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The Effect of Minor Element Addition on Thin Walled Brass Casting

N. Tamsü Selli, C. Imer Ozgü

Thin walled brass faucet casting is an important requirement of the industry in terms of both transportation and cost. Fluidity of molten metals is one of the important issues for thin walled castings. In this study, various metallic powders were added to the brass alloy in order to increase the fluidity of brass alloy and to provide casting at low pressures. Aluminum and nickel metallic powders were chosen as special additives. It is aimed to increase the fluidity of the brass composition by adding minor elements to the composition. In this work, the microstructure and melt fluidity of a (CuZn39Pb1Al-C) brass alloyed by small additions of aluminum and nickel were studied. These two metallic elements were added to the main melting furnace at amount of 0.0055 wt.%, 0.03 wt.% and 0.05 wt.%. The microstructures were investigated with the help of scanning electron microscopy equipped with energy dispersive X-Ray analysis (SEM/EDX) for determining significant changes of the properties. In particular, the addition of 0.03 % by weight of nickel facilitated the casting and reduced the casting pressure by 80 mbar. This reduction in the casting pressure resulted to thickness value decreased by 55% compared to the standard.

KEYWORDS: BRASS CASTING, FAUCET, THIN WALLED CASTING.

INTRODUCTION

Non-ferrous metals and their alloys are used in industry to produce ornaments, utensils, cables, machine component etc., because they are easy to form by casting, rolling, forging and machining [1]. One of the most important example is the use of brass alloys. The most important places for the use of brass alloys is also brass faucets. Brass faucets has high corrosion and high mechanical strength properties. Thin walled faucet production is one of the most challenging study in the foundry industry. The demand of thin walled section in this industry is continuously increasing due to their light weight related to economical reasons and transportation of the products. The most critical parameter for thin section brass casting is to control the fludity of the melt. Fluidity strongly depends on two variables : the metal related variables and mould related variables. Metal related variables are: viscosity, surface tension, superheat, mechanism of solidification, oxide film and non metallic inclusion formation, specific weight, melting point; mould related variables are: thermal physical properties, temperature, gas permeability, metallostatic pressure, surface characteristics

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[2- 6]. One of the most important parameters affecting the fluidity is the melt viscosity (Eq.1). In the viscous force F:

$$F = \eta S \frac{dv}{dx} \quad \text{1)}$$

Where η is the kinematic viscosity coefficent of the melt, S is the contact area between two flow layers, and dv/dx is the velocity gradient. η is closely associated with the temperature [7]. The viscous forces in the fluid tend to cause slow-moving regions in the fluid to move faster and the faster-moving regions to move slowly. Thus on a microscopic scale, the viscosity of a fluid determines a measure of the frictional forces acting on an atom in the moving fluid. Viscosity is crucial for a fluid system since it helps to categorize the fluids based on the change of viscosity with external parameters such as temperature, pressure and shear rate. Since all fluids exhibit a decrease of viscosity with increase in temperature and pressure to categorize fluids [8]. During the casting of these thin walled parts, the tendency of the bulk component, is to solidify before filling the entire mould [9]. Ziolkowski et al. [10] noted that some defects due to the misrun of the casting in thin walled sections may be seen. The fast solidification rate of the thin walled sections cause insufficent feeding of the body. Voigt et al. [6] showed that when the surface tension increases in the mould wall which reduces the fillability of thin sections are reduced. They used various mould coatings (such as graphite, an alcohol-based zircon wash, chromite and commercial coatings like Ceramcoat, Velvaplast etc.) and they determined that coatings reduce the surface tension and casting fillability increases. Li et al. [7] investigated the effect of the casting temperature of the melt. They stated that increasing casting temperature promotes the completion of the filling process. Therefore, achieving this condition is difficult due to the production circumtances. Besides of these factors, also metal composition has a crucial effect on fluidity of the melts and fillability of the moulds. However, increasing the casting temperature has a limitation in that, for production of premium quality casting with increased mechanical properties casting temperature should be as low as possible [2]. Campbell et al. [11] stated that the oxide contents of melts of the common Al-7%-0.4 Mg alloy will reduce the fluidity of the material. In addition, this study showed that a few mass per cent addition of Sn reduces the fluidity on pure Al. Wang et al. [12] studied the effect of Fe addition in the molten aluminum alloy. Increasing Fe amount decreases the fluidity of the alloy. Also Gowri and Samuel [13] reported that Fe content decreases the fluidity of the A380 die casting alloy. And also the addition of Zn to A380 alloy decreased the fluidity of the molten metal. On the contrary addition of Cu to the A380 alloy resulted increasing fluidity of the alloy. In the literature, there are many composition studies for aluminum and iron alloys, while there are few studies on brass alloys fluidity. S. Lassmann [14] reported that if iron content in the brass exceeds 0.03 wt.% and silicon 0.002 wt. %, hard inclusions formation promoted. Romankiewicz et al. [15] also investigated the influence of the chemical composition of selected armature brasses on the formation of hard inclusions. However, these studies focused on hard inclusions in brass faucet, and did not give enough information about composition effect on fluidity. Apart from the major alloying element zinc, small additions (less than 5 %) of other alloying elements affect the structure and mechanical properties of brasses such as strength, machinability, corrosion resistance etc. [16-18]. Nickel, manganese, aluminum, tin, and silicon, listed in approximate order of increasing effectiveness which improve the mechanical properties by solid solution strengthening and also improve the corrosion resistance. Hardening in these systems is great enough to make useful objects without encountering brittleness associated with second phases or compounds [18, 20, 21]. Aluminum is one of the most common element present in the composition of brasses (0.2-0.7 wt.%). Aluminum improves castability, reduces the zinc evaporation and protects the melt from the oxidation at high temperature. In addition, aluminum increases the volume faction of beta phase in microstructures [18-21]. When dissolved in the α solid solution and the β phase, aluminum increases the ultimate tensile strength, the strength, and the hardness and affects the phase transformation temperatures. Moreover, aluminum inhibits dezincification, and also it increases toughness and the corrosion resistance of brasses by forming a protective Al_2O_3 oxide film on their surfaces [17, 22, 23]. Garcia et al. confirmed that the Al has a significant effect on grain size, when 0.25% Al was added to Cu-Zn-Sn brass alloy, and the grain size rating increased from 2 to 4.5 [24]. Reducing the grain size improves hot tearing resistance, casting fluidity and enhances surface finish of various alloy systems [25]. Alloying elements modify the structure in both constituents and sizes [26]. These modifications can effect the metal related casting properties of the alloys such as fluidity. The addition of nickel can modify the properties of brass alloy due to changing microstructure and chemical composition of phases [16]. Nickel improves the strength, density, corrosion resistance of the alloy and decreases the tendency of the brasses to corrosion cracking, reduces the amount of dezincification [17, 23]. Under the light of these literature surveys, thin walled section parts of the brass can be casted by adding minor elements in the composition. In this study, aluminum and nickel metallic powders are used for obtaining thin walled castings by changing the fluidity of the alloy. Decreasing viscosity and increasing fluidity of the alloy can be evaluated by comparing the casting pressures and flow length of the brass samples.

EXPERIMENTAL PROCEDURE

Materials and Methods

The present work involves studying the effect of some special metallic powders on the thin walled section castings of copper-zinc-lead-aluminum (CuZn39Pb1Al-C) alloy as cast. Leaded brass alloy (CuZn39Pb1Al-C) which consists of copper, zinc and other minor additions is selected according to European Standards (EN 12165) and 4MS Initiative, as shown in Table 1.

Tab.1 - Standard Copper-zinc-lead-aluminum (CuZn39Pb1Al-C) alloy chemical composition (wt.%)

Element (%)	Cu	Zn	Al	Pb	Si	Fe	Ni
wt. (%)	58-63	Remainder	0,3-0,9	0,2-1,4	≤0,05	≤0,3	≤0,2

For obtaining the thin walled brass casting parts, metallic aluminum (>98% purity) and nickel (>99% purity) powders were selected (Ege Nanotek Chemical Industry/Turkey and Ortam Metal Chemical Industry/Turkey) and added as minor metallic additions in the leaded brass alloy (CuZn39Pb1Al-C) melt. Chemical composition of alloy is determined using SpectrolabTM M9 optical emission spectrometer.

Preparation of the Composition & Production Process

The melting and casting process of copper-zinc-lead-aluminum (CuZn39Pb1Al-C) alloy is carried out in low pressure die casting in Artema Eczacibasi Company industrial line. The production process of taps is given in Fig. 1 as a flowchart.

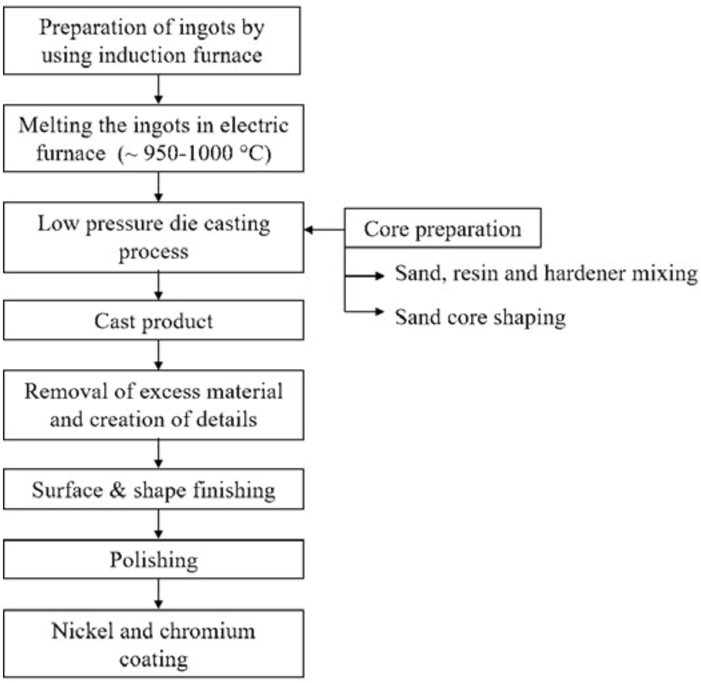

Fig.1 - Process flow chart of faucet production.

During the casting process mold is covered by with a special powder mixture. It is used as a protective cover to prevent oxidation and also prevent contaminations [27]. During standard low pressure die casting process, different amout of the pure metallic powders were added to composition seperately. Each experiment was carried out by adding different amount of metallic aluminum and nickel powder (Table 2) in a casting ladle. Then, the ladle was immersed into the standard leaded brass composition melt in electric furnace. Addition amount of metallic nickel and metallic aluminum powder in the standard brass composition (CuZn39Pb1Al-C) during low pressure casting process are given in Table 2. A1, A2, A3 represents aluminum addition and N1, N2, N3 represents nickel addition in the standart brass composition (Table 1). The maximum weight percent was determined considering the standard faucet chemical composition interval. The production process of the composition was performed by producing the 100 faucet products of each of the composition. For thin walled sytem, fluidity of the melt was determined by the pressure reduction during the casting. Faucet weight with standard leaded brass composition was measured and was found approximately 1000 g.

Tab.2 - Preparation procedure of the casting compositions.

Compositions	Type of metallic powder additive	wt.%	Production Pieces (faucets)
A1	Aluminum	0,0055	100
A2	Aluminum	0,03	100
A3	Aluminum	0,05	100
N1	Nickel	0,0055	100
N2	Nickel	0,03	100
N3	Nickel	0,05	100

Testing and Examination Process

The testing and examination processes are used to determine the effect of the composition on the faucets quality performance. "TS EN 817: Sanitary tapware: Mechanical mixing valves (PN 10)-General technical specifications" standard is used to control the leak tightness of the product. This standard specifies characteristics with which mechanical mixing valves need to comply. Specifically, it specifies dimensional, leak tightness, pressure resistance, hydraulic performance, mechanical strength, endurance and acoustic characteristics. Samples are subjected to compressed water in a period of time to observe the pressure tightness and pressure resistance of the product. "TS EN 248: Sanitary tapware: General specifications for electrodeposited coatings of Ni-Cr" is used to control the corrosion resistance of the product. In this test method sanitary tapware is subjected to neutral saline-spray for minimum 200 hours. After completing the salt-sprey test, samples are controlled for corrosion defects.

Strip Fluidity Measurement

This test provides a true and wider representation of actual casting conditions and is therefore, also popularly called as 'Casting fluidity test' since it measures the ability of the metal to fill a mould of different cross section. In this test, the drag portion of the mould has four strip of equal length, equal width and of different thickness. These strips are fed by a perpendicular sprue on the down runner which is also molded in the drag half. The length of the metal flow in all strip mould summed together or individual strip mould is taken as a measure of casting fluidity [2].

Standard leaded brass composition, aluminum and nickel added brass compositions strip fluidity test were carried out to investigate the change of the casting fluidity. In order to examine the fluidity of these alloy compositions strip fluidity test mould was used (Fig. 2).

Fig.2 - Strip fluidity test mould.

Before casting the mould was preheated and after that special powder mixture was applied over the inner surface of the mould. These trials were carried out ten times for one composition. Photographic view of strip fluidity test samples are shown in Fig. 3. In case of the strip fluidity mould, both the individual strip lengths as well as the sum of all the four strip lengths were determined as the function of different compositions used.

Fig.3 - Photographic view of strip fluidity test.

Microstructural Analysis

Microstructure analyses of cast products were performed using a Zeiss™ Supra 50 VP and Hitachi™ Regulus 8230 scanning electron microscope (SEM) equipped with energy dispersive X-Ray analysis (EDX). To reveal the phase structure, cast product surfaces were etched using two different solutions. 100 ml distilled water and 10 g FeCl3H2O powder were mixed together and 6 ml of HCl was added in the mixture (solution 1). Etching was performed for about 10 seconds using solution 1. After etching with ferric chloride solution, surface of the product was washed with distilled water to remove the etching solution residues. Solution 2 was prepared by using 100 ml distilled water and 10 g K2Cr2O7 powder. These components were mixed together and 5 ml H_2SO_4 was added in the mixture (solution 2). Second etching was performed for about 20 seconds using solution 2. Surface of the cast product was washed again to remove the remaining etching solution.

RESULTS & DISCUSSIONS

Variation of the filling pressure versus compositional change

In order to produce thin walled brass casting faucets, composition studies were carried out and metallic nickel and metallic aluminum powders were added to the CuZn39Pb1Al-C composition. Reduction of the casting pressure during the casting process and also fillability of the die were determined the performance of the compositions with metallic additions. Fig. 4 shows the pressure reduction during casting versus the compositions. All pressure reduction values were taken from the brass casting machine and all measurements were carried out for 100 trials for each composition, and mean values were calculated.

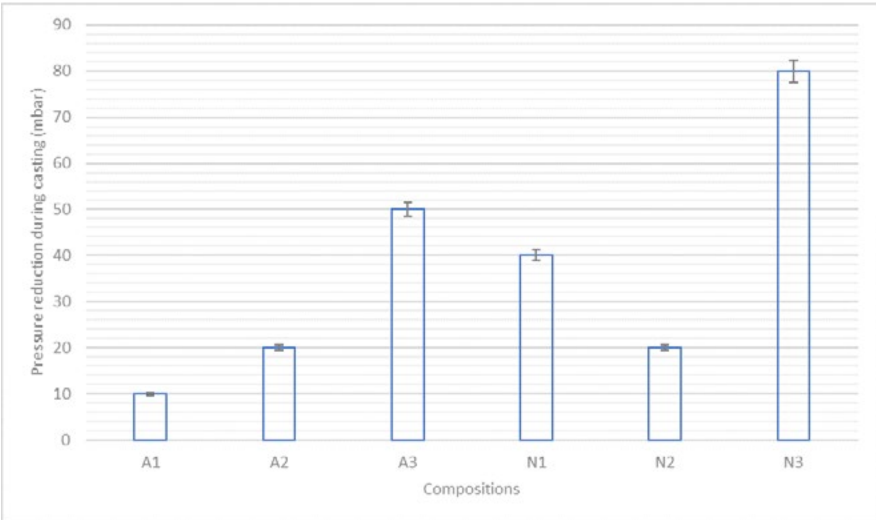

Fig.4 - Filling pressure change during casting of the composition.

Usually, copper alloys intended for permanent mold casting process contain various amounts of aluminum which is added to improve casting fluidity in permanent mold casting [25]. Casting pressures of the faucets during process is constant at all times. Addition of 0.0055 wt.% metallic aluminum powder to the CuZn39Pb1Al-C composition, A1 composition, caused 10 mbar drop in filling pressure. The casting pressure decreased 20 mbar by means of 0.03 wt.% metallic aluminum powder addition as seen in Fig. 2 (A2 composition). When aluminum powder amount increased to 0.05 wt.%, the casting pressure decreased by 50 mbar. Unlike aluminum addition, nickel addition in the system caused significant decrease in casting pressure. The pressure reduction is 20 mbar with the addition of nickel to the composition at a rate of 0.0055 wt.%. The pressure reduction was 80 mbar by increasing nickel addition to 0.05 wt.%. The optimum amount of nickel addition was found to be 0.05 wt.%.

The viscosity change according to the additions in the composition have been calculated according to Eq. 1. Results are represented in Fig. 5. Calculations have been carried out by taking the casting parameters during casting. Viscous force (F) and velocity gradient values were taken the brass casting machine database. Contact area of the samples (S) were constant for all samples because one type of product mould was used, and this value was 150 cm2. All measurents were carried out for 100 trials for each composition, and mean values were calculated. The viscosity dropped significantly with increasing nickel level in the composition especially up to 0.05 wt.%. This effect could be explained the pressure drop of casting.

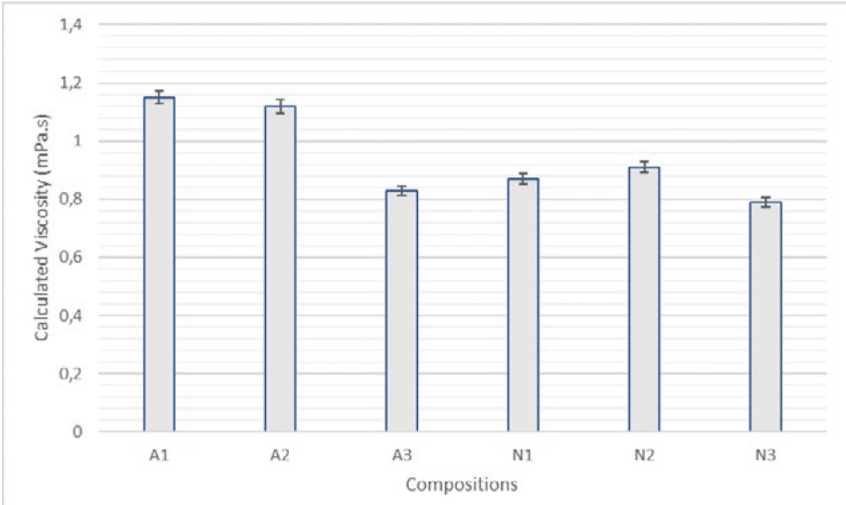

Fig.5 - Calculated viscosity of the composition according to the casting variables.

Microstructural evaluation

The microstructure of standard leaded brass faucet (Fig. 6) contains α-phase precpitated into the β-phases with lead (Pb) particles (white particles) distributed through the structure [28]. The alpha/beta interphase boundaries are high interfacial energy sites and hence, potential lead distribution centres [29]. SEM micrographs were produced using back-scattered electrons (BSE), which exhibits high sensitivity to the atomic mass of the individual elements. BSE images display atomic number (Z) contrast with brighter regions being generated from areas of higher average atomic number. In the case of standard leaded brass faucet the basic components are Cu, Zn, Pb, thus it is expected that the brighter BSE intensity might be originated from Pb particles. Fig. 6 shows the standard leaded brass faucets microstructure.

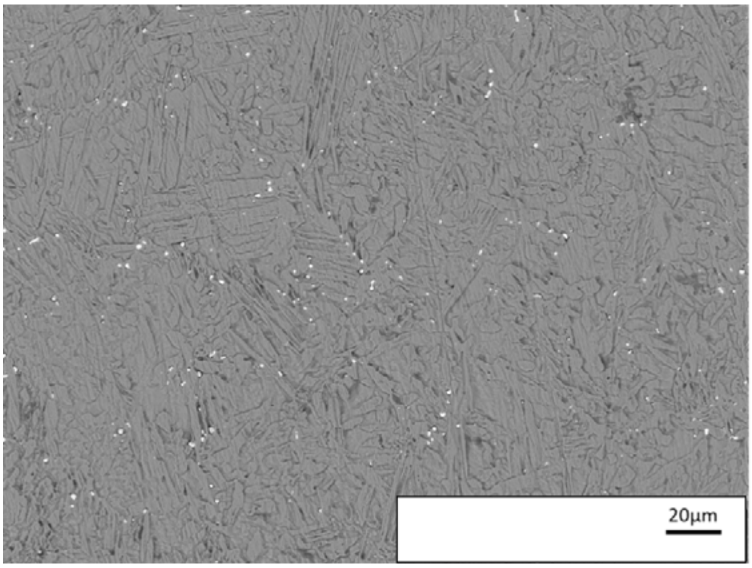

Fig.6 - SEM image of the standard leaded brass faucet after casting process.

Standart leaded brass faucet microstructure with elemental and phase distribution structure after casting process is given Fig. 7. SEM studies revealed an alpha-beta dual phase structure with a fine distribution of non-dissolved lead particles [29]. Lead is not soluble in copper alloys. It segregates to the eutectic liquid and solidifies as pure lead particles along the interdendritic regions and grain boundaries [25, 30].

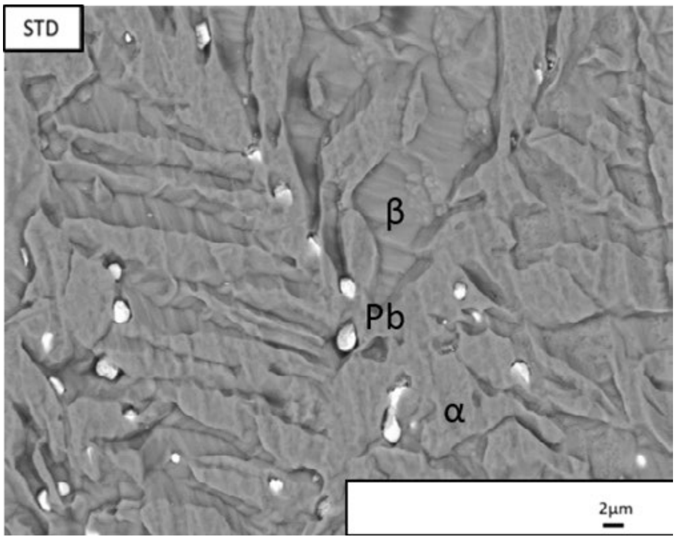

Fig.7 - SEM micrograph of standard leaded brass faucet microstructure with phase distribution and Pb after casting process.

In Fig. 8 the microstructures of increasing amount of aluminum in the leaded brass composition are presented. Phase structure consisted of α phase crystals precipitated in a β phase matrix as shown in Fig. 8. While A1 and A2 microstructures are similar to the standard one, some particles have been observed to settle in grain boundaries in A3 microstructure. Sadayapan et al. [21] investigated effects of grain refiners at different alloys. By contrast with our experiments, after addition of 0.35 wt.% Al in Cu-36 wt.% Zn alloy, aluminum reduces the grain size marginally. The microstructure is modified from a interlocking dendritic structure to a fine feathery structure. García et al. [24] and Sadayappan et al. [25] confirmed that Al has a significant effect on grain size, when 0.25% Al was added to Cu-Zn-Sn brass alloy. It is known that different alloy compositions show distinct microstructural effects. Aluminum is known as a promoter of beta phase in Cu-Zn alloys and considered at least 6 times effective than Zn. In other words, 1 wt.% Al addition is as effective as 6 wt.% Zn addition. Casting faucet microstructure (Fig. 8c) contains much more beta phase than cast standard faucet microstructure (Fig. 8a).

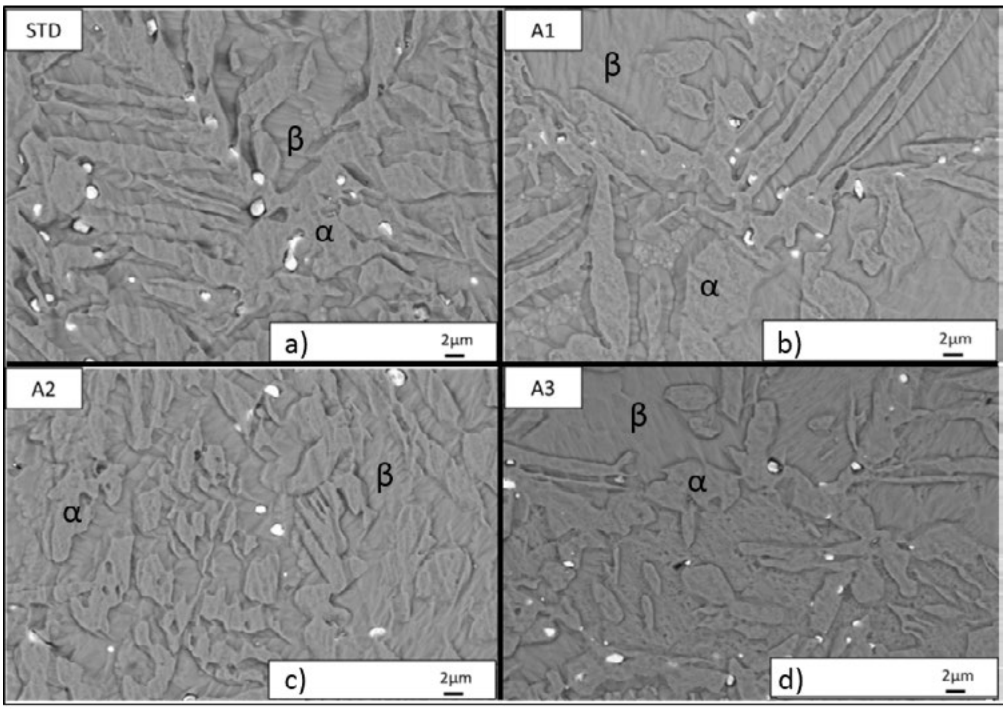

Fig.8 - Comparison of the microstructure images of the standard leaded brass composition with (a) standard (b) 0.0055 wt% (c) 0.03 wt.% (d) 0.05 wt.% aluminum added compositions

The microstructure of cast faucet samples was studied by micro-area quantitative analyses and elemental compositions in microstructure was determined. In the standard brass faucets, EDX analysis after casting showed copper, zinc and lead in the microstructure (Fig. 9). Alpha (copper rich) and beta (zinc rich) phases and Pb particles were observed from EDX measurements. Elemental analysis results showed that wt.% 56 Cu, wt.% 44 zinc was present at α-phase and β-phase had wt.% 45 Cu, wt.% 55 zinc approximately. At scanned area wt.% 77 Pb, wt.% 15 Cu and wt.% 8 Zn was determined.

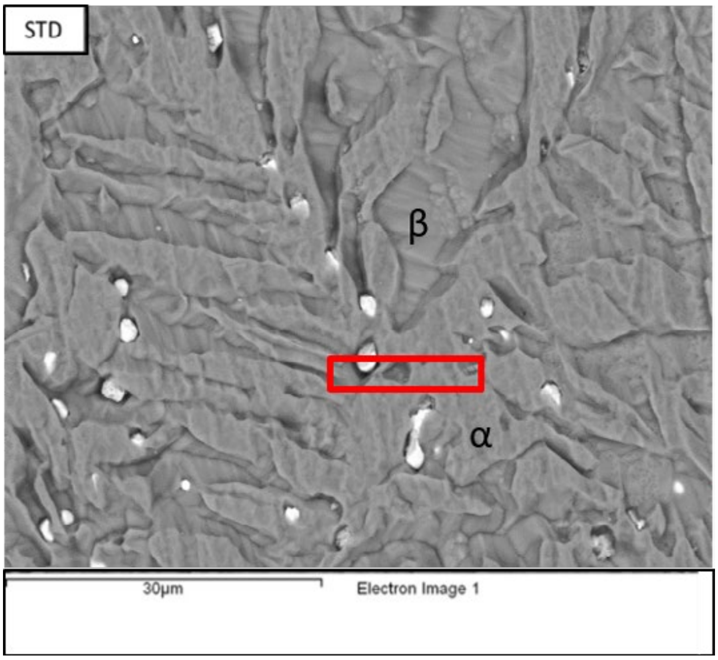

Fig.9 - SEM micrograph of the faucet with standard leaded brass composition.

The result of the EDX study of A3 composition, which enables the thin section casting to be performed with lower pressure with aluminum addition, is given in Fig. 10. The white particles in the microstructure (Fig. 10) are lead-rich particles revealed by EDX measurements at Spectrum 1 area [29]. Elemental analysis results showed that wt.% 51.2 Cu, wt.% 48.8 zinc present at scanned area of α-phase (Spectrum 2) and β-phase had wt.%48 Cu, wt.% 50,6 zinc and wt.% 1.4 Al, approximately (Spectrum 4).

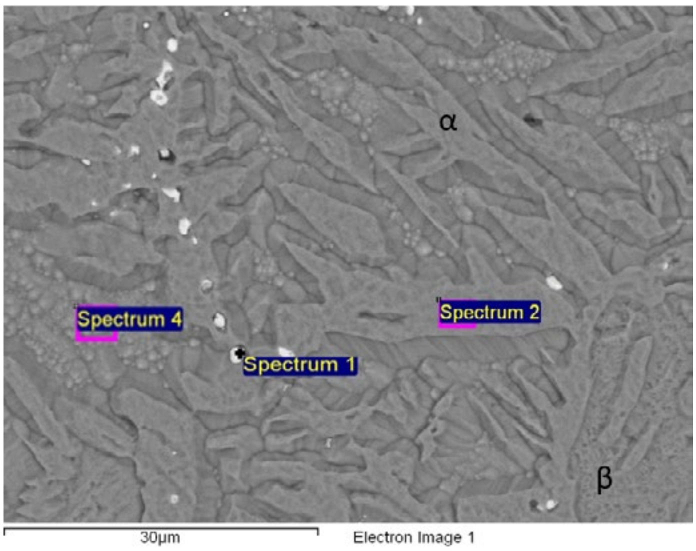

Fig.10 - SEM micrograph of the brass faucet with A3 composition.

Some alloying additions have a large effect on the structure of brass, by altering the proportion of alpha, betta, or gamma phase present. Alloying elements like Al lead to the increase of the area fraction of hard intermetallic phases in the brass matrix [30]. The addition of aluminum was increased up to 0.05 wt.% in this study (A3). The alloy matrix has a duplex phase microstructure both alpha and beta phases. Microstructure of the standard leaded brass faucet consists of copper, zinc and small amounts of aluminum as pointed with different areas in Fig. 9. Discrete lead particles are primarily founded in grain boundaries and inter-dendritic regions [24]. When alloying elements are added with large amounts, the coarser and brittle intermetallic compounds form in the grain boundaries and that causes cracks and sealing problems [30].
Since the thickness of the castings could not be reduced to the desired level with the addition of aluminum for thin section trials, the addition of nickel metallic powder was continued. Different amounts of metallic nickel powder was added to the melting furnace according to the Table 2. The microstructures of the compositions with increasing nickel addition (0.0055 wt.%, 0.03 wt.%, 0.05 wt.%) are presented in Fig. 11a-d, respectively. According to the standard brass faucet composition (Fig. 11a), nickel content was increased to 0.0055 wt. % (Fig. 11b) and casting pressure was decreased approximately 40 mbar. It is believed that nickel addition increases the fluidity of the alloy. After this trial, nickel content of the brass composition was increased to 0.03 wt.% (Fig. 11c) and increasing nickel content (N2) caused coarse microstructure and it made casting process difficult [7]. However, increasing the nickel content to 0.05 wt. % (Fig. 11d), it was observed that the microstructure was re-fined and a homogeneous microstructure was obtained. In N3 microstructure clear needles was observed. Microstructural re-finement of copper based alloys is aimed at improving the pressure tightness of plumbing components [19, 21].

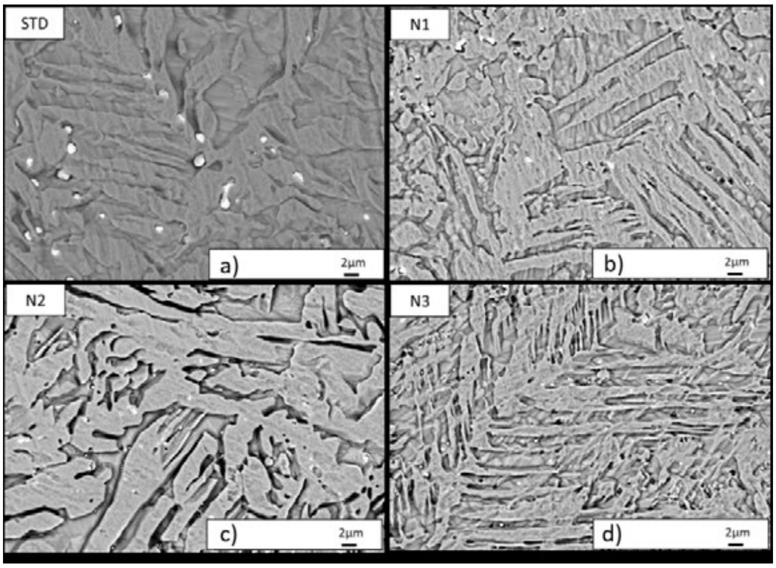

Fig.11 - Comparison of microstructural images of (a) standard (b) 0.0055 wt.% (c) 0.03 wt.% (d) 0.05 wt% nickel-added cast compositions.

The maximum reduction in the filling pressure was achieved with the addition of nickel at the maximum level (0.05 wt.%), and thin section samples were able to be cast at this low pressure. Fig. 12 shows the microstructure of the brass faucets obtained after casting with the maximum nickel addition (0.05 wt.%), defined as N3 composition. According to the analysis taken from the Spectrum 2 point (white area) is characterized as lead-rich particle. Elemental analysis results showed that wt.%53 Cu, wt.%47 Zn present at Spectrum 2 point (the α-phase brass). Spectrum 4 elemental analysis result showed that this area might be referred as β-phase with wt.% 43 Cu and wt.% 56 Zn. Scan result of bigger area (red area) showed nickel peaks in the EDX analysis but the amount of nickel is quite minor than copper and zinc. Nickel rich areas could not observed in the microstructure as clear as aluminum containing areas in the grain boundaries like A3 composition (Fig. 10).

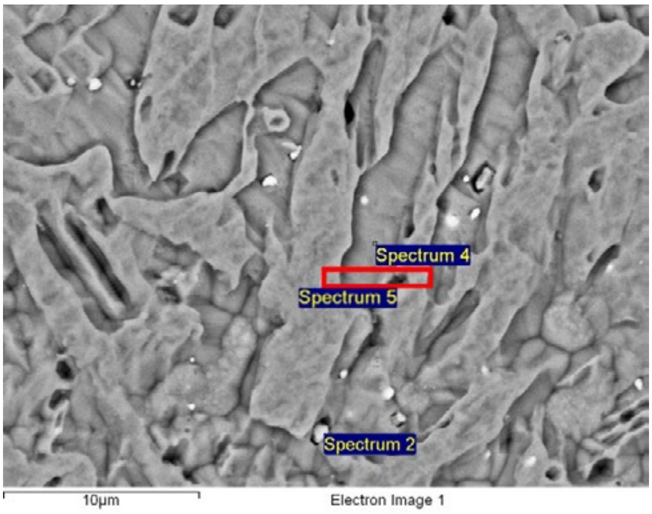

Fig.12 - SEM micrograph of N3 composition with EDX analysis points.

Strip Fluidity Test Results

Strip fluidity test results are given in Table 3. The higher the viscosity, the lower will be fluidity of the liquid metal. This information is supperted by fluidity length measurements. It is observed that the lengths of the strips of aluminum and nickel added compositions were longer according to the standard leaded brass composition. It's believed that increasing fluidity of the alloy compositions effect the strip. Our experiments also showed that when fluidity lengths are increased, the casting pressures of the alloys are decreased.

Tab.3 - Strip fluidity test results of the samples depend on the compositions.

Compositions	Flow Length (mm) Mean±S.D.*
A1	226±6
A2	240±8
A3	320±6
N1	293±7
N2	270±5
N3	365±5
S.D.*: Standard Deviation	

Standard Quality Test Results & Wall Thickness

For the thin walled brass casting process, 6 different compositions (A1, A2, A3 and N1, N2, N3) was prepared and low pressure die casting process was carried out. Corrosion and leakage tests of at least 100 faucets of all compositions (A1, A2, A3) were performed according to TS EN 248 and TS EN 817, respectively. Test results were presented in Table 4.

Tab.4 - Standard test results of brass faucets after casting.

Compositions	Corrosion Test Result (200 hours)	Reduction of the thickness according to standard composition	Leakage Test results	Crack ratio (%)
A1	Passed	%40	Passed	0
A2	Passed	%40	Passed	0
A3	Passed	%45	Passed	3-5
N1	Passed	%40	Passed	0
N2	Passed	%30	Passed	3-5
N3	Passed	%55	Passed	0

According to these results, the addition of aluminum to the leaded brass composition resulted a reduction in thickness by 40 %, however, when addition amount of the aluminum was increased, the cracks formed due to the high amount of aluminum deposition around the grain boundaries. Therefore, the aluminum amount that can be worked in production of cast brass faucets was held 0.03 % by weight. For nickel addition, at least 100 pieces for all the compositions (N1, N2, N3) were tested for corrosion and leakage according to TS EN 248 and TS EN 817, respectively. However, the number of cracks in N2 composition increased. Fluidity of the N2 composition was less than N1 and N3 and this behavior made casting difficult. During casting with N2 composition crack ratio increased up to 5 %. Crack sample of the faucet surface is seen in Fig 13.

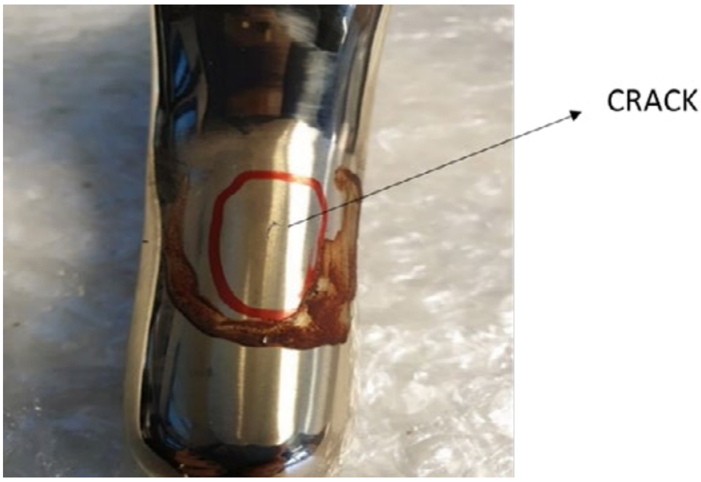

Fig.13 - Crack sample of the faucet surface.

According to the standard brass composition, N3 composition is provided the reduction of thickness. Cross-sectional images of standard brass faucet and thin walled (N3) brass faucet are seen in Fig. 14a and Fig. 14b, respectively. N3 composition caused approximately 55 % reduction of thickness with respect to standard composition (Table 4).

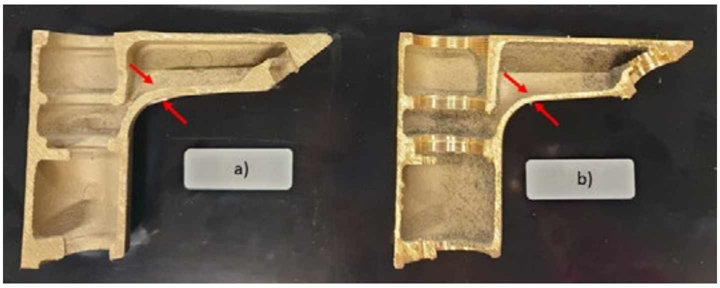

Fig.14 - Cross-sectional area of a) standard, b) N3 brass samples after casting.

CONCLUSIONS

In this study, it has been showed that thin walled brass faucet can be successfully produced with controlled CuZn39Pb1Al-C melt composition. In addition, it has been found that aluminum and nickel metallic powder addition to the melt due to the reduction of the casting pressure. The addition of aluminum provided high fluidity in the melting composition during casting. Therefore, in higher increments of the aluminum up to 0.05 wt.% (A3 composition), it was found that aluminum deposited in the grain boundaries that caused cracks and sealing problems. For nickel metallic powder addition, there has been a significant decrease in casting pressure. The casting pressure reduced as 80 mbar by increasing nickel addition to 0.05 wt.% (N3 composition). And also it is observed that the microstructure was refined and homogeneous. This composition was provided the reduction of the wall thickness by 55 % ratio, when compared to standard faucet. Accordingly, for studied N3 composition, thin wall brass faucets can be successfully produced according to brass faucet corrosion and leakage standards (TS EN 248 and TS EN 817).

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