Effect of Cooling on Porosity in Low Pressure Die Casting

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ABSTRACT

Low pressure die casting process for Aluminum alloys is widely adopted in the manufacturing of automotive parts such as engine and transmissions. Porosity and shrinkage are one of the major defects observed in casted parts during machining. A defect such as Porosity and shrinkage becomes more concern if it is observed in the functional area of the part which may impact quality and functionality of parts during service. The probability of these types of defects observed more in parts which have compact design & thickness variation across part to reduce the weight of the product. In this paper, the study has been carried out to reduce and shift the surface porosity/shrinkage into non-functional zone based on experimental analysis by using cooling in low pressure die casting. Critical zone or functional area of the automotive component selected for study purpose. Natural cooling, air cooling, and water cooling are applied to metallic core pin of the component during experimental analysis to study the effect of cooling on porosity.

Keyword: - *Low Pressure Die Casting, Porosity, shrinkage, Natural cooling, Air cooling and water cooling*

1. INTRODUCTION

Pressure Die Casting is one of the technology which shown definite growth in usages in recent years. This is due to automotive & manufacturing industries growth in recent years. Low pressure die casting is one of casting process in foundry technologies which is mostly used for manufacture aluminum alloys, copper alloy or Zinc alloy casting. In Low Pressure Die Casting, Mould is placed above sealed crucible having molten metal. Molten metal is inserted in Die from sealed crucible by application of low air pressure (above atmospheric pressure). Low pressure created in the sealed crucible by compressed air/inert gas to feed molten metal through feeding tube and gate with low turbulence in Die. Pressure is controlled by PLC control system and after the metal has solidified, Air/inert gas pressure is stopped. Molten metal below riser remains in molten state and goes back to the crucible. After cooling, Parts removed from die with help of ejection pins & collected in holding tray attached to the machine.

Casting defects such as Porosity and shrinkage are one of the main defects relate to the solidification of the metal in the mould. Porosity occurs in casting in the form of pin hole porosity or gas porosity. This porosity is caused by the gases absorbed by molten metal.it is mainly hydrogen which is responsible for pin hole porosity. During solidification, the gas is released and in driving itself out of the metal it creates small voids throughout the casting, called pin holes. Gas porosity becomes more pronounced with higher melting temperature and slower solidification of metal. During solidification of metal, there is volumetric shrinkage. This should be adequately compensated by feeding, failing which voids will be produced in casting. These voids may exist on the surface as depression, called surface shrinkage. This defect occurs on account of inadequate and improper gating, riser and chilling, due to which proper directional solidification does not take place.[1]

When we machined casting parts, Porosity is exposed on the surface at functional zone during machining of components which leads to rejection of parts. These types of defects reduce the quality of components & also hamper production rate which results in an increase of production cost of parts. In this paper, analysis has been carried out to minimize or shift the surface porosity into nonfunctional zone based on the experimental study by inducing Natural cooling, in low pressure die casting.

2. LITERATURE REVIEW

Porosity cannot vanish and the best strategy to reduce porosity is to better understand the formation of porosity, determine appropriate strategies to prevent its occurrence. Early analysis by Pellini (1953) was conducted to investigate the formation of porosity. Results showed that temperature gradient plays an important role in the formation of porosity, and this was discussed in detail by Niyama et al. (1981) with a number of commercial casting experiments. Niyama et al. (1981) recognized that a threshold of the temperature gradient depended on both shape and size of a particular casting, should be obtained to avoid shrinkage porosity [2].

A.V. Kuznetsov and M. Xiong studied the dependence of microporosity formation on the direction of Solidification. Their computational results suggest that the comparison of samples obtained by two techniques, the traditional unidirectional solidification “against the gravity” and the solidification “along the gravity”, can be a valuable tool for validation and calibration of microporosity formation models. The study shows that a simple change of the direction of solidification reverses the effect of gravity and therefore can show whether gravity effects are correctly simulated by the model. [3]

Jer-Haur Kuo has used an interactive computer simulation system to study to aid in the determination of the pressure- time relationship when filling a low pressure cast iron to eliminate filling defects while maintaining its productivity. The pressure required to fill a casting process in a low-pressure casting process can be separated into two stages. The first step is to exert pressure to force the molten metal to increase. In the ascending tube to the casting grid, which varies from casting to casting due to the fall of the molten metal level in the Oven while the second step is to add additional pressure to push the molten metal into the cavity of the die in a manner that will not cause much turbulence and have the proper fill pattern to avoid gas trapping while Now productivity. One of the main efforts in this study is to modify the filling simulation system with the ability to directly predict the occurrence of gas. The porosity developed earlier to interactively determine the appropriate grid speed for each part of the casting. The pressure required for filling the die cavity can then be obtained from the simulations. The operating principles and the interactive analysis system developed are then tested on an automotive wheel manufactured by the low pressure casting method to demonstrate how the system can help to determine the appropriate pressure, time relationships, p-t curve, Necessary to produce a Casting without sacrificing productivity [4].

L. Kucharcik, Porosity is one of the major defects in aluminum castings, which results in a decrease of mechanical properties. Porosity in Aluminum alloys is caused by solidification shrinkage and gas segregation. The final amount of porosity in aluminum castings is mostly influenced by several factors, as the amount of hydrogen in the molten aluminum alloy, cooling rate, melt temperature, mold material, or solidification interval. This article deals with the effect of chemical composition on porosity in Al-Si aluminum alloys. For experiment was used Pure Aluminum and four alloys: AlSi6Cu4, AlSi7Mg0, 3, AlSi9Cu1, AlSi10MgCu1. [5].

D.R. Gunasegaram, aluminum-alloy permanent mold casting of varying section thicknesses was sought. The aim was to either modify or eliminate the defect by manipulating those parameters so that the lower inlet manifold casting would pass a leak test. The study was carried out ‘off-line’ using numerical simulations of the casting process. This was because the just-in-time production schedule of the busy mass production automotive foundry involved did not allow for any interruptions to accommodate physical experimentation. In a relatively novel approach, the design of experiments (DOE) method was employed to limit the number of simulations required, realizing significant savings in both labor cost and the time spent to arrive at a solution. Mold coat thickness and mold temperature were identified as the vital two parameters from a field of five potential factors nominated by experienced foundry personnel. It was determined that a thicker mold coat and a higher mold temperature would modify temperature profiles in the casting in such a way as to move the shrinkage porosity away from the critical location to less critical regions in a dispersed form. This solution would assume greater importance in applications where there is only a limited supply of feed metal either due to geometric constraints or due to a conscious effort aimed at increasing.

There are many investigations already have been done in the field of foundry related to porosity and shrinkage. This analysis leads to improvements in castings & reduction in defects.

3. EXPERIMENTAL PROCEDURES

3.1 Material –

Material from the same batch is used for all iterations done during the study of this topic. Aluminum Alloy AlSi7Mg0.3 (EN AC 42100 EN 1706) is used to carry out this study. Raw material chemical & mechanical properties are as given in Table 1 & Table 2.

Table-1 Chemical Composition

Material Grade		Chemical specification							
AlSi7Mg0.3 T6		Si	Fe	Cu	Mn	Mg	Ti	Zn	Al
	Spec %	6.5-7.5	0.19 max	0.05 max	0.10 max	0.25-0.45	0.08-0.25	0.07 max	Rest
	Value%	7.14	0.117	0.0034	0.0031	0.401	0.150	0.007	92.16

Table-2 Mechanical Properties

Material Grade		Mechanical specification			
AlSi7Mg0.3 T6		YS (Mpa)	UTS (Mpa)	EL % (Min)	HRB
	Spec	210 min	290 min	4%	90 min
	Value	280	311	7.18	95

3.2 Machinery-

Trail work during the investigation is performed on Low Pressure Die Casting Machine, General specifications of this machine given in Table 3.

Typical views of the component die and metallic core pin specification with section view are given below. Metallic core pin modified at an end to accommodate cooling arrangements of air & water.

S. No.	**Table-3** Machine Specification	
1	Movable die plate (mm)	800
2	Stationary die plate (mm)	800
3	Open / Shut height (mm)	600
4	Metal holding volume (kg)	500 Kg
5	Dimensions (LxWxH) (mm)	1000x1000x2600
6	Process Control	PLC
7	Ejection System	Top Ejection
8	Options	Part handling device. Die cooling device

Fig -1 View LPDC Machine

Fig -2 LPDC Bottom Die View with Metallic Core Pin

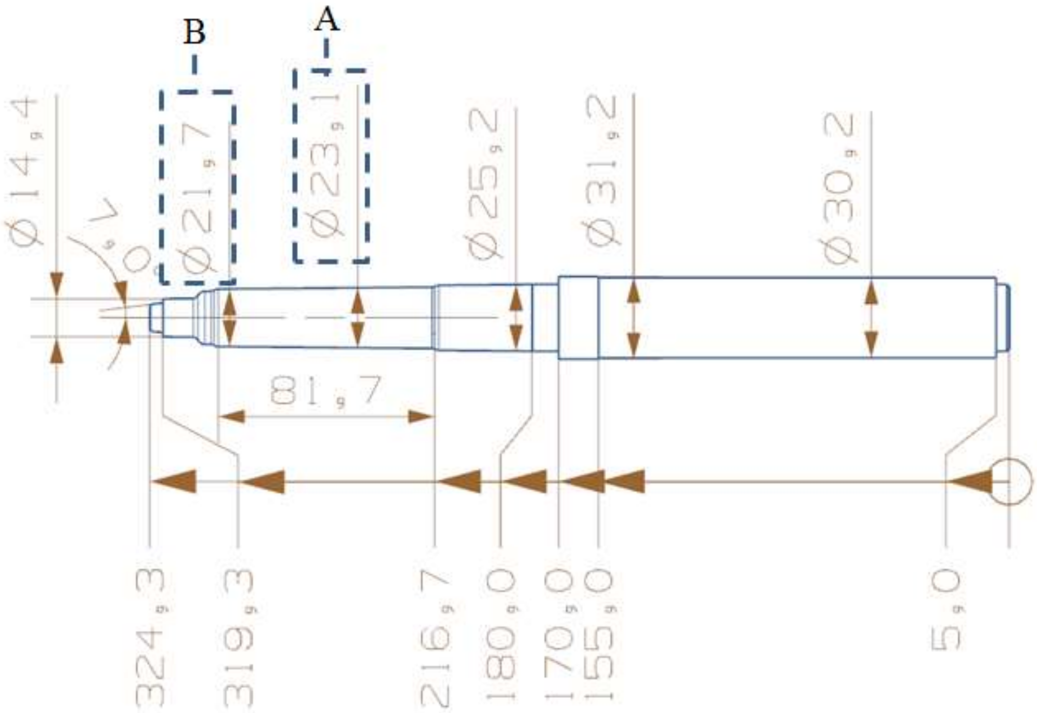

Fig -3 Metallic Core Pin Size

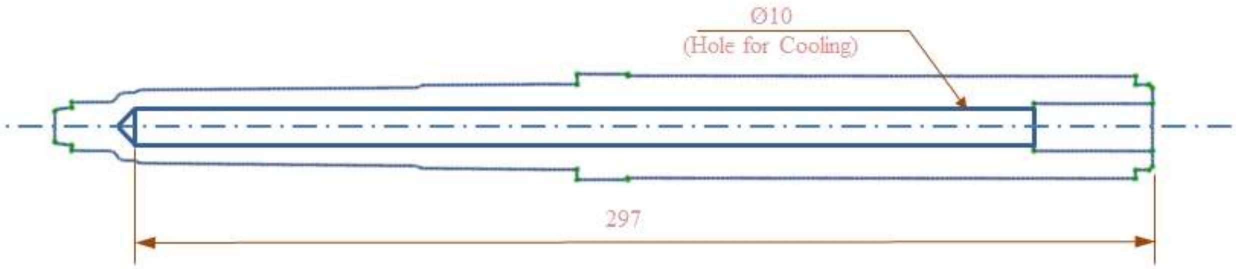

Fig -4 Metallic Core Pin Sectional view

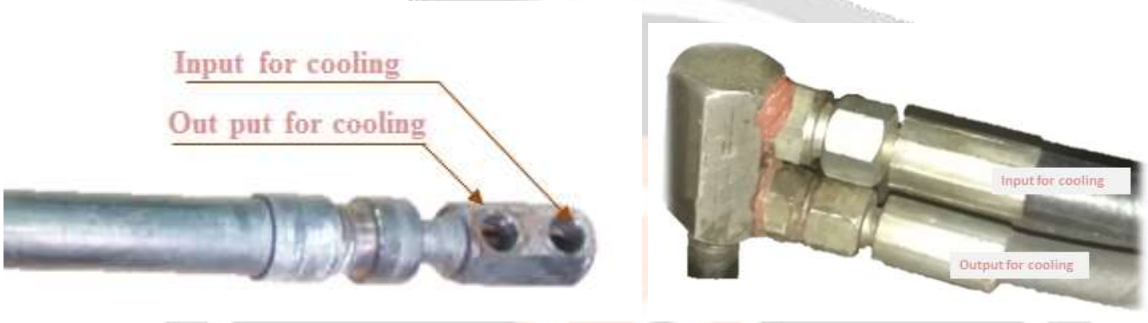

Fig -5 A&B Metallic Core Pin cooling Fitment view

3.3 Inspections Method –

Components study area is cylindrical, deep hole & Defects analysis with naked eyes very difficult. To ensure good visualization & detection of the defect in all function area of the component, Endoscopy is used. Endoscopy has a high resolution of 752x582 pixels. Porosity in component investigated based on comparative method. This is standard practice during the inspection of components in production. Evaluation of porosity/defects is carried out based on below acceptance criteria

a) Maximum dimension of a pore: 0.4mm
b) Minimum distance between the hole edges 6mm
c) Pores with max dimension of 0.2 mm are not considered
    -No exceptions are admitted

4. METHOD

Machining setup arranged as per process requirement and Metallic core pin is modified to accommodate air-water cooling equipment. To investigate further as per scope of the study, 3 trials have been performed by arrangements of natural cooling, air cooling, water cooling processes in hollow metallic core pin.

Total 12 casting per iteration were produced and machined in the machine shop for further analysis of results.

Process parameters followed during the study are given below in Table-4 and parameters other than the interest of study were kept constant.

Table-4 Experimental Parameters

Experiment No.	Metal Temp (C)	Feeding Time & Pressure	Solidification Time (Sec)	Bottom Die Block Temp (C)	Top Die Block Temp (C)	Core Pin Diameter AT (A)/(B)	Internal Hole in Core Pin for Cooling	Depth of Internal Hole in Core Pin	Type of Core Pin Cooling	Cooling Rate in Core Pin
1	710 (±10)	T1=10 Sec P1=150 mbar T2=30 Sec P2=280 mbar T3=60 Sec P3=320 mbar T4=110 Sec P4=320 mbar	60	420 (±10)	350 (±10)	Ø23.1 / Ø21.7	Ø10	297	Natural Cooling	N/A
2							Ø10	297	Air Cooling	3.5 to 4.5 Kg/cm2
3							Ø10	297	Water Cooling	3.5 to 5.5 LPM

5. RESULTS AND DISCUSSION

Trial-1 results are observed good as compared to trial 2 & 3, which have natural cooling in metallic core Pin and results of trials are given in Table-5 & chart-1.

Natural cooling shows good results during the study as compared to other trial air cooling and water cooling. Study zone in part is away from the gate and it is at end of part geometry. Solidification starts from study zone and natural cooling shows good results due to better solidification pattern.

Table-5 Parts Trial Report Summary

Acceptance criteria	Trial-1	Trial-2	Trial-3
OK	7	6	7
Upto 0.2	5	3	3
Above 0.2	0	3	2
REJECT (>0.4)	0	0	0
TOTAL	12	12	12

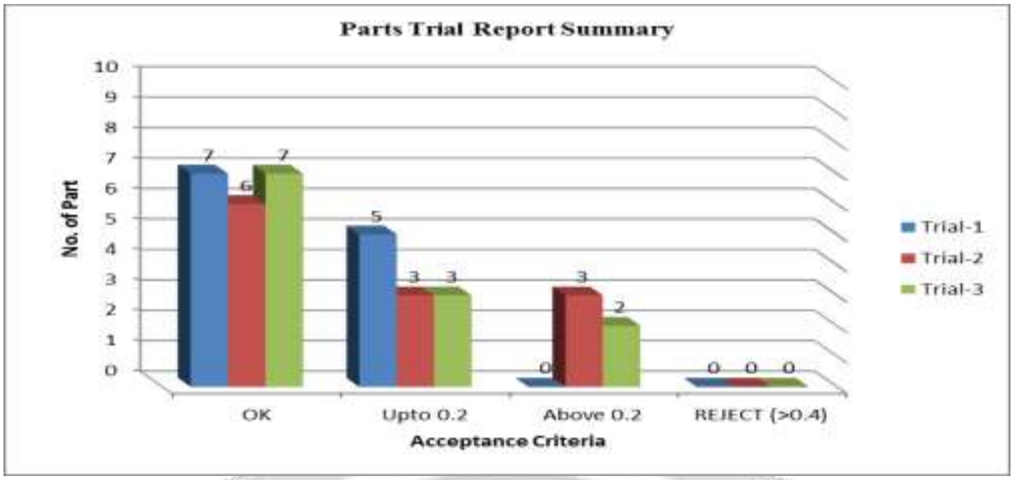

Chart -1: Parts Trial Report Summary

5. CONCLUSIONS

Casting defects can be reduced by improving directional solidification from the edge of casting and progress towards gating system in castings. When directional solidification is overlooked by progressive solidification defects are generated in casting. Casting defects also can be simulated with Computer Aided Casting Simulation Technique & can be reduced in the initial phase of development. It has been studied that natural cooling in metallic core pin of casting at the functional area of component shows good result due to better directional solidification. Porosity/shrinkage can be minimized by improving solidification pattern in casting processes and process parameters/condition can be obtained using the experimental analysis.

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