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Design and Analysis of High Pressure Die Casting Die for Gear Box Cover

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Abstract—This paper discribes the design and analysis of High Pressure Die Casting Die foran automobile component engine gear box cover . Design equations are analytically derived for initial calculations of the main dimensions such as tonnage capacity, shot weight,gate design, runnerdesign, overflow and venting design.Furthermore, a comprehensive static finite element method analysis on the Bottom Blosterof a die for finding the stresses and deflection. The factor safety was found to be 8.7.

Index Terms—High Pressure Die casting Die, ADC-12, Shot weight, Gating, Runner, Overflow, Venting, BottomBloster

1 INTRODUCTION

High pressure die casting, often shortened to Pressure Die Casting, is a repetitive process where identical parts are cast at high production rates by injecting molten metal under pressure into a metal die. High pressure die casting is ideally suited to high production rates, and wall thickness can be as little as 1-2.5mm.

This paper includes various design variables in HPDC die of a two wheeler gear box and static finite element method analysis on the Bottom Blosterof a die for finding the stresses and deflection.

2 DESIGN PROCESES

2.1 Methadology

The design specifications of HPDC die comprises tonnage capacity of a machine, shot-weight,gate design, runnerdesign, overflow and venting design.Generally components from HPDC die Al,Cu,Zn.As per requirement of the customer the component is made by ADC-12.

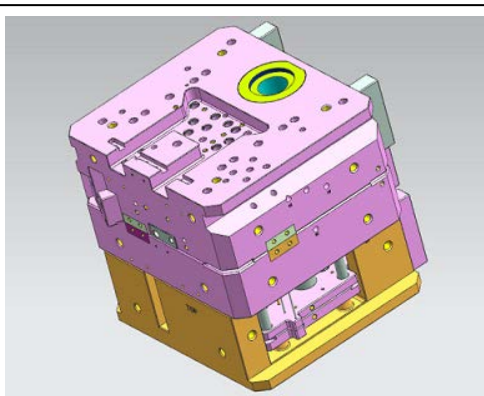

Fig. 1. Design of Proposed HPDC

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Material: Aluminium alloy ADC-12
Density: 2820 Kg/m3
Composition:
Silicon 11.3%,Iron 1.3%,Copper 2.5%,Manganese 0.5%, Magnesium 0.3%,Nickel 0.5%,Zinc 1.0%,Tin 0.3%,Al Balance.
Mechanical Properties:
Melting temp 620 ^oC,Tensile strength 331 MPa,
Density 2.82 gm/cm^3,Heat capacity 0.963 J/g ^ok,Thermal conductivity : 92 watt/m ^ok

2.3 Tonnage Capacity of a Machine

1. Weight of the component = 2.61 kg
2. Over flows and Runners weight = 1.044 kg(40% of compo nent weight)
3. Total Weight (m) = 2.61+ 1.044 = 3.654 kg = 3654 gm
4. Density of the metal ADC12 (d_1)= 2.82 gm/cm^3
5. Volume of the component (Vt) = m/d_1= 3654/2.82 = 1295.744 cm^3 = 1295744 mm^3
6. Minimum wall thickness of the component = 2.8mm
7. Injection pressure = 800 kg /cm^2= 8 kg/mm^2
8.Projected area of the component = 59500 mm^2.
9.Runners and over flows projected area = 20160 mm^2(40% of the component projected area)
10. Total projected area = Projected area of the component + Runners and over flows projected area = 59500+ 20160 = 77350 mm^2.
11. Total force acting on the die = Total projected area × Injec tion pressure = (77350 × 8)/1000 = 618 Tons
12. Locking force require =F × 1.2=618 × 1.2=741 tons

According to the locking tonnage calculations and availability of machine we select the 938T machine which can exert the clamping force of 938 Tons

2.4 Shot Weight Calculation

1. Weight of the component = 2.61 kg
2. Over flows and Runners weight = 1.044kg (40% of component weight)
3. Total Weight (m) = 2.61+ 1.044 = 3.654 kg = 3654 gm
4. Density of the metal ADC12 (d_1)= 2.82 gm/cm^3
5. Total volume of the component (V_t) = m/d_1= 3654/2.82 = 1295.744 cm^3 = 1295744 mm^3
6. Actual shot volume = Vt + biscuit volume= Vt + $(\pi/4)d_2^2h$
Where h = biscuit thickness, d_2= diameter of plunger

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7. Effective stroke length = $L - h$
   Where Stroke length for machine is (L)=350mm,Biscuit thickness (h)=50 mm = 350 – 50=300 mm
8. Assume fill ratio (f) =75 % [HMT Details]
9. Volume delivered by machine $= \pi\, d_2^2 \times (L/4) \times f$
10. Actual shot volume = Volume delivered by machine
   $V_t + (\pi/4) d_2^2 h = \pi d_2^2 \times (L/4) \times f$ 1295744 $+ \pi/4 \times d_2^2 \times 50$
   $= \pi d_2^2 \times (300/4) \times 0.75$
   $d_2^2 = 9426.70$
   $d_2 = 97.09$ mm
11. Plunger diameter = 100 mm
12. Actual Shot volume = $V_t + (\pi/4)\, d_2^2 h$
   $= 1295744 + (\pi/4) \times 97^2 \times 50$
   $= 16.652 \times 10^5$ mm^3
13. Shot weight = Shot volume × density(gm/mm3)
   $= 16.652 \times 10^5 \times (2.82 \times 10^{-3})$
   = 4695 gm = 4.695 kg

2.5 Gating Design

1. Gate thickness (tg) = 0.8 × min wall thickness of casting
   = 0.8 ×3 = 2.4mm
2. Fill rate= (volume of cavity & overflow)/fill time(from standards) = 1295744/0.10 = 129.574×10^5 mm^3/s
3. Gate area (Ag) = Fill rate /gate velocity
   $= (129.574 \times 10^5)/41757.6 = 310.30$ mm^2
4. Gate length(Lg)=Total area of the gate (Ag)/ gate thickness (tg) = 310.300/2.4 =130 mm
5. Land (L_1)= 0.8 to 2.0 mm ,lelecting land L_1 as 2.0mm

2.6 Runner Design

1. Runner area (Ar) =2.1×Gate area × number of cavities
= 2.1 ×310.300 ×1 = 651.63 mm^2
2. Width of runner (W) = (Area of runner)$^{1/2}$ = (651.63)$^{1/2}$
   = 25.52 mm
3. Depth of runner = W/1.8 {width = (1.6 to 1.8) ×Depth}
   (1.8 is selected)= 25.52/1.8= 14.17 mm

2.7 Overflow Design

Overflow Area = 0.5 × Gate area = 0.5 × 310.30 = 155 mm^2.

2.8 Venting Design

Venting area = 30 to 50% of gate area (30% is selected)
= 310.300 × 0.30 = 93.09 mm^2

3 Analysis and Results

Die casting dies are exposed to very high mechanical loading but they are only allowed elastic deformation. since these dies are expected to produce parts that meet the demand for high precision, it is evident, therefore that any deformation of the bottom bloster affect the final dimension of a part as well as shrinkage of the material being cast during the cooling stage. Besides this, undue deformation of bottom bloster can result in undesirable interference with casting process. Thus the rigidity of the moving bolster determines the quality of the castings as well as reliable operation of the dies and the maximum deflection allowable in the bottom bloster is 0.2mm .

Stresses in high pressure casting dies are caused due to two main reasons, they are

1. Load caused by closing mechanism of the machine
2. Thermal stresses due to temperature of the molten aluminium alloy.

This chapter describes stress analysis of moving bolster,finite element analysis is used to calculate the expected maximum deflection for computed structural loads.

3.1 Deformation due to Von mises stresses

Inputs for von mises stresses

Material of die frame	Cast iron
Compressive yield strength	8.27×10^8 N/m^2
Tensile yield strength	2.76×10^8 N/m^2
Modulus of elasticity	1.24×10^{11} N/m^2
Density	7.2×10^3 kg/m^3
Poison`s ratio	0.29
Locking force on the die	938 Tons

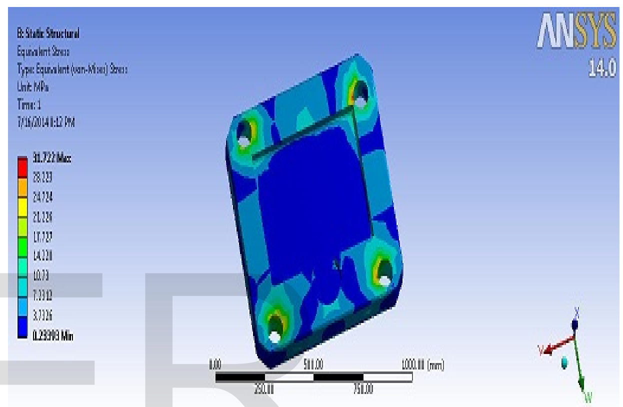

Fig. 2. Von mises stress in Bottom Bloster

Output from analysis

Max von mises stresses in bottom bloster= 31.722Mpa
$= 31.72 \times 10^6$ N/m^2
Min von mises stresses in bottom bloster=0.233 Mpa
$= 0.233 \times 10^6$ N/m^2
Factor of safety $= 2.76 \times 10^8 / 31.72 \times 10^6 = 8.7$

3.2 Deformation due to Von mises stresses and Thermal stresses in Bottom Bloster

Inputs for von mises stresses and Thermal stresses

Material of die frame	Cast iron
Compressive yield strength	8.27×10^8 N/m^2
Tensile yield strength	2.76×10^8 N/m^2
Modulus of elasticity	1.24×10^{11} N/m^2
Density	7.2×10^3 kg/m^3
Poison`s ratio	0.29
Locking force on the die	938 Tons
Die temperature	200 ^oC

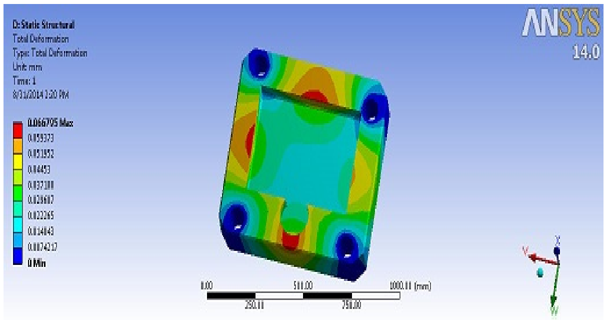

Fig. 3.Deformation due Von mises Stresses and Thermal stresses

Output from analysis
Max. Deformation obtained in the frame = 0.06 mm
Min. Deformation obtained in the frame = 0 mm

Results on the foregoing analysis of the die frame it is observed that

1. Max von mises stress obtained is 31.72×10^6 N/m^2 which is with in yield strength of the material of 2.76×10^8 N/m^2.The factor safety found to be 8.7.
2. Max Deflection Obtained is 0.06mm due to von mises stresses and thermal stresses.
3. Above deflection is within the limit of 0.2mm.Hence the design is safe.

4 Mould Trail

5 From the analysis report the following input parameters were set in the injection moulding machine for trial of die.

TABLE 1
PROCESSING PARAMETERS IN TRAIL T_1

TRAIL NO:T_1					
No. Cavities : 01 Raw material : ADC12 Tonnage applied : 938T Component weight : 2.61kg					
	Process Parameters	**Time** (sec)			
1	Die cleaning time	8.4	10	Shot Volume	16.65mm^3
2	Lubrication time	6.6	11	Shot Weight	4.695kg
3	Mould closing time	12.4	12	Plunger Velocity	4.2 m/sec
4	Pouring Time	9.2	13	Intensification Pressure	800 kg/cm^2
5	Injection time	7.3	14	Temperature of crucible	600 ^{0}c
6	Dwell time	28.4	15	Filling plunger velocity	4.5 m/sec
7	Mould opening time	9.5	16	Die temperature	200 ^{0}c
8	Extraction time	8.6	17	Total weight of the HPDC Die	3.0T
9	Total Cycle Time	90.4			

Observations:
1. Shot volume =16.65 mm^3
2. Intensification pressure = 800 kg/cm^2
3. Total cycle time = 90.4 sec

Trial T_1 was successfully done and the components were obtained without any defects. Hence, T_1 values are fixed for mass production. These components are inspected as per the component drawing provided by the customer.

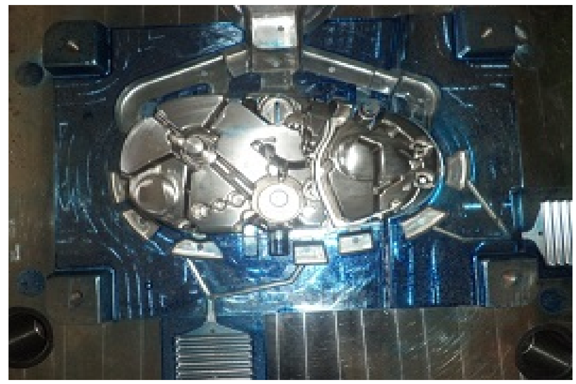

Fig. 4. HPDC Die during Trail1

Fig. 1. Engine Gear box Cover after Trail1

6 CONCLUSION

The High pressure die casting die was designed, analyzed and manufactured. Stress in the die due to injection pressure and locking force of the machine was analyzed using ANSYS 14.0 and the design was proved to be safe.

From the thesis the following conclusions were arrived
1. Manufacturing HPDC die was done according to customer requirement.
2. Stress due to Injection pressure and locking force in the Bottom bloster
• Max stresses obtained is 31.72×10^6 N/m^2 ,which is with in yield strength of the material of 2.76×10^8 N/m^2 and the

factor of safety is 8.7

3. Deflection in Bottom Bloster

• Max Deflection Obtained is 0.06mm due to von mises stresses and thermal stresses. which is in the limit of 0.2mm

• Max Deflection is within the limits. Hence design is safe

4. Total cycle time obtained from trail T_1 is 90.2sec.

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