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ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.24425/118803

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (2299-2944)
Volume 18
Issue 1/2018

9 – 14

2/1

# Determination of the Technological Parameters Process for Continuously Cast Brass Ingot

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Received 31.08.2017; accepted in revised form 02.02.2018

## Abstract

This article discusses issues related to continuous casting of brass. The tested material was CuZn39Pb2 brass with the use of continuous casting and different parameters of the process. The position consists of a melting furnace with a graphite refining pot of about 4000 cm3 chuting capacity, a graphite crystallizer of 9,5 mm nominal diameter, a primary and secondary cooling system and an extracting system as well. The analysis was carried out in terms of technological parameters of the process and type of charge. Highlighted: feedrate ingot, number of stops, and technological temperatures. The surface quality of the obtained ingots and the structure were analyzed. The most favorable conditions were indicated and technological recommendations indicated. They have been distinguished for ingots for plasticity and other technologies. Favorable casting conditions are low feed and low temperature. Due to the presence of impurities coming from the charge it is disadvantageous to have Ni greater than 0.053% by mass, and Fe more than 0.075% by mass. It is recommended to maintain a high zinc content in the melt which is associated with non-overheating of the metal during casting and earlier melting.

**Keywords:** Brass, Continuous casting, Recycling

## 1. Introduction

The continuous casting method is commonly used in the manufacture of brass [1-4]. Determination of process parameters refers to the formation of a liquid and solid phase separation layer [5 - 7]. The use of waste materials results in distortion of this layer and does not allow the use of known models [8-12] Especially when raw materials for its production materials are of quite different composition [13-15]. Therefore, it is necessary to carry out research on the optimization of process parameters in relation to the recyclable materials used.

## 2. Own Research

The tested material was CuZn39Pb2 (according to European Standard CW612N) brass with the use of continuous casting and different parameters of the process. Whilst the research the influence of the amount of spent cooling liquid in primary circulation, times of granulation stops and casting quality feed were tested. Chemical composition of CuZn39Pb2 brass is given in table 1.

Table 1.
Chemical composition of the test alloy, [% mass]

| Cu | Pb | Al | Fe | Ni | Sn | other | Zn |
|---|---|---|---|---|---|---|---|
| 59÷60 | 1.6÷2.5 | ≤0.05 | ≤0.3 | ≤0.3 | ≤0.3 | ≤0.2 | rest |

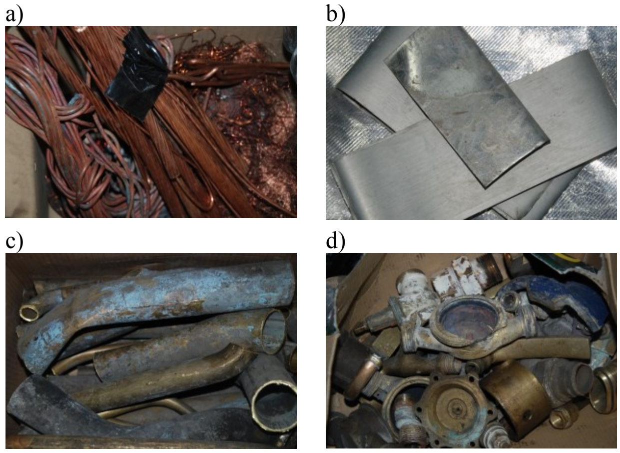

Fig. 1. Batch assortment, where: a) copper scrap, b) zinc scrap, c) CuZn40Pb2 scrap, d) CuZn39Pb2 scrap

The feedstock for the casting process was scrap-metal. The feedstock underwent preliminary selection with the use of mobile spectrometers. The furnace feedstock is presented in fig. 1.
Size of the feedstock corresponded 8000g of complete CuZn39Pb2 alloy containing 2% zinc surplus above the demanded limit. In table 2 the proportions are given. The continuous casting process was held in laboratory conditions at an authorial research position destined to test processes of such kind. The position consists of a melting furnace with a graphite refining pot of about 4000 $cm^3$ chuting capacity, a graphite crystallizer of 9,5 mm nominal diameter, a primary and secondary cooling system and an extracting system as well.

Table 2.
Proportions of used materials, [g]

| Cu | Pb | Al | Fe | Ni | Sn | other | Zn |
|---|---|---|---|---|---|---|---|
| **Species to obtain (CuZn39Pb2)** | | | | | | | |
| 4760 | 164 | 4 | 24 | 24 | 24 | 16 | 2984 |
| **Batch (CuZn40Pb2)** | | | | | | | |
| 457 | 24 | 0 | 2 | 2 | 2 | 2 | 298 |
| **Batch (CuZn39Pb2)** | | | | | | | |
| 4074 | 140 | 3 | 21 | 21 | 21 | 14 | 2554 |
| **Batch (other)** | | | | | | | |
| 229 | - | - | - | - | - | - | 192 |

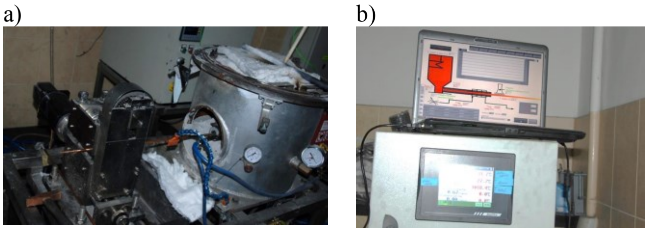

Fig. 2. Research workstation where: a) general view of continuous casting workstation, b) a set monitoring continuous casting process parameters

General view of the workstation and the monitoring and controlling system is presented in fig. 2. Continuous monitoring and controlling system (pict.2b) of specific work parameters allowed to set: material feed, the length of stop to crystalize, water spend in primary cooling.
Below in table 3 continuous casting parameters of CuZn39Pb2 alloy for cast no 1. Below in table 4 parameters of continuous casting for 2÷12 pressurized castings are juxtaposed.

Table 3.
Casting parameters – CuZn39Pb2 alloy - I

| The feed rate | Stoppage | The amount of water | T metals | T water | T cast |
|---|---|---|---|---|---|
| [mm] | [s] | [l/min] | [°C] | | |
| 2 | 5 | 0.7 | 1045 | 21 | 85 |

Table 4.
Correlation of CuZn39Pb2 alloy continuous casting parameters

| No | The feed rate | Stop-age | The amount of water | Temperature °C | | |
|---|---|---|---|---|---|---|
| | | | | Metals | Water | Cast |
| 1 | 2 | 5 | 0.7 | 1045 | 21 | 85 |
| 2 | 5 | 5 | 0.7 | 1050 | 21 | 110 |
| 3 | 10 | 5 | 0.7 | 1050 | 21 | 150 |
| 4 | 10 | 3 | 0.7 | 1050 | 21 | 155 |
| 5 | 10 | 1 | 1.7 | 1055 | 21 | 230 |
| 6 | 5 | 1 | 3.3 | 1045 | 21 | 240 |
| 7 | 5 | 1 | 6.6 | 1085 | 21 | 260 |
| 8 | 10 | 3 | 1.7 | 1050 | 21 | 230 |
| 9 | 10 | 5 | 0.7 | 1050 | 21 | 240 |
| 10 | 8 | 2 | 0.7 | 1035 | 21 | 235 |
| 11 | 5 | 2 | 0.7 | 1035 | 21 | 230 |
| 12 | 7 | 3 | 0.7 | 1060 | 21 | 240 |

On the basis of consecutive research the assessment of obtained continuous castings was done:

- the visual assessment of all the obtained castings,
- the assessment of surface roughness,
- the analysis of chemical composition,
- the assessment of the castings structure quality.

Below in fig. 4 juxtaposition of all the obtained castings is presented. Below in table 5 the results of roughness measurements for particular castings are juxtaposed.

The research of chemical composition was held with OXFORD instruments spectrometer. Foundry-Master Xpert. which was equipped with copper and zinc alloys analysis patterns. Below in fig. 6 a spectrometer and samples subjected to chemical composition analysis are presented.

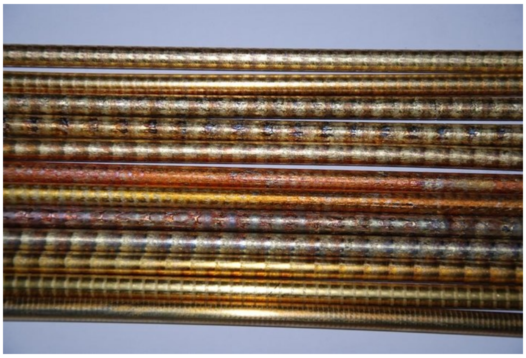

Fig. 4. CuZn39Pb2 alloy continuous castings where the order: bottom – casting no 1. top – casting no 12 is preserved

The surface roughness assessment of samples included the research held by the use of HommelWave roughness meter. The measurement was done by the use of a measuring head type T1E. The metrological range was 80µm. metrological length was 4.80mm. Lc 0.250mm. The exemplary results of roughness measurement is presented in fig. 5.

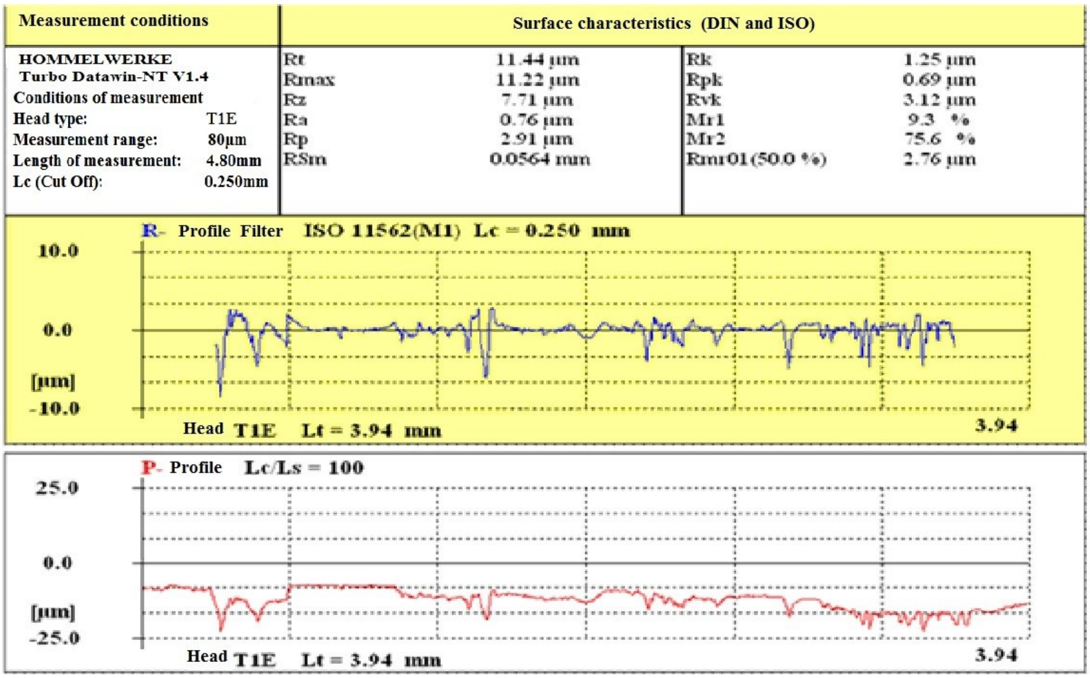


Fig. 5. The result of casting 1 from CuZn39Pb2 alloy surface roughness research

Table 5.
The results of roughness measurement for CuZn39Pb2 alloy

| No | Rt | Rmax | Rz | Ra | Rp | RSm | Rk | Rpk | Rvk | Mr1 | Mr2 | Rmr01(50%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | μm | μm | μm | μm | μm | mm | μm | μm | μm | % | % | μm |
| 1 | 11.44 | 11.22 | 7.71 | 0.76 | 2.91 | 0.0564 | 1.25 | 0.69 | 3.12 | 9.3 | 75.6 | 2.76 |
| 2 | 15.82 | 15.82 | 7.75 | 0.70 | 4.72 | 0.0434 | 0.95 | 1.62 | 3.33 | 12.6 | 78.9 | 4.69 |
| 3 | 6.73 | 5.82 | 5.32 | 0.69 | 2.90 | 0.0456 | 1.65 | 0.66 | 1.97 | 8.1 | 78.0 | 2.75 |
| 4 | 16.64 | 15.88 | 12.23 | 1.76 | 7.74 | 0.0606 | 4.66 | 2.16 | 4.26 | 7.7 | 81.7 | 7.51 |
| 5 | 27.03 | 27.03 | 15.69 | 2.08 | 12.44 | 0.0901 | 4.55 | 4.66 | 6.08 | 11.7 | 78.5 | 12.47 |
| 6 | 20.63 | 20.63 | 11.16 | 1.47 | 11.13 | 0.0849 | 4.97 | 2.34 | 3.42 | 9.0 | 86.1 | 11.13 |
| 7 | 29.79 | 29.79 | 17.02 | 2.17 | 15.97 | 0.0718 | 4.62 | 4.24 | 7.87 | 11.9 | 80.3 | 15.84 |
| 8 | 14.35 | 14.35 | 7.94 | 1.00 | 6.76 | 0.0637 | 1.99 | 2.56 | 3.06 | 7.8 | 73.4 | 6.64 |
| 9 | 22.81 | 22.64 | 12.75 | 2.01 | 13.52 | 0.0681 | 5.38 | 4.99 | 5.24 | 8.9 | 81.8 | 13.60 |
| 10 | 14.27 | 13.24 | 10.10 | 1.54 | 6.67 | 0.0727 | 4.31 | 2.05 | 3.41 | 11.4 | 81.9 | 6.71 |
| 11 | 5.55 | 5.55 | 3.06 | 0.43 | 2.97 | 0.0544 | 0.93 | 0.71 | 1.62 | 14.7 | 77.9 | 2.93 |
| 12 | 16.20 | 16.20 | 8.28 | 1.26 | 6.87 | 0.0575 | 1.97 | 2.39 | 3.89 | 16.1 | 71.7 | 6.80 |

Table 6.
Analysis of the chemical composition of individual samples. (Al less 0.0002% mass). [% mass]

| No | Cu | Zn | Pb | Sn | Fe | Ni | other |
|---|---|---|---|---|---|---|---|
| 1 | 61.7 | 36.0 | 1.7 | 0.18 | 0.17 | 0.05 | 0.04 |
| 2 | 61.5 | 36.2 | 1.7 | 0.18 | 0.17 | 0.05 | 0.05 |
| 3 | 61.8 | 36.0 | 1.6 | 0.17 | 0.17 | 0.05 | 0.05 |
| 4 | 60.8 | 37.0 | 1.6 | 0.17 | 0.17 | 0.05 | 0.05 |
| 5 | 62.4 | 35.4 | 1.6 | 0.16 | 0.17 | 0.05 | 0.04 |
| 6 | 62.5 | 35.3 | 1.6 | 0.17 | 0.17 | 0.05 | 0.04 |
| 7 | 62.6 | 35.2 | 1.6 | 0.17 | 0.18 | 0.05 | 0.04 |
| 8 | 62.5 | 35.3 | 1.6 | 0.17 | 0.18 | 0.05 | 0.05 |
| 9 | 63.2 | 34.6 | 1.6 | 0.17 | 0.18 | 0.05 | 0.05 |
| 10 | 62.2 | 35.6 | 1.6 | 0.17 | 0.17 | 0.05 | 0.05 |
| 11 | 63.100 | 34.730 | 1.691 | 0.182 | 0.181 | 0.054 | 0.062 |
| 12 | 63.290 | 34.590 | 1.641 | 0.182 | 0.182 | 0.054 | 0.060 |

The quality assessment of continuous castings produced from CuZn39Pb2 alloy was accomplished also on the basis of structure. Below in fig. 7 structure of continuous casting nr 1 is pictured. This sample is treated as a reference sample. Structure analysis was performed in cross section and longitudinal direction.

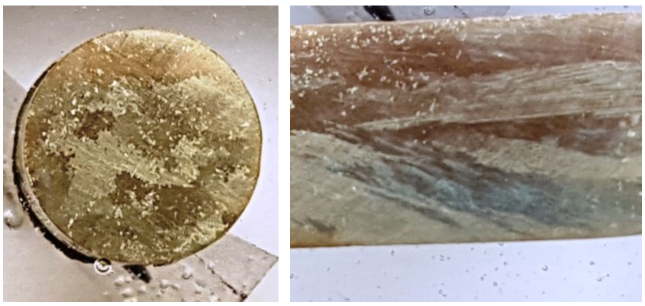

Fig. 7. Structure of cast No. 1 from CuZn39Pb2 alloy (x2.5)

The objective of these studies was to evaluate the effects of the influence of technological parameters on the formation of the structure of the ingot mainly for its later use in plastic forming processes.

Below in fig. 8 chosen pictures of castings no 6 and 7 produced at the constant feed 5 are presented. In fig. 9 photos of castings produced at feed rate 9 are shown. All the parameters of the continuous casting process are specified in table 4.

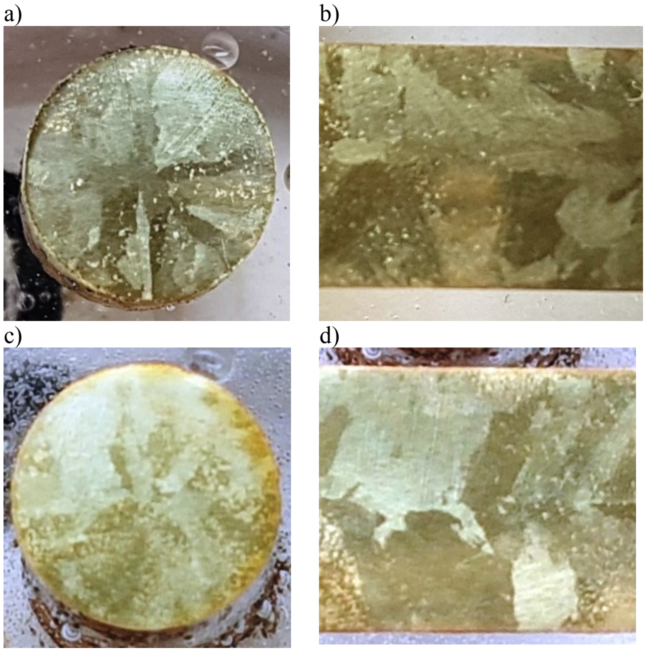


Fig. 8. Structure of CuZn39Pb2 castings where: a). b) cast 6. c). d) cast 7 (x 2.5)

Fig. 9. Structure of CuZn39Pb2 castings - cast 8 (x1.5)

## 3. Summary

It was observed that the obtained castings can be divided: (A) in terms of surface quality. B) in terms of grain size in the transverse structure. They differ also in orientation. The castings marked 1.2.3.6.7.8 and 11 had a smooth surface and were free from cracks. Castings 5.9.10 and 12 had visible surface defects. The grain size (0.5-2 mm) - casts 3.5.7 and 9; large grain (more than 2 mm) - castings 1.2.4.6.8 and 11. Orientations: axial. even surfaces - castings 1.2.3.4.5.6.8.11 and 12. not axial and uneven surface - casts 7. 9 and 10.

In conclusion. it was found that the most favorable casting conditions is low temperature at the inlet of the mold and low feed speed of the feeders to the crystallizer. The tests showed that samples designated as: 1.2.4 and 11 are suitable for further plastic processing. They were obtained mostly for the conditions of: low deputies of the casting and low water cooling rate. Interesting. however. were the trials 6 and 8 in which a uniform grain structure was obtained with different cooling conditions - higher feed rate and higher water expenditure in the crystallizer. In general. increasing the temperature of overheating liquid metal while increasing the feed rate and flow of water led to the formation of surface defects in the ingots.

It was considered that the conditions generated in trials 3 and 7 still allow the use of ingots for applications other than plastic working. The conditions planned in samples 5.9.10 and 12 were considered unfavorable for further processing and as final products.

Due to the presence of impurities in the bearing charge. the nickel content is greater than 0.053% by weight and iron over 0.075% by weight. The presence of increased amounts of lead and tin is preferred. The test results also indicate that it is advantageous to maintain a high content of zinc in the alloy - at the upper limit according to the standard.

## Acknowledgements

This project was supported by the National Center for Research and Development under Grant No. PBS3/A5/52/2015 (PBS3/244 864/PP/MMB).

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