Design and manufacturing of complex moulds for powder injection moulding

Industrial Engineer

Miguel Angel Enríquez Baranda
Final Project of Industrial Engineer
Design and manufacturing of complex moulds for powder injection moulding

PIM TECHNOLOGY

PROCESS

- Feedstock Elaboration → Powder + Binder → Pellets
- Injection Moulding
- Debinding → Solvent or Thermal
- Sintering
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INJECTION MOULDING MACHINE

INJECTION MACHINE

- Hydraulic System
- Control System
- Screw
- Barrel
- Hoper
- Supports

Mould tool ➔ Plates
- Fix
- Mobile
- Ejectors

1. Index
2. PIM technology
3. Moulding machine
4. Mould design
5. Moulded Parts
6. Mould Cost
7. Conclusions
8. Questions
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FIXED SUPPORT

MOBILE SUPPORT

FIXED PLATE

MOBILE PLATE

EJECTOR
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PLATES AND SUPPORTS ASSEMBLY

FIXED PLATE  MOBILE PLATE

DISPOSITION
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TOTAL ASSEMBLY
MOULD DESIGN

DESIGN PROCESS

► Part Dimensions

► Cavity Location ➔ Part geometry

➔ Blank mould availability

► Nozzle

CONIC NOZZLE

HOT RUNNER
Runner System

Circular  Trapezoidal  Semi-Circular

SECTION

LOCATION
Ejection System

PART EXTRACTION

EJECTORS CUT

\[ L = (12 + 12.10 + 45.10) - L_{RUNNER} - L_{COLDTRAP} \]
Cold Trap ➔ Improves part homogeneity

**DIMENSIONS**

\[ L_{\text{Cold Trap}} = 1.5 \times D_{\text{runner}} \]

- **Main Runner**
  - Semi-Circular
  - \( \Phi = 4 \text{ mm} \)
- **Cold Trap**
  - \( \Phi = 4 \text{ mm} \)
  - \( L = 6 \text{ mm} \)
- **Ejector Hole**
  - \( \Phi = 3 \text{ mm} \)
- **Toroid Section**
- **Flow Direction**

Source: J.P. Beaumont *Runner and Gating Handbook*
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Vents ➔ Remove compressed gases (air)

LOCATION: Last area to fill

Source: J.P. Beaumont Runner and Gating Handbook
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 Heating System  Improves injection process

ELECTRICAL HEATER

WATER HEATER
MOULDS

DESIGNED

Toroid
Flat Specimen
Dog-Bone Specimen
Microstep

MANUFACTURED

Toroid
Double Cavity
Switch Valve
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TOROID

- Magnetic properties characterisation (Fe-Si 2.7%)
- Feedstocks
  - ADVANCED METALWORKING PRACTICES
  - HES-SO VALAIS

GREEN PART

SINTERED PART

PART FILL
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DOG - BONE

- Testing mechanical properties
- Feedstocks: Aluminium oxide ($Al_2O_3$ - 99%)
  ➞ INMATEC

PART FILL

GREEN PART
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FLAT SPECIMEN

- Testing mechanical properties
- Feedstocks: Aluminium oxide ($Al_2O_3 - 99\%$)

→ INMATEC

**Switch over point = 2.9 cm³
Volume = 0.95 cm³**

PART FILL

GREEN PART
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MOULD COSTING METHODS

Rhode Island University (RI)
Boothroyd. Dewhurst and Knight (BDK)

HES-SO Valais

Source: Randall M. German PIM: Design and Applications
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HES-SO VALAIS TOOL COSTING METHOD

TOTAL COST = MATERIALS + LABOUR + (ACCESORIES)

MATERIALS = PLATES + EJECTORS
  ➔ PLATES = MOBILE + FIX + EJECTOR
  ➔ EJECTORS = n° x C unit

LABOUR = C unit x Manufacturing time

MANUFACTURING TIME = SETUP + FIX-MOBILE + EJECTOR
  ➔ SETUP = Machine preparation
  ➔ FIX MOBILE = Base Time + Complexity
    Base: Basic holes and chamfer
    Complexity: Xp (perimeter, length, width)
    Historical time manufacturing - Interpolation
    \[ X_p = \left( \frac{P}{L} \right) \cdot \left( \frac{P}{W} \right) \]
    \[ t_{COMPLEXITY} = 4.05 + \frac{X_p}{107.51} \]
  ➔ EJECTOR = Base Time + Complexity
    Base: Basic holes and chamfer
    Complexity: Number of holes x drilling time
COMPARISON METHOD RESULTS

<table>
<thead>
<tr>
<th>MOULD / METHOD</th>
<th>RHODE ISLAND</th>
<th>B.D.K.</th>
<th>HES-SO VALAIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOROID</td>
<td>CHF 1.830</td>
<td>CHF 2.886</td>
<td>CHF 1.864</td>
</tr>
<tr>
<td>DOUBLE CAVITY</td>
<td>CHF 2.418</td>
<td>CHF 1.741</td>
<td>CHF 2.463</td>
</tr>
</tbody>
</table>

RHODE ISLAND ≈ HES-SO VALAIS

B.D.K. ➔ Sensitive small width variations
        ➔ Consider number of parts moulded
CONCLUSIONS AND PERSPECTIVES

➤ Five moulds designed ➔ Two manufactured and tested
➤ Ferromagnetic toroids moulding OK
➤ Double cavity mould with switch valve OK
➤ Cost method compared ➔ Usefully to create HES-SO method

➤ Microstep mould
➤ Heating system ➔ Room temperature not enough
➤ Hot nozzle
QUESTIONS TIME

Thank you for your time
FLOW ENTRANCE

Flow Direction  Main Runner
Φ = 4 mm
SPRUES

<table>
<thead>
<tr>
<th>Submarine or Tunnel Gate</th>
<th>Pinpoint or Restricted Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of 0.049-0.060 inch (1.25-1.524 mm)</td>
<td>Diameter of 0.064-0.070 inch (1.625-1.778 mm), or 10% of wall thickness</td>
</tr>
<tr>
<td>An edge gate located below the parting line or moulded surface</td>
<td>A restricted opening between the runner and moulded part. Normally used with thin wall parts.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fan or Edge Gate</th>
<th>Tab Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter normal ( \approx 1/8 )</td>
<td>Safe from welds</td>
</tr>
<tr>
<td>A common gate located in the sidewall of the part to prevent restriction of resin flow. Normally used with multi-cavity, two-platen moulds.</td>
<td>Used for most orientation when a large volume is needed for mould fill. The tab helps avoid surface splatter due to high shear, direct gating, or ejection.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sprue Gate</th>
<th>Flash Gate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A long, shallow, rectangular edge gate</td>
</tr>
<tr>
<td>Recommended for single cavity moulds requiring symmetrical filling (usually used with circular parts)</td>
<td></td>
</tr>
</tbody>
</table>
### MOULD MATERIAL

<table>
<thead>
<tr>
<th>Material No.</th>
<th>Code</th>
<th>AVIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>M01-001</td>
<td>XGOD156</td>
<td>450 F9</td>
</tr>
</tbody>
</table>

#### Chemical composition (mass analysis, %)

<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>Cr</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25–0.35</td>
<td>+1.00</td>
<td>+1.40</td>
<td>+0.20</td>
</tr>
<tr>
<td>0.25–0.35</td>
<td>0.25</td>
<td>1.50</td>
<td>1.50-17.0</td>
</tr>
</tbody>
</table>

#### Physical properties

- **Morsing hardness**: 250 – 300 HB
- **Achimotive hardness**: 62-65 HRC
- **Tensile strength 80,500 MPa**
- **Density**: 1.99 g/cm³

#### Characteristics

- Plastic mold steel
- Good resistibility to wear and erosion, high hardness and good wearability

#### Applications

- Used in injection molding processes for components where high wear resistance is required.

#### Heat treatment

<table>
<thead>
<tr>
<th>Process</th>
<th>Temperature</th>
<th>Cooling medium</th>
<th>Hardness after heat treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moulding</td>
<td>850 – 900°C</td>
<td>Oil</td>
<td>350 HB</td>
</tr>
<tr>
<td>Hardening</td>
<td>850 – 1000°C</td>
<td>Water</td>
<td>500 HRC</td>
</tr>
<tr>
<td>Tempering</td>
<td>600 – 650°C</td>
<td>Oil</td>
<td>300 HRC</td>
</tr>
</tbody>
</table>

#### Mould Design

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#### Mould Material

- MOULD MATERIAL

#### Moulded Parts

- Moulded Parts

#### Mould Cost

- Mould Cost

#### Conclusions

- Conclusions

#### Questions

- Questions