical data, for the same I got sponsorship from Advent Tool Tech Pvt. Ltd., Pune and new case study is considered for this work. Initially using Taguchi method, Design of Experimentation (DOE) performed, for this Minitab software is used for arriving at the optimum level for the factors for the same historical data for similar components have been referred. Finally the results obtained by DOE have been used as input parameters for the machine and component is produced accordingly, then for getting optimum value, each parameter is varied from set value to its minimum/maximum value by keeping other parameters to its constant value, simultaneously component is checked for quality. Minimum or optimum value is the second last value at which we get defect free part at optimum cycle time. The same procedure is repeated for other parameters for getting their optimum values. Finally the results obtained by analytical and experimentation found good agreement with least deviations.

KEYWORDS- *Aluminum alloy, Die casting, Design of Experimentation.*

I. INTRODUCTION

Die casting is an ideal process for making precision castings in high volume from low melting point alloys. Liquid metal is injected at high velocities into a vented cavity in a steel die, where it cools and solidifies before being ejected as a finished casting. The quality of die casting and its cycle time basically depends upon various process parameters like solidification time, molten temperature, injection pressure and plunger velocity, if thesenot controlled precisely, can create defects in the casting and increases the cycle time. For all these parameters a greater attention is required, which and when adequately determined and adjusted, result in an improved quality of the die cast part and decreases cycle time. In these castings, there are various defects in manufactured parts. One of the major defect is porosity, which causes duo to imprisonment of air in the liquid metal during the filling stages of die casting process. Internal porosity can also appear in the form of shrinkage, due to premature solidification of the metal in the gate. Hot tears duo to rapid solidification rate or smaller cooling time.

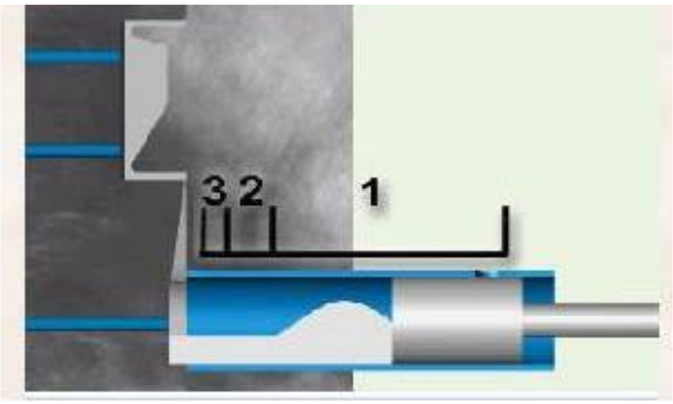


Fig. 1. Entrapped air below the metal wave[5].

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.

II. LITERATURE REVIEW

M.R. Baroneet al. 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 et al. designed and optimized the runner and gating systems for the die casting by numerical simulation. A commercial CAE package (MAGMA soft) 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.[2].

Guilherme Ourique Verran et al. in their paper describe the results obtained in a study performed in partnership between LabFund/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. Leeet al. 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].

The utilization of CAE (computer aided engineering) simulation tools is now well accepted and widely used by the casting industry as a powerful design tool. The recent developments in this area are the simulation tools that not only make filling/solidification simulation capabilities available, but also allow the die casting designer to integrate die casting and machine parameters into the simulation [6].

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[7], which is based on a linear isoparametric finite-element method to solve momentum and mass conservation equations.

Baker et al. [8], 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.

III. METHODOLOGY

3.1 Statistical analysis-

There are various techniques to analyze and solve work related problems. They are usually recognized as “BASIC PROBLEM SOLVING TECHNIQUES”. Every techniques have its own merit and demerit. The members of quality circle need to be trained in the application of these techniques. In this work, an experimental DOE (design of experiments) methodology was used for optimizing process parameters of die casting process.

3.1.1 Concept of design of experimentation (DOE) –

DOE is a systematic approach to investigation of a system or process. A series of structured tests are designed in which planned changes are made to the input variables of a process or system. The effects of these changes on a pre-defined output are then assessed. The experimental design is the manner in which the researcher randomly assigns the treatment to the experimental units. DOE is important as a formal way of maximizing information gained while minimizing resources required. It has more to offer than 'one change at a time' in an experimental method.

A designed experiment is extremely helpful in discovering the key variables influencing the quality characteristics of interest in the process. A designed experiment is an approach to systematically varying the controllable input factors in the process and determining the effect these factors have on the output product parameters. Statistically designed experiments are invaluable in reducing the variability in the quality characteristics and in determining the levels of the controllable variables that optimize process performance and product quality also result from using designed experiment. Designed experiments are a major off line quality control tool, because they are often used during development activities and early stages of manufacturing, rather than as a routine on line or in process procedure. They play a crucial role in reducing variability. Following are the steps for performing DOE,

- Choosing appropriate responses (output variables).
- Choosing appropriate factors (input variables).
- Setting appropriate factor ranges or levels.
- Creating documentation for the experiment.
- Managing the experiment as it takes place.
- Reporting and presenting results (ANOVA).
- Decision Making.

3.2 Historical study-

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 similar in shape i.e.- Magneto cover-1 and Magneto cover-2 , then their process parameters observed and studied carefully. Then 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 and finally the mean readings of melting temperature, injection pressure, plunger velocity and cooling time are calculated for further reference, which are shown in the table 3 and table 6.

3.2.1 Magneto cover 1 –

- Material – Cast aluminum.
- Melting temperature- 660°C.
- 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 machine and its tonnage- Cold chamber die casting machine, 80 ton.
- Weight= 0.31 Kg.
- Input process parameters for Magneto cover 1-

Table 2: 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
684	205	2.2	7	44	Ok
686	200	2.2	7	45	Ok
685	200	2.2	7	44	Ok
685	205	2.2	7	44	Ok

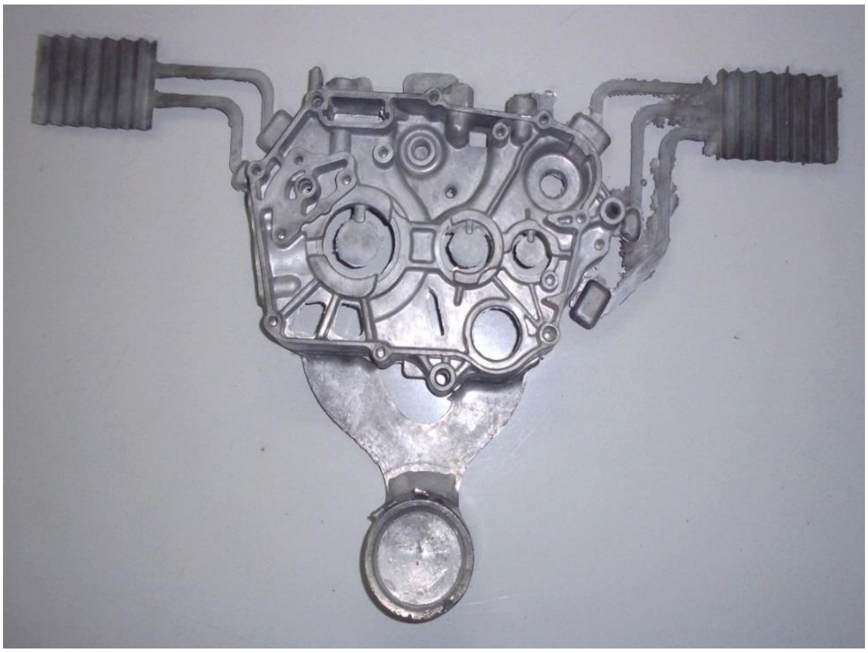


Fig. 2. Magneto cover 1.

3.2.2 Magneto cover 2 –

- Material – Cast aluminum.
- Melting temperature- 660°C.
- Composition-

Table 3: 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= 0.425 Kg.
- Input process parameters for Magneto cover 2-

Table 4: 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	210	2.1	8	51	Ok
687	210	2.1	8	52	Ok
686	210	2.1	8	51	Ok
684	205	2.1	8	51	Ok
686	210	2.1	8	51	Ok
686	210	2.1	8	52	Ok

- Mean input process parameters for Magneto cover 2-

Table 5: Input process parameters

.Melting temp. in ^{0}C	Injection pressure in bar	Plunger velocity in m/sec	Cooling time in sec.
686	209	2.1	8

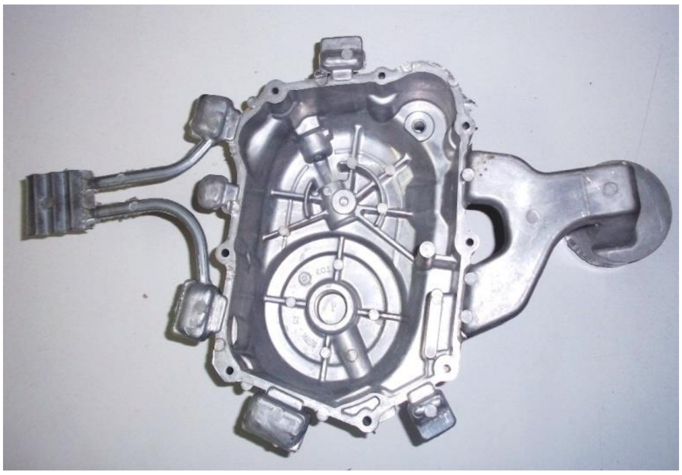


Fig. 3.Magneto cover 2.

By referring the mean readings for both parts, it can be concluded that the range of process parameters available for my 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.

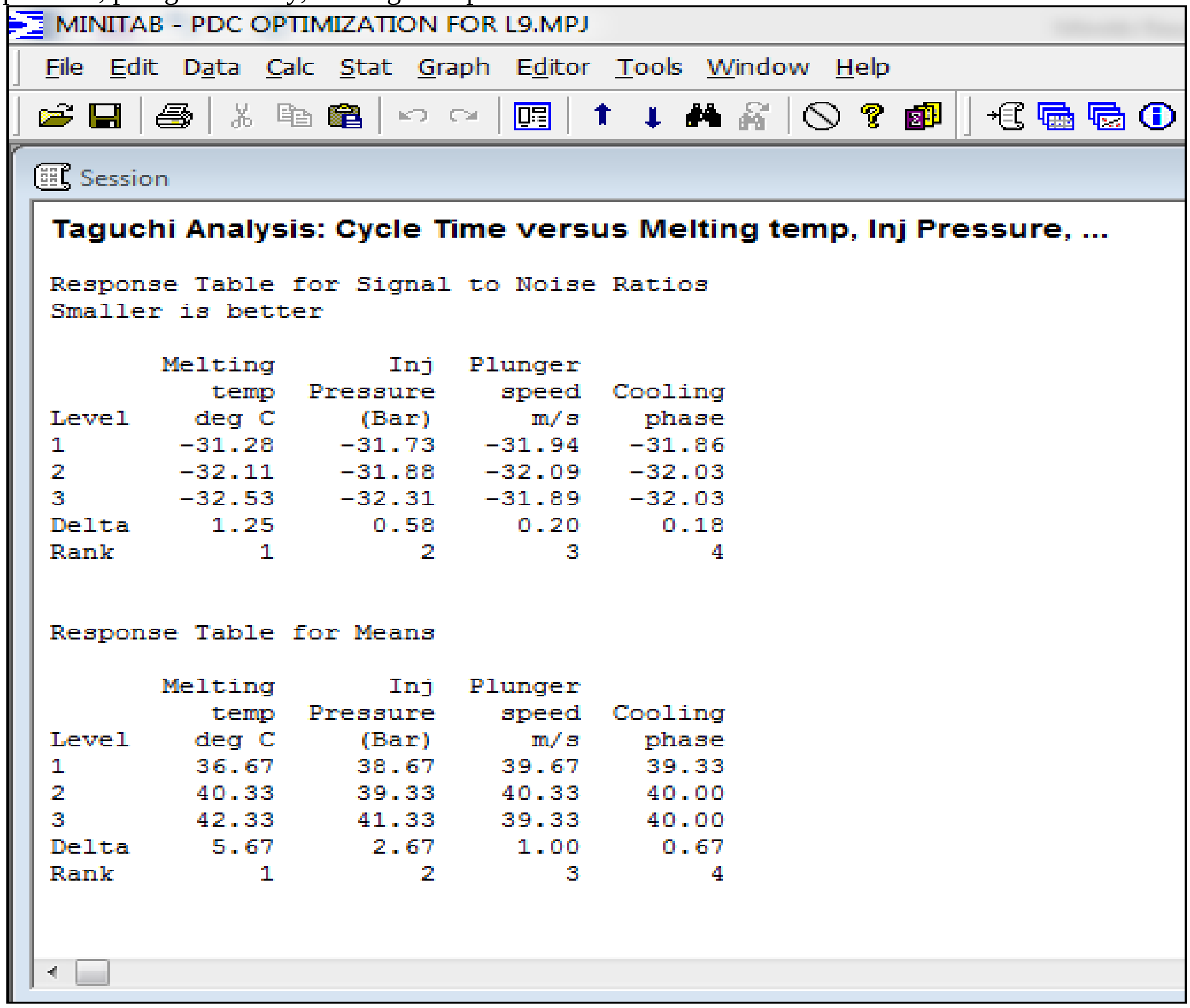
The following table shows, the optimum solution for given set of parameters is given by value having maximum SN ratio i.e: -30.88.

Table 6: Input process parameters for case gear meter.

Melt temperature in ^{0}C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Cycle time in sec.	SN ratio	Mean
680	**160**	**2**	**4**	**35**	**-30.88**	**35**
680	170	2.15	4.5	37	-31.36	37
680	190	2.5	5	38	-31.59	38
684	160	2.15	5	40	-32.04	40
684	170	2.5	4	39	-31.82	39
684	190	2	4.5	42	-32.46	42
690	160	2.5	4.5	41	-32.25	41
690	170	2	5	42	-32.46	42
690	190	2.15	4	44	-32.86	44

3.3 Taguchi analysis-

The ranking shows that melt temp plays very imp role, then followed by Melt temp, injection pressure, plunger velocity, cooling time parameter.



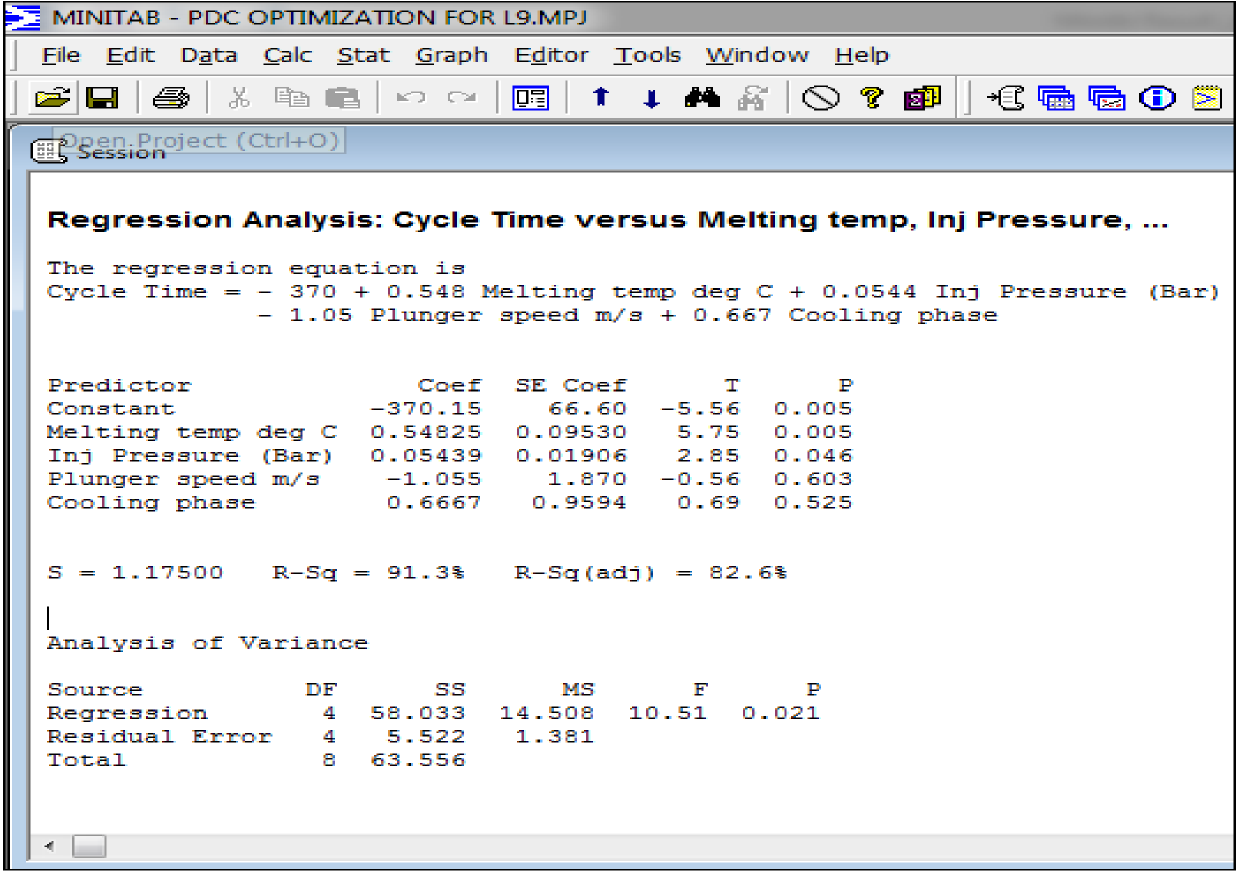
```
Taguchi Analysis: Cycle Time versus Melting temp, Inj Pressure, ...

Response Table for Signal to Noise Ratios
Smaller is better

       Melting      Inj  Plunger
          temp Pressure    speed  Cooling
Level    deg C    (Bar)      m/s    phase
1       -31.28   -31.73   -31.94   -31.86
2       -32.11   -31.88   -32.09   -32.03
3       -32.53   -32.31   -31.89   -32.03
Delta     1.25     0.58     0.20     0.18
Rank         1        2        3        4


Response Table for Means

       Melting      Inj  Plunger
          temp Pressure    speed  Cooling
Level    deg C    (Bar)      m/s    phase
1        36.67    38.67    39.67    39.33
2        40.33    39.33    40.33    40.00
3        42.33    41.33    39.33    40.00
Delta     5.67     2.67     1.00     0.67
Rank         1        2        3        4
```

Fig. 4. Taguchi analysis.

3.4 Regression analysis-

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+0.046×160-0.603×2+0.525×4=14.071 ------(4).



```
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
```

Fig. 5. Regression analysis.

3.5 Graphical analysis-

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.

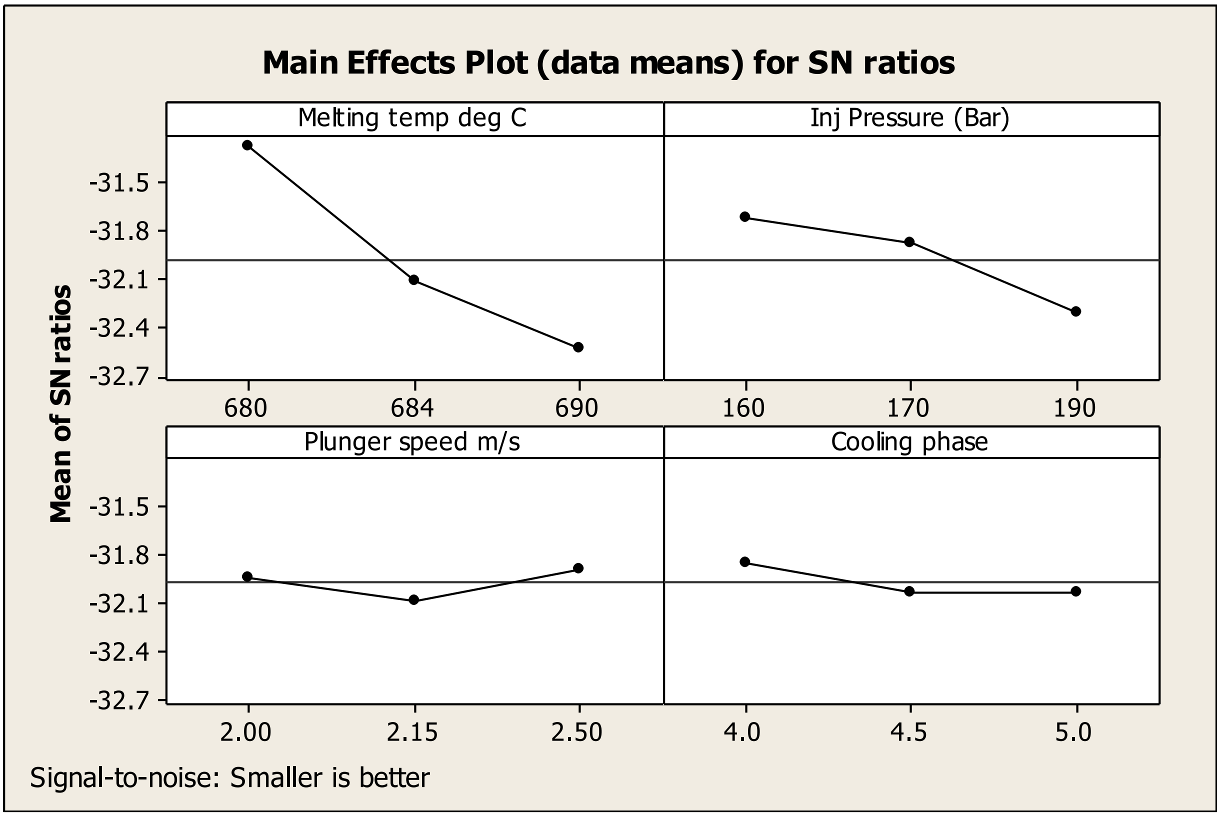


Fig. 6. Graph of process parameters Vs SN ratio.

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.

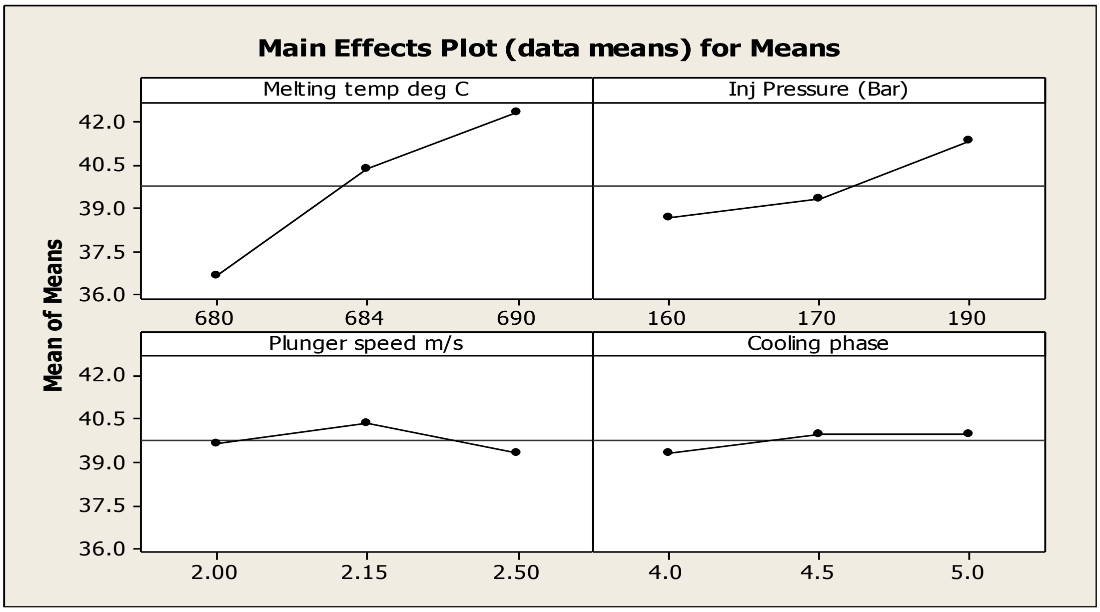


Fig 7. Graph of process parameters Vs Mean.

IV. EXPERIMENTAL WORK

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 case gear meter 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 are set as input for machine, which are shown in the following table.

Table 7: Input process parameters for case gear meter.

Melt temperature in ^{0}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.

4.1 Case study details-

- **Name of component-** Case gear meter.
- **Material** – Cast aluminium.
- **Composition-**

Table 8: 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.
- **No. of cavities-** Two.

4.2 Experimental results-

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 during actual experimentation. 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. By referring Taguchi analysis, which shows that melt temperature can greatly minimize the cycle time, then followed by injection pressure, plunger velocity and cooling time and accordingly process parameters are varied as per their rank. For safer side and for avoiding defects, values of few process parameters are kept at lower side. The optimum results obtained for all process parameters are shown in the following different tables.

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 nearer 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 changes that optimum level for melt temperature could be 678^{0}C or 679^{0}C. So for this reason 675^{0}C is taken as starting range for variation of melt temperature. The temperature 675^{0}C is the extreme last range, because under this temperature fluidity of metal starts to get affected due to fall in temperature. Similarly, by referring both graphs for temperature, then variation is done in between start and end point. In this way optimum value for temperature is obtained.

Table 9: Optimum temperature reading

Melt temperature in ^{0}C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Defect	Remark
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

Above table shows **679^{0}C** is the optimum temperature reading for case gear meter.

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 nearer in between 160-190 bar. But in actual practice usually a lower value say 120 bar or 130 bar is selected for safer side and during experimentation 120 bar is taken as starting range. The optimum value for the same is obtained in the following way.

Table 10: Optimum injection pressure reading

.Melt temperature in ^{0}C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Defect	Remark
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, i.e-1mm	Not ok
679	157.5	1.5	6	Flash ,i.e-1mm	Not ok
679	**155**	1.5	6	-----	Ok

Above table shows **155 bar** is the optimum injection pressure reading for case gear meter.

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 nearer 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 11: Optimum plunger velocity reading.

Melt temperature in ^{0}C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Defect	Remark
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

Above table shows **1.8 m/s** is the optimum plunger velocity reading for case gear meter.

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 nearer in between 4.0-4.5 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.

Melt temperature in ^{0}C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Defect	Remark
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

Above table shows **5 sec** is the optimum cooling time reading for case gear meter.

After getting the optimum readings for each parameters then by using similar set up cycle time for twenty jobs is noted by using stop watch for given optimum readings and actual component is produced which is shown in the Fig. 8., the obtained different cycle times are shown in the following table.

Table 13: Cycle time for optimum process parameters.

Melt temperature in ^{0}C.	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						

Fig. 8. Case gear meter.

V. COMPARISON BETWEEN DOE AND EXPERIMENTAL RESULTS

Majorly DOE results are in agreement with the experimental results, within small deviation or difference. Each parameter has its own effecton cycle time as well as on die cast quality. If we referrer the following table we can state that values obtained by both techniquesare almost closer to each other and the results of the two applied methods proved that the deviations are acceptable.

Table 14: DOE and Experimental results.

	Melt temperature in ^{0}C.	Injection pressure in bar.	Plunger velocity in m/s.	Cooling time in sec.	Cycle time in Sec.
DOE.	680	160	2	4	35
Experimentation.	679	155	1.8	5	35.94
Difference.	1(↓)	5(↓)	0.2(↓)	1(↑)	0.94(↑)
Percentage of increase/decrease.	0.147(↓)	3.125(↓)	10(↓)	25(↑)	2.686(↑)

VI. CONCLUSION

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

- Basically the quality of die casting and its cycle time depends upon its process parameters, which need to be determined and adjusted if needed, for getting better quality and optimum cycle time.
- 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= 679 ^{0}C, Injection pressure=155 bar, Plunger velocity= 1.8 m/sec and cooling time= 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 experimental results 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.

ACKNOWLEDGMENTS

I would like to thank Prof. V. V. Potdar (Guide) for his valuable guidance and timely suggestions for completing this work and Mr. S. S. Kulkarni, for his cooperation in this study, especially in the experimental tests.

REFERENCES

[1]. M.R. Barone, D.A. Caulk, “Analysis of liquid metal flow in die casting”,Internationaljournal of engineering science, vol.38,page 1279-1280, 2000.

[2]. B.H. Hu, K.K. Tong, X.P. Niu,“Design and optimisation of runner and gating systems for thedie casting of thin-walled magnesium telecommunication partsthrough numerical simulation”, Journal of materials processing and technology, vol. 105, page 128-129, 2000.

[3]. GuilhermeOuriqueVerran, Rui Patrick Konrad Mendes, Marco Aurelio Rossi, “Influence of injection parameters on defects formation indie casting Al12Si1,3Cu alloy:Experimental results and numeric simulation”,Journal of materials processing technology, vol.179, page 190-192, 2006.

[4]. D.H. Lee , P.K. Seo, C.G. Kang,“Die design by filling analysis of semi-solid injection forging process and their experimental investigation”,Journal of materials processing technology, vol.147, page 45-47, 2004.

[5]. A. Hosseini, E.Azarsa, B.Davoodi, Y.Ardahani, “Effect of Process Parameters on the Physical Properties of Wires Produced by Friction Extrusion Method”, International Journal of Advances in Engineering & Technology, Vol. 3, Issue 1, pp. 592-597, March 2012.

[6]. M. Imad Khan, Yakov Frayman and Saeid Nahavandi, “Modelling of porosity defects in high pressure die casting with a neural network”, CRC for cast metals manufacturing (CAST), page 1,Deakin university, victoria 3217, australia.

[7]. C.H.E. Tseng, D.R. Askeland, “Study of the EPC mold filling process using metal velocity and mass and energy balances” , AFS Trans, page 520, 1992.

[8]. F. Faura, J. Lopez, J. Hern´andez, “On the optimum plunger acceleration law in the slow shot phase of pressure die casting machines”,International Journel of Machine Tools Manufacturing, vol. 41, page 173–176,2001.

[9]. G. Backer, M. Ranganathan, J. Heimsch, M. Mclaughlin, W. Kim, “Simulation of Flow-induced Gas Entrapment and its Effects on Porosity in Aluminum Die Castings”, North American Die Casting Association Transactions, page 44–46 Indianapolis, USA, 2001.

AUTHORS’ BIOGRAPHY

Mulla J.G. graduated in production engineering from Shivaji university, Kolhapur and perceiving master degree in Mechanical (Manufacturing process) Engineering from Solapur university, Solapur. He has three years of industrial experience and five years of teaching experience. His fields of specialization are Automobile Engineering and Manufacturing Engineering. At present he is working as lecturer in mechanical engineering department in A.G. Patil Polytechnic Institute, Solapur.

V.V. Potdar graduated in mechanical engineering from Karnataka university , Dharwad and obtained master degree in Mechanical (Production engineering) Engineering from shivaji university, Kolhapur. Perceiving doctorate (CFD) from JNTU, Hyderabad. His fields of specialization are CFD, ESA, CAD/CAM/CAE. He has about three years of industrial experience and twenty six years of teaching experience in teaching graduate and post graduate classes. At present he is working as vice principal in A.G. Patil Institute of Technology, Solapur.

Swapnil S.Kulkarni Director, Able Technologies India Pvt. Ltd., Pune. The Company offers Engineering Services and Manufacturing Solutions to Automotive OEM’s and Tier I and Tier II Companies. He is a Graduate in Industrial Engineering with PG in Operations Management. With around 20 years of working experience in the domain of R&D, Product Design and Tool Engineering, he has executed projects in the Automotive, Medical and Lighting Industry. His area of interest is Research and Development in the Engineering Industry as well as the emerging sector of Renewable Energy.