Influence of pressure mould material on the durability of coating a thermal and anti-erosion barrier

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Abstract

This study presents the research results of the durability of coating (thermal and anti-erosion barrier) of a mincer cap casting pressure mould. Tests were conducted with the use of an IDRA OL320 pressure machine. Durability of the mould with TiN coating applied by PVD was analyzed. The geometrical structure of the mould surface was assessed. It was found that the surface roughness and precipitations of metallurgical origin in the mould material, as well as the surface roughness of the coating do not influence the barrier life-span as much as microcracks on the mould surface do.

Key words: high pressure die casting, anti-erosion barrier, pressure mould durability

1. Introduction

The increase of pressure mould durability allows for reducing the costs of casting production. The latest works on this problem focus on the application of thermal and anti-erosion barriers to the mould surface. Such barriers also increase the smoothness of mould surface, which gives a better quality casting surface. Anti-erosion barriers ensure an increase in productivity as they help to limit down-times caused in particular by castings adhering to moulds.

Although founders are interested in this method of increasing a mould’s life-span, they have too little objective comparative data to be able to choose appropriate mould material, method of heat or heat and chemical treatment, as well as coating [1-4].

Thus, the aim of this study was to obtain data on the reasons of damages to the TiN coating applied on a WCLV steel mould surface that underwent heat treatment as well as heat and chemical treatment.

2. Experimental conditions and form

The pressure mould of mincer nut casting (Fig. 1) was produced of WCLV (0.55% C, 1.68% Si, 6.35% Cr, 1.73% Mo, 1.39% V, the rest Fe).

The mould was heat treated (hardening in oil from a temperature of 1020 °C, tempering in 650 °C). The mould hardness after heat treatment was 42 ± 2 HRC. The mould nitriding was conducted in a Seco-Warwick furnace. Before nitriding, the mould surface was activated by sand blasting. The nitriding process was performed in two stages. First stage: nitriding atmosphere containing 60% NH3, temperature 450 °C, for 2 hours. Second stage: ammonia content in the exhaust atmosphere was reduced to 25%, temperature 520 °C, for 10 hours. Then, the charge was cooled together with the furnace down to the ambient temperature.
The nitride treated surface was of a uniform, light grey colour. The thickness of the nitride layer assessed on the control sample was 190 μm. The hardness of the nitride treated layer under the surface was 1050 HV5. The mould surface was activated by sand blasting. The TiN coating was applied using the Rübig technology.

The microstructure and results of the barrier material analysis have been presented in Fig. 2. Tests were conducted using a scanning microscope JEOEL 500, fitted with a microanalyser. Material for the experiment was taken from the form after tests of wear.

Test were conducted with a foundry mould that used to work on a pressure machine IDRA OL320. The mould was poured with liquid AlSi12S alloy, taken from the heating furnace located at the pressure machine.

To assess the condition of the mould surface, after each 500 pours, the form was taken out of the pressure machine and it underwent a visual examination. The visual examination focused mainly on these cavity areas which were exposed to the straight blow of molten metal stream (Fig. 1c). The geometrical structure of the mould surface was assessed in the (A) area.

<table>
<thead>
<tr>
<th></th>
<th>at. %</th>
<th>wt.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>36.121</td>
<td>23.600</td>
</tr>
<tr>
<td>N</td>
<td>42.247</td>
<td>32.189</td>
</tr>
<tr>
<td>Al</td>
<td>10.664</td>
<td>15.652</td>
</tr>
<tr>
<td>Ti</td>
<td>10.968</td>
<td>28.559</td>
</tr>
</tbody>
</table>

Fig. 2. Microstructure and results of the microanalysis of chemical constitution of the mould thermal and anti-erosion barrier

Out of approx. forty parameters, distribution and function describing properties of the surface geometrical structure and profile, the altitude parameters of sample surfaces were selected: the Sₚ, Sₛ, Sₜ and Sₐ. Sₚ parameter is the distance between the elevation line and pit line on the surface. Sₛ is the arithmetic mean of the surface deviation from the average value. Sₜ is the arithmetic mean of the absolute altitude of the five highest elevations and the five lowest pits. Sₚ is the quadratic mean of the surface deviation from the averaging surface.

If broken-out sections occurred on the mould surface, impermissible build ups appeared on the casting surfaces. The presence of build ups and broken-out sections on the mould surface resulted in the decision to scrap it. Samples were cut of the mould to find the reason for anti-erosion barrier wear.

3. Experimental results and analysis

After the first 500 pours, the foundry mould was taken off the machine and inspected. No wear of the anti-erosion barrier was found.

Example 3D view and an isohypse chart of the mould cavity surface, of the area most exposed to molten metal stream impact, after 500 pours, has been presented in Fig. 3.

The values of the geometrical structure parameters of the mould surface, after 500 pours equal: Sₚ = 16.6 μm, Sₛ = 1.86 μm, Sₜ = 15.8 μm and Sₐ = 2.34 μm.

After 8,000 pours, no wear visible to the naked eye were found on the mould.

Example 3D view and an isohypse chart of the mould cavity surface, of the area most exposed to molten metal stream impact, after 8,000 pours, has been presented in Fig. 4.
The values of the surface geometrical structure parameters increased after 8,000 pours by $\Delta S_r = 6.7 \, \mu m$, $\Delta S_a = 0.97 \, \mu m$, $\Delta S_z = 0.9 \, \mu m$, $\Delta S_q = 1.18 \, \mu m$, if compared to the surface condition after 500 pours. This proves that micro damages of the mould surface have occurred.

Clear symptoms of mould surface wear in the areas most exposed to melted metal stream impact (point A in Fig. 1) were noticed after 13,500 pours (Fig. 5).

![Fig. 5. View of the mould cavity area most exposed to the impact of molten metal pouring from the inlet system Mould after 13,500 pours](image)

Example 3D view and an isohypse chart of the mould area most exposed to the impact of molten metal pouring from the inlet system, after 13,500 pours, has been presented in Fig. 6.

![Fig. 6. Example 3D view and an isohypse chart of the mould cavity surface, of the area most exposed to the impact of molten metal pouring from the inlet system. Mould after 13,500 pours](image)
A clear increase in mould surface geometrical structure parameters was found, if compared to the mould condition after 500 and 8,000 pours (Table 1).

Table 1. Values of surface geometrical structure parameters

<table>
<thead>
<tr>
<th>Number of mould pours</th>
<th>S_t</th>
<th>S_6</th>
<th>S_p</th>
<th>S_d</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>16,60</td>
<td>1,86</td>
<td>15,80</td>
<td>2,34</td>
</tr>
<tr>
<td>8,000</td>
<td>23,30</td>
<td>2,83</td>
<td>16,70</td>
<td>3,52</td>
</tr>
<tr>
<td>13,500</td>
<td>56,50</td>
<td>3,77</td>
<td>45,50</td>
<td>6,70</td>
</tr>
</tbody>
</table>

The parameter that increased particularly high was $S_t$. This was because large pits appeared in the analyzed surface area. The $S_t$ parameter is an altitudinal parameter of the surface geometrical structure and it does not give the most useful information on the altitudinal wear progress.

The casting surface roughness visible in Fig. 7 was an effect of the mould surface damage.

The roughness on the casting surfaces was so wide and deep that it disqualified the castings because of aesthetics. Thus, a decision was taken that the mould with such damaged surface must be regenerated.

It was decided that the regeneration would include cleaning (polishing) the surface and applying a new coating. The mould prepared in this way underwent further tests. It was revealed that after 3,500 pours, inadmissible damage of the mould cavity surface occurred, in the same areas as before. Thus, the total time of mould operation was 17,000 pours. On account of the above, a decision was taken to scrap the mould and perform metallographical tests. Samples for tests were cut of the areas with visible wear.

Example results of the anti-erosion barrier examination have been presented in Fig. 8 & 9.

The results obtained prove that the anti-erosion barrier is damaged by the occurrence of broken-out sections and cracks. Barrier damage is an effect of broken-out sections occurring at the mould material (Fig. 10).

Microanalysis of the area where mould material cracks appeared revealed an increased oxygen content.

Fig.8 Example results of mould surface tests in the area of excessive wear
Fig. 9. View of areas with a damaged barrier. Mould surface right section

Table 1

<table>
<thead>
<tr>
<th>Point</th>
<th>Oxygen content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at. %</td>
</tr>
<tr>
<td>1</td>
<td>46.367</td>
</tr>
<tr>
<td>2</td>
<td>50.066</td>
</tr>
<tr>
<td>3</td>
<td>56.222</td>
</tr>
<tr>
<td>4</td>
<td>57.331</td>
</tr>
</tbody>
</table>

Fig. 10. Results of the oxygen content examination in the area of mould material microcracks

Observation of the anti-erosion barrier in the areas without broken-out sections indicate that a continuous, even though partially damaged, barrier is present even at the roughness (pits) of the surface (Fig. 11a) and at precipitations (Fig. 11b). These precipitations contain carbon, silicon, iron, aluminum, as well as oxygen (Fig. 12).

a)

b)
3. Conclusions

It was found that excessive wear of the mould occurred in the areas most exposed to the impact of molten metal stream.

At the first stage of operation, the barrier wear was uniform. The first symptoms of mould micro wear, not discovered at visual inspection, were revealed as a result of surface geometrical structure analysis after 8,000 pours.

A significant increase in mould wear in the areas most exposed to the impact of molten metal stream, noticeable at visual inspection, was found after 13,500 pours.

The mould degradation resulted in the occurrence of broken-out sections and build ups at the frontal surface of nut casting.

The analyzed mould after polishing and applying a new coating layer demonstrated surface damages as soon as after 3,500 pours. These damages caused occurrence of impermissible broken-out sections and build ups on the surface of nut casting.

It was revealed that the degradation of the anti-erosion barrier takes place because of the presence of broken-out sections and build-ups. It starts in the areas of the mould material microcracks.

In the areas of the mould material microcracks, there is an increased oxygen content. It may be believed that the microcracks could occur during mechanical or heat treatment of the mould.

It was found that the surface roughness and precipitations of metallurgical origin in the mould material do not influence the barrier life-span as much as microcracks on the mould surface do.

Elimination of the reason for which the mould material microcracks appear will result in an increase in the anti-erosion barrier endurance and, as an effect, increase the mould’s life-span.

References


