RESEARCH ON THE DEFORMABILITY OF M95 BRASS OBTAINED BY CONTINUOUS CASTING PROCESS

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Abstract

The article presents the influence of the metallurgical process condition on the parameters of drawing M95 brass rods obtained in the continuous casting process. This work has investigated the effect of input material composition (scrap selection), diversified casting speed (various feeding and stopping time) to allow for crystallization and cooling intensity on cast quality, including solid particles removal. Studies were conducted on cast made of M95 brass and included the research on: mechanical and electrical properties, elastic constants and also comparison of density of particular casts. Casts obtained in continuous casting process were subject to deformability tests in the drawing process. The drawing process was carried out on samples with the diameter range of 9.5 to 4.45 mm. The research produced the flow curves for the tested materials. Comparison of this curves allows to determine the influence of metallurgical synthesis parameters of M95 brass on flexibility and force parameters in drawing process.

Keywords: Continuous casting process, M95 brass, drawing, deformability, metal forming

1. INTRODUCTION

Brass is one of the most widespread and most widely used alloys in the world. This material is widely used in many industries, mainly due to good strength, electrical properties as well as high corrosion resistance. Moreover, it is a material that is prone to metal forming and is also technologically attractive. Brass in grade M95, which is the subject of the study, often undergoes technological processes related to the manufacture of workpieces processed by means of metal forming, coated with ornamental and protective coatings. Therefore, it is very important that the obtained material be free of structural defects, surface defects and impurities. This may cause technological issues during the manufacture of target products or prevent the achievement of proper mechanical and electrical properties [1 - 4].

Brass has a relatively low melting point and good castability, which makes it a material that is often used in the casting process. Different proportions of alloy elements in the form of copper and zinc allow a wide manipulation of the properties of the obtained casts. One of the most popular ways of obtaining this material is continuous casting. The most important stage of the continuous casting process is crystallization. Crystallization conditions affect the structure, properties as well as speed and ability to realize the process. During continuous or semi-continuous casting, the liquid metal flows into the crystallization zone and then crystallizes as a result of the heat transfer through the cooling unit. The ability to remove heat is one of the most critical parameters limiting maximum productivity. A diagram of the crystallization zone for continuous casting is shown in **Figure 1**. Very important parameters in continuous casting are also the coolant flow speed through the cooling unit and speed of casting [5, 6].

Due to the high prices of certified foundry batches (the so-called ingots), qualified waste (in-house scrap) as well as low quality scrap copper alloys, research is being carried out on the possibility of obtaining full value waste products [7].

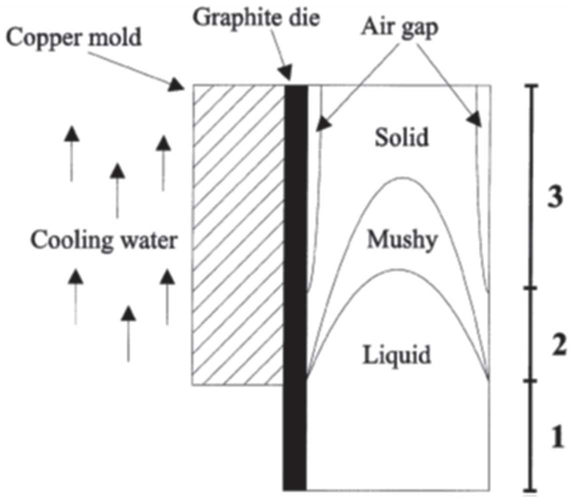

Figure 1 Schematic presentation of the interface between the casting and the mold [6]

2. MATERIALS AND METHOD

The test material in the form of M95 brass was obtained in a laboratory continuous casting line at the Department of Non-ferrous Metals, AGH University of Science and Technology, using a wide range of measurement parameters. The research line consists of an induction furnace with a graphite pot with a batch capacity of about 4000 cm^3, a 9.5 mm graphite crystallizer, a primary and secondary cooling unit, and a draw system. The station is fitted with control and measurement equipment to monitor a number of casting parameters. Station for continuous casting tests and the interface of the measuring unit are shown in **Figure 2**.

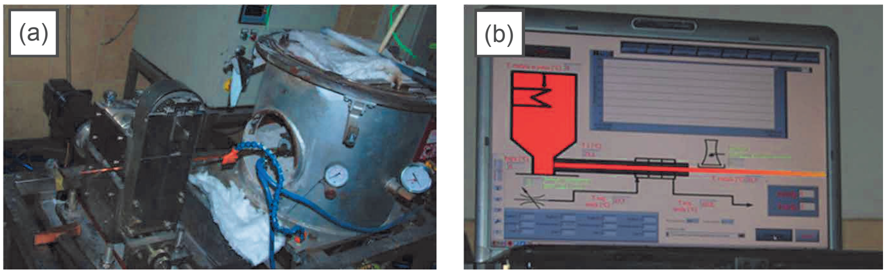

Figure 2 Station for continuous casting tests (a) with measuring unit (b)

This set-up allows controlling both kinetic and thermal casting parameters. The M95 alloy is made from waste materials in the form of scrap copper, zinc and M62, M63 brass. The types of scrap and their forms are presented in **Figure 3**.

Figure 3 Batch material in scrap used for casting: (a) copper scraps; (b) brass scraps; (c) zinc scraps

The study included the manufacture of 10 brass casts in M95 grade using a varied set of process parameters. The continuous casting process was carried out taking into account different casting speeds in the feed stroke range from 2 to 10 mm, time from 1 to 5 seconds, and various cooling rates controlled by the flow of cooling medium through the primary cooler in the range of 0.7 to 6.6 l/min. The continuous casting process was carried out at 1020 °C. Detailed parameters of the casting process of the batch material analyzed in this paper are presented in **Table 1**. The images of casts are shown in **Figure 4**.

Table 1 Parameters of the casting process

Casting No.	Continuous casting speed		Cooling intensity
	Stroke (mm)	Downtime (s)	Speed of water flow (l/min)
1	2	5	0.7
2	5	5	0.7
3	10	5	0.7
4	10	3	0.7
5	10	1	1.7
6	5	1	3.3
7	5	1	6.6
8	10	3	1.7
9	10	5	0.7
10	8	2	0.7

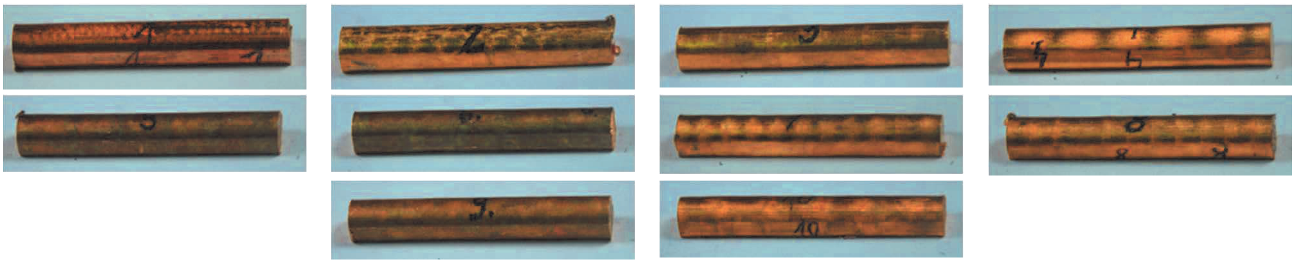

Figure 4 Allows obtained in the course of conducted research

The obtained material was subjected to density, Vickers hardness and electrical conductivity analysis. Moreover, elastic constants were tested for selected materials. Density studies were conducted using the Archimedes method. For this purpose, a weighing scale was used to measure mass in various media (i.e. air and demineralized water) together with a temperature sensor. Hardness measurements were performed using the Tuckon 2000 automatic hardness meter with the HV5 hardness scale. Electric properties studies were based on the measurement of conductivity specific to the method of measuring eddy currents. The study was conducted using the SIGMATEST 2.069 unit. Elastic constant tests for selected materials were based on defectoscopic measurements. The study involved the EPOCH XT ultrasonic flaw defectoscope and the V1091 longitudinal wave head. The test equipment is shown in **Figure 5**.

Then, the obtained casts were subjected to a cold drawing process from an initial diameter of 9.5mm to 4.55mm. The study was carried out using a chain drawing bench (**Figure 6**). The materials thus produced were subjected to a uniaxial tensile test to determine their tensile strength and yield strength. These tests were carried out on a Zwick/Roll Z020 tensile testing machine with a maximum allowable force of 20 kN (**Figure 7**).

Samples with a measuring base of 50mm were used for the tests. The data thus obtained was used to prepare work hardening curves of obtained materials.

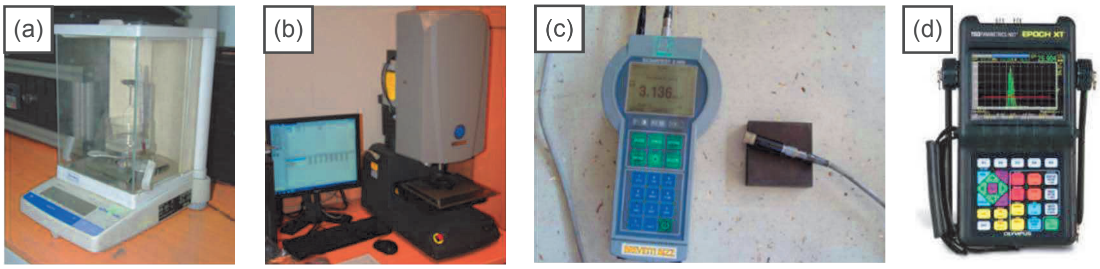

Figure 5 Measurement equipment: (a) weighing scales; (b) hardness meter; (c) SIGMATEST; (d) ultrasonic defectoscope

Figure 6 Drawing bench

Figure 7 Tensile testing machine

3. RESULTS AND DISCUSSION

The results of materials obtained by continuous casting under various process conditions are presented in **Table 2**.

Table 2 Results of properties tests of obtained casts

Cast number	Density	Hardness	Electrical conductivity	Yield strenght $R_{p0.2}$	UTS
	(g/cm³)	*HV5*	*(MS/m)*	*(MPa)*	*(MPa)*
1	8.8105	79.8	27.74	92.50	175.48
2	8.8250	72.8	27.67	123.00	185.25
3	8.8269	79.8	27.66	133.04	208.07
4	8.8263	80.5	27.64	120.77	184.70
5	8.8288	85.4	27.74	129.74	215.60
6	8.8303	80.9	27.77	129.17	213.71
7	8.8304	79.6	27.71	122.31	202.33
8	8.8279	86.7	27.70	126.53	190.47
9	8.8255	80.4	27.72	120.75	197.87
10	8.8269	83.5	27.78	121.60	191.92

It can be noted that the density of all tested materials is 8.83 g/cm^3. The observed differences in casting densities obtained under various crystallization conditions are at the level of statistical error. The next column shows the results of Vickers hardness measurements. The obtained brass casts in M95 grade are characterized by a hardness of 72.8 - 86.7 HV5. The lowest hardness HV5 is found in cast 2, while the highest was in cast 8. The difference in observed hardness scores is 13.9 HV5. The conducted electrical conductivity tests do not show any significant differences in the values obtained. The results of electrical conductivity oscillate between 27.64 - 27.78 MS/m. The highest electrical conductivity is found in cast 10, while the lowest is in cast 4. On the basis of the mechanical properties tests performed, larger differences in the results can be observed. For casts from 2 to 10, the yield strenght oscillates between 120 and 133 MPa. For cast 1, this is only 92.5 MPa, which is the lowest of all results. A similar observation is found in the analysis of ultimate tensile strength results. The lowest value was found for cast 1, equal to 175 MPa. The rest of the results range from 185 to 215MPa. Based on the investigations on the casts obtained, there is no apparent effect of continuous casting parameters on the obtained results such as: density, hardness, electrical conductivity, yield strength and ultimate tensile strength.

Based on the ultrasonic wave transition time, the sample was measured by Young's modulus for three selected casts. The **Figure 8** shows the received signals for the test samples. Studies have shown that Young's modulus for castings 2, 6 and 7 is 109 GPa, 129 GPa and 116 GPa, respectively.

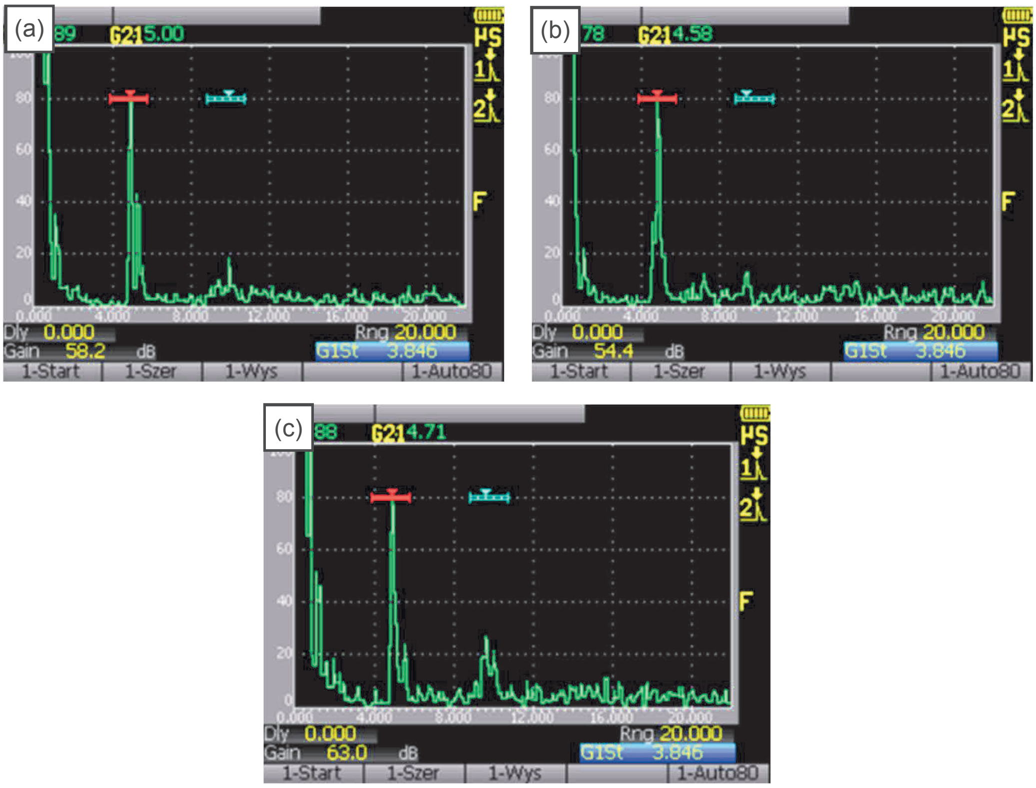

Figure 8 Defectoscope screen: (a) echo of cast 2; (b) echo of cast 6; (c) echo of cast 7

As part of the research, wires with diameters of 6.65 mm, 6.00 mm, 5.80 mm, 5.70 mm, 5.48 mm, 5.30 mm, 5.30 mm, 5.00 mm, 4.80 mm and 4.45 mm were produced in the cold drawing process. These were then subjected to uniaxial tensile test to determine the yield strength of the material. Based on the results obtained (**Table 3**), the yield strengh curves were drawn as a function of the true strain, as shown in **Figure 9**. By analyzing the results, it was found that the lowest yield strength was measured in materials made from casts 1 and 2. Whereas the highest yield strength is observed for wires made of casts 4 and 7.

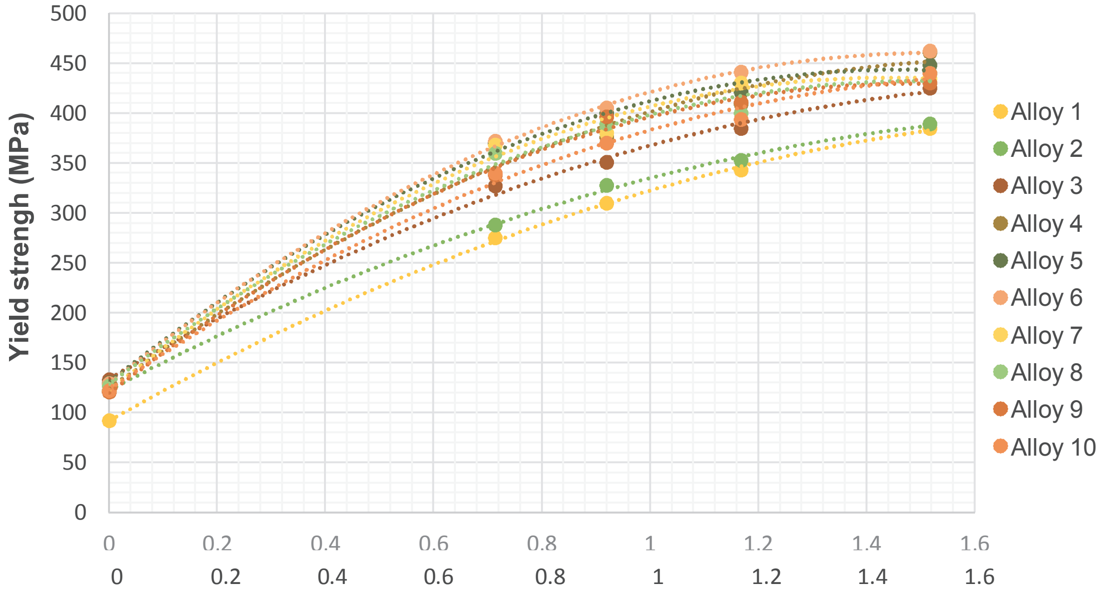

Figure 9 Characteristics of yield strength of casts 1-10 and the wires made as a function of the elongation coefficient

Table 3 Yield strength of casts 1-10 after different stages of drawing

Cast number	Yield strength $R_{0,2}$ (MPa)				
	Φ 9.50 mm	Φ 6.65 mm	Φ 6.00 mm	Φ 5.30 mm	Φ 4.45 mm
1	92	275	310	343	385
2	123	288	328	353	389
3	133	327	351	385	425
4	121	370	376	409	461
5	130	370	400	421	448
6	129	372	405	441	462
7	122	368	380	430	435
8	127	360	389	400	440
9	121	338	396	411	430
10	122	340	370	394	440

4. CONCLUSION

The paper presents a comprehensive study of M95 brass obtained from scrap on a laboratory continuous casting line using variable alloy crystallization parameters. Based on the results obtained in the tests conducted on casts 1-10, ie. density, conductivity, hardness and mechanical properties, there is no significant influence of the continuous casting parameters on the properties of the casts obtained. Larger differences, however, are observed for mechanical properties obtained in wires made from these casts. The obtained work-hardening curves show that casts 4 and 7 have the highest degree of consolidation, while casts 1 and 2 exhibit the smallest degree. The stress amplitude for different deformation stages of samples 1 to 10 is about 70 MPa. It is also observed that these differences are reproducible after successive stages of drawing. The surface quality of the wires received in individual draws was satisfactory.

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