RESEARCH PROJECT

High Pressure Die Casting Defects and Simulation Process by Computer Added Engineering (CAE)

ME8109 – CASTING AND SOLIDIFICATION OF MATERIALS

Presented by: Irshad Ali (Student # 500482510) Dated: 29th February, 2012
1. Introduction of High Pressure Die Casting.

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   - Sub-surface Defects.

   - Introduction.
   - Modeling of the casting process.
   - Simulation of the casting process system.
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   - Solidification process simulation.
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Introduction of High Pressure Die Casting:

High pressure die casting is a manufacturing process in which molten metal is injected with a die casting machine under force using considerable pressure into a steel mold or die to form products.

HPDC provide:

• Excellent dimensional accuracy.

• The smooth surfaces of Product.

• Casted parts require no machining except the removal of flash around the edge and possible drilling and tapping holes.

• High pressure die casting production is fast and inexpensive relative to other casting processes.
Introduction of High Pressure Die Casting:

**Process Cycle of High Pressure Die Casting:**

- Molten metal into the shot sleeve.
- Plunger movement.
- Rapid die filling.
  (The steel die Pressurized hydraulically by the plunger).
- The die is opened.
- The casting is ejected.
- Spray die lubricant.

**High pressure die casting Mechanism:**
Introduction of High Pressure Die Casting:

Product Application of HPDC:

• Transportation Industry (Specially Automotive), Electronic Industry, Medical equipments, Consumer Industry, Telecommunication Industry, Instrumentation and Tools (Hand & Power)

High pressure die casting Products:
High Pressure Die Casting Defects:

Depending on the location of the casting defects, they can be divided into two major categories, namely “Surface” and “Subsurface” defects.

Surface Defects:

- Surface defects are occurring on the surface or near to the surface (exposed to surface) of the castings.
- Surface defects in high pressure die castings can result from deficiencies at any stage of the manufacturing process.

A. Flash:

The occurrence of molten material seeping out of the mold cavity and solidifying.
B. **Unfilled sections (Misrun):**
This is usually caused by the metal solidifying before it fills the cavity.
- The metal was too cold.
- It could be too small a sprue, gate.
- Insufficient shot volume.
- Slow injection.
- Low pouring temperature.

C. **Hot Tearing:**
A part defect, sometimes called hot cracking, which describes cracks that result from shrinkage. If a part is not allowed to shrink freely and encounters an obstruction, the solidified material will crack. The main causes of problems are Non-uniform cooling rate.
Sub-surface Defects:
Sub-surface defects are not visible to the naked eye due to their occurrence below the surface of the castings.

A. Non-metallic inclusions:
Inclusions occur as varying types with differing sizes and shapes.
• Aluminum oxides are of different crystallographic or amorphous forms as films, flakes, and agglomerated particles.
• Magnesium oxide is typically present as fine particulate.
• Spinals can be small hard nodules or large complex shapes.
• Refractory and other exogenous inclusions may be identified by their appearance and composition.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Types observed</th>
<th>Potential source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonmetallic exogenous</td>
<td>Various refractory particles, Al₄C₃, etc.</td>
<td>Refractory degradation, remelt ingot, refractory/metal reactions</td>
</tr>
<tr>
<td>Nonmetallic in situ</td>
<td>MgO, Al₂O₃ films, clusters, and dispersoids; MgAl₂O₄ films and clusters</td>
<td>Melting, alloying: metal transfer turbulence</td>
</tr>
<tr>
<td>Homogeneous halide salts</td>
<td>MgCl₂-NaCl-CaCl₂, etc.</td>
<td>Poor separation of fluxing reaction products</td>
</tr>
<tr>
<td>Particle/salt</td>
<td>MgCl₂-NaCl-CaCl₂/MgO, etc.</td>
<td>Salt generated during chlorine fluxing of magnesium-containing alloys, filter and metal-handling system releases</td>
</tr>
</tbody>
</table>
High Pressure Die Casting Defects:

B. Shrinkage and Porosity defects:
Porosity and Shrinkage is the formation of voids inside the castings either through the entrapment of gas, improper pressure configuration in HPDC machines and Improper Solidification of material.

The problem can be divided into three major types:

- **Gas porosity:**
The gas porosity is the porosity in casting due to the presence of gas.

- **Shrinkage porosity:**
The shrinkage porosity is due to shrinking of metal, so that the metal loses volume and hence more metal is required to fill the gaps (voids) produced.

- **Flow porosity:**
Melt related porosity formation because hydrogen entrapment in HPDC is not a big problem. Hydrogen can be considered seriously if the scrap is re-melted.
Simulation in High Pressure Die Casting Process

Product development paradigm appears to be more heuristic and experience-based than deep scientific simulation, evaluation, analysis, and calculation. It is thus time-consuming, error-proof, and needs a lot of experimental tryout and verification in the workshop for ‘proof-of-concept’.

**Simulation helps to determine:**

- Process routing and process parameter configuration.

- Verify the die design based on the revealed flow behavior and solidification phenomena.

- The filling and solidification behavior related to product quality and defect forming mechanism.

- Physical basis and useful information for product quality improvement and defect avoidance.
**Simulation in High Pressure Die Casting Process**

**Modeling of the casting process:**
Modeling will represent the casting processes by models from physical and mathematical perspectives.

![Diagram showing the association among process, modeling, simulation, and output variables.](Figure 2)
Simulation in High Pressure Die Casting Process

Simulation of the casting process system:
The following Figure presents a process-based simulation framework for prediction of casting defects.

Figure 3. The process-based simulation paradigm for prediction of casting defects.
Behavior and information revealed via CAE simulation:
CAE simulation of the entire casting system reveals filling and solidification behavior in the casting process and identifies the necessary information related to product quality and defect formation.

➤ **Filling process simulation:**
- Melt-front positions, turbulence in the melt movement and filling smoothness.
- Filling sequence in the casting and determination of overflow and venting locations.

➤ **Solidification process simulation:**
- The last solidification area and the location of ingate.
- Solidification sequence and the temperature distribution in the casting and die.
- Shrinkage and porosity distribution in the casting.

➤ **Stress analysis in casting:**
- Distortion of the casting and Die stress analysis and thermal deformation prediction
- Optimized casting system design such as feeding system design.
Behavior and information revealed via CAE simulation:
CAE simulation of the entire casting system reveals filling and solidification behavior in the casting process and identifies the necessary information related to product quality and defect formation.

The layout of the casting filling system
The design of the overflow is in such a way that the two overflow locations are located at the last filling places.
**Simulation Parameters Setup:**

- The cast material is AlSi9Cu3; a widely-used die cast material.
- The die material is X38CrMoV5.
- The CAE simulation is Magmasoft.
- The pouring temperature of the melt is 670°C.
- The liquidus and solidus temperatures are 578°C and 479°C.
- All the die components have an initial temperature of 150°C.
- Five cycles of simulation are conducted to reach a stable condition.
Finding of Simulation Process:

- The melt-front advancement position in filling process.
- Unreasonable filling pattern and the defect caused.
  (a) Simulation predicted irrational flow
  (b) The real defect revealed by experiment.

The two melt streams push the air into the centre of the flange and finally there is air entrapment in the centre of the flange. Since there is no efficient venting mechanism and the entrapment air blocks the melt flow.
Finding of Simulation Process:

- solidification result of predicted by CAE simulation

- It shows the hottest area and thus it is the last solidification area in the cast.

- This would mean that there is no melt feeding for the last solidification area when it is solidified.

- When the melt is fully solidified, the volume contraction from liquid to solid occurs.

- To void this uneven temperature distribution in the solidification process, a better designed cooling system is needed.

Defect caused by the unreasonable temperature distribution in the solidification process. (a) Simulation result; (b) real part
The simulation-enabled casting quality prediction and defect evaluation.

Reduces trial-and-error in the workshop as the process is virtually realized and verified by computer.

Quality issue can be pinpointed and the related solutions can be proposed.
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18. E. Rooy, The Use of Molten Metal Filters to Eliminate Air Pollution and Improve Melt Quality, AFS Trans., 1968