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Comparative Analysis of the Work of Berilium Bronze Mould

Stoyan PARSHOROV[1], Deyan KANCHEV[2]

[1] Institute of Metal Science, Equipment and Technologies
with Hydro- and Aerodynamics Centre "Acad. A. Balevski",
Bulgarian Academy of Sciences, e-mail: st.parshorov@gmail.com

[2] Ideal-Standard-Vidima AD, Sevlievo, Bulgaria

Abstract
The aim of the present work is to investigate the reasons for faulting of beryllium bronze mould used for casting of brass parts.
The investigation is focused on the constructional and technological requirements of the beryllium bronze tool equipments.
Based on the investigations carried out can be concluded that the recrystallization, adhesion and diffusion processes in the material are reasons for the crack appearance.

Keywords: mould, beryllium bronze, fault, reasons

1. Introduction

The purpose of this study is to determine the causes of failure and destruction of an insert of mold for casting serial details of brass.

2. Material and methodology

Object of the research is an insert from a mold for casting brass plumbing fittings in the factory Ideal-Standard-Vidima AD, Sevlievo. The material from which the tool is made is a rod with standard composition DIN CuCo2Be (2.1285) – 0.4-0.7% Be, 0.8-1.3% Ni, 0.8-1.3% Co, the rest copper, imported from Italy with the relevant certificate of quality and chemical composition. The alloy is used for the production of molds for casting brass products and is characterized by the fact that it withstands work under severe thermal and cyclic loads. Operating thermal casting cycles include melting at 1000°C and quenching in an aqueous emulsion with graphite. The duration of the cycle is of the order of 2-3 minutes.
The investigated insert is an element of the mold, which works at the most severe temperature regime. It is the first to absorb the mechanical and thermal shock when the liquid metal enters the mold. The investigated insert failed during the first few castings, as a network of cracks was formed on it in the area of its heaviest temperature-loaded part. This leads to a change in the geometry of the cast part and the waste of the production. The problem is whether the insert material is supplied with cracks.
This would allow a complaint to be made to the manufacturer. Otherwise, the reasons for premature failure of the insert will be related to the conditions of the production cycle and in particular non-compliance with technological regimes and regulations. In connection with the set task, a segment is cut from the conical part of the insert, one end of which is the place containing the network of cracks, and the other – worked in normal operation and does not contain visible defects – Fig.1.

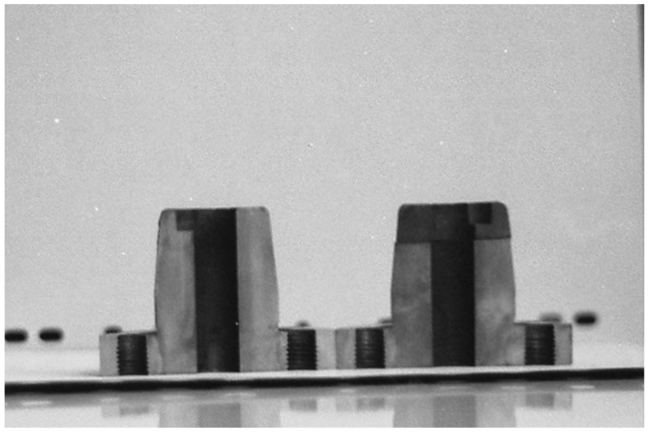

Fig.1. Insert of mold for casting brass products

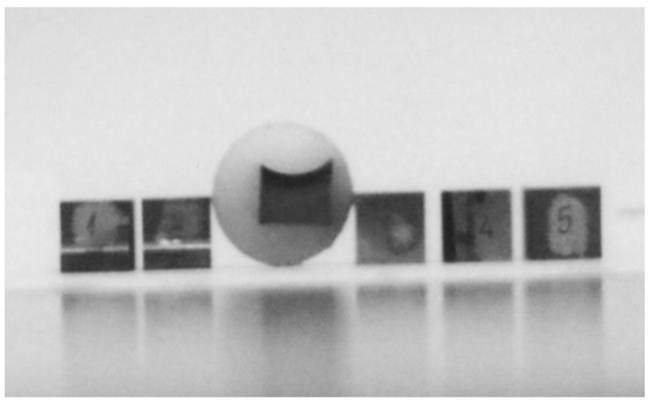

Fig.2. Micro simples from the investigated insert

From the mentioned two places of the detail micro simples are made, as shown in Fig.2, which were examined with a standard optical microscope.

3. Results and discussion

In order to analyze the results obtained, the thermal conditions under which the material from which the insert is made must be obtained must be taken into account.
Normally, parts and tools that are made of beryllium bronze are subjected to hardening and aging. Hardening allows the alloying elements, in particular the beryllium compounds, to be dissolved in copper and a single-phase α-solid solution to be formed. It is characterized by low strength and high ductility. As the temperature decreases, the already saturated α-solid solution solidifies dispersion, forming γ-phase particles (Cu-Be), which greatly increase the strength of the material and its resistance to the appearance of fatigue cracks. The solubility of beryllium in copper below 300°C is below 0.2%, which makes it possible for the alloy to age dispersion. The presence of nickel and cobalt is mandatory in such alloys, as they do not normally form inter metallic compounds with copper, remain in the solid solution and increase its resistance to hypothermia.
In practice, the technology of making beryllium bronze rods involves heating the work piece to the temperature of the single-phase region deformation in the temperature range 700-900^{o}C, then delayed cooling is carried out simultaneously an isothermal decomposition of the solid

solution and dispersion hardening at lower temperatures. This means that the insert is practically not heat-treated in the normal mode – hardening and aging, and its structure is the result of complex history of cooling. In this sense, it is not clear how and to what extent the processes of separation of the dispersed phase in the solid solution of the studied sample took place. Therefore, a critical comparative analysis of the condition of the two simples is made later in our research.

The simple, made of the undamaged part of the insert, has a structure characteristic of the alloy from which the part is made. Liquation and copper oxides are observed along the grain boundaries, located unevenly on the observed surface. There are no changes and uncharacteristic structures or cracks that could be the reason for the decommissioning of the insert or its destruction. On the damaged side of the part with the naked eye can be seen a layer that does not belong to the outer surface of the tool, which we assumed that most likely stuck brass from the casting of the part. Such an adhesion of metal can be due to several reasons, both technological and structural:

- Unprotected with grease, left uncovered when immersing the tool in the bath with the suspension of aqueous solution of graphite-based grease.
- Poor preheating of the tool before starting the casting process, which leads to weakening of the adhesive forces between the coating and the tool.
- Poor design solution, in which the metal falls at high speed on a small area at the defect site and "washes away" the protective coating and local overheating of the tool occurs by generating high internal stresses. In order to establish the nature of the available slander, it was examined metallographic. It has a specific color and structure from that of the main instrument material.

A more detailed study of the structure at higher magnification revealed that the observed layer is composed of three different layers separated from each other.

The innermost layer is composed of consolidated grains, which are probably a consequence of recrystallization in the metal. Saturated α-solid solution with γ-solid solution particles was observed. At 800^0C the alloy is quenched and the α-solid solution is separated, and at cooling to 300^0C, the γ-solid solution is separated.

The resulting structure resembles martensite. It consists of very fine plates arranged almost perpendicular to each other.

The second layer has a structure typical of brass, which appeared as a result of contact between the brasses on the surface of the tool. Probably the high diffusion mobility of zinc at high temperatures is the reason for the penetration of zinc into beryllium bronze. The presence of high compressive forces resulting from the pouring of the liquid metal and the high temperature has contributed to the adhesion interaction of the two surfaces. In the contact layer there is a new structure – α-brass, with a content of non-zinc up to 40%, which in the hot state has high ductility, but low strength and durability.

In the process of continuous heating and cooling at the boundary of the two layers, internal thermal stresses appear and those caused by dilatation differences between the two materials, which are the reason for the singing of the cracks observed in the outermost layer of the section.

The cracks in the outermost third layer are spread over the entire surface and do not have a specific direction of propagation. They are longitudinal and transverse, different in length and diameter and spread in the adjacent (middle) layer. The many cracks do not allow its structure to be observed and it remains unclear.

4. Conclusion

A comparative analysis of the structure of a defective insert made of a mold for casting brass parts showed that:

- The sticking of the casting material on the tool and the failure is caused by non-compliance with design and technological requirements for the tool.
- Falling of the protective coating and high temperatures and loads in the casting process has caused a change in the structure of the alloy and has led to the failure of the insert.
- The course of recrystallization in the superheated material of the tool is accompanied by the appearance of adhesion and diffusion processes in the surface layer, violating the geometry of the tool.
- High internal stresses from temperature and dilatation stresses have led to the appearance of cracks, which led to the failure of the tooling.
- The metallographic structure of the defect-free part of the insert gives grounds to claim that it was delivered by the manufacturer without defects.

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