Ability of the CuSn10 and CuSn5Zn5Pb5 brasses fulfillment of plaster mould cavity during underpressure casting

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Abstract

Results of research on ability of a plaster mould cavity to be filled up on casting with alloy CuSn10 and CuSn5Zn5Pb5 are presented in this paper. The cylindrical plaster mould ø110x290 was casting using underpressure in the Vacuum Pressure Casting Machine VC500D of Indutherm. The size of mould cavity was ø15x200 mm and gauge: 2,0; 1,0; 0,8 and 0,6 mm, the temperature of pouring alloy was 1120, 1140, 1160, 1180 and 1200°C, temperature of plaster mould in the casting moment was 400, 500 and 600°C. The effectiveness of a mould cavity to be filled up on the difference distance from the centre of the mould was assesmented too used to mould cavity 10x200 mm and gauge: 2,0; 1,0; 0,8 and 0,6 mm.

On the base of the results of the investigation its possible to reach a conclusion, that the best temperature of casting and temperature of the plaster mould t_m=500÷600°C. The distance of mould cavity from the mould centre doesn’t have a practical meaning for its ability to be filled up.

Keywords: Innovative foundry technologies and materials, Precision casting, Plaster mould, Underpressure casting

1. Introduction

Casting In gypsum plaster moulds aide with underpressure is one of the most precise methods for preparation of precision castings of Cu, Al, Zn i Mg. Applied underpressure allows to obtain the casts of very thin walls, of thickness even below 1 mm [1] of significant area. This method allows also to obtain very precise representation of the model. These advantages caused the wide application of this method in jewelry and prosthetic as well as in precision industry.

Currently in the Department of Materials Technologies and Production Systems of Technical University of Lodz studies on the technology of plaster mould and plaster-bonded investment casting using of vacuum are conducted within the frame of Research Project No. N N508 3886 33 financed by Polish Ministry of Science and Higher Education [2÷12].

The results of investigations on determination of the most advantageous preparation conditions for thin-walled brass casting of CuSn10 CuSn5Zn5Pb5, with consideration given to mould temperature and alloy temperature.
2. Scope and methodology of researches

The goal of the researches was to determine the influence of the alloy $t_{zal}$ and the mould $t_f$ temperature and cavity dimensions on the fulfillment ability of CuSn10 and CuSn5Zn5Pb5 brasses during vacuum casing.

2.1. Scope of researches

Following range of parameters was applied:
- alloys CuSn10 and CuSn5Zn5Pb5 temperatures: $t_{zal}$=1120, 1140, 1160, 1180, 1200°C,
- mould temperature: $t_f$=400, 500, 600°C,
- mould cavity dimensions:
  - to determine the fulfillment ability in dependence on the alloy temperature $t_{zal}$ and mould temperature $t_f$ and cavity dimensions: 200 x 15 x g (g=2,0; 1,0; 0,8 and 0,6 mm)
  - to determine the fulfillment ability in dependence on the distance from the mould axis: 200 x 10 x g (g=2,0; 1,0; 0,8 and 0,6 mm)

As a measure of the fulfillment ability the percentage of liquid brass running was taken.

2.2. Materials

Following Materials were used during researches:
- a) jewellery plaster-bonded investment powder Gold Star XL made by Hoben of following parameters [14]:
  - powder-water ratio W/G=0,40 for flow ø 120 mm
  - setting time: start: $t_{wp}$=16'30'' (14'40''*)
    end: $t_{wk}$=18'00'' (16'00''*)
  - bending strength: $R_g^u$=1,2 MPa (2,2MPa*)
  - gypsum mass mixed mechanically [7],
- b) jewellery model wax (green) delivered by Vigor in form of sheets of thickness g=0,8; 0,6; 0,5 mm,
- c) distilled water,
- d) - brass CuSn10 of tin content 9,0÷11,0% and total impurities content 1%,
  - brass CuSn5Pb5Zn5 of tin content 4÷6%, zinc 4÷6% and lead 4÷6% and total impurities content 1%.

2.3. Methodology

2.3.1. Gypsum plaster and experimental forms preparation

The plaster was prepared in vacuum mixer St. LOUIS 82 in following procedure:
- pouring of weighted dry powder into the mixer chamber,
- degassing under vacuum during 120 sec,
- adding measured amount of distilled water,
- mixing the slurry under vacuum during 210 sec at mixer speed n=150÷350 rpm
- pouring the slurry into the laboratory ware (in the vacuum casting moulds chamber).

2.3.2. Experimental model

Two types of models were used during researches:
- A. Model for determination of the fulfillment ability in dependence on the alloy temperature $t_{zal}$ and mould temperature $t_f$ and cavity dimensions consisting of four vertical wax stripes (p. 2.1) symmetrically mounted around vertical sprue of diameter 10 mm (fig. 1a).
- B. Model for determination of the fulfillment ability in dependence on the distance from the mould axis consisting of four vertical wax stripes (p. 2.1) mounted in groups of three on four arms placed symmetrically around vertical sprue of diameter 10 mm (fig. 1b).
2.3.3. Experimental mould

A. Mould preparation

Experimental moulds were prepared in perforated cylinders made of heat-resisting steel of dimensions ø110x290 mm in accordance with following procedure:

– placing the bush on the plate with mounted pattern and its aliment with the sprue,
– sealing the contact between the bush and the palte by elastic mass,
– pouring the degassed gypsum mix,
– setting and drying the mix under ambient conditions during 2h.

B. heat treatment

Preliminary dried moulds were baked in resistant furnace chamber APE 800 in accordance with the scheme presented in figure 2.

Fig. 2. The plot of heat treatment process course of experimental moulds

2.3.4. Preparation of experimental castings

Brass was melted in Vacuum Pressure Casting Machine VC 500D INDUTHERM under argon atmosphere. Experimental castings were prepared in accordance with following procedure:

– brass melting and heating to temperatures 1120, 1140, 1160, 1180 and 1200°C respectively,
– removing the mould from the furnace APE 800 and placing into VC 500D chamber,
– temperature checking of the mould in the sprue pass,
– closing the chamber and degassing under vacuum during 90s,
– casting the mould (from melting crucible under argon atmosphere),
– 120 s brake for the cast to solidify,
– opening the chamber and removing of the mould,
– immersing the mould in the cold water to remove the gypsum mix and the cast.

3. Discussion

3.1. The fulfillment ability in dependence on the alloy temperature t_{zal} and mould temperature t_f and cavity dimension g

The results of the tests are presented in figures 3 and 4. On this base it can be stated that from the viewpoint of the cavity fulfillment the most advantageous temperature of the liquid alloy is 1200°C, and this dependence is more clear for brass CuSn5Zn5Pb5 for which the 100% of the fulfillment of the mould cavity of thickness g≥0,8mm and 60% for thickness g=0,6 can be obtained (for t_f=600°C ). For CuSn10 brass under the same conditions these parameters are equal 100% and 50% respectively. However in previous researches [5] it was shown that the best temperature for cast quality should be 1140°C. At this temperature the CuSn5Zn5Pb5 brass has better fulfillment ability at mould temperature t_f=600°C (100% for g≥0,8mm and 43% for g=0,6mm) than CuSn10 (100% for g≥0,8mm and 35% for g=0,6mm).

At lower mould temperatures (t_f=500°C and 400°C) CuSn10 brass fulfills better the mould achieving always 100% in cavity of g≥0,8mm and 50÷20% for g=0,6mm. The situation is more complicated in case of CuSn5Zn5Pb5 brass. The cavity of g≥0,8mm of temperature t_f=500°C is fulfilled in 100% at casting temperature t_{zal}=1160÷1200°C and 75% (t_{zal}=1140°C) and 65% (t_{zal}=1120°C). Mould of temperature t_f=400°C (g≥0,8mm) is completely fulfilled only at t_{zal}=1200°C. In the range of temperatures t_{zal}=1180÷1120°C cavity fulfillment of g≥0,8mm is equal 90÷60%, respectively.

It can be stated that in optimum for this technology temperature of casting t_{zal}=1140°C the CuSn10 brass fulfills all cavity of thickness g≥0,8mm of the mould at temperature t_f=600-400°C. For mould cavity of g=0,6 mm the fulfillment under the same conditions is equal 35÷22%, respectively. In case of CuSn5Zn5Pb5 brass, cast at t_{zal}=1140°C the 100% fulfillment of cavity of g≥1,0mm is achieved at t_f=600°C, 75% for cavity g=0,8 at t_f=500°C and 72% at t_f=400°C. For cavity g=0,6mm the fulfillment is better than in case of CuSn10 and is equal 43% at t_f=600°C, 32% at t_f=500°C and 40% at t_f=400°C.

The interesting phenomenon can be observed – namely the coldest mould (t_f=400°C) the better fulfillment of the cavity (t_f=500°C).

This can be explained by analysis of shrinkage characteristic of set gypsum plaster Gold Star XL. It exhibits the shrinkage about 50% higher in the range of temperature 500-400°C than in the range 600-500°C [7], what causes the bigger cracks divergence. The casts made of CuSn5Zn5Pb5 brass in the mould of t_f=400°C have very significant almost disqualifying flashes (Fig. 5). In case of CuSn10 brass the flashes are not present what is probably the result of worst castability of this alloy.
Fig. 3. The ability of the cavity fulfillment by CuSn10 brass in dependence on dimension g, casting temperature $t_{\text{zal}}$ and mould temperature $t_f$

Fig. 4. The ability of the cavity fulfillment by CuSn5Zn5Pb5 brass in dependence on dimension g, casting temperature $t_{\text{zal}}$ and mould temperature $t_f$
In casts prepared from both alloys there are sometimes, (usually on the thinner stripes), small misruns (Fig. 6). It refers only to the stripes not fully cast. The misruns appear randomly on the inner or outer side of the stripes at the top of the sprue or just below. In some casting there is no misrun in some there can be even two or three of them.

This phenomenon can be connected with two problems: anhydrite decomposing starting at 750÷800°C connected with O2 and SO2 emission [5,13] and the phenomenon of microcracking of the mould. At places microcraks do not appear or their amount is low the intensity of gases emission from the mould surface is higher than the ability by t the mould material to be transferred. This causes the pressure of the produced gasses does not allow the full casting of the mould.

The separate problem is the susceptibility to cracking of obtained casts. The significant shrinkage of the brass causes the stripes show the hot cracking (Fig. 5, 6). In case of CuSn10 stripes of g=0,6mm crack often, of g=0,8mm sometimes. The stripes of g=2,0 mm never crack, while in stripes of g=1,0 cracks along whole length appear very seldom. The CuSn5Zn5Pb5 casts crack more often. Practically all stripes of g=0,6mm were broken. It refers to stripes of g=0,8mm, in them most reveals cracks. Stripes of g=2,0 mm don’t crack, but those of g=1,0mm breake much of those cast from CuSn10. These differences come from the much more higher volume shrinkage of the CuSn5Zn5Pb5 [5]. Discussed cracks appeared in completely unpredictable way and the straight determination of the dependence theirs presence in terms of casting temperature, mould temperature or strip thickness was impossible. The reasons for this were the properties of the mould material consisting of gypsum, silicon and cristobalite. The shrinkage of such material after heat treatment is of complicated nature [7], what in combination with linear shrinkage of the brass results in significant stresses in the stripes what leads to hot cracking. This problem requires further investigations.

3.2. The ability of mould cavity fulfillment in dependence on the distance from its axis

After analysis of the researches results presented in p. 3.1. the experimental castings were prepared in moulds at temperatures t=-500°C and 600°C cast with alloy of temperature t_zal=1120 and 1200°C. In both cases the 100% cavities running were obtained independently on their position from the mould axis. In some parts of the castings the misruns have been presented of random character.

<table>
<thead>
<tr>
<th>Cast material</th>
<th>Cavity dimension g, mm</th>
<th>Cavity fulfilment L, %</th>
<th>t_zal, °C</th>
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<tr>
<td></td>
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<td>1200</td>
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<td>B10</td>
<td>2</td>
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<td>1</td>
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<td>0,8</td>
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<td>0,6</td>
<td>70±5</td>
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<td>B55</td>
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<td>100</td>
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<td>100</td>
<td>90±5</td>
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<td>0,8</td>
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<tr>
<td></td>
<td>0,6</td>
<td>60±10</td>
<td>40±10</td>
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</table>

The conclusion is that the uniform running was achieved in all cases independently on the relative position from the sprue. The single misruns appeared in the stripes of g=0,6mm in case of CuSn10 alloy and of g=1,0÷0,6 mm for CuSn5Zn5Pb5 were of random character and its dimensions were 5÷10mm (2,5÷5%).

So high fulfilment percentage can be the results of the highly disadvantageous positioning in the experimental mould. Such set was taken purposely because in real production both in jewellery and technical ones patterns are placed very closely in the mould cavity for the sake of the efficiency and economics of the production.

It can be supposed that in case of observed moulds, the small cracks, always present in the gypsum moulds caused the flow of the transported gas from the interior of the cavity through relatively narrow dams between cavities and the low thickness of the wall between polar cavity and the performed surface of the bush allowed efficient transfer of the gases outside the mould. This phenomenon is also confirmed by presence of the small (up to 1mm) flashes at the edges of the stripes.
4. Conclusions

Analysis of obtained results allow to formulate following conclusions:

1. The casting technology of bronzes CuSn10 and CuSn5Zn5Pb5 in gypsum moulds with use of vacuum allow preparation of thin-walled castings production of dimensions that cannot be achieved in other methods.

2. In case of CuSn10 brass the casting temperature as well as mould temperature do not influence the fulfillment the cavity of dimension g≥0.8mm.

3. CuSn5Zn5Pb5 brass these parameters do not influence the fulfillment the cavity of dimension g≥1.0mm.

4. The significant internal stesses are presented in the investigated bronzes during the cooling in solid state cause the red brittleness and in result the cracking of casting walls.

5. The investigated bronzes should be cast at t=400°C have very big flashes in CuSn10 castings such phenomenon does not appear.

6. The position of the cast in the mould measured in terms of its distance from the centre axis does not influence the fulfillment ability of the cavity by investigated bronzes.

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References


