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

Lenka Kuchariková[1], Eva Tillová[1], Richard Pastirčák[2], Milan Uhríčik[1], Denisa Medvecká[1]
[1]Faculty of Mechanical Engineering, Department of Materials Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovakia. E-mail: lenka.kucharikova@fstroj.uniza.sk, eva.tillova@fstroj.uniza.sk, milan.uhricik@fstroj.uniza.sk, denisa.medvecka@fstroj.uniza.sk
[2]Faculty of Mechanical Engineering, Department of Technological Engineering, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovakia. E-mail: richard.pastircak@fstroj.uniza.sk

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 thicknes 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 lighweight manufacturing in the vehicle industry. In the fulfilments 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 aplication still increase thanks good properties and good castability (weight, strength, light weight, workability and relative low cost, and so on) Fig. 1 [4-8]

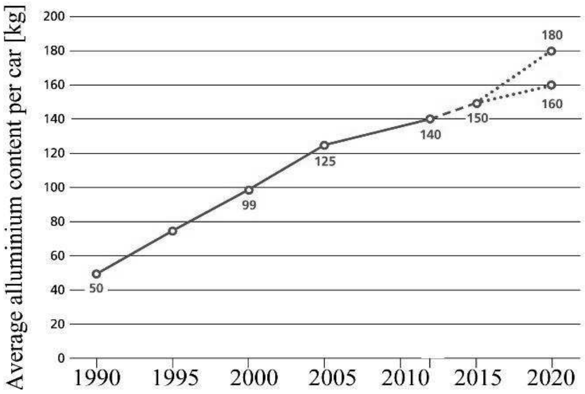


***Fig. 1** Evolution of average aluminium conent per car produced in Europe [5]*

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 thicknes, size and shape. The propertties are therefore different and are depemnding 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 aluminum 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).

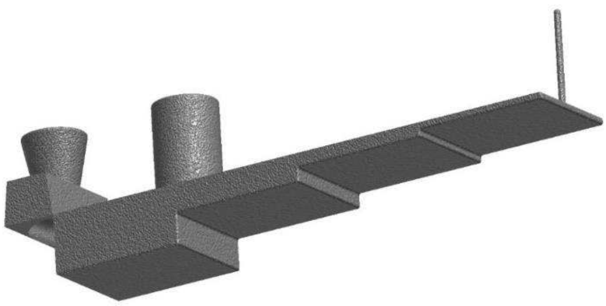


***Fig. 2** The cast with different wall thickness from experimental alloy*

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 plases with using metal analyzer SPETROMAXx.

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. Smaples for metallographic observation vere 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.

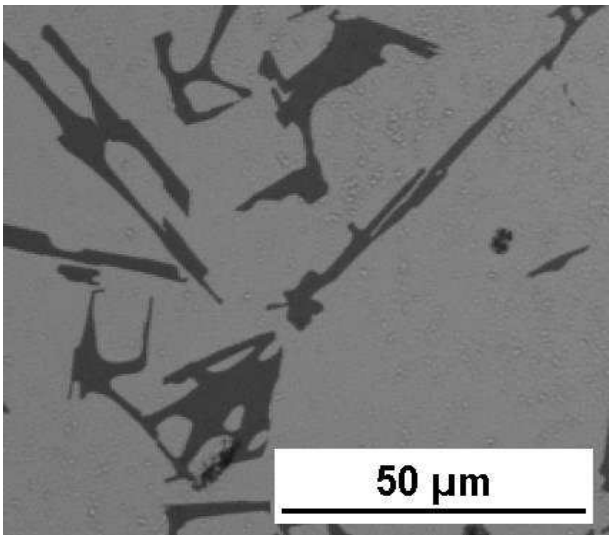
The Brinell hardness (load 62.5 kp, dwell ball with diameter 2.5 mm and time 10 s) was measured six times on each samples. The resulting value represent the average value of the measured Brinell hardness.

3 Results and discussion

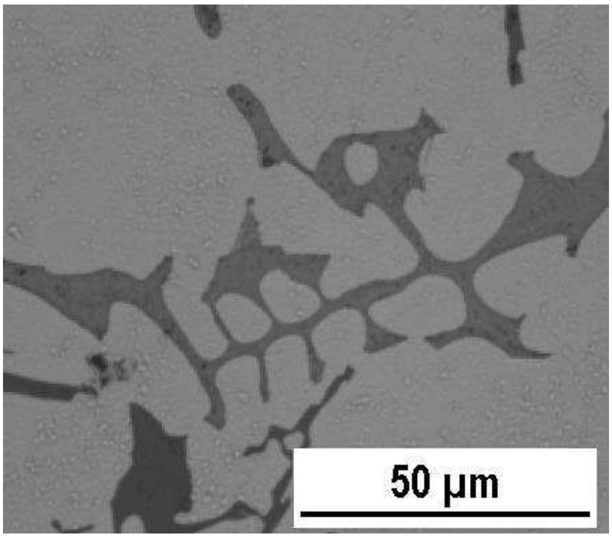
The chmical analysis shows that each samples have the same chemical composition so the different wall thicknes does not to lead to extreme changes in chemical compositions (Table 1). The chemical composition of experimental materials still corresponding with standarts.

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

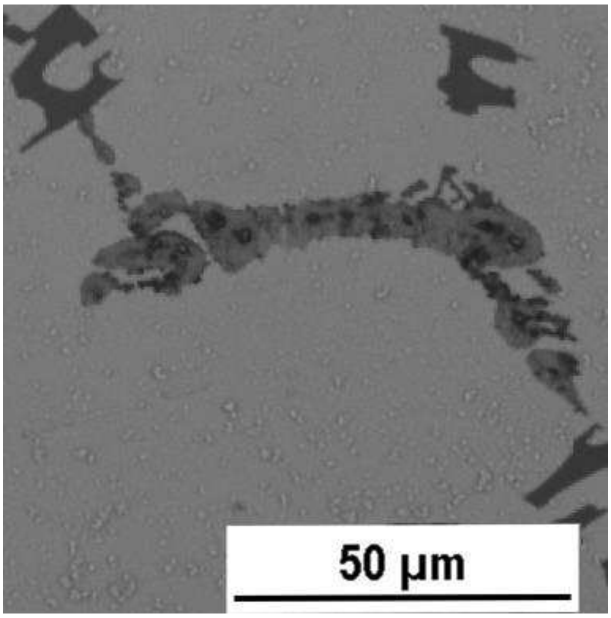
	Al	Si	Cu	Fe	Mg	Mn	Zn	Ti	Cr	Ni	Pb	Sb
Samples A	87.7	6.61	3.59	0.447	0.247	0.457	0.626	0.139	0.023	0.031	0.079	0.018
Samples B	87.9	6.42	3.44	0.492	0.229	0.519	0.609	0.143	0.027	0.029	0.072	0.015
Samples C	87.9	6.54	3.50	0.450	0.236	0.461	0.620	0.143	0.023	0.029	0.067	0.016
Samples D	87.9	6.47	3.53	0.474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



a) eutectic



b) Fe-rich phases $Al_{15}FeMn_3Si_2$



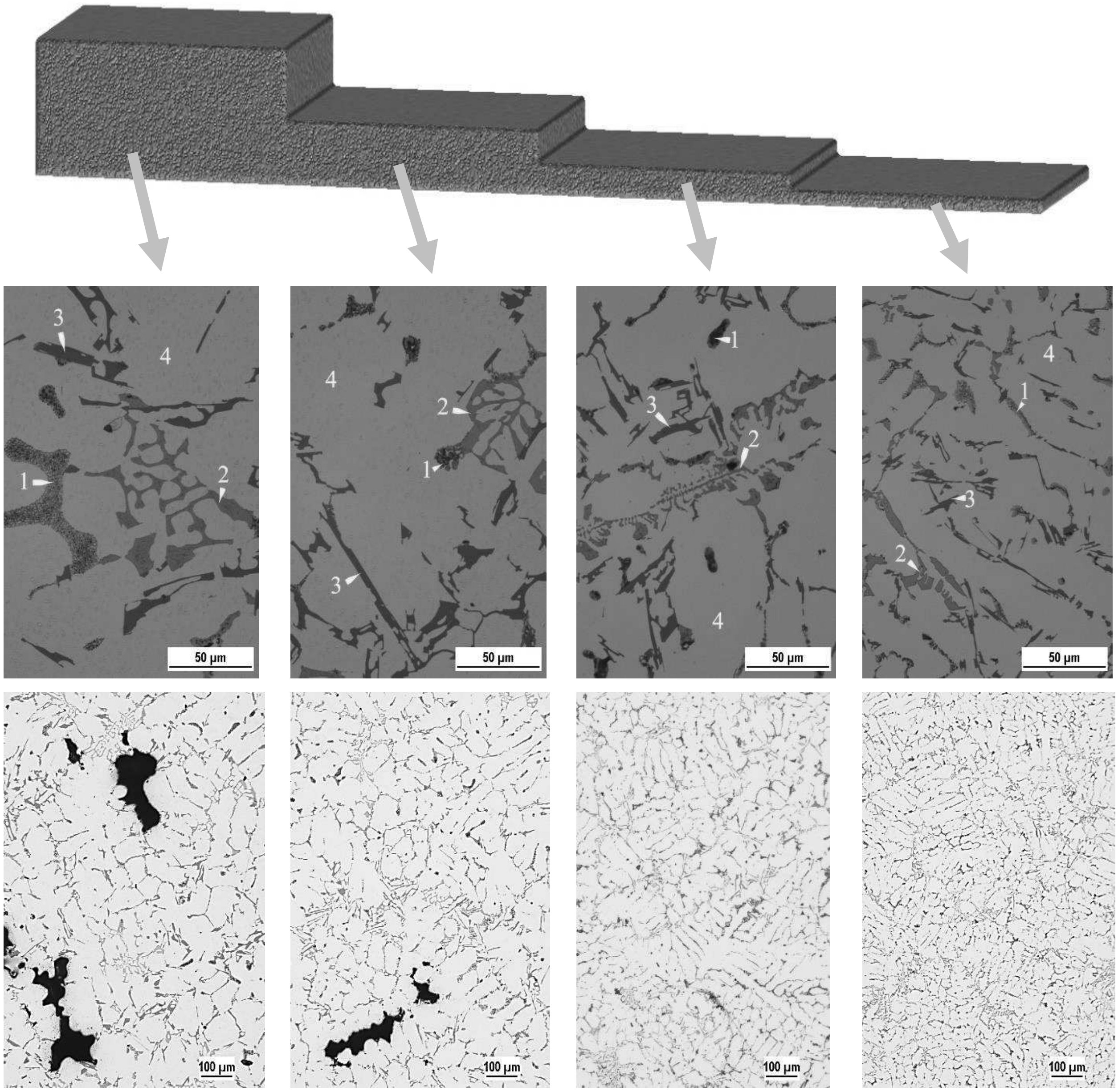
c) Cu-rich phases Al-Al_2Cu-Si

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

The experimental alloy is hypoeutectic aluminium cast alloy and microstructure consist of eutectic (mechanical micture of α phase and eutectic Si particles), Fe-rich phases in form skeleton particles ($Al_{15}(FeMn)_3Si_2$) and Cu-rich phases like ternary eutectic phase (Al-Al_2Cu-Si) (Fig. 3) [13-16]. The different wall thickness did not lead to formation other types of intermetallic phases (Fig. 4).

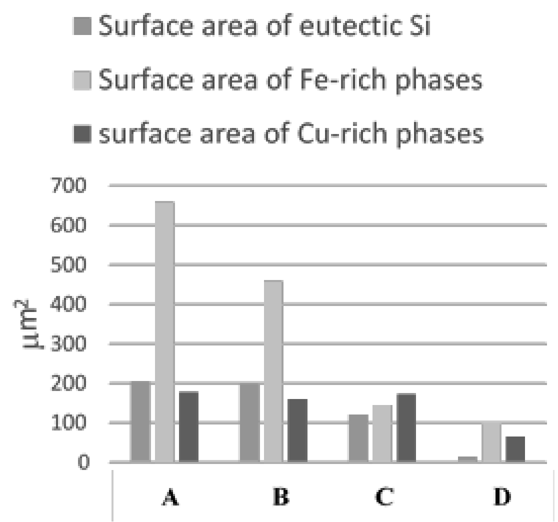
The assesment of microstructure of different wall thicknes of casts shows that the samples A (with the thickest wall 25 mm) have the largest size of each measured microstructural features characteristics (Fig. 4, 5). The size of Fe-rich phases has about 660 µm^2, eutectic Si particles 204 µm^2, Cu-rich phases 179 µm^2 whille samples D (with the thinnest wall) has the size of Fe-rich phases has about 101 μm^2, eutectic Si particles 16 μm^2, Cu-rich phases 67 μm^2 (Fig. 4, 5a). The size of microstructural features consequently decrease with decreasing wall thickness (Fig. 4). The results of assessment also confirmed that as the thickness of a casting part increases the porosity comes in the inner (Fig. 4). The surface fraction assessment shows that samples B (with the 12 mm wall thickness) have the highest values (Fig. 5b). The surface fraction of Si was a little higher in thicker samples (A, B), of Fe-rich phases was in thicker samples two or three times higher comparison to thinner samples and Cu-rich phases surface fraction is similar for each samples (Fig. 5).

Brinell hardness measurements confirmed increasing hardnes with decreasing wall thickness. The HBW 2.5/62.5/10 of samples A was 83, for samples B 85, for samples C 90 and for samples D 90. The results shows that at lower Brinell hardness is surface area (size) of microstructural features higher than at higher Brinell hardness (Fig. 5c). The same results shows SDAS factor and fineness of the matrix dendrites (Fig. 5d). The samples with small value of SDAS factor and the finest matrix (samples with the thinner wall) have the highest Brinell hardness. The increasing is about 6 % of Brinell hardness in the thinnest samples comparison to thicker.

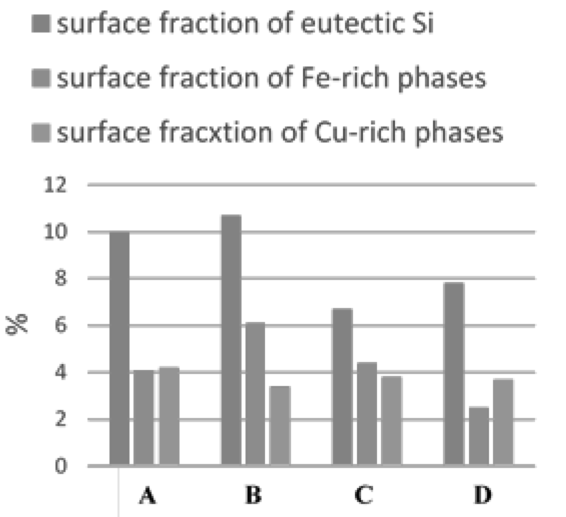


a) samples A *b) samples B* *c) samples C* *d) samples D*

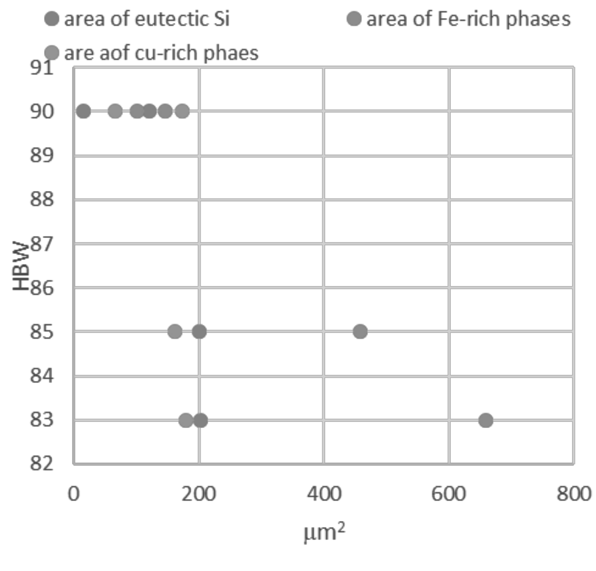
Fig. 4 *The microstructure of experimental samples according to wall thickness.1-Al-Al_2Cu-Si phase; 2-$Al_{15}FeMn_3Si_2$; 3-eutectic Si particles; 4- α phase*



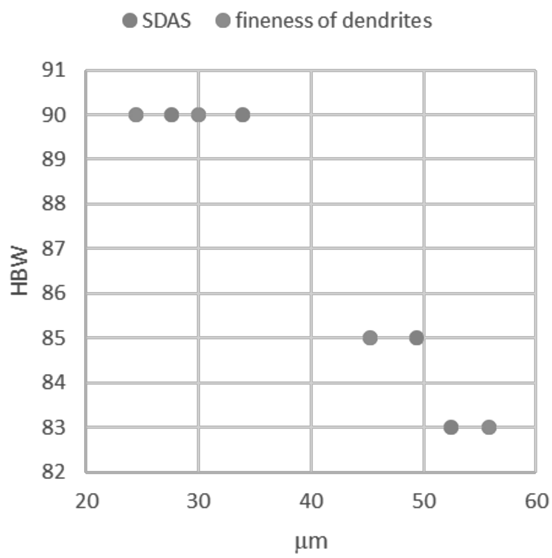
a) surfaces area of microstructural features



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 thiner wall as wit thicker wall.

These results confirmes 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.

Acknowledgement

This work has been supported by the grant projects N^o 049ŽU-4/2017, N^o 1/0398/19, N^o 012ŽU-4/2019. This work was supported under the project of Operational Program Research and Innovation: Research and development activities of the University of Zilina in the Industry of 21st century in the field of materials and nanotechnologies, No. 313011T426. The project is co-funding by European Regional Development Fund.

References

[1] TISZA, M., CZINEGE, I. (2018). Comparative study of the application of steels and aluminium in lightweight production of automotive parts. In: *International Journal of Lightweight Materials and Manufacture*, Vol. 1, pp. 229-238.

[2] FARINA, M.E., BELL, P., FERREIRA, C.R.F., DEDAVID, B.A. (2017). Effects of solidification rate in the microstructure of Al-Si5Cu3 aluminium cast alloy. In: *Materials researchs*, Vol. 20, No. 2

[3] SAHU, A., BHAT, M.N., KUMAR, A., PRATIK, A., KUMAR, A. (2014). Effect of section thickness on the microstructure and hardness of gray cast iron. In: *International journal of engineering research and technology*, Vol. 3, No. 7, pp. 35-40.

[4] POPROCKÁ, R., BOLIBRUCHOVÁ, D. (2017). Iron intermetallic phases in alloz based on Al/Si/Mg bz applzing manganese. In: *Archives of foundry engineering*, Vol. 17, No. 3, pp. 217-221

[5] Aluminium in cars. Unlocking the light-weighting potential. Available online at: https://www.european-aluminium.eu/media/1326/aluminium-in-cars-unlocking-the-lightweighting-potential.pdf

[6] UHRÍČIK, M., PALČEK, P., CHALUPOVÁ, M., FRKÁŇ, M. (2018). The influence of the structure on the fatigue properties of aluminium alloys for the casting. In: *MATEC Web of Conference*, Vol. 157, Article number 0701322nd Slovak-Polish Scientific Conference on Machine Modelling and Simulations, MMS 2017; Sklene Teplice; Slovakia; 5 September 2017 through 8 September 2017; Code 135294

[7] GLORIA, A., MONTANARI, R., RICHETTA, M., VARONE, A. (2019). Alloys for aeronautic applications: state of the art and perspectives. In: *Metals*, Vol. 9, No. 6, pp. 662

[8] JAMBOR, M., NOVÝ, F., BOKŮVKA, O., TRŠKO, L. (2019). The natural aging behavior of the AA 2055 Al-Cu-Li alloy. In: *Transportation research procedia,* Vol. 40, pp: 42-45.

[9] Sectors of aluminium casting. Available online at: http://www.cofundi.com/en/sectores/automoci%C3%B3n

[10] BALA, C.K., KHAN, R.H. (2014). Rate of solidification of aluminium casting varying wall thickness of cylinrical metallic moulds. In: *Leonardo journal of sciences*, Vol. 25, pp.-19-30.

[11] Wall thicknesses in die casting parts. Available on-line at: https://www.chinasavvy.com/wall-thicknesses-in-die-casting-parts

[12] TILLOVÁ, E., FARKAŠOVÁ, M., CHALUPOVÁ, M. (2013). The role of antimony in modifying of Al-Si-Cu cast alloy. In: *Manufacturing Technology*, Vol. 13, No. 1, pp. 109-114.

[13] BOLIBRUCHOVÁ, D., ŽÍHALOVÁ, M. (2013). Possibilities of iron elimination in aluminium alloys by vanadium. In: *Manufacturing technology*, Vol. 13, No. 3, pp. 289-296.

[14] HURTALOVÁ, L., TILLOVÁ, E., CHALUPOVÁ, M. (2015). Possibilities of Fe-rich phases elimination with using heat treatment in secondary Al-Si-Cu cast alloy. In: *Metalurgija*, Vol. 54, N. 1, pp. 39-42.

[15] HURTALOVÁ, L., TILLOVÁ, E., CHALUPOVÁ, M., BELAN, J., VAŠKO, A. (2014). Microstructure vontrol of secondary A231 cast alloy used in automotive industry. In: *Manufacturing Technology*, Vol. 14, No. 3, pp. 326-333.

[16] GRZNIČIN, M., LUKÁČ, I. (2014). Identification of intermetallic phases in the alloy AlSi6Cu4. In: *Manufacturing technology,* Vol. 4, No. 2, pp. 160-166.

10.21062/ujep/374.2019/a/1213-2489/MT/19/5/797
Copyright © 2019. Published by Manufacturing Technology. All rights reserved.