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Analysis of Gravity Die Casted Aluminium parts using MAGMA

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Abstract— The main objective of this paper is to determine casting defects generally happening in an aluminium die casting process and efforts have been taken to identify the tools which eliminate the casting defects. In global prospective this study briefs the application of the various tools that are used in the industries for improvement of quality in foundry industry. In our national prospective these tools are not so popular, hence this study will help us to utilise the available technology through which the productivity is enhanced with safe and economical means. The QC tools were used to analyse the casting condition of the given pattern with three dimensional simulations for the result preparation. This work has been carried out to improve the quality of the pattern which is made with gravity die casting process and this was achieved through continuous quality control operation with QC tools, then it was taken to test in some simulation software. The latest trend available in casting and foundry shops are the scientific approach in optimization of all kind of fields including optimization of defects in castings. These trends are incorporated in the analysis of aluminium die casting.

Keywords— Casting defects, Die, 7 QC Tools, Simulation Software, Ceramic filters

I. INTRODUCTION

Aluminium die casting is widely used for the possibility of obtaining component with complex geometry in high production rates. This method uses the molten metal to force at high pressure to prepare die. The mold cavity is created using hard tool steel. A disadvantage of this technology is that the inevitable presence of shrinkage cavities, often coupled with other defect: cold fills, alumina skins, dross and entrapped air bubbles[1].The influence of casting defects on the material properties of cast aluminium alloys has been investigated by a number of authors[1-5], with porosity being the most common defect encountered. Fatigue properties of cast aluminium components strongly depend on casting defects and microstructural characteristics. However, there are different opinions as to which are the critical microstructural characteristics [2].

Today in India most foundry industries are using the traditional system of working in which logics are restricted more to thumb rule approach rather than a more scientific approach by which the productivity can be increased in multi folds for a slightly higher price. The present study basically reveals the advantage of scientific approach over the traditional practice in these industries wherein there are more small scale players than the large scale manufacturers. The initial investment for the foundries with traditional approach is not so higher than other industries. For this study the part body maxum-II component has been considered, it is the control valve to regulate the flow of compressed dry air and steel balls/pallets in the shot blasting machine. This component is made of AL 356T6 material. The geometry of this component is asymmetrical shape with tapered projection on either side with a rectangular base. This component is being produced in gravity die casting process. There were quality issues in the form of casting defects.

Combining of all methods making use of image analysis, geometrical shapes coefficients and neural network will make it possible to achieve the better efficiency of class recognition of flaws developed in the material [3].In the most reviewed techniques, radioscopy is the accepted way for controlling the quality of aluminium die cast pieces through computer aided analysis of x- ray images. Since the contrast between the flaw and a defect free neighbourhood is distinctive, the detection is usually performed by thresholding this feature [4].

In aluminium die casting, the tools are exposed to erosion, corrosion and soldering due to the frequent contact of the tool surface to the casting alloy, to heat checking and gross checking due to thermal fatigue and to oxidation due to high pouring temperature [5]. If the alloys are subjected to cast process, large number o shrinkage porosities will be produced within its microstructure due to its long solidification range. Among the innovative and conventional foundry process for aluminium alloys, low pressure die casting is characterized by several advantages, including high yield, excellent control of operating parameters, good metallurgical and technological quality.

This study has been carried out to find the way to eliminate the casting defects and this has been achieved by analysing for proper positioning of runner and riser to exhaust the air from die cavity during pouring and uniform metal filling so that the casting defects due to the air is avoided and the pouring process like, free flow of materials through the passage of die cavity are studied.As well as study for modifying the gating design, runner/riser position, material composition and the component design were carried out. Finally for narrowing down the problem QC tools and simulation tools were used to improve the process for eliminating the rejection. The study has been carried out in foundries in Coimbatore where there are more small scale industries with low capital, who can leverage the advantages of this QC tools and simulation software.

II. PROBLEM DEFINITION

The dynamic test using QC tool and simulation software were run on standard specimen (Fig 1) casted in AL 356 T6 with gravity die casting technique. The casting result shows that the distribution of molten metal was uneven throughout the bottom portion of the specimen at the current riser position and defects were noticed at this portion. These defects might leads to rejection of the whole part. The top and bottom portions were seems good in quality.

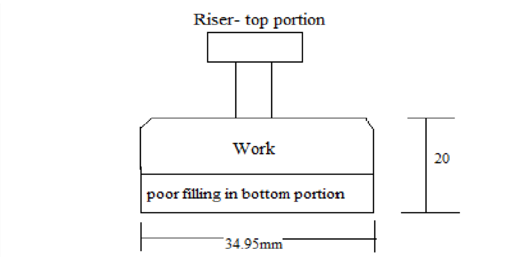


Fig 1 Geometry and dimensions of the standard specimen used in the study

The alloy is melted in oil fired furnace at 740 degree celcious, and then modified by adding Al-0%Sr master alloy to achieve the target strontium level of 0.02 wt%. The chemical and physical properties of the material Al 356T6 are listed in Table 1 and 2.

III. MATERIALS AND METHODOLOGY

Table 1 shows the chemical composition of the alloy used in the study. Reported values refer to several measurements taken on different specimens and production components. The percentage in weight of the different elements ~~is~~ falls within the standard chemical composition of the alloy (UNI EN 1706).

Table 1 Chemical composition of Al alloy (AL 356 T6) used in the study

Range	Alloys							
	Si	Cu	Fe	Mn	Mg	Zn	Sn	Ni
Min	6.97	0.002	0.086	0.003	0.381	0.006	0.001	0.004
Max	7.38	0.003	0.108	0.005	0.425	0.009	0.002	0.007

Table 2 shows physical properties like temper, tensile strength ~~and~~ Yield strength and elongation in %. The table reads the standard values of the given material Al356T6. The governing characteristics of the physical properties were measured and analyzed to satisfy its physical requirements.

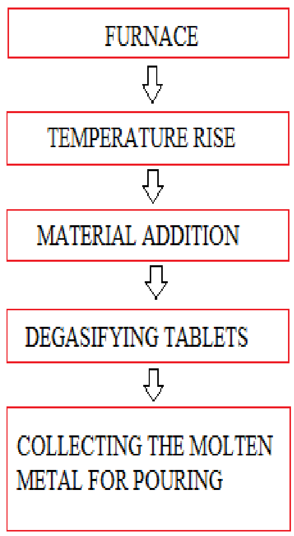
Table 2 Physical properties of the specimen

ANSI	Temper	Tensile stress	Yield stress	Elongation in percentage
356	T6	207	138	3

The die material was made up of spheroidal graphite iron which was specially used due to its pores nature that help the uniform spread of die coat for the easy ejection of the component from the mould.

Fig 2 shows the process chart of the metal preparation for the casting process that explains ~~its self~~ the melting process of the alloy metal.

Fig 3 shows the part production process in gravity die casting. In this process a permanent mould is used which was taken through some pre process like coating of internal surface of the die to ease the ejection process of the part solidified in the die. Molten material was carefully poured to ensure uniform distribution of molten metal in the casting part. Solidification is the important step which needs enough care in selecting the cooling time and temperature.



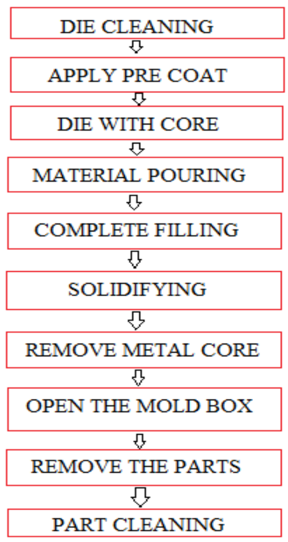


Fig 2 **Fig 3**

Fig 2 Process char for metal preparation

Fig 3 Process chart for part production

The equipments like Furnace, die and ladle were used for the study and the Die coat was mixed in correct proportion

Die temperature was ~~lifted~~ raised and maintained ~~to~~ at correct level. Appropriate safety clothing and apparatus were used. It was applied in correct sequence and in a safe manner according to standard operating procedures. It was correctly placed on the frame and fastened firmly to the frame and the Die was correctly located and closed. Then 'C 'clamps were attached and tightened to the required torque. Air cooling arrangement was made ready to cool the die and to maintain required temperature.

Molten metal was collected in the ladle and the pouring was done manually in such a way that Porosity and lamination are avoided. Conditions were identified that contribute to inferior castings to eliminate rejects. Die was allowed to cool for adequate time.

The c clamp was removed and tapping the ejector pin. ~~Whenever any sticking of material is noticed die avoid sticking~~. The die was cleaned for further pouring. The components were de-gated and the flashes were removed safely. The component is put for Shot blasting as per the standard operating procedures. Parts are removed and stored in a manner that minimizes damage.

The sample part is taken for Chemical analysis and remedial action were taken as required as per the standard operating procedures. Furnace was dossed and/or degassed to standard operating procedures after completion of the completing pouring process. Work area was cleaned and maintained for further pouring. The moulded parts were then taken for machining and subsequent finishing operation. The parts are then cleaned for any machining burrs or scraps. The parts are then packed as per the standard operating procedure and preserved for shipping to the customer.

Table 4 shows the various characteristics of gravity die casting and compared with other two processes - sand casting and pressure die casting

Table 3 Comparative methods in casting process

Si no	characteristics	gravity die casting	sand casting	Pressure die casting
1	pouring method	ladle/manual	ladle/manual/ automatic	coveyor/nozzle
2	Filling time	10-30s	10-30s	10-15s
3	Cycle time	1min	1min	30s
4	Mold temperature	High	High	Low
5	Dimensional accuracy	++	+	+++
6	Productivity	+	++	+++
7	Quality	+ +	+	+++
8	Cost	Low	Medium	High
9	Surface finishes	Good	Medium	Best
10	Core material	Metal core	Sand core	Metal core

IV. RESULTS AND DISCUSSION

The problem has been solved by considering two iterations; iteration 1 states the result of existing design without any modification and iteration 2 states the result of proposed modification to increase quality.

The potential cause that was identified using various QC tools was then confirmed with the help of simulation software (MAGMA). The simulation results are ~~attached~~ given below.

Fig 4 is shows ~~ing~~ the material composition of existing design which was analyzed through software.Fig.5 shows the casting properties of the existing design that include machine allowance, gates, cores, molds and feeders.

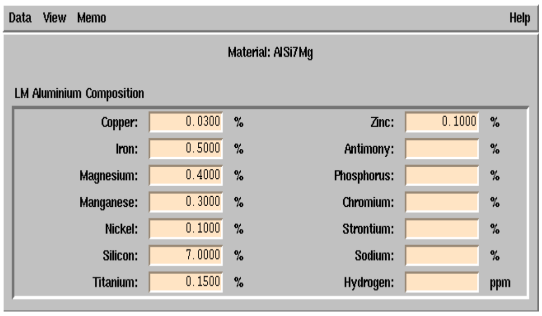


Fig.4 composition of existing design

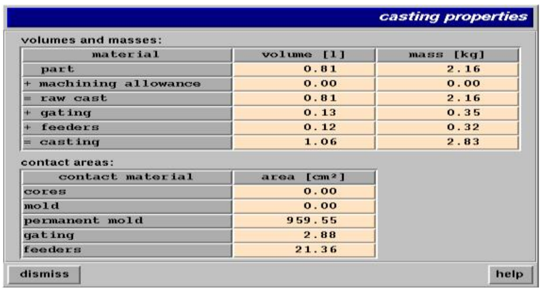


Fig.5 casting properties of existing design

Findings of iteration-1 during pouring and filling are shown in the fig.6 and fig.7. These figures state that no turbulence is noticed in the system were filling takes place. Only cold metal was filled in the risers that means a temperature drop of around 150 deg c from the pouring temperature was happened which was higher than solidus temperature.

Fig.7 shows the progressing of metal filling in the existing design which is helpful to find the temperature variation at the parts during metal filling.

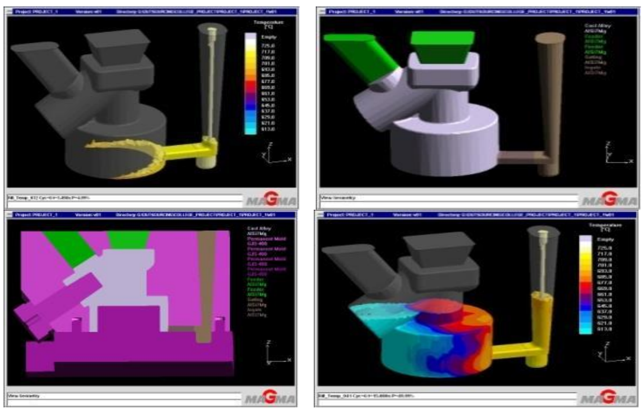


Fig.6 component, die, start of filling

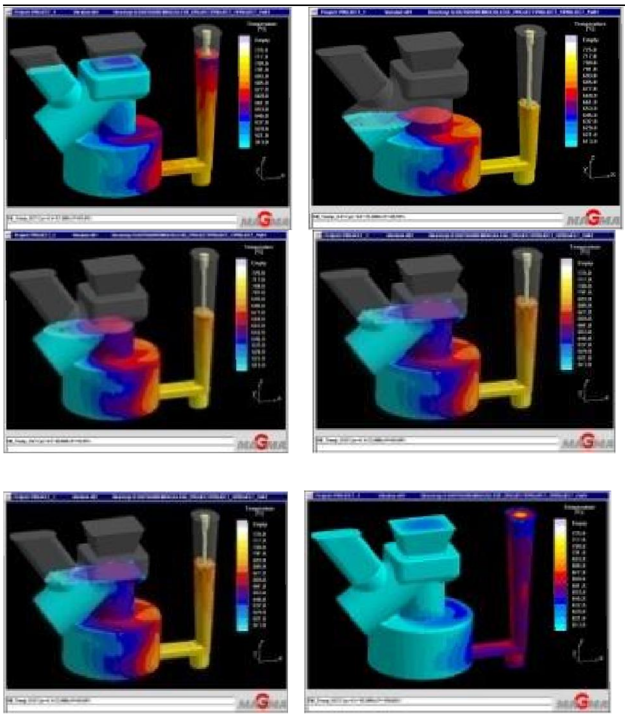


Fig.7 filling stages of molten metal

Iteration-2 with changes in feeder size and provision of chamfer in the negative stress area is shown in fig.8. It is very clear that a slight design variation has only been done in the existing design for the improvement.

Fig.8 is the modified design used to improve the properties and quality of the product

Fig.9 shows the material composition of the modified design which is similar to the existing composition.

Fig.10 is shows casting properties of the modified design in which area of feeder was increased slightly but the permanent mold area was reduced. In the new design the weight of the new design was slightly increased.

Fig.11 shows the filling of molten metal in mould cavity after modification of the design. From this it is evident that possible porosity location is outside the component area, riser area and hence so the increase in feeder size has eliminated the porosity problem.

Fig.12 shows the possible porosity location in the casted products. The available porosity is being at the unwanted surface of the product so the rejection is reduced.

Fig.13 shows the stress concentration in the pointed area were the stress was in negative area before modification but after the modification the stress is in positive side, which will avoid crack formation in the casting.

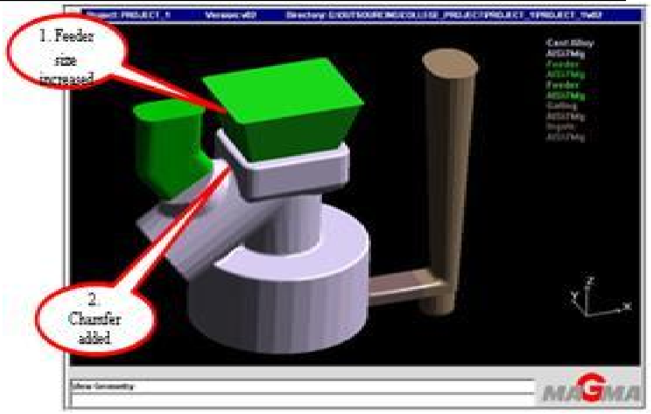
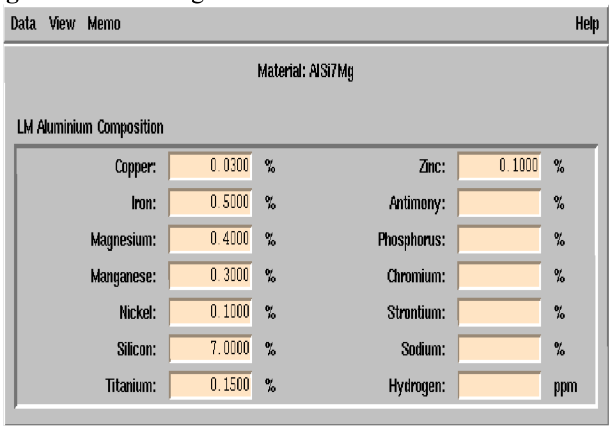


Fig.8 modified design



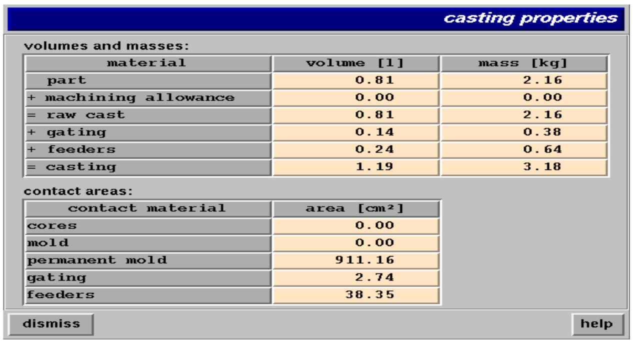
Data View Memo Help

Material: AlSi7Mg

LM Aluminium Composition

Copper:	0.0300	%	Zinc:	0.1000	%
Iron:	0.5000	%	Antimony:		%
Magnesium:	0.4000	%	Phosphorus:		%
Manganese:	0.3000	%	Chromium:		%
Nickel:	0.1000	%	Strontium:		%
Silicon:	7.0000	%	Sodium:		%
Titanium:	0.1500	%	Hydrogen:		ppm

Fig.9 composition of modified design



casting properties

volumes and masses:

material	volume [l]	mass [kg]
part	0.81	2.16
+ machining allowance	0.00	0.00
= raw cast	0.81	2.16
+ gating	0.14	0.38
+ feeders	0.24	0.64
= casting	1.19	3.18

contact areas:

contact material	area [cm²]
cores	0.00
mold	0.00
permanent mold	911.16
gating	2.74
feeders	38.35

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Fig.10 casting property of new design

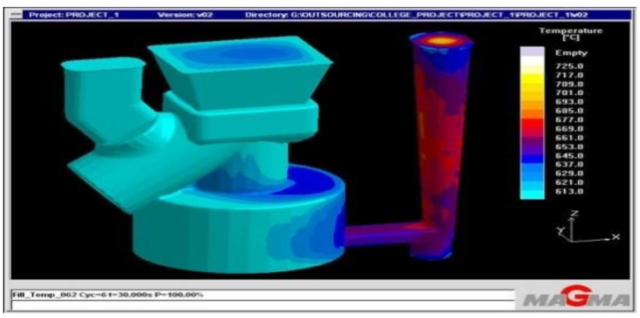

Fig.11 filling molten metal after modification

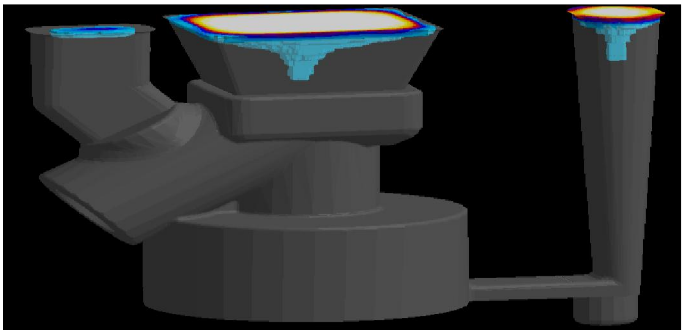

Fig.12 possible porosity location

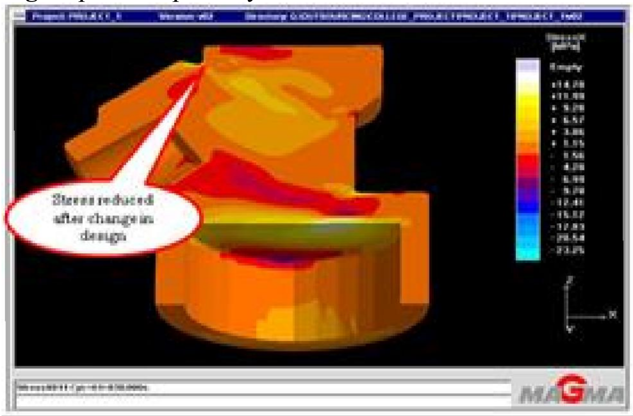

Fig.13 stress concentration in modified design

Table 4 shows the cost comparison of the traditional and simulation methods for problem solving.

Table 4 comparison of various cost

	~~Order/month in nos.~~ ~~Volume/annum in nos.~~ ~~Rate per piece in Rs.~~	~~300~~ ~~3600~~ ~~1125~~	
Sl no	Description	Traditional method	Software simulation method
1	Development period	2 months	15 days
2	rejection	25%	3%
3	Simulation cost	0	22, 000
4	loss due to trial & error (per unit-1125)	6, 75, 000	1, 68, 750
5	labour cost	5000	1000
6	Die modification cost	6000	2000
7	EB charges-development period(per unit-4)	600	100
	Total Cost	6, 86, 600	1, 93, 850

V.CONCLUSION

In gravity die casting of Aluminium parts, computer simulation can be a useful tool for rapid process development. Limitation of the conventional die design and gating design can be overcome. By this software simulation tool a real time simulation can be carried out which can help the industries to serve their customer in shortest lead time.

In today's scenario skilled workforce is in great demand, hence retaining them is very difficult. In such cases, this simulation software comes handy as the results delivered are close to the reality. Advantages of computer simulation based design has been established and the procedures arrived are described and have been demonstrated to the foundry with the application of MAGMA Soft simulation software.

This study strongly demonstrates that the foundries can derive mileage by resorting to finite element analysis simulations, usage of QC tools and by following the methods derived out the tools for casting process development, optimization of process, better productivity, and safe environment with minimum wastage and for the better society.

Since all the resource like, raw material, water, manpower, are becoming scarce, it is best suited for today's scenario to depend on this simulation softwares.

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