Evaluation of Bubblers and Baffles for Cooling of Die Casting Dies

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Introduction

Background:

 HttpHeaders:  

 Thermal fatigue cracking of die inserts is a constant problem in die casting industry.  

 High temperature of die surface is the most frequent cause of thermal fatigue cracking, because it promotes higher thermal stress and accelerates softening.  

 A temperature threshold exists, below which the thermal fatigue damage is minimal.  

 Bubblers and baffles are typical water cooling devices for die inserts, slides and cores.
**Effect of Overheating to H13 Die Steel**

- Specimen: Ø1”×0.5”, Premium Grade H13 Steel, quenched and tempered to 46 HRC.

<table>
<thead>
<tr>
<th>Time (hours)</th>
<th>1000 °F</th>
<th>1050 °F</th>
<th>1100 °F</th>
<th>1150 °F</th>
<th>1200 °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour</td>
<td>No.1</td>
<td>No.5</td>
<td>No.9</td>
<td>No.13</td>
<td>No.17</td>
</tr>
<tr>
<td>10 hours</td>
<td>No.2</td>
<td>No.6</td>
<td>No.10</td>
<td>No.14</td>
<td>No.18</td>
</tr>
<tr>
<td>50 hours</td>
<td>No.3</td>
<td>No.7</td>
<td>No.11</td>
<td>No.15</td>
<td>No.19 (15h)</td>
</tr>
<tr>
<td>100 hours</td>
<td>No.4</td>
<td>No.8</td>
<td>No.12</td>
<td>No.16</td>
<td>No.20 (20h)</td>
</tr>
</tbody>
</table>
• Discussion: Critical temperature is between \(1050^\circ F\) and \(1100^\circ F\). If the die insert surface temperature can be kept below \(1050^\circ F\), the service life of the die insert will be prolonged.
The Effect of Temperature on Thermal Fatigue Cracking
Different Immersion Times

The Effect of Immersion Time

15,000 cycles

Total Crack Area $[\times 10^6 \text{ m}^2]$
The Effect of Thermal Cycling on Thermal Fatigue Cracking
Different Immersion Times

The Effect of Immersion Time

Total Crack Area \([x \times 10^6 \text{ m}^2]\)

Number of Cycles

- 5 sec
- 7 sec
- 9 sec
- 12 sec

all below 0.2

5000 10000 15000
The Effect of Temperature on Thermal Fatigue Cracking
Different Cooling Line Diameters

The Effect of Cooling Line Diameter

Temperature [F]

Total Crack Area [x10^6 m^2]

15,000 cycles
Illustration of Bubblers and Baffles Used in the Experiment
Schematic of Water Flows Directed by Bubbler and Baffle

- Water Flow Directed by Bubbler
- Water Flow Directed by Baffle
Geometry Details of Bubbler Cooled Specimen

A-A Section

Bubbler

Gap Between Bubbler and Specimen

Specimen

Bottom T/C

1.5” OD

9/16” ID

0.2”

0.06”

1”
<table>
<thead>
<tr>
<th>Geometry Details of Bubbler Cooled Specimen (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Diameter of Bubbler [inch]</td>
</tr>
<tr>
<td>Outer Diameter of Bubbler [inch]</td>
</tr>
<tr>
<td>Wall Thickness of Bubbler [inch]</td>
</tr>
<tr>
<td>Inner Section Area of Bubbler [inch^2]</td>
</tr>
<tr>
<td>Bubbler/Specimen Gap [inch]</td>
</tr>
<tr>
<td>Bubbler/Specimen Annular Area [inch^2]</td>
</tr>
</tbody>
</table>
Geometry Details of Baffle Cooled Specimen

Specimen

Baffle

Controlled Gap Size

A-A Section

\[ \phi 1.5'' \]

\[ \phi \frac{9}{16}'' \]
Cooling Efficiency Evaluation of Bubblers and Baffles in Molten Aluminum

Dip In-Dip Out Experimental Setup

Furnace

Molten A356: 1350 °F (600lb)

Specimen
(Cycle time: 25s in/25s out)

Water Inlet

Water Outlet

Flow Meter

Thermocouple
The Specimen Used in Dip In- Dip Out Experiment
Data Processing for Dip In-Dip Out Experiment

\[ \bar{T} = \frac{1}{n} \sum_{i=1}^{n} T_i \]
Difference of Specimen Surface Temperatures with/without Water Cooling (Dip In-Dip Out Experiment; 1” Immersion)

Average Peak Temperature [F]

<table>
<thead>
<tr>
<th>Flow Rate of Cooling Water through 0.17” Bubbler [gallon/minute]</th>
<th>Average Peak Temperature [F]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1312</td>
</tr>
<tr>
<td>0.41</td>
<td>915</td>
</tr>
<tr>
<td>0.83</td>
<td>900</td>
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<tr>
<td>1.38</td>
<td>892</td>
</tr>
<tr>
<td>2.15</td>
<td>882</td>
</tr>
<tr>
<td>3</td>
<td>875</td>
</tr>
<tr>
<td>3.7</td>
<td>874</td>
</tr>
</tbody>
</table>
Cooling Effect of Bubblers and Baffles on “Hot Spot”
(Dip In-Dip Out Experiment; 1” Immersion)

![Graph showing the effect of bubblers and baffles on average peak temperature with varying flow rates of cooling water. The graph indicates that the average peak temperature decreases as the flow rate increases for all tested configurations. There are three types of bubblers: 0.17”, 0.307”, and 0.214”, and two types of baffles: Gap Area=0.09 inch² and Gap Area=0.17 inch². The 0.307” Bubber and the 0.214” Bubber show the most significant decrease in average peak temperature with increasing flow rate.]
Effect of Bubbler Size and Water Jet Velocity on the Efficiency of “Hot Spot” Cooling
(Dip In-Dip Out Experiment; 1” Immersion)

Water Jet Velocity

\[ V = \frac{F}{A} = \frac{4F}{\pi d^2} \]

where

- \( F \) — Flow Rate
- \( A \) — Section Area
- \( d \) — I.D. of Bubbler
Effect of Water Velocity on Baffles’ Cooling Efficiency on “Hot Spot”
(Dip In-Dip Out Experiment; 1” Immersion)

Velocity of Cooling Water: \( V = \frac{F}{A} \)

where: \( F \) — Flow rate; \( A \) — Gap Area

Graph showing the relationship between Velocity through Gap [feet/second] and Average Peak Temperature [°F]. The graph indicates that as velocity increases, the average peak temperature decreases. Two data sets are shown with different gap areas: 0.17 inch\(^2\) and 0.09 inch\(^2\).
Position of Thermocouples for 4.5” Immersion Experiment
Cooling Efficiencies of a Bubbler and a Baffle for a Large Area

(Dip In-Dip Out Experiment; 4.5” Immersion)

Immersion Depth: 4.5”
- Bubbler; I.D=0.17”
- Baffle; Gap Area=0.09 inch^2
Conclusions

- The surface temperature of a die casting die plays an important role in the failure of the die. Overheating to die steel results in degradation of the microstructure and softening of the steel.

- The use of a bubbler or a baffle can be very effective in lowering the surface temperature of a die insert, core or slide.

- A baffle is more suitable to cool a certain area, while a bubbler is better for cooling a specific “hot spot”.

- For a given insert and cooling mode, higher flow rates improve cooling leading to lower surface temperature.
Conclusions (continued)

- For a given cooling line and flow rate a bubbler with a smaller inner diameter has a better cooling efficiency at the “hot spot” than a bubbler with a larger inner diameter.

- At same flow rate, high velocity of cooling water enhances the heat transfer between the cooling water and the sidewall of a cooling line. For design and application purposes it is preferable to set up a high velocity of cooling water in a cooling line in order to lower surface temperatures.