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

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Abstract—This paper describes the design and analysis of High Pressure Die Casting Die for an 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, runner design, overflow and venting design. Furthermore, a comprehensive static finite element method analysis on the Bottom Bloster of 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, Bottom Bloster

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 Bloster of a die for finding the stresses and deflection.

2 DESIGN PROCESSES

2.1 Methodology

The design specifications of HPDC die comprises tonnage capacity of a machine, shot-weight, gate design, runner design, 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.

2.2 Material Study

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 °C
- Tensile strength 331 MPa
- Density 2.82 gm/cm3
- Heat capacity 0.963 J/g °K
- Thermal conductivity : 92 watt/m °K

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 component weight)
3. Total Weight (m) = 2.61 + 1.044 = 3.654 kg = 3654 gm
4. Density of the metal ADC12 (d1)= 2.82 gm/cm3
5. Volume of the component (Vt) = m/d1= 3654/2.82 = 1295.744 cm3 = 1295744 mm3
6. Minimum wall thickness of the component = 2.8mm
7. Injection pressure = 800 kg/cm2 = 8 kg/mm2
8. Projected area of the component = 59500 mm2
9. Runners and over flows projected area = 20160 mm2 (40% of the component projected area)
10. Total projected area = Projected area of the component + Runners and over flows projected area = 59500 + 20160 = 77350 mm2
11. Total force acting on the die = Total projected area × Injection 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 = 1.044 kg (40% of component weight)
3. Total Weight (m) = 2.61 + 1.044 = 3.654 kg = 3654 gm
4. Density of the metal ADC12 (d1)= 2.82 gm/cm3
5. Volume of the component (Vt) = m/d1= 3654/2.82 = 1295.744 cm3 = 1295744 mm3
6. Actual shot volume = Vt + biscuit volume = Vt + (π /4)d2h

Where h = biscuit thickness, d2 = diameter of plunger
7. Effective stroke length = L - h
   Where Stroke length for machine is (L) = 350 mm, Biscuit thickness (h) = 50 mm = 350 - 50 = 300 mm
8. Assume fill ratio (f) = 75 % [HMT Details]
9. Volume delivered by machine = \( \pi d^2 \times \frac{(L/4)}{f} \)
10. Actual shot volume = Volume delivered by machine = \( V_t + \left( \pi d^2 \times \frac{(L/4)}{f} \right) \times 50 \)
    = \( \pi d^2 \times (300/4) \times 0.75 \)
    \( d^2 = 9426.70 \)
    \( d = 97.09 \) mm
11. Plunger diameter = 100 mm
12. Actual Shot volume = \( V_t + \left( \pi d^2 \times \frac{(L/4)}{f} \right) \times 50 \)
    = \( \pi d^2 \times (300/4) \times 0.75 \)
    \( d^2 = 9426.70 \)
    \( d = 97.09 \) mm
13. Shot weight = Shot volume \times 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 \times \text{min wall thickness of casting}
   = 0.8 \times 3 = 2.4 \text{mm}
2. Fill rate = (volume of cavity & overflow)/fill time (from standards) = 1295744/0.10 = 129.574 \times 10^5 \text{mm}^3/s
3. Gate area (Ag) = Fill rate / gate velocity
   = \( 129.574 \times 10^5 \div 41757.6 = 310.30 \) mm²
4. Gate length (Lg) = Total area of the gate (Ag) / gate thickness (tg) = 310.300/2.4 = 130 mm
5. Land (L1) = 0.8 to 2.0 mm, selecting Land L1 as 2.0 mm

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

2.7 Overflow Design
Overflow Area = 0.5 \times \text{Gate area} = 0.5 \times 310.30 = 155 \text{mm}².

2.8 Venting Design
Venting area = 30 to 50\% of gate area (30\% is selected)
    = 310.30 \times 0.30 = 93.09 \text{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 bolster 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 bolster 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 bolster is 0.2 mm.

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 aluminum 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 \times 10^8 \text{N/m}²
Tensile yield strength 2.76 \times 10^8 \text{N/m}²
Modulus of elasticity 1.24 \times 10^{11} \text{N/m}²
Density 7.2 \times 10^3 \text{kg/m}³
Poison’s ratio 0.29
Locking force on the die 938 Tons

Output from analysis
Max von mises stresses in bottom bolster= 31.722Mpa
=31.72 \times 10^6 \text{N/m}²
Min von mises stresses in bottom bolster=0.233 Mpa
= 0.233 \times 10^6 \text{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 \times 10^8 \text{N/m}²
Tensile yield strength 2.76 \times 10^8 \text{N/m}²
Modulus of elasticity 1.24 \times 10^{11} \text{N/m}²
Density 7.2 \times 10^3 \text{kg/m}³
Poison’s ratio 0.29
Locking force on the die 938 Tons
Die temperature 200 °C
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 $31.72 \times 10^6$ N/m² which is within yield strength of the material of $2.76 \times 10^8$ N/m². The factor safety found to be 8.7.
2. Max Deflection Obtained is 0.06 mm due to von mises stresses and thermal stresses.
3. Above deflection is within the limit of 0.2 mm. Hence the design is safe.

4 MOULD TRAIL

5 FROM THE ANALYSIS REPORT THE FOLLOWING INPUT PARAMETERS WERE SET IN THE INJECTION

TABLE 1
PROCESSING PARAMETERS IN TRAIL T1

<table>
<thead>
<tr>
<th>TRAIL NO:T1</th>
<th>No. Cavities : 01 Raw material : ADC12 Tonnage applied : 938T Component weight : 2.61kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Parameters</td>
<td>Time (sec)</td>
</tr>
<tr>
<td>1 Die cleaning time</td>
<td>8.4</td>
</tr>
<tr>
<td>2 Lubrication time</td>
<td>6.6</td>
</tr>
<tr>
<td>3 Mould closing time</td>
<td>12.4</td>
</tr>
<tr>
<td>4 Pouring Time</td>
<td>9.2</td>
</tr>
<tr>
<td>5 Injection time</td>
<td>7.3</td>
</tr>
<tr>
<td>6 Dwell time</td>
<td>28.4</td>
</tr>
<tr>
<td>7 Mould opening time</td>
<td>9.5</td>
</tr>
<tr>
<td>8 Extraction time</td>
<td>8.6</td>
</tr>
<tr>
<td>9 Total Cycle Time</td>
<td>90.4</td>
</tr>
</tbody>
</table>

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 $31.72 \times 10^6$ N/m², which is within yield strength of the material of $2.76 \times 10^8$ N/m², 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 T1 is 90.2sec.

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REFERENCES