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Optimization of Parameters of High Pressure Die Casting Process for Minimising the Porosity of Aluminium Alloy

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Abstract: **The present problem is based on reducing the porosity in a high pressure die casting process. Three important casting parameters viz. metal temperature, die gate velocity and solidification pressure were selected. Ranges of these parameters were set. A particular material was taken for the purpose. Experiments were conducted for 27 combinations obtained from 3 parameters and 3 ranges & results collected. A very effective method for optimization, Response surface methodology was applied. Experimental data were fed to the software and the optimum combination of parameters which will minimise the porosity of the casting within the given range were found. Experiment was conducted with this optimum set and difference between practical & theoretical values of porosity was calculated. This was found to be minimal.**

Keywords — die gate velocity, HPDC, metal temperature, optimization, porosity, solidification pressure.

I. Introduction

Casting is the melting of solid material heated to a special temperature and pouring the material into a special cavity or mould in order to get a proper shape. The metals that are mostly cast are iron, steel, aluminium, brass, bronze, magnesium and certain zinc alloys. Casting process involves some parameters which include die gate velocity, metal temperature, die temperature, piston velocity, solidification pressure. During casting it is seen that a lot of defects are obtained in final product. The present research work is concentrated on finding the best optimal conditions involving the prime factors responsible to minimise the porosity (defect) of aluminium alloy ($AlSi_9Cu_3$) used in experiment. The prime factors are the parameters used in die casting which are solidification pressure(P), metal temperature(T) and die gate velocity(V).

A. Die Cast Process

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mould cavity. The mould cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mould during the process. Most die castings are made from zinc, copper, aluminium, magnesium, lead and tin-based alloys.

II. Casting Parameters

For Die casting a number of factors [9] are to be kept in mind in order to get the required final product. Since HPDC [8] has considerably higher speed than any other metal forming process, due to complexity of the process and the number of variables, optimization of the process is essential. In particular cases there are issues related to control of die temperature, solidification of the components, quality control of the castings, and more important, development or use of a coherent and integrated system. The mechanical properties of a die-cast product are principally related to the die temperature, the metal velocity at the gate, and the applied casting pressure. If these parameters are not adequately controlled, various defects within the finished component will occur.

A. Solidification Pressure

In casting the molten metal is solidified under high pressure in most `cases. The solidification pressure plays an important role in casting. In cases of die casting the molten metal is pressed into the mould at a high pressure of 150 to 1200bar.

B. Metal Temperature

Metal temperature is an important factor for die casting process. If the temperature is too low the molten metal will not flow into all the cavity and apertures of the casting. Too hot temperature of molten metal will result in longer time of solidification.

C. Die gate velocity

The die gate velocity is another important factor for casting. As the gate velocity increased, the quality

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of casting surface finish is improved. Die gate velocity is responsible for the part filling. Very high speeds in this stage can result in die casting porosities.

III. CASTING DEFECTS

A casting defect [2] is an undesired irregularity in a metal casting process. Defects are defined as conditions in casting that can be corrected or removed. There are many types of defects which result from many different causes. Some of the solutions to certain defects can be the cause for another type of defect. In die casting the most common defects are gas porosity, shrinkage porosity, hot tears, and flow marks. Porosity[9] is one of the main defects that directly affect the strength of the final product.

IV. MATERIAL MEANS

The material used for die casting in the experiment is aluminium alloy. $AlSi_9Cu_3$ is used in the experiment as they are characterized by medium mechanical properties, good strength at elevated temperatures, good foundry properties and corrosion resistance. It contains aluminium which is light weight and can be moulded [1] to any shape. The chemical composition of the alloy is as given in Table 1. Rectangular plates with dimensions 200x100x20mm were formed after casting.

Table 1: Chemical composition of aluminium alloy:-

Element	Si	Cu	Mn	Mg	Fe	Zn	Ni	Al
Wt (%)	9.5	3.0	0.4	0.5	0.9	1.0	0.3	84.4

V. EXPERIMENTAL SETUP

The experiment was performed in a High Pressure Die Casting Machine[8] [10]. Aluminium alloy of $AlSi_9Cu_3$ was used as molten metal. Experiments were conducted with certain casting parameters within the range. The factors[9] that were focused upon while performing the experiments are metal temperature, die gate velocity and solidification pressure. Casting was done by pouring the molten metal into the metal cavity in order to get the desired shape. With different combinations obtained from 3 parameters & 3 levels, 27 such experiments were conducted and corresponding data were recorded.

Table 2: Casting parameters:-

Sl No.	Metal Temperature (^0C)	Die Gate Velocity (m/sec)	Solidification Pressure (bar)
1.Low	550	1.1	230
2.Medium	680	2.8	410
3.High	810	4.1	550

VI. DESIGN OF EXPERIMENTS

The best way to optimize within a range is the full factorial design of experiment method. In design of experiment a range for each factor is set for performing a particular experiment and analysis to get a specific response. One can consider as many no. of levels according to the degree of experiment they want to perform. More the level more the range is selected for a particular experiment. Here three levels were selected for the given ranges. The first level, called low level, is named as level 1, second level is called the medium level, named as level 2 and the third level is called the high level, named as level 3.

Table 3: The combination of the factors and corresponding porosity found after experiment are as follows:-

Sl No.	Metal Temperature(0 C)	Die Gate Velocity (m/sec)	Solidification Pressure (bar)	Porosity (%)
1	550	1.1	230	1.080
2	550	1.1	410	0.767
3	550	1.1	550	0.445
4	550	2.8	230	1.075
5	550	2.8	410	0.790
6	550	2.8	550	0.468
7	550	4.1	230	1.050
8	550	4.1	410	0.810
9	550	4.1	550	0.415
10	680	1.1	230	0.935
11	680	1.1	410	0.690
12	680	1.1	550	0.339
13	680	2.8	230	1.005
14	680	2.8	410	0.720
15	680	2.8	550	0.360
16	680	4.1	230	1.060
17	680	4.1	410	0.745
18	680	4.1	550	0.425
19	810	1.1	230	0.963
20	810	1.1	410	0.675
21	810	1.1	550	0.397
22	810	2.8	230	0.990
23	810	2.8	410	0.740
24	810	2.8	550	0.425
25	810	4.1	230	1.007
26	810	4.1	410	0.765
27	810	4.1	550	0.404

VII. ` RESULTS AND DISCUSSION

Effects of different parameters on porosity are found by Response Surface Methodology [8] through minitab software from the experimental data.

A. Surface Plots

In Fig.1 porosity is represented in 'z' axis, metal temperature is represented in 'x' axis and die gate velocity is represented against 'y' axis. The generated surface represents the variation of porosity with metal temperature and die gate velocity. Here solidification pressure is kept steady at 390 bar. The fig. show that porosity initially

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decreases with increase in metal temperature and increases slowly at high temperatures. Also it increases steadily with increase in die gate velocity..

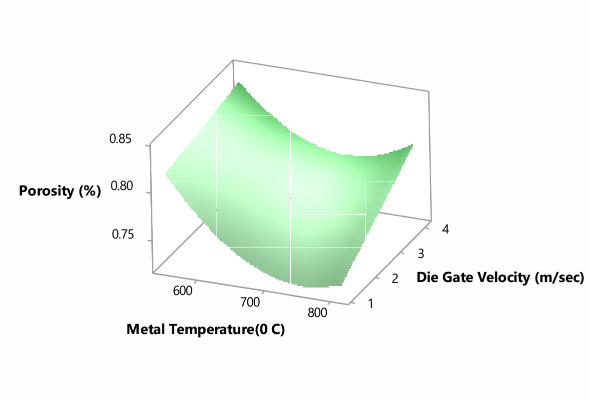


Fig.1 Surface plot of porosity verses metal temperature and die gate velocity

Fig.2 shows the variation of porosity, represented in ‘z’ axis, against metal temperature, in ‘x’ axis and solidification pressure in ‘y’ axis. Here die gate velocity is kept steady at 2.6 m/s and porosity varies with corresponding values of metal temperature and solidification pressure. Here porosity practically remains unchanged with increase in temperature & decreases very fast with increase in pressure.

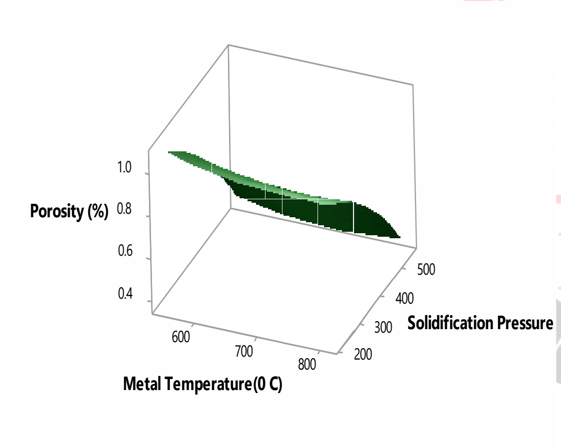


Fig.2 Surface plot of porosity verses metal temperature and solidification pressure

In Fig.3 porosity is represented in ‘z’ axis, die gate velocity in ‘x’ axis and solidification pressure in ‘y’ axis. Here metal temperature is kept steady at 680^{0}C. The generated surface show that porosity increases very slowly with increase in die gate velocity and it decreases steadily with increase of solidification pressure.

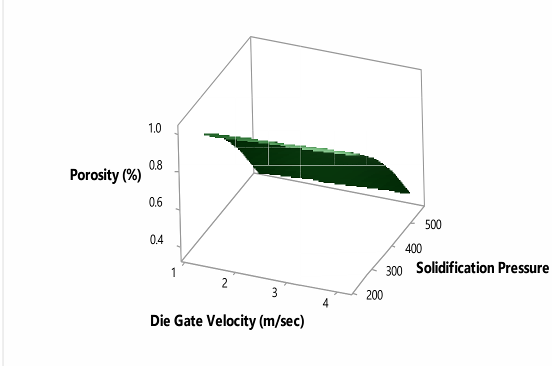
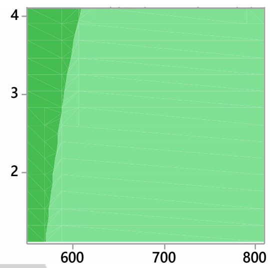
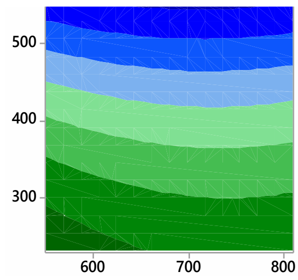


Fig.3 Surface plot of porosity verses die gate velocity and solidification pressure

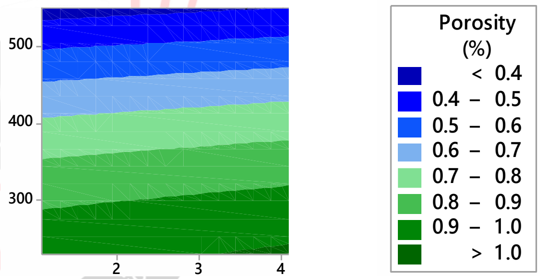
Fig 4: Contour plots of Porosity(%):-



Die gate velocity to Metal Temperature



Solidification pressure to Metal Temperature



Solidification Pressure to Die gate velocity

Here contour plots are shown which represent the previously shown three dimensional surface on a two dimensional plane. The above graphs represent contour plots of the experiments from which certain values of the parameters are obtained.

The hold values thus obtained from the graph are as follows:-

Metal Temperature= 680

Die Gate Velocity= 2.6

Solidification Pressure= 390

B. Theoretical Values of Porosity using Hold value:

By using the above hold values in RSM following equation is obtained :-

The theoretical value thus obtained is:

Porosity (%) = 2.549 - 0.003797*T - 0.0310*V -

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0.000146*P + 0.000002*T*T - 0.000003*P*P + 0.000067*T*V + 0.000001*T*P
= 0.681656 %

C. Practical Value of Porosity by experiment:

Metal Temperature(0C)	Die Gate Velocity (m/s)	Solidification Pressure(bars)	Porosity(%)
680	2.6	390	0.401

Difference Between Theoretical and Practical Value is
= (0.681656 - 0.401) = 0.280656%

The difference thus obtained is very small hence result obtained theoretically are very close to practical values.

Here the value thus obtained is nearer to optimum values.

VIII. Conclusion

The present research work is based on finding the optimal conditions involving the prime factors responsible to minimise the porosity (defect) of aluminium alloy ($AlSi_9Cu_3$) used in experiment. Prime factors are the parameters used in die casting which are solidification pressure, metal temperature and die gate velocity. It is seen that proper combination of influencing parameters will help in reducing the porosity in the cast considerably. Also, it was established that closeness between the practical & theoretical result is commendable with only 0.68% difference.

Acknowledgement

The authors are thankful to S R Enterprise for giving the opportunity to perform the experiments.

References

[1] K. Omura et al , studied the problem of molten metal level control in continuous casting. He deals with the problem of molten metal level control in continuous casting. Under normal circumstances, proportional integral derivative (PID) control performs quite well, but abnormal conditions (in particular nozzle clogging/unclogging) require manual intervention.

[2] M. Dussud et, al ,developed a model on minimisation of casting defects by analysing the root causes of some casting defects in ABMI industries.

[3] Yarlagadda and Chiang, discussed artificial intelligent neural network system to generate the process parameters for the pressure die casting process

[4] Wang et, al, studied die casting defects and accurately determined the corresponding causes, as well as recommended corrective actions to eliminate defects.

[5] B. Kalandyk , discussed continuous casting process in which product usually got cracked due to internal structure.

[6] Adil Mohamed, designed a feeder design for casting. He have done research on feeder design for casting. In this paper, a feature-based solid modelling integrated with a fuzzy expert system was developed

[7] Rajesh Rajkolhe, J. G. Khan, casting defects and their remedies. His paper also aims to provide correct guideline to quality control department to find casting defects and will help them to analyze defects which are not desired.

[8] Sarah Howe, an Adaptive Neuro-Fuzzy Inference System model for High Pressure Die Casting.

[9] Lee et al. studied the effect of process parameters on porosity distributions in high pressure die cast AM50 Mg-alloy.

[10] Rai et al. have developed a generic ANN-based HPDC process model for providing real time assistance to machine operators in setting optimal process parameters during various phases of a moulding process cycle.

[11] Zhao et al. used the Finite Difference Method to study the effect of porosity on the mechanical properties of plate ADC 12 die castings.

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