Magnesium research activities

Tsinghua-TOYO research center of Mg & Al alloys processing technology

Tsinghua University

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Outline

- Background
- Research Progress
- Ongoing Research Work
Magnesium alloys

- Strength/ weight ratio
- Excellent damping capacity
- Non-magnetic, EMF shielding
- Good heat dissipation
- High castability
- Excellent machinability
- Longer tooling life
WORLD ANNUAL PRIMARY MAGNESIUM PRODUCTION, BY COUNTRY, 2001

China: 48%
Canada: 20%
Norway: 8%
Russia: 11%
Israel: 7%
France: 4%
Brazil: 1%
Kasakhstan: 1%
Serbia and Montenegro: 1%

Total: 425,800 tons

Primary Magnesium Production of China

Data from Chinese Magnesium Association, 2003
U.S. Structural Applications of Magnesium Alloys, 2001

Western World Distribution and Demand for Magnesium

Year 2000
Demand Base 408,000 tonnes

- Magnesium Die-Casting (32%)
- Aluminium Alloying (45%)
- Other (10%)
- Iron/Steel (13%)

Year 2010
Demand Base 925,000 tonnes (estimated)

- Magnesium Die-Casting (64%)
- Aluminium Alloying (24%)
- Other (4%)
- Iron/Steel (8%)

Source: Estimates calculated from projections in Automotive Demand from IMA/Hydro Magnesium
Challenges for Magnesium Die Casting Process

- Design expertise & process development
- Corrosion protection of Mg components
- High temperature properties
Tsinghua-TOYO R&D Center of Magnesium and Aluminum Alloys Processing Technology

- Jointly Established with TOYO Machinery & Metal Co., Ltd
- Equipped with a set of 650-ton automatic Mg. and Al. alloys die-casting machine, Mg. and Al. melting furnaces, die temperature controller, vacuum system, and data logging system for cavity pressure and die temperature measurement
Research Contents

- Process development of Magnesium Die Casting Process for Automobile Components
- Die Casting Magnesium Alloys
- Melt protection technology
- Surface protection technology of Magnesium die casting components
First Magnesium Component for FAW (Cylinder head cover)

300 Hongqi cars were installed the magnesium cylinder head cover (AZ91D) for test running in Dec. 2002, and now the component is in normal production for all Hongqi Cars.
Casting structure & Die Design

- Heating channel
- Cooling channel
- Casting
Experimental Design

- Low Speed Injection (LSI) stage;
- High Speed Injection (HSI) stage;
- Start position of HSI stage;
- Casting pressure;
- Biscuit thickness;
- Pouring temperature;
- Shot sleeve temperature;
- Die temperature;
- 54 schemes for AZ91D alloy and 12 schemes for A356 alloy
Schematic diagram of the parameters for the LSI stage

<table>
<thead>
<tr>
<th>Speed Level</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.1 m/s</td>
</tr>
<tr>
<td>II</td>
<td>0.2 m/s</td>
</tr>
<tr>
<td>III</td>
<td>0.4 m/s</td>
</tr>
<tr>
<td>IV</td>
<td>0-0.4 m/s</td>
</tr>
<tr>
<td>V</td>
<td>0-0.2-0.4 m/s</td>
</tr>
</tbody>
</table>

Position of the liquid metal across the separating cone
Positions for Pressure Measurement and Test Samples

P1-Runner, P2, P3-Casting, P4-Overflow.
Evaluation of the Castings

- External quality
- X-ray examination
- Mechanical Properties
- Density
- Microstructure
Influences of different processing conditions on the quality and properties of the castings

<table>
<thead>
<tr>
<th>Process parameters</th>
<th>Quality Index</th>
<th>Surface quality</th>
<th>Tensile strength</th>
<th>Density</th>
<th>Gas porosity</th>
<th>Gas holes &amp; Shrinkage porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSI velocity ↑</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>HSI velocity ↑</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Position from LSI to HIS ↑</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Casting Pressure ↑</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Position of PI ↑</td>
<td>U</td>
<td>O</td>
<td>U</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Accelerated LSI ↑</td>
<td>U</td>
<td>U</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>U</td>
</tr>
<tr>
<td>Time of PI ↑</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Biscuit Thickness ↑</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>U</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>DST</td>
<td>X</td>
<td>X</td>
<td>U</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>DPT</td>
<td>X</td>
<td>X</td>
<td>U</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Cavity Pressure Profiles

- $P_F$ — Maximum filling pressure
- $P_{TP}$ — Maximum transferred pressure of the Intensification pressure to the casting
- $t_{TP}$ — Holding time of the transferred pressure

Cavity pressure of position P3 under different casting pressure
Influences of cavity pressure variables on quality of castings

Influence of mold filling pressure on surface quality

Influence of cavity pressure and holding time on density of castings

Influence of cavity pressure on tensile strength
Die casting process of a cold chamber die casting machine
Mold filling simulation
Thermal balance analysis
Thermal stress analysis of dies

Before die open

After die open

Stress value
1.59 D+06
1.43 D+06
1.27 D+06
1.11 D+06
9.54 D+05
7.96 D+05
6.38 D+05
4.80 D+05
3.22 D+05
1.64 D+05
6.17 D+03

Stress value
8.84 D+05
7.98 D+05
7.08 D+05
6.20 D+05
5.32 D+05
4.44 D+05
3.55 D+05
2.87 D+05
1.79 D+05
9.14 D+04
3.34 D+03
Deformation of dies

Before die open

After die open

Final deformation of the die
Numerical simulation of low speed injection stage and Optimization

Three phases of metal flow in die casting process

- Shot sleeve
- Gating system
- Casting
The metal flow and gas entrapment in the shot sleeve were simulated under different velocities, the results show that there exists a critical value for the LSI velocity.
Gas entrapment in shot sleeve under constant LSI velocities
Constant LSI velocity
Optimum injection scheme

Velocity, m/s

Optimum scheme

Piston position, mm

④
Simulation LSI stage-Accelerated scheme

Velocity, m/s

Piston position, mm
Gas entrapment in shot sleeve under accelerated LSI velocities
Accelerated LSI velocity
Optimum injection scheme
Ongoing research work

- Systematically study the influences of process parameters on the quality, microstructure, and mechanical properties of magnesium die castings
- Experimental study on vacuum die casting, ultra low speed die casting of magnesium alloys
- Die casting magnesium alloys
Gas content for various processes

(Data from *High Integrity Die Casting Processes* by Edward J. Vinarcik, 2003)
Step shape die
Vacuum die casting process

- Vacuum technology for mg die casting process
- Influence of vacuum parameters on quality of mg die castings
- Materials castability and properties by vacuum die casting process
- Heat treatment properties of vacuum die cast parts
Local intensification pressure technology

- Effects of local intensification pressure on the cast parts
- Design consideration for local intensification pressure technology
Mechanical properties
Summary

- Progress in experimental studies and numerical simulation of Mg die casting process
- Ongoing research work include: high vacuum die casting process, ultra low speed die casting process, die casting magnesium alloys and melt protection technology
Thanks for your attention!

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