# Application of Response surface Methodology for improving the quality of Pressure die casting components

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***Abstract:*** *Roughness is a significant parameter when annoying to find out whether a surface is appropriate for a definite purpose. Rough surfaces often wear out more quickly than smoother surfaces. Rougher surfaces are normally more vulnerable to corrosion and cracks but they can also aid in adhesion. The study dealing with pressure die casting process to fabricate an automotive valve closer component with better surface finish on LM6 by varying intensification pressure, shot velocity and pouring temperature. Experiments were carried in 120 technocrat pressure die casting machine. A surface roughness tester SJ-206 used to determine the surface roughness quickly and accurately of a material. It can be noted that the response such as and surface roughness can be computed proficiently through the linear model settled in this experiment. The direct and interactive effect of process factors on response within the range of exploration can be considered with ease from the RSM and the surface and contour plots indicates the intermediate level of chosen level of intensification pressure, shot velocity, pouring temperature decreases the surface roughness. So the intermediate level is optimum level.*

***Key Words:*** *Surface roughness, Response Surface methodology, Regression, Contour, Surface plots*

## 1. INTRODUCTION:

Pressure die casting is main platform in the contribution of improving the mechanical properties in industrial applications and also has greater potential to achieve Smooth uniform surface and internal soundness in the cast components. A great number of publications by a variety of authors reproduce the significance in these parameters. Review of literature on mechanical properties optimization have been done in the past by most of the authors. Various optimization methodologies have been used to improve solutions for optimization of complex problems in many applications. This paper reviewed the ideal selection of casting parameters in pressure die casting process using Response surface methodology. This study deals with review in different parametric optimization like intensification pressure, shot velocity and pouring temperature to enhance the mechanical properties surface roughness. The survey showed that there are many papers in the field of casting parameters optimization using RSM which will provide the effective results. The surface roughness is very essential in the point of quality of a product and a factor that highly influences manufacturing cost. The mechanism behind the formation of surface roughness is very dynamic, complicated and process dependent. It is very difficult to calculate its value theoretical analysis. The correct setting of process parameters is very important. The die casting parameters are set by past experience and trial and error methods. Researchers have attempted to model the complex die casting process and studied the effects of various process parameters on the quality than smoother surfaces. Rougher surfaces are normally more vulnerable to corrosion and cracks, but they can also aid in adhesion, since it will not only result in degraded mechanical properties of the castings but also has a negative effect on the machinability and surface properties of castings. Studies have shown that surface roughness formulation is a complex phenomenon where the final amount, size, distribution of pores and micro voids are determined by several independent process parameters. Statistical regression analysis-based techniques namely DOE, Taguchi and Response surface methodology were used to identify and analyse the effect of process parameters in pressure die casting. These methods provide precise information about the process. However, it is not possible to correlate the findings with the physics of the process. An optimization strategy based on desirability function approach (DFA) along with the response surface methodology has been used to optimize process parameters in pressure die casting process. Soft computing based approaches namely ANN, GA were used to optimize process parameters in pressure die casting process. However, these techniques require huge data and precise input-output relations for accurate results. Real- world situation consists of many variables and complex input-output relationship.

## 2. EXPERIMENTAL WORK:

The experiments have been performed on horizontal pressure die casting machine DC 400 K. The standard short sleeve is coupled with maximum shot capacity for aluminium 6.9 kg. A locking force with 400 tones capacity inbuilt in the setup and an electric furnace provided with maximum capacity of melting temperature $2000^0$ C with 1000 litre capacity. After pouring molten metal, intensification pressure with shot velocity were applied at holding time of 15 seconds and retained on the solidifying molten metal for duration of 60 seconds to produce sound casting of automotive valve closing size of 65 mm diameter. The molten metal from the bottom pouring furnace was transferred into the preheated die through preheated pathway within few seconds, so as to avoid melt temperature loss and turbulence of molten metal flow. The different levels of intensification pressure was applied on the molten metal by lowering the punch which is attached to the hydraulic unit with varying shot velocity and molten temperature. The casting components were produced and surface roughness of the components was measured by means of surface tester. Mitutoyo SJ 201 Surface tester is a surface roughness measuring device shown in the figure 3 which is provided with exchangeable diamond stylus of radius of 5µ, which sensing the horizontal and vertical deflection from any surface gives roughness value.

Fig 1. Pressure die casting machine

Fig 2. Casting Components


Fig 3. Mitutoyo SJ 201 Surface tester

**3. PROCESS PARAMETERS:**

Intensification pressure, shot velocity and pouring temperature are the parameters chosen for the experiment. To ensure the accuracy of the results, three samples were fabricated for each of the parameter combinations. In this study, these casting parameters were chosen as the independent input variables.

Table 1 Levels of process parameters

| Factors | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Intensification pressure ($Kgf/cm^2$) | 180 | 200 | 220 |
| Shot velocity (m/s) | 0.4 | 0.5 | 0.6 |
| Pouring temperature ($^0C$) | 640 | 670 | 700 |

Table 2 Orthogonal array L9 Design

| Trials | Intensification pressure ($Kgf/cm^2$) | Shot velocity (m/s) | Pouring temperature ($^0C$) |
|---|---|---|---|
| 1 | 1 | 1 | 1 |
| 2 | 1 | 2 | 2 |
| 3 | 1 | 3 | 3 |
| 4 | 2 | 1 | 2 |
| 5 | 2 | 2 | 3 |
| 6 | 2 | 3 | 1 |
| 7 | 3 | 1 | 3 |
| 8 | 3 | 2 | 1 |
| 9 | 3 | 3 | 2 |

Table 3 Orthogonal array L9 Design with response

| Trials | Intensification pressure ($Kgf/cm^2$) | Shot velocity (m/s) | Pouring temperature ($^0C$) | Surface roughness (µm) |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 4.576 |
| 2 | 1 | 2 | 2 | 7.047 |
| 3 | 1 | 3 | 3 | 8.929 |
| 4 | 2 | 1 | 2 | 6.521 |
| 5 | 2 | 2 | 3 | 5.803 |
| 6 | 2 | 3 | 1 | 9.567 |
| 7 | 3 | 1 | 3 | 3.384 |
| 8 | 3 | 2 | 1 | 8.586 |
| 9 | 3 | 3 | 2 | 8.714 |

## 4. RESULTS AND DISCUSSIONS

### 4.1. Determination of the Regression model and Evaluation of Statistical

The Regression equation, ANOVA and graph is generated by using Minitab software. The regression equation is give the relationship among Intensification pressure, shot velocity, pouring temperature and surface roughness. The equation is given by,

Surface roughness ($R_a$) = 2.62 + 0.022 Intensification pressure + 2.12 Shot velocity + 0.055 pouring temperature

Table 4 Regression Analysis

| Predictor | Coefficient | SE Coefficient | T | P |
|---|---|---|---|---|
| Constant | 2.617 | 1.1030 | 2.37 | 0.007 |
| Intensification pressure ($Kgf/cm^2$) | 0.022 | 0.2701 | 0.08 | 0.939 |
| Shot velocity (m/s) | 2.1215 | 0.2701 | 7.85 | 0.001 |
| Pouring temperature ($^0C$) | 0.055 | 0.2701 | 2.85 | 0.047 |

| | | |
|---|---|---|
| S = 0.359413 | R-Sq = 98.31% | R-Sq (adj) = 97.23% |

The goodness of fit is elucidated by the determination coefficient (R-Sq).In this study, the value of determination coefficient is 0.983 which is indicated that 2% of the entire distinctions are not explained by the regression model. The adjusted determination coefficient is 0.972 whereas the adjusted determination coefficient is very closer to the determination coefficient which indicates a good relationship between the responses and the experimental results.

### 4.2. RSM Graphs

The Contour plots and Surface plots Surface roughness $V_s$ Intensification pressure, shot velocity, pouring temperature are obtained as depicted in figure 4 to 9. The surface and contour plots indicates the intermediate level of chosen level of intensification pressure, shot velocity, pouring temperature decreases the surface roughness. So the intermediate level is optimum level. The optimization plot (Fig 10) also showed same kind of result.

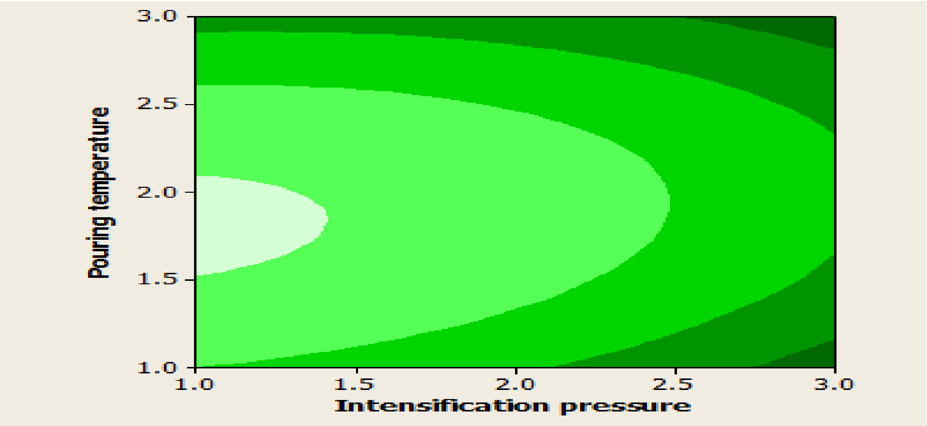


Fig 4 Contour plot for Surface roughness $V_s$ Intensification pressure and pouring temperature

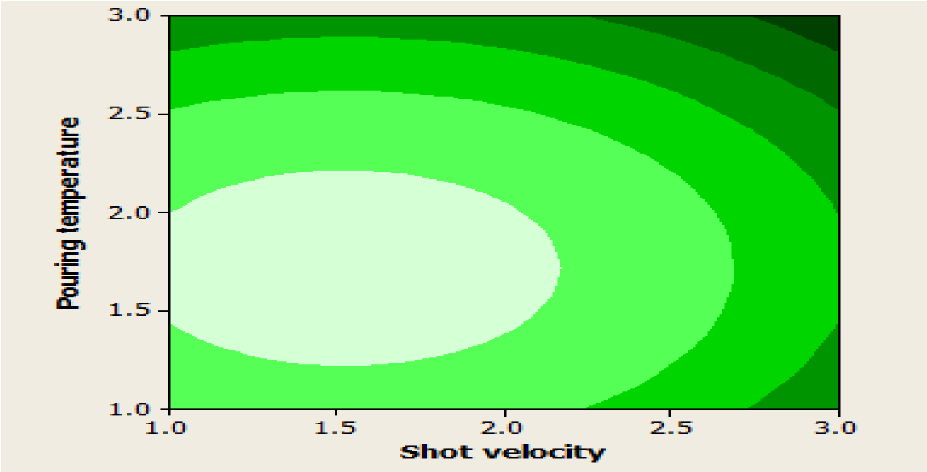


Fig 5 Contour plot for Surface roughness $V_s$ Shot velocity and pouring temperature

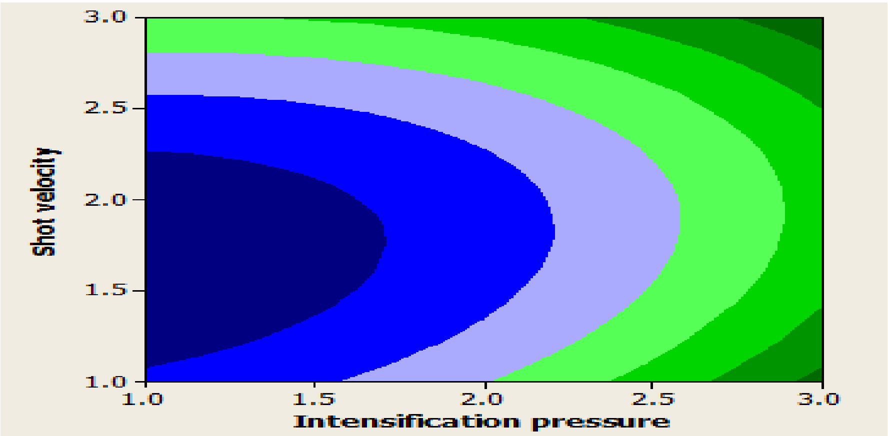


Fig 6 Contour plot for Surface roughness $V_s$ Intensification pressure and shot velocity

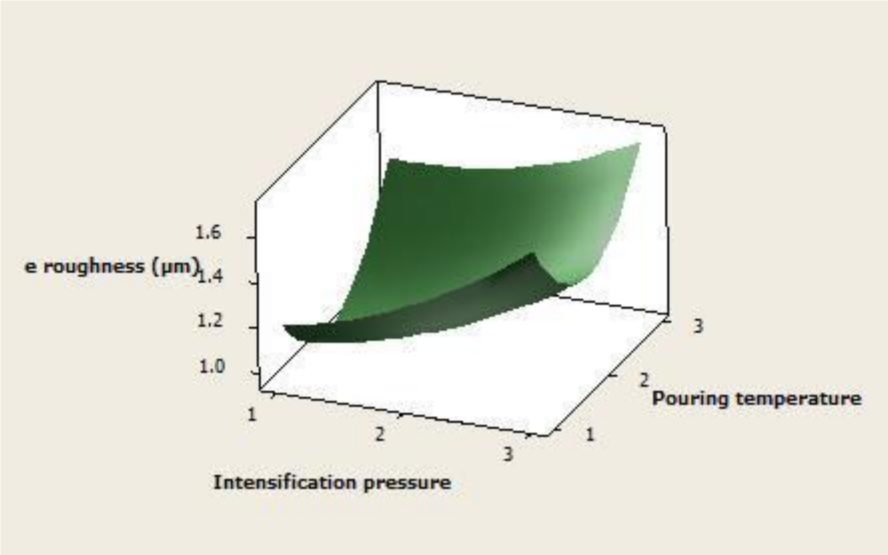


Fig 7. Surface plot for Surface roughness $V_s$ Intensification pressure and pouring temperature

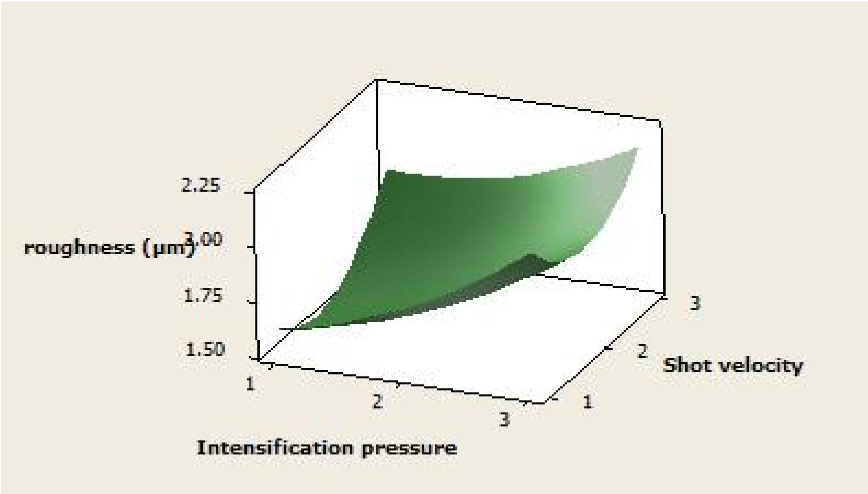


Fig 8. Surface plot for Surface roughness $V_s$ Intensification pressure and Shot velocity

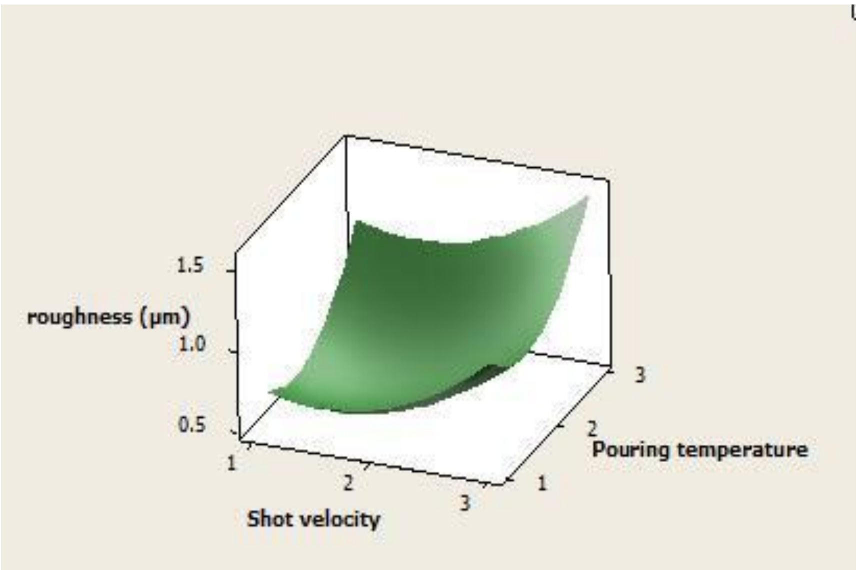


Fig 9. Surface plot for Surface roughness $V_s$ Shot velocity and pouring temperature

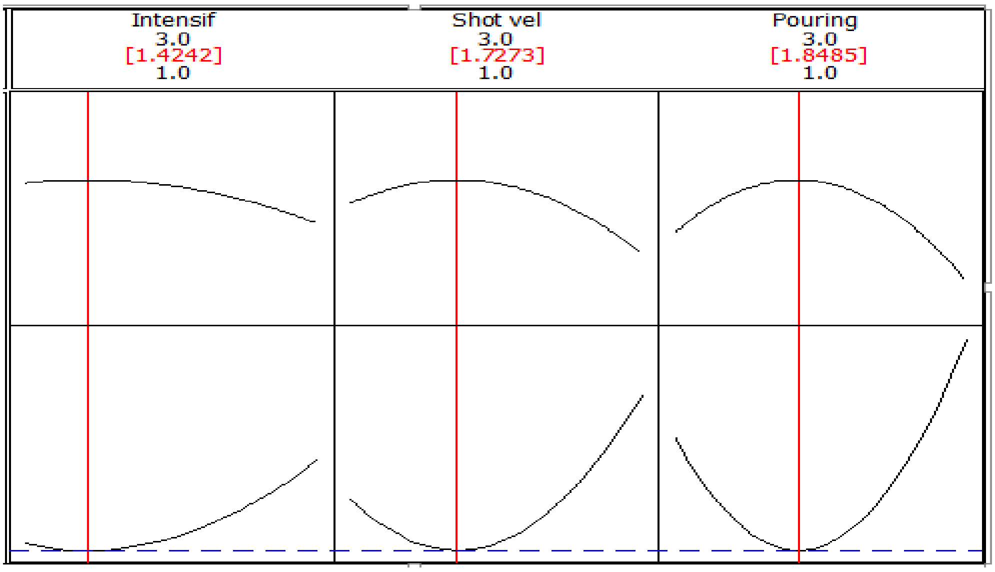


Fig 10. Optimization Plot

**5.3. Normal Probability plot Graph**

The normal probability plot graph is attained by using the regression equation and the trials values. It is a graphical exemplification for evaluating whether data set is normally disseminated or not. The graph should provide nearly in a line. So the errors are distributed normally.

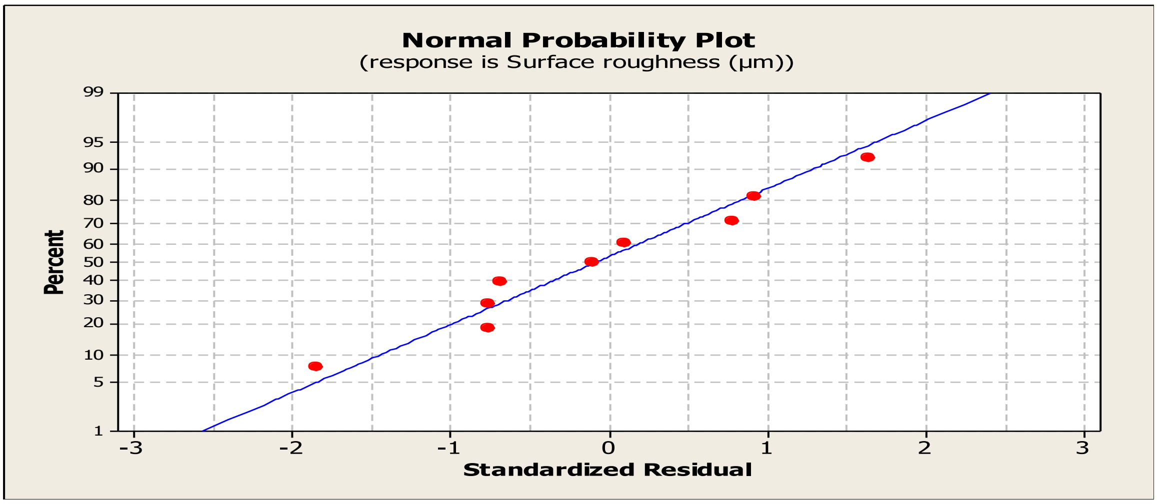


Fig 11 Normal probability plot

**5. CONCLUSION:**

In this paper, Response Surface Methodology is used to obtain the Surface roughness of the casting components produced in pressure die casting machine. The following conclusions are done by this experiment,

- The response such as and surface roughness can be computed proficiently through the linear model settled in this experiment. The direct and interactive effect of process factors on response within the range of exploration can be considered with ease from the RSM
- The process parameters for completing the desired response can be obtained from the mathematical model.
- The surface and contour plots indicates the intermediate level of chosen level of intensification pressure, shot velocity, pouring temperature decreases the surface roughness. So the intermediate level is optimum level.
- The normal probability plot graph is obtained in the form of straight line so the errors are distributed normally.
- In Regression analysis, the adjusted determination coefficient is very closer to the determination coefficient so evaluation of delamination factor is done by effectively and efficiently.

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