Effect of Wall Thickness on the Quality of Casts from Secondary Aluminium Alloy

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This paper will investigate the changes in size and amount of the microstructural features in secondary aluminium casts associated with different wall thickness. The experimental samples were casting into the sand mould. The changes were documented and assessment by using optical microscope and methods of quantitative analysis. The results shows that increasing wall thickness lead to formation larger second phases and coarsening of the matrix, which lead to decreasing mechanical properties.

Keywords: wall thickness, aluminium alloy, sand mould casting, size of microstructural features

1 Introduction

The strict and further increasing rigorous environment restrictions concerning the amount of harmful emissions produced by vehicle, and simultaneously the higher safety requirements lead to research activities pertaining to lightweight manufacturing in the vehicle industry. In the fulfilsment of these requirements, the weight reduction has an important role [1]. Also the casting process is more economical than any other process of metal manufacture [2,3]. Therefore, usage of aluminium casts alloys in industry application still increase thanks good properties and good castability (weight, strength, light weight, workability and relative low cost, and so on) Fig. 1 [4-8]

![Fig. 1 Evolution of average aluminium content per car produced in Europe](image)

The current applications of aluminium alloys in transport industry are for starter motor support, armored vehicle housing, sensor adapter, connecting rod support, electronics system box, EGR systems castings, housing for vibration reduction system, gear arm, housing for agriculture vehicle, armrest pieces for pilot and copilot, net collecting drums, turbo and so on [9]. All of these castings have a different wall thickness, size and shape. The properties are therefore different and are dependening on the quality of cast process and also pouring temperature, initial temperature of the mould, shape and size of the mould, mould wall thickness, material of the mould, time of pouring into the mould, and composition of the metal [2, 10]. The typical minimal wall thickness for a large aluminium casts is 2.032 mm for small castings 1.016 mm [11].

However the sand casting is the most convenient process in foundry thanks that most of the liquid metal can be poured into the sand mould and any size can be cast, the experimental material was casted in to the sand mould. Also, solidification rate of molten metal in the sand mould depends on the thermal conductivity of the mould material, casting design and the direction of heatflow into the mould wall. Therefore were casted experimental samples with different wall thickness [3].

2 Experimental material and procedure

The main aluminium casts alloys are AlSi(Cu, Mg) alloys. These materials contain silicon due to its capability to increase fluidity, elevated temperature resistance to cracking, and feeding characteristics. In addition, silicon is the only alloying element that added to aluminum does not increase the specific mass of the alloy. Copper and magnesium increase strength and toughness in AlSi alloys, as well as provide hardening phases that precipitate during the aging thermal treatment [2,12]. Therefore as the experimental material was used AlSi6Cu4. The melt of AlSi6Cu4 cast alloy was poured into a sand mould and was casted to the shape of cast like on Fig. 2 with different wall thicknesses of 25 mm (samples A), 12 mm (samples B), 6 mm (samples C) and 3 mm (samples D) (Fig. 2).
AlSiCu aluminium alloys belongs to the most versatile alloys, has very good casting characteristics and is used for a very wide range of applications thanks very good machinability and proof strength [6,13]. The chemical composition of each samples were measured on five different places with using metal analyzer SPEROMAXX.

The type, size and shape of microstructural features (fineness of dendrites, SDAS factor, surface area and surface fraction of eutectic Si and Cu-rich and Fe-rich phases) were investigated by using optical microscope Neophot 32 conected with quantitative analyses software NIS Elements 4.0. Samples for metallographic observation were prepared by using automat TegraSystem (grinding, polishing and chemical etching). About 60 measurements of each characteristic were made on one sample and the resulting value represent the average value of the measurements.

The Brinell hardness (load 62.5 kp, dwell ball with diameter 2.5 mm and time 10 s) was measured six times on each samples. The resulting value represent the average value of the measured Brinell hardness.

### 3 Results and discussion

The chemical analysis shows that each samples have the same chemical composition so the different wall thicknes does not to lead to extreme changes in chemical compositions (Table 1). The chemical composition of experimental materials still corresponding with standarts.

#### Tab. 1 The chemical composition of experimental samples

|       | Al  | Si  | Cu  | Fe  | Mg  | Mn  | Zn  | Ti  | Cr  | Ni  | Pb  | Sb  |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Samples A | 87.7 | 6.61 | 3.59 | 0.447 | 0.247 | 0.457 | 0.626 | 0.139 | 0.023 | 0.031 | 0.079 | 0.018 |
| Samples B | 87.9 | 6.42 | 3.44 | 0.492 | 0.229 | 0.519 | 0.609 | 0.143 | 0.027 | 0.029 | 0.072 | 0.015 |
| Samples C | 87.9 | 6.54 | 3.50 | 0.450 | 0.236 | 0.461 | 0.620 | 0.143 | 0.023 | 0.029 | 0.067 | 0.016 |
| Samples D | 87.9 | 6.47 | 3.53 | 0.474 | 0.237 | 0.484 | 0.618 | 0.145 | 0.025 | 0.030 | 0.068 | 0.017 |

![Image a) eutectic](image-a.png)

**Fig. 3 The basic microstructural features in experimental alloys**

The experimental alloy is hypoeutectic aluminium cast alloy and microstructure consist of eutectic (mechanical mixture of α phase and eutectic Si particles), Fe-rich phases in form skeleton particles (Al₁₅(FeMn)₃Si₂) and Cu-rich phases like ternary eutectic phase (Al-Al₂Cu-Si) (Fig. 3) [13-16]. The different wall thickness did not lead to formation other types of intermetallic phases (Fig. 4).

The assessment of microstructure of different wall thicknes of casts shows that the samples A (with the thickest wall 25 mm) have the largest size of each measured microstructural features characteristics (Fig. 4, 5). The size of Fe-rich phases has about 660 µm², eutectic Si particles 204 µm², Cu-rich phases 179 µm² while samples D
The microstructure of experimental samples according to wall thickness. 1-Al$_2$Cu-Si phase; 2-Al$_{15}$FeMn$_3$Si$_2$; 3-eutectic Si particles; 4-α phase.
a) surfaces area of microstructural features

b) of surface fraction of microstructural features

c) of Brinell hardness changes depending on area size of microstructural features

d) of Brinell hardness changes depending on size of matrix dendrites

**Fig. 5 The experimental results**

**4 Conclusions**

The results of this study shows that increasing wall thickness lead to formation of larger microstructural features and decreasing hardness:

- The eutectic Si particles were for about 92% higher, the Fe-rich phases for about 85% and Cu-rich phases for about 63%, in the thickest samples comparison to samples with the smallest wall thickness.
- The SDAS factor was for about 48% higher and thickness of dendrites of matrix for about 55%, in the thickest samples comparison to samples with the smallest wall thickness.
- Brinell hardness value was for 6% higher in samples with thinner wall as with thicker wall.

These results confirms differences properties in different wall thickness of casting. Therefore is very important to have a good condition, for example: pouring temperature, initial temperature of the mould, shape and size of the mould, time of pouring into the mould, and so on at casting process of casting with different wall thickness.

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