

Design & Analysis of HPDC Process for Aluminum Alloy ADC12

Mr. Pratik Pandey¹, Prof. Rameshwar V. Chavan²

¹M.Tech (Mechanical Engineering) Deogiri Institute of Engineering & Management Studies Aurangabad, Maharashtra, India.

²Assistant professor, Department of Mechanical Engineering, Deogiri Institute of Engineering & Management Studies Aurangabad, Maharashtra, India.

Abstract - This paper describes optimization of die design in high pressure die-casting (HPDC) of ADC12 alloy by experimental observation and numerical simulation with the use of statistical tools. The goal of this research is to determine the optimum die design to minimize incidence of these defects and thus maximize production of parts without defects. In HPDC, molten metal is injected into the die at high speed (40-60 m/s for aluminum alloys). Die design plays an important role on the rate of rejected parts. Therefore, flow patterns of molten metal in HPDC of an automotive component with very complex geometry were examined to determine the optimal die design.

Key Words: High pressure die-casting die, HPDC Design, HPDC Simulation, HPDC porosity issue, Cylinder head component.

1. INTRODUCTION

The high pressure die-cast process is used to produce parts from aluminum, magnesium, copper and zinc. Parts produced by this process conform accurately to the die size, have favorable mechanical features, and are low in cost. This process also enables production of parts with complex shapes. This production process thus has a wide range of applications and is used to make millions of parts in a variety of industries, including the aircraft and automobile industries and electrical appliance manufacture. Different parameters influence the production of the accepted parts which are produced by high-pressure die casting method the same as melt temperature, injection pressure, die temperature, the complexity of the parts shape, injection speed and so on. In this research the effect of die temperature on occurred defects in produced parts is investigated.

1.1 Cylinder Head Component

When a new part is designed for the first time, it may have a very complex shape depending on the design constraints. These constraints may be due to lack of space, the need for an aerodynamic shape, or a set of performance parameters. This is apparent in the parts examined in this research project, which relates to a new engine (BS-6) (CYLINDER HEAD COMPONENT).

Fig -1: Cylinder Head casting



The complexity of a part produced in the die-cast process is an important factor in its manufacture. Increased complexity can lead to an increase in the number and types of manufacturing defects. Die-cast design and parameters of the production conditions must therefore be optimized to minimize manufacturing defects. Runner position, location and number of overflows and form of cooling ducts are among the most important design parameters, and melting temperature, alloy composition and mold surface temperature are among the influential production parameters.

1.2 Material Considered

In this research the effect of die Flow condition on occurred defects in produced parts is investigated. Initial conditions for experiments were ADC12 material .Die Flow behaviour in high-pressure die casting is optimized by

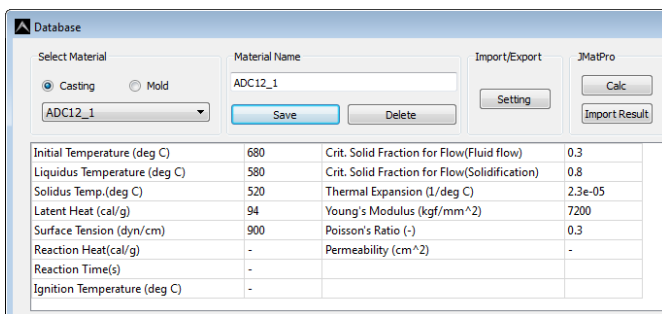


Fig -2: Cylinder Head casting

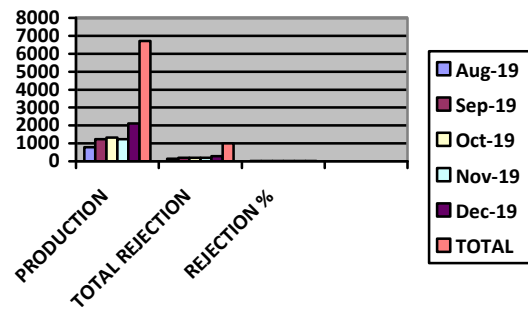


Chart -1: Rejection Data Six Month

experimental observation and numerical simulation. Cylinder head with a very complicated geometry was chosen as an experimental sample. Die temperatures at the initial step and the final filling positions were measured and the differences between these values were calculated. Statistical tools were used to facilitate interpretation of data from the die-cast experiments. ADSTEFAN software was used to simulate the fluid flow and solidification step of the part, and the results were verified by experimental measurements. Experimental test results and changes in the simulated model were used to obtain conditions for improving the quality of the manufactured parts.

2. Problem Identification

Due to the commencement of BS-6 norms, all the components having rapid development requirement. The below table of problem is been developed from six month data

Table -1: Problem Statement Table

Sr.No.	Type Of Problem	Measured Value
1	Shrinkage Porosity	Level-A(As per ASTM guide 0.348cm ³)
2	Air porosity	Diameter 0.06 pin hole observed in X-ray
3	Process cost increased	Due to defects many iteration to get acceptable casting(1min 40 Sec time loss observed)

Parts observed having shrinkage porosity and air porosity at various location due to the inappropriate filling condition, improper die temperature behavior.

Due to such type of defects in the casting overall production cycle is getting affected and reduce in overall targets for production observed. Such defects were more prominent when they will not get addressed properly by calculation tools or analysis.

Fig -3: Defects Picture of casting



Above picture of component is having impurity of porosity in sealing area which is happened due to improper filling of component and variable thickness regions having imbalance of temperature regions due to which solidification of various region cause shrinkage porosity defect.

3. Design Calculation

Table -2: Basic parameter consideration

Sr.No.	Details	Value
01	Projected Area	26237mm ²
02	Clamping Force	622.7T
03	Locking Force	623.44T

3.1 Gate Calculations.

$$\begin{aligned} \text{GATE THICKNESS} &= t/3. \\ &= 6/3. \\ &= 2.0 \text{ mm.} \\ \text{GATE VELOCITY} &= 60 \text{ m/sec.} \\ \text{FLOW RATE} &= \text{VOL. OF COMP.} \times 1000/60. \\ &= 237.93 \times 1000/60. \\ &= 3965.65 \text{ cm}^2/\text{sec.} \\ \text{GATE AREA} &= \text{flow rate} / 100 \times \text{gate velocity.} \end{aligned}$$

3.2 Runner

Table-3 Basic parameter consideration for material feed system

Sr.No.	Runner Area	Calculated value
01	Flow Area	1.8 cm ²
02	Runner Thickness	10mm
03	Overflow Depth	6mm
04	Overflow Width	12mm

3.3 Machine Parameter

Table-4 Basic parameter consideration for machine

Sr.No.	Detail	Value
01	MACHINE	630LK
02	HYDRAULIC PRESSURE	140 kgf/cm ²
03	Hydraulic cylinder diameter (Dn)	134.7 MM
04	Dry shot velocity (Vd)	6m/sec
05	Plunger Penetration	250 MM
06	Injection Stroke	600 MM

CASTING PARAMETER

INPUT
 CASTING WALL THICKNESS = 2.5 MM
 CASTING WEIGHT = 1696.98 gm
 WEIGHT OF OVERFLOW = 133.62 gm
 WEIGHT OF RUNNER = 576.18 gm
 BISCUIT THICKNESS = 23 MM
 NUMBER OF CAVITIES = 1
 ALLOY = ACD-12
 DENSITY = 2.5 g/cc

$$\text{WEIGHT OF BISCUIT} = \frac{\pi}{4} * \text{PLUNGER DIA METER}^2 * \text{BISCUIT THICKNESS}$$

$$= \frac{\pi}{4} * 80^2 * 23$$

$$= 288.9 \text{ gm}$$

SHOT WEIGHT = (CASTING WEIGHT + WEIGHT OF OVERFLOW) * NO.OF.CAVITIES + WEIGHT OF RUNNER + WEIGHT OF BISCUIT

$$\begin{aligned} &= (1696.98 + 133.62) * 1 + 576.18 + 288.9 \\ &= 2695.7 \text{ gm} \end{aligned}$$

DIE PARAMETER

FIX SIDE HOUSING = 230 MM

DIFFUSER PROJECTION = 25 mm

TARGET GATE VELOCITY = 45 m/sec

MIN. GATE VELOCITY = 25 m/sec

MAX. GATE VELOCITY = 40 m/sec

RUNNER RATIO WITH RESPECT TO GATE AREA = 1.5 times

EFFECTIVE SHOT SLEEVE LENGTH = (INJECTION STROKE - PLUNGER PENTRATION)

+ (FIX SIDE HOUSING - DIFFUSER PROJECTION)

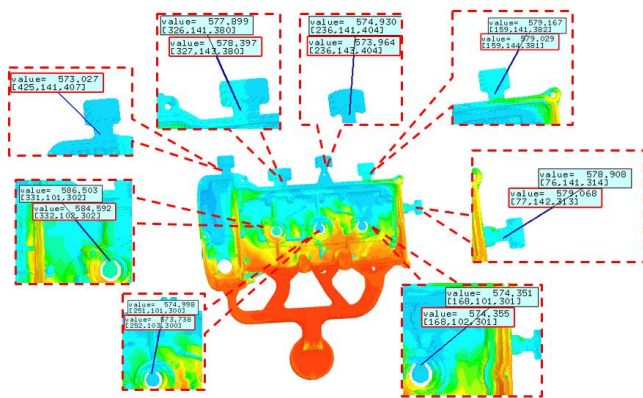
$$= (600 - 250) + (230 - 25)$$

$$= 555 \text{ mm}$$

4. Simulation Activity

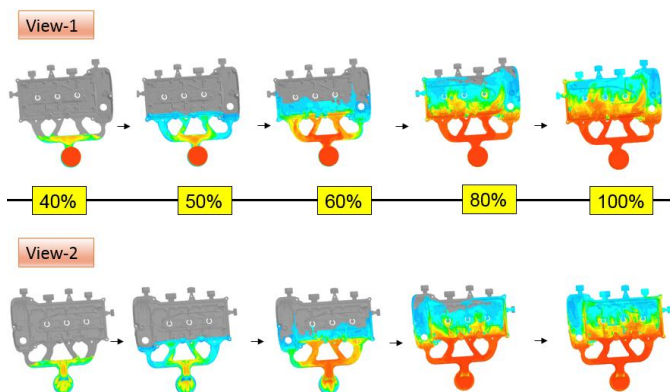
Adstefan is a physics-based computer program designed for the calculation of fluid flow, thermal and thermo mechanical phenomena encountered during the manufacture of metal castings, as well as the resulting microstructure features obtained in the cast components. A typical casting is produced by pouring liquid metal into a suitably prepared mold cavity containing the topology of the part to be manufactured. As a result of energy extraction through the mold walls, the liquid metal cools and solidifies, producing a consolidated metal part. The soundness and overall quality of cast metal parts is strongly influenced by the details of the liquid metal flow during mold filling and the time-dependent temperature field during solidification.

Fig -3: Thermal balancing Picture of casting



As shown above in the picture we have done the thermal balancing at all the critical profile of component. We have checked the end temperature of the casting which is coming nearby 590°C which is the liquidous temperature of aluminium alloy.

Fig -4: Flow results of casting



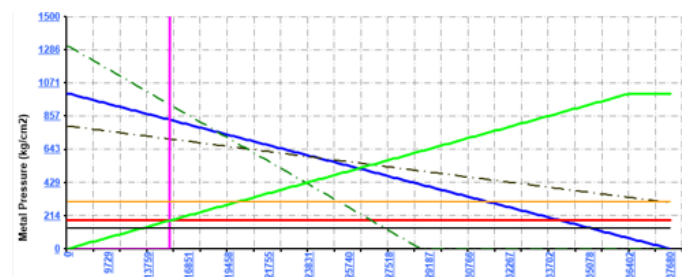
As we can see the flow results in Fig-4 is showing the aluminium flow in various percentage inside the cavity and approaching component in one end to other end manner. Flow always need to approach the component in

such manner that it fill fill component in uniform manner and component gating in such a manner that it should have to fill component profile in proper manner.

4.1 Pressure Discharge Graph PQ² (Static Tool used)

In highpressure diecasting always we need to balance the pressure with respect to discharge, which we can also call as PQ² chart where we are calculating all the material flow behaviour inside the die with respect to machine selected and by this calculation we can assure the consideration of machine is perfect for the desired component.

Fig -5: Pressure Discharge calculation graph



Above graph showing the the die can run in optimum second face velocity at 3.5m/s with the sleeve length of 510mm, there will be column of machine capacity is still available to put more pressure and velocity if required.

Always we have to design the die for the optimum performance of machine where we can get advantage to address the stringent casting requirement.

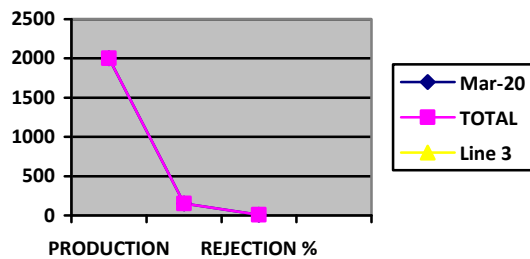
5. Comparison

As per our earlier observation of similar casting there was subsequent location of defects which we have treated with proper placement of runner gating location and positions of overflow to maintain the thermal balancing of die.

Fig -5: Rejection data for march 2020

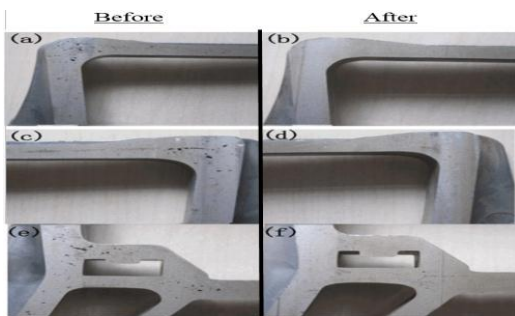
MONT H	PRODUCTIO N	TOTAL REJECTIO N	PERCENTAG E OF REJECTION
March 2020	2000	152	7.58
TOTAL	2000	152	7.52

Chart -2: Rejection Data March Month 2020



We have simulated the calculated result in ADSTEFAN Software and found the Thermal balancing is good enough to maintain aluminum in liquid stage and there is good material approach is observed to component profile so as to fill the component properly.

Fig -5: Pressure Discharge calculation graph



As shown in chart 2 there is rejection decreased to 7.5% from 15% and which is desirable as per NADCA guidelines.

It is also compared in Fig-5 regarding the different cross section of casting having problem earlier and now there is no problem as such.

6. CONCLUSIONS

- 1- Experiments showed that die temperature of 180°C and pouring temperature of 685°C and 690°C are optimal with respect to die quality.
- 2- Over flow location are good to entrap all oxidized material, as well the size of overflow is sufficient enough to take oxidized material out from die.. Die temperatures were shown to have an effect on number of defects.
- 3- Type 1 was the most frequent defect type when die temperature was below 200 °C. Defect types 1 and 2 were more frequent when the die temperature was above 200 °C. The optimum die temperature to minimize defects was 190-205 °C.

- 4- Metal Temperature to be above 700°C in furnaces so that after ambient temperature loss also it should reach the flow requirement of aluminum alloy. There is no visual and structural defects observed after verse so the casting production is regularized.

REFERENCES

- [1] W. Kurz and D.J. Fisher. Fundamentals of Solidification. Switzerland: Trans Tech Pub., 4th edition, 1998.
- [2] J.W. Gibbs, H.A. Bumstead, and W.R. Longley. The Collected Works of J. Willard Gibbs. Longmans, Green and Co, 1928.
- [3] J.D. Van der Waals. Translation of J. D. van der Waals' [3]"The thermodynamic theory of capillarity under the hypothesis of a continuous variation of density". Journal of Statistical Physics, 20(2):200-244, 1979
- [4] J.W. Cahn and J.E. Hilliard. Free energy of a no uniform system. I. Interfacial free energy. The Journal of Chemical Physics, 28:258, 1958.
- [5] J.W. Cahn. Free energy of a no uniform system. II. Thermodynamic basis. The Journal of Chemical Physics, 30:1121, 1959.
- [6] J.W. Cahn and J.E. Hilliard. Free energy of a no uniform system. III. Nucleation in a two component incompressible fluid. The Journal of Chemical Physics, 31:688, 1959.
- [7] D.W. Oxtoby and R. Evans. Nonclassical nucleation theory for the gas-liquid transition. The Journal of Chemical Physics, 89:7521, 1988.
- [8] D.W. Oxtoby. Density functional methods in the statistical mechanics of materials. Annual Review of Materials Research, 32(1):39-52, 2002.
- [9] S.F. Jones, G.M. Evans, and K.P. Galvin. Bubble nucleation from gas cavities a review. Advances in colloid and interface science, 80(1):27-50, 1999.
- [10] E.N. Harvey, W.D. McElroy, and AH Whiteley. On cavity formation in water. Journal of Applied Physics, 18:162, 1947.
- [11] R.A. Outlaw, D.T. Peterson, and F.A. Schmidt. Hydrogen partitioning in pure cast aluminum as determined by dynamic evolution rate measurements. Metallurgical and Materials Transactions A, 12(10):1809-1816, 1981.
- [12] J. Campbell. Castings. Butterworth-Heinemann, 2003.
- [13] R.B. Dean. The formation of bubbles. Journal of Applied Physics, 15:446, 1944.