Effects of finishing on the surface quality of precision castings

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Abstract

The paper presents some manufacturing problems concerning leaded brass casting using the precision casting method. It shows that the quality of the alloy depends on the intermetallic phase compounds known as hard inclusions that are formed in the alloy. The intrusions, composed mainly of iron, have also negative influence on obtaining good quality i.e. smooth surfaces of products. One of the methods to improve surface smoothness proposed by authors is to apply additional copper plating and fine polishing.

Key words: Defects of castings; CuZn37Pb alloy 3; Finishing; Surface texture; Surface quality

1. Introduction

It is predicted that in the XXI century foundry engineering will employ new technologies to ensure high quality of products and maximum reduction of energy and material consumption. New technologies will also make use of all the possibilities offered by materials to obtain best possible casting quality. The new technologies will use computerized production systems to control casting quality and introduce air-tight sealing process of casting and utilize or recycle all waste products to protect the environments. Additionally, further specialization of foundry plants and manufacturing process will be introduced [1].

Literature studies \{2-4\} have shown without doubt that the leading trends of modern foundry technologies are going to be centered around precision castings. The precision castings methods are characterized by relatively high automation of manufacturing process. For precision castings large scale and mass production has been proved to be economically advantageous [5,6].

More advantages are created by the possibility of the process automation that ensures the repeatability of product qualities and obtaining relatively high quality parameters not only for the material but also surface texture of the manufactured products. Owing to the above the castings produced in this way are widely used in a large number of industrial branches such as aviation industry, car manufacture, gas turbine production and also sports equipment and medical implant production [7,8]. The metal components of the castings are mainly composed of non-ferrous metals, special alloys of nickel and cobalt, alloys of titanium and noble metals. This technology is used to produce monocrystal structure castings or the ones resulting from directional solidification. The main directions to develop the method of smelting models are focused on producing large and complex castings using computer modeling and design of manufacturing process, rapid prototyping of tooling and, first of all, introducing new casting alloys and industrial robots.

Apart from the microstructure the final quality of the products is influenced by the quality of surface texture. There are...
a large number of surface engineering methods that enable us to obtain required high quality parameters. However, not all of them can be used for precision casting. Due to the above an attempt has been made in this paper to present only the most relevant ones showing their applications for the precision castings made of leaded brass and manufactured by the injection method.

2. Research objective

One of the most dynamically developing foundry technologies in the beginning XXI century has been precision casting. This method is used to manufacture, among others, such elements as taps made of CuZn37Pb3 alloy (1). The technological process to produce these elements involve injection of liquid alloy into the mould and fast cooling.

The literature on the subject [9-11] shows that the formation of both the internal microstructure of the brass as well as the surface texture is a complex problem. In the process we have to deal with intermetallic phases, known also as hard inclusions that occur in the material microstructure. The inclusions, especially those of larger size, can constitute a serious problem of material machining. They can cause both much faster machine tools wear and damage.

The investigations carried out by the authors have confirmed literature reports that the main component of the intermetallic phases that constitute the releases is iron – usually about 60% (by weight) – Fig. 3. Moreover, the releases contain a considerable amount of silicon up to 25% (by weight). The remaining components include Cu, Zn, Mn, Pb, O, Al, Ni about 15%.

Hard inclusions of the intermetallic phases can be very often found on product surfaces. They have a significant influence on the surface quality by synergically intensifying additional oxidation that occurs on the liquid metal-mould material boundary (Fig. 4).

Hard inclusions also make it difficult to machine the surface of castings, for example, to use the polishing method. During the process the inclusions undergo spalling very easily and the particles produced (during the process) being usually larger in size than the polishing grains will cause uncontrolled scratching of the polished surfaces. The conducted observations of the surfaces of the taps (Fig. 5) showed that the scratching constitute a very serious problem when it comes to meeting the product specifications i.e. to attain the level of roughness – Rz < 2,5 µm denoted by the broken line on Fig. 1b.

3. Results of investigations

The investigations carried out by the authors have confirmed literature reports that the main component of the intermetallic phases that constitute the releases is iron – usually about 60% (by weight) – Fig. 3. Moreover, the releases contain a considerable amount of silicon up to 25% (by weight). The remaining components include Cu, Zn, Mn, Pb, O, Al, Ni about 15%.

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Fig. 3. Energetic spectrum of elements constituting hard inclusions

Fig. 4. View of surface faults on the tap casting made of CuZn37Pb3 alloy

Fig. 5. View of the tap surfaces following a) casting, b) polishing, c) copper plating , d) copper plating and polishing
Measurements of the tap surfaces carried out immediately after casting showed a wide range of roughness parameters – Table 1. As the result, the first step taken to improve surface quality involved mechanical polishing. The process resulted in a considerable reduction of parameters of roughness dispersion, particularly Ra. However, it was not possible to meet product specifications on the critical surfaces Rz < 2.5 µm. Due to above additional surface treatment (electroplating) aimed to reduce the value of Rz parameter was performed. To achieve this, a short term copper electroplating in a drum was carried out. As a result of the treatment a copper coating of 2-4 µm in thickness on the electric taps was formed but it proved only a partial success: the roughness expressed in terms of Rz parameter was considerably lower, however the obtained level was equal to the acceptable value limit and for some cases was even a little higher. Consequently it was necessary to use additional finishing which involved a very fine polishing practically without any application of an abrasive compound. Only after this treatment was it possible to satisfy the product specifications concerning the surface quality described by designer as critical. The surface roughness characterized by Rz parameter was lower than 2.5 µm. (table 1).

4. Conclusions

A comprehensive analysis of the whole investigative material made it possible to formulate the following conclusions:
1. the formation of both the microstructure as well as the surface texture of the products made of CuZn37Pb3 alloys should be carried out by taking into account the negative processes caused by intermetallic components that form the so called hard inclusions,
2. if the surface roughness Rz parameter is required to be below 2.5 µm, there is a need to perform additional finishing,
3. one of the methods to reduce the roughness level is product surface treatment – polishing, copper plating and finally fine polishing.

Table 1.

<table>
<thead>
<tr>
<th>Nr</th>
<th>Surface treatment</th>
<th>Ra [µm]</th>
<th>Rz [µm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Casting</td>
<td>1.0÷10.0</td>
<td>2.0÷20.0</td>
</tr>
<tr>
<td>2.</td>
<td>Polishing</td>
<td>0.1÷0.8</td>
<td>1.0÷5.0</td>
</tr>
<tr>
<td>3.</td>
<td>Copper plating</td>
<td>0.1÷0.6</td>
<td>1.0÷2.8</td>
</tr>
<tr>
<td>4.</td>
<td>Copper plating + polishing</td>
<td>0.1÷0.4</td>
<td>0.8÷2.5</td>
</tr>
</tbody>
</table>

References