The Analysis of Homogeneity of the Chemical Composition in Castings Made of Aluminum Alloy

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In the paper there were carried out experimental researches that aimed the establishing of the homogeneity of chemical composition in castings in temporary forms made of aluminum alloy. In this way, the aluminum alloy AC-AIMg5(Si) was poured and 5 samples were made with diameters between Ø 20 mm respectively Ø 60 mm. It was determined the chemical composition of each sample in three distinct points, and the obtained results were statistically processed and there were determined the following parameters: Avg (Average), SD (standard deviation), RSD (relative standard deviation), and based on these there was established the influence of the castings diameter on the homogeneity of chemical composition.

Keywords: chemical composition, aluminum alloy, casting, homogeneity

Non-ferrous alloys can be a combination of two, three or more elements. Between these chemical elements the following relations may exist based on their ability to dissolve fully, partly or not at all in liquid or solid form [1, 2]: - total soluble (miscible) in the liquid form and the solid form; - total soluble in liquid form but insoluble in solid form; - total soluble in liquid form and partially soluble in solid form; - insoluble both in solid and in liquid form. In the specialty literature there are discussed in detail these cases under thermal equilibrium diagrams, binary or ternary. These diagrams represent graphical relations, drawn according to the temperature and concentration, showing state of equilibrium change of the alloys according to these coordinates. The equilibrium diagrams offer the possibility of establishing the state of alloys at a certain concentration depending on the temperature and to determine the existing phases in terms of quantity and quality points. They allow to follow the phase transformations that occur in heating or cooling and identifying the structural constituents which are obtained by phase transformation [3, 4].

Regarding the contraction of aluminum alloys it is superior to the cast iron, about 1,2 to 1,7 %, and fluidity is high, oxidability is high and there is a high tendency of embrittlement. To avoid microcracks it is necessary an additional degassing of the alloy and the use of foundry molds which allowing very smooth evacuation of gas from cavity-generating of the piece. At the gravitational casting, filters must be provided for retaining slag and big vents with the role of feeder. Aluminum alloys can pour (there are special marks for this processing) by presented molding processes [5, 6]. A particular problem that occurs in casting alumnium alloys refers to the appearance of the phenomenon of segregation. Thus, the phenomenon of segregation can occur at the level of the wall of piece and in this case it is called major segregation, but can also occur at the crystal level when it is called minor segregation and consists of differences between concentrations of chemical elements and occurred during a phase solidification. As it is shown in figure 1, at the T_1 temperature, the separate phase has the concentration C_1, at the T_2 temperature, it has the concentration C_2, and so on.

Thus, a free separately crystal in the liquid mass will have the axial area richer in the component A, and marginal zone richer in the component B. This uneven distribution of components of alloys in casting pieces, as a result of the segregation process, exert an unfavorable influence affecting their functional and technological properties [7, 8].

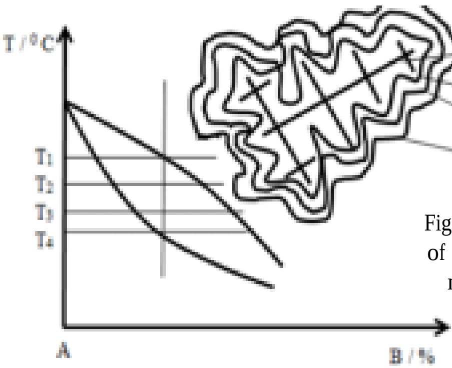

Fig. 1. The emergence of the phenomenon of minor segregation

The phenomenon of segregation can be prevented by a series of technological measures such as: increasing the cooling rate of the piece, changing the composition of the alloy, thermal treatments of annealing of homogenization etc. [9, 10].

Experimental part

The main aluminum alloys indicated for use in casting processes are: siluminium Al-Si (ATSi12, ATSi4MgMn) which have a good and very good castability (ATSi5Ca1) with reduced tendency to cracking and good good compactness. Siluminium's properties can be improved by modifying the alloy; Al-Mg alloys (ATMg10, ATMg9Si, ATMg10Fe) which have a poor castability with reduced tendency to crack and medium compactness; Al-Cu alloy (ATCu4Ti, ATCu8, ATCu10Mg), which have an average castability, have a tendency to crack on cooling, and average compactness; Al-Zn alloys (ATZn10Si7, ATZn5Mg) which hve good castability with reduced tendency to crack and medium compactness.

For the experimental research was made a number of 5 samples of castings of aluminum alloy EN AC-AIMg5(Si). These samples have been made for five different diameters, figure 2, namely: a - sample Ø 20 mm, b - sample

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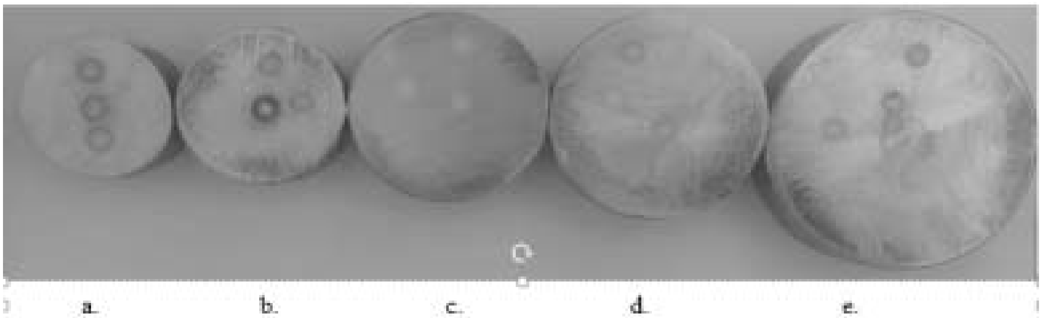

Fig. 2. Cast samples of aluminum subjected to chemical analysis: a – sample Ø 20; mm, b – sample Ø 30 mm; c – sample Ø 40 mm; d – sample Ø 50 mm; e – sample Ø 60 mm .

Ø 30 mm, c - sample Ø 40 mm, d - sample Ø 50 mm, e - sample Ø 60 mm.

For casting in dry temporary forms of aluminum alloys there were used following mixtures: mixture model; stuffing mixture. Mixture model was prepared in a Hummers mill, where there were executed forms after the following recipe: Aghires sand dried (max humidity 0.5 %) = 80 %; clay = 15 %; water = 5 / %. The introduction of the components was made using graduated beaker in the following order: dry sand; Clay (approx. 3 min.); water (mix 5 min.). Stuffing mixture was prepared by the following recipe: recirculated forming mixture - 94 %; bentonite - 1 %; water -5 %.

To determine the chemical composition of aluminum castings there was used a spectrometer, type ARL QUANTODESK, with the following features: flat field optical spectrograph with one entrance slit, grating and solid-state detector wavelengths from 170 to 410 nm purged with argon focal length; 200 mm slit width; 10 µm type of detector; photodiode 7x7µm at 7 µm pitch Grating type: Holographic 755 groves/mm Average resolution: 30 pm/pixel Sample stand: argon flushed table Source Type: Hi-Rep condensed Arc Frequency: 100, 200, 400 and 600 Hz Software User interface; Ambient temperature: 15 – 30 °C/ Short term variations within these limits must not exceed 2°C/h Relative. To avoid microcracks there was made the additional degassing of the alloy and at the same time as using gravity casting, filters were used to retain slag and big vents with the role of feeder.

Results and discussions

To determine the chemical homogeneity of the castings there were made measurements in 3 different points of each sample, namely a point in the center of the sample and two points in the middle area of the sample. The data concerning on the chemical composition of each sample are shown in tables 1-5 where was made a processing of the data on the chemical composition, namely: Avg (Average), SD (standard deviation), RSD (relative standard deviation).

From the analysis of obtained results regarding the homogeneity of the chemical composition of aluminum castings. one of the parameters allowing the best analysis is RSD (relative standard deviation). Thus, from the observation of this parameter for each specimen and each chemical element there were observed following*:*

-for Al the best homogeneity of the chemical composition of the sample was observed at the sample with diameter Ø 30 mm, RSD = 6.5994 and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm, RSD = 25.452;

-for Si the best homogeneity of the chemical composition was observed at the sample with diameter Ø 30 mm, RSD = 13.842, and the sample with the most

Table 1
THE CHEMICAL COMPOSITION OF THE CAST SAMPLE MADE OF ALUMINUM WITH DIAMETER Ø 20 mm / %

	Al	Si	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ca	Pb	Sn
1	58.86	0.930	0.254	0.730	6.19	0.189	2.493	22.62	0.1685	0.0072	0.2393	0.3140
2	82.86	3.482	0.407	0.998	7.504	0.192	2.656	18.01	0.1812	0.0084	0.0711	0.3287
3	72.42	1.231	0.253	0.987	20.38	0.186	2.961	17.03	0.1882	0.0078	0.0111	0.2887
Avg (Average)	71.38	1.881	0.305	0.902	13.36	0.189	2.703	7.341	0.1793	0.0078	0.1071	0.3105
SD (standard deviation)	12.034	1.3948	0.0087	0.1490	6.517	0.003	0.237	13.06	0.010	0.0006	0.1183	0.0203
RSD (relative standard deviation)	16.860	74.149	29.062	16.511	148.7	1.787	8.792	17.21	5.567	7.90	110.39	6.5238

Table 2
THE CHEMICAL COMPOSITION OF THE CAST SAMPLE MADE OF ALUMINUM WITH DIAMETER Ø 30 mm / %

	Al	Si	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ca	Pb	Sn
1	68.69	0.898	0.229	0.936	12.63	0.195	2.879	11.80	0.119	0.0081	0.101	0.341
2	75.21	1.154	0.367	0.636	2.359	0.213	3.020	14.55	0.195	0.0096	0.435	0.394
3	78.25	1.157	0.380	0.906	0.294	0.224	3.529	13.20	0.201	0.0097	0.102	0.430
Avg (Average)	74.05	1.070	0.325	0.926	5.094	0.211	3.143	13.18	0.198	0.0091	0.212	0.388
SD (standard deviation)	4.8868	0.1481	0.0834	0.0172	6.604	0.014	0.3417	1.377	0.003	0.0009	0.193	0.045
RSD (relative standard deviation)	6.5994	13.842	25.614	18.538	129.67	6.989	10.874	10.44	1.501	9.4394	91.268	11.57

Table 3

THE CHEMICAL COMPOSITION OF THE CAST SAMPLE MADE OF ALUMINUM WITH DIAMETER Ø 40 mm / %

	Al	Si	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ca	Pb	Sn
1	64.36	1.161	0.318	0.859	10.75	0.173	2.751	7.010	0.1806	0.0087	0.1453	0.367
2	75.94	1.489	0.345	0.962	15.39	0.216	3.516	9.051	0.2045	0.0088	0.1564	0.360
3	88.81	1.137	0.425	0.425	3.707	0.209	2.866	8.001	0.1850	0.010	0.427	0.371
Avg (Average)	76.37	1.262	0.363	0.902	9.948	0.199	3.044	8.026	0.1900	0.009	0.243	0.366
SD (standard deviation)	12.227	0.1966	0.055	0.0531	5.881	0.023	0.412	0.295	0.0127	0.0012	0.1599	0.0055
RSD (relative standard deviation)	16.010	15.576	15.246	5.885	59.11	11.69	13.54	8.371	6.6816	12.231	65.757	1.5037

Table 4

THE CHEMICAL COMPOSITION OF THE CAST SAMPLE MADE OF ALUMINUM WITH DIAMETER Ø 50 mm / %

	Al	Si	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ca	Pb	Sn
1	95.26	2.958	0.135	0.331	6.191	0.014	0.274	19.81	0.028	0.005	0.008	0.007
2	60.04	0.950	0.199	1.036	8.192	0.173	3.041	29.84	0.180	0.006	0.093	0.275
3	66.25	1.040	0.251	0.921	10.91	0.193	3.125	21.57	0.181	0.008	0.329	0.332
Avg (Average)	73.85	1.650	0.195	0.763	8.431	0.123	2.146	23.74	0.130	0.005	0.140	0.202
SD (standard deviation)	18.796	1.134	0.058	0.377	0.377	0.106	1.621	14.926	0.088	0.004	0.169	0.177
RSD (relative standard deviation)	25.452	68.747	29.652	49.495	47.19	87.01	75.55	7.913	67.85	74.79	120.41	87.752

Table 5

THE CHEMICAL COMPOSITION OF THE CAST SAMPLE MADE OF ALUMINUM WITH DIAMETER Ø 60 mm / %

	Al	Si	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Ca	Pb	Sn
1	75.19	1.361	0.423	0.989	16.001	0.229	3.893	9.609	0.227	0.013	0.336	0.399
2	66.52	0.892	0.287	0.773	18.291	0.186	2.794	8.662	0.178	0.007	0.211	0.348
3	74.46	1.205	0.295	0.854	13.997	0.210	3.198	8.020	0.187	0.007	0.137	0.386
Avg (Average)	72.06	1.153	0.335	0.872	16.096	0.208	3.295	8.761	0.197	0.009	0.225	0.378
SD (standard deviation)	4.8073	0.2385	0.0764	0.1094	9.158	0.021	0.559	4.201	0.262	0.003	0.103	0.026
RSD (relative standard deviation)	6.6715	20.678	22.763	12.540	41.18	10.41	16.871	6.937	13.26	34.515	45.91	6.984

heterogeneous chemical composition was the one with diameter Ø 20 mm, RSD = 74.149;

-for Cu the best homogeneity of the chemical composition was observed at the sample with diameter Ø 40 mm, RSD = 15.246 and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm, RSD = 29.652;

-for Mn the best homogeneity of the chemical composition was observed at the sample with diameter Ø 40 mm, RSD = 5.885 and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm. RSD = 49.495;

-for Mg the best homogeneity of the chemical composition was observed at the sample with diameter Ø 50 mm, RSD = 47.19 and the sample with the most heterogeneous chemical composition was the one with diameter Ø 20 mm. RSD = 148.7;

-for Cr the best homogeneity of the chemical composition was observed at the sample with diameter Ø 20 mm, RSD = 1.787, and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm. RSD = 87.01;

-for Ni the best homogeneity of the chemical composition was observed at the sample with diameter Ø 20 mm. RSD = 8.792, and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm, RSD = 75.55;

-for Zn the best homogeneity of the chemical composition was observed at the sample with diameter Ø 60 mm, RSD = 6.937. and the sample with the most heterogeneous chemical composition was the one with diameter Ø 20 mm, RSD = 17.21;

-for Ti the best homogeneity of the chemical composition was observed at the sample with diameter Ø 30 mm, RSD = 1.501. and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm, RSD = 67.85;

-for Ca the best homogeneity of the chemical composition was observed at the sample with diameter Ø 20 mm, RSD = 7.90 and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm, RSD = 74.79;

-for Pb the best homogeneity of the chemical composition was observed at the sample with diameter Ø 60 mm, RSD = 45.91 and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm, RSD = 120.41;

-for Sn the best homogeneity of the chemical composition was observed at the sample with diameter Ø 40 mm, RSD = 1.5037, and the sample with the most heterogeneous chemical composition was the one with diameter Ø 50 mm, RSD = 87.752.

Conclusions

The results obtained in experimental research, but also by their statistical processing demonstrate the following:

-all obtained castings are not homogeneous in terms of chemical composition noticing the differences in chemical composition between different functions of the same piece, but also between pieces with different diameters;

-from the analysis of main chemical elements that compose the cast aluminum alloy was found that Al has the best homogeneity of the chemical composition in the case of the sample with diameter Ø 30 mm, and the most heterogeneous chemical composition was found at the sample with diameter Ø 50 mm. In case of Si the best homogeneity of the chemical composition of the sample was observed at the sample with diameter Ø 30 mm, and the most heterogeneous chemical composition of the sample was obtained for the sample with diameter Ø 20 mm. Mg had the best homogeneity of the chemical composition at the sample with diameter Ø 50 mm, and the most heterogeneous chemical composition at the sample with diameter Ø 20 mm. Zn had the best homogeneity of the chemical composition in the case of the sample with diameter Ø 60 mm and the most heterogeneous chemical composition in the case of the sample with diameter Ø 20 mm;

-al shows the best homogeneity of the chemical composition of pieces with a high diameter, Mg, Zn, Si have the best homogeneity of the chemical composition of pieces with smaller diameter.

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