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CHEMICAL COMPOSITION AND METALLURGICAL PURITY OF IN 713C SUPERALLOY EFFECT ON TECHNOLOGICAL PARAMETERS FOR PRODUCTION OF AIRCRAFT ENGINE CRITICAL COMPONENTS

Rafal Cygan(*), Pawel Rokicki
Faculty of Mechanical Engineering and Aeronautics, Rzeszow University of Technology, al. Powstancow Warszawy 8, Rzeszow 35-959, Poland
(*)*Email:* rafal.cygan@cppcorp.com

ABSTRACT

Aircraft engines components, including high and low pressure turbine blades and vanes, made of nickel and cobalt based superalloys, during long-term operation, are exposed to mass forces at elevated temperatures as well as corrosive agents. These conditions cause very high quality requirements for castings, both in terms of dimensional requirements, surface condition, as well as micro- and macrostructure. Quality of supplied charge materials is of fundamental importance for quality of castings, as all the bad qualities of the alloy transform naturally to the casting.

Keywords: superalloys, chemical analysis, investment casting, aerospace.

INTRODUCTION

Thermal-derivative analysis is used in the foundry industry in order to quickly identify the most important technological features of the casting alloy. This method allows to meet the actual material properties and to adopt technology to delivered alloy batch and its chemical composition.

Tested nickel superalloys are prepared in the form of ingots according to chemical composition and requirements contained in relevant material standards. The main task for the supplier is to preserve these requirements with regard to acceptable tolerances. Therefore, individual supplies (melts) of the feed material differ in chemical composition in the range covered by standards. Greater differences can occur if dealing with an alloys from different suppliers. These differences may be due to melting procedure (technology), variations in the devices used in the process and various sources of input materials [1-5].

The differences described above affect the casting process. Even small differences in the temperature at which process undergoes, which is associated with solidification process, may impair developed casting. As a result, casting defects (eg. porosity) can be obtained that go beyond the standard limits values[6-8].

In meaning of the quality, the ATD test allows to catch alloys contaminated in the manufacturing process. Since inclusions and slagging, present in the alloy, interfere with solidification, ATD curve will present transformations that do not occur in the pure alloy. Similarly, one can pick up abnormalities in the chemical composition[9].

Knowing temperature of the alloys phase transformations leads to assessment of their quality and allows comparison of them. With an appropriate ATD curves basis and results obtained for the individual melts it is possible to operate a process in such a way to obtain the best possible casting taking into account unique properties of alloy that was delivered[10-11].

The following article presents ATD results for comparison of melts from one supplier and summarizes them with an alloy made according to the same standard but by another manufacturer.

ATD TEST STAND

ATD investigation was carried out in a vacuum induction melting furnace VSG 25P by Balzers (Fig. 1).

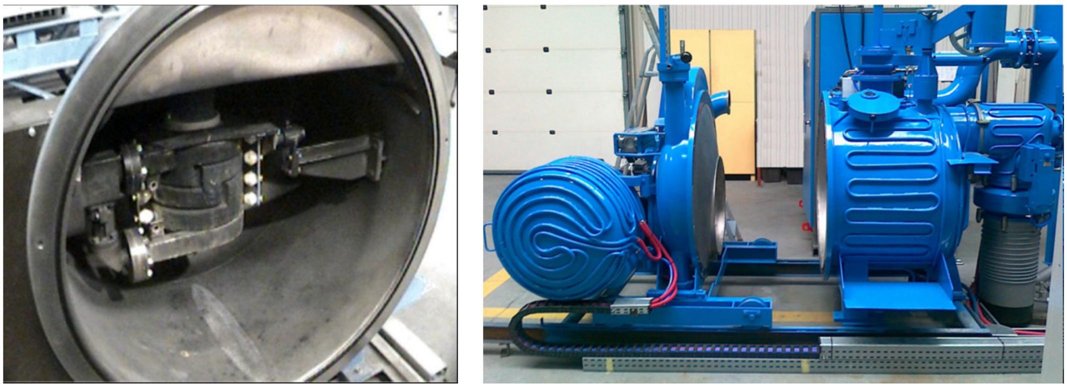


Fig. 1 - VSG 25P vacuum induction melting furnace by Balzers.

The research covered IN 713 C nickel-based superalloy provided in form of ingots weighing 7.5-8.5 kg. Alloy was induction melted in a disposable crucible. The use of disposable crucible prevents contamination of the alloy with remnant from the previous process. After melting and temperature stabilization, inductor power has been turned off. Molten metal was cooled with continuous measurement of temperature of the alloy. The system remained in the furnace vacuum chamber to complete the study. For the measurement B-type thermocouple in the quartz glass housing was used. To register temperature data logger of the furnace was introduced.

RESULTS

Three different batch portions coming from different melts were used for the research (Tab. 1.)

Table 1 - Alloys suppliers designations

Supplier	**Supplier A**	**Supplier B**
Alloys designations	A1	B
	A2	

For the analysis, chemical composition obtained from the alloy supplier was used. Mechanical test consisted of tensile strength test at a temperature of 1800F with 22 ksi force. As a result of the test, time to rapture and elongation at break were given. In addition authors studied hardness of the material (Tab. 2.)

Table 2 - Materials mechanical parameters

Symbol	Specimen	Load [ksi]	Temperature [F]	Time [h]	A4 %	HRC
Standard		22	1800	Min 23	Min 4	30-40
A1	1	22	1800	81.0	7.0	38
A2	1	22	1800	72.3	5.0	38
B	1	22	1800	65.0	6.0	38

Table 3 - Chemical composition of examined alloys.

Comp	**Standard**		**masterheat A1**		**masterheat A2**		**masterheat B**	
%	**min**	**max**	**Suppliers**	**Investigation**	**Suppliers**	**Investigation**	**Suppliers**	**Investigation**
C		0.20	0.102	011	0.105	011	0.12	0.11
S		0.015	5 ppm	0.001	6 ppm	0.002	00007	0.002
Si		100	< 0.01	0.00	0.01	0.00	< 0.01	0.00
Mn		1.00	< 0.001	0.00	< 0.001	0.00	< 0.02	0.00
Al	5.50	6.50	6.11	5.73	6.10	5.75	5.92	5.88
Co		1.00	< 0.05	0.01	< 0.05	0.02	0.03	0.04
Cr	13.00	15.00	13.65	14.32	13.74	14.54	14.05	14.93
Ti	0.75	1.25	0.82	0.89	0.81	0.90	0.89	0.96
Fe		3.00	0.019	003	< 0.10	003	003	0.04
B	0.005	0.015	0.010	0.012	0.011	0.013	0.010	0.009
Mo	350	5.50	4.24	4.43	4.23	4.41	4.36	4.52
Zr	0.05	0.12	0.06	0.06	0.06	0.07	0.08	0.08
Nb+Ta	1.00	3.00	2.18	2.31	2.17	2.37	2.30	2.49
Cu		0.50	< 0.001	0.00	< 0.001	0.00	< 002	000
Bi		0.5 ppm	< 0.2 ppm	< 0.3 ppm	< 0.2 ppm	< 0.3 ppm	< 0.1 ppm	< 0.3 ppm
Pb		10 ppm	< 0.5 ppm	< 0.5 ppm	< 0.5 ppm	< 0.5 ppm	< 0.2 ppm	< 0.5 ppm
Se		3 ppm	< 0.5 ppm	< 1 ppm	< 0.5 ppm	< 1 ppm	< 0.1 ppm	< 1 ppm
Te			< 0.2 ppm	< 0.5 ppm	< 0.2 ppm	< 0.5 ppm	< 0.1 ppm	< 0.5 ppm
Tl			< 0.2 ppm	< 0.2 ppm	< 0.2 ppm	< 0.2 ppm	< 0.2 ppm	< 0.2 ppm
Ni+Co		remain	remain	remain	remain	remain	remain	remain

RESULTS ANALYSIS

(a) (b)

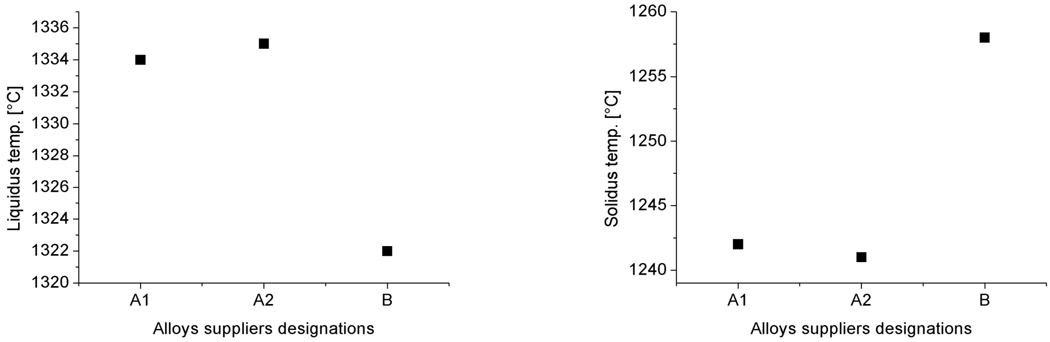
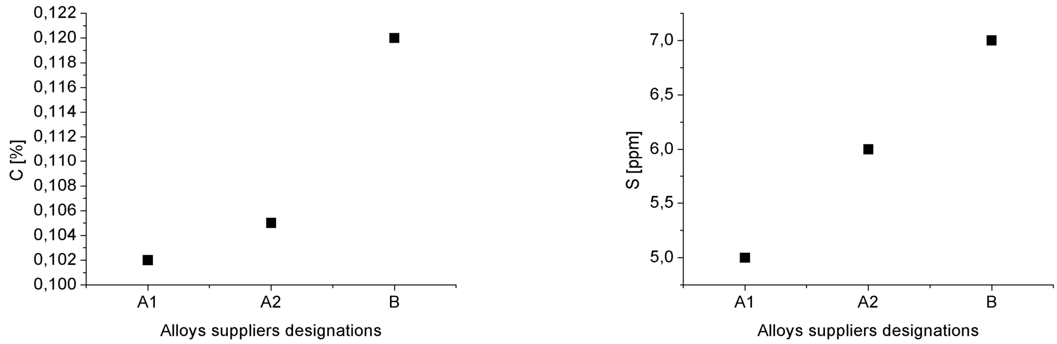
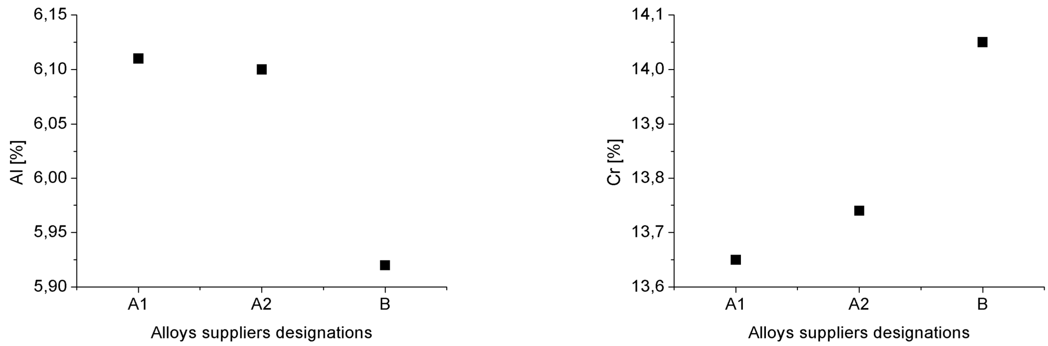


Fig. 2 - (a) Liquidus and (b) solidus temperature of investigated alloys.

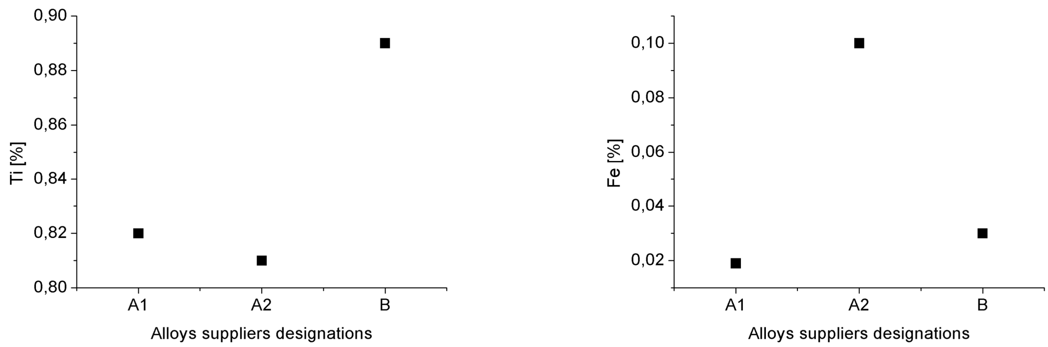
(a) (b)



(c) (d)



(e) (f)



(g) (h)

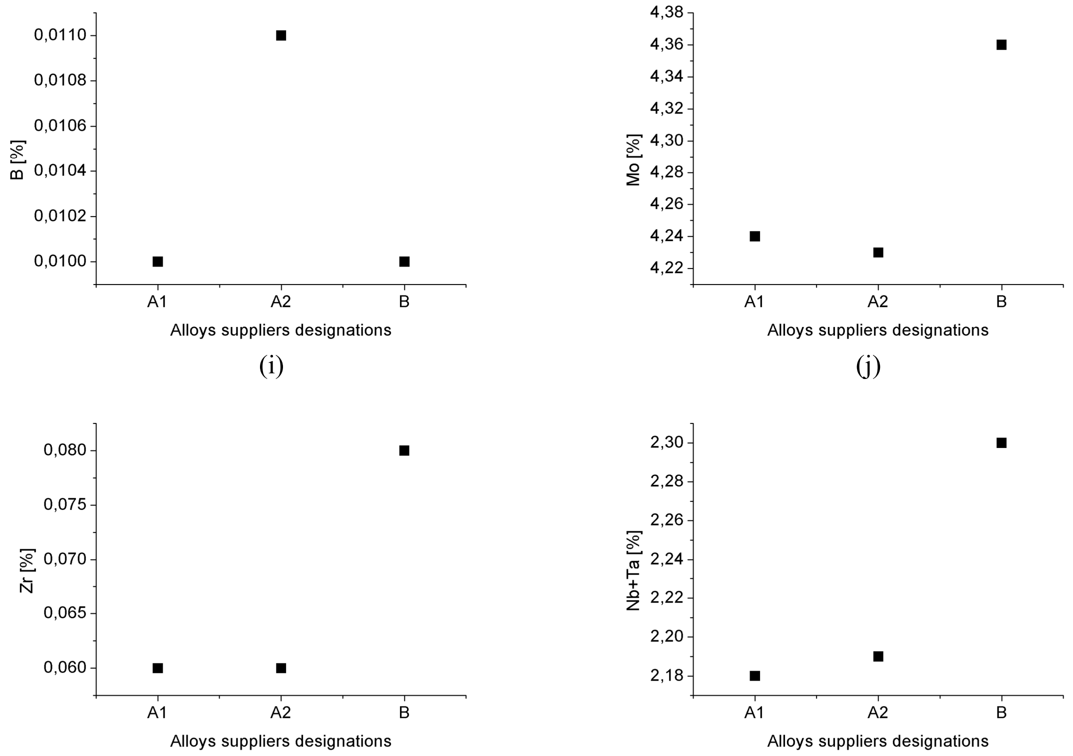
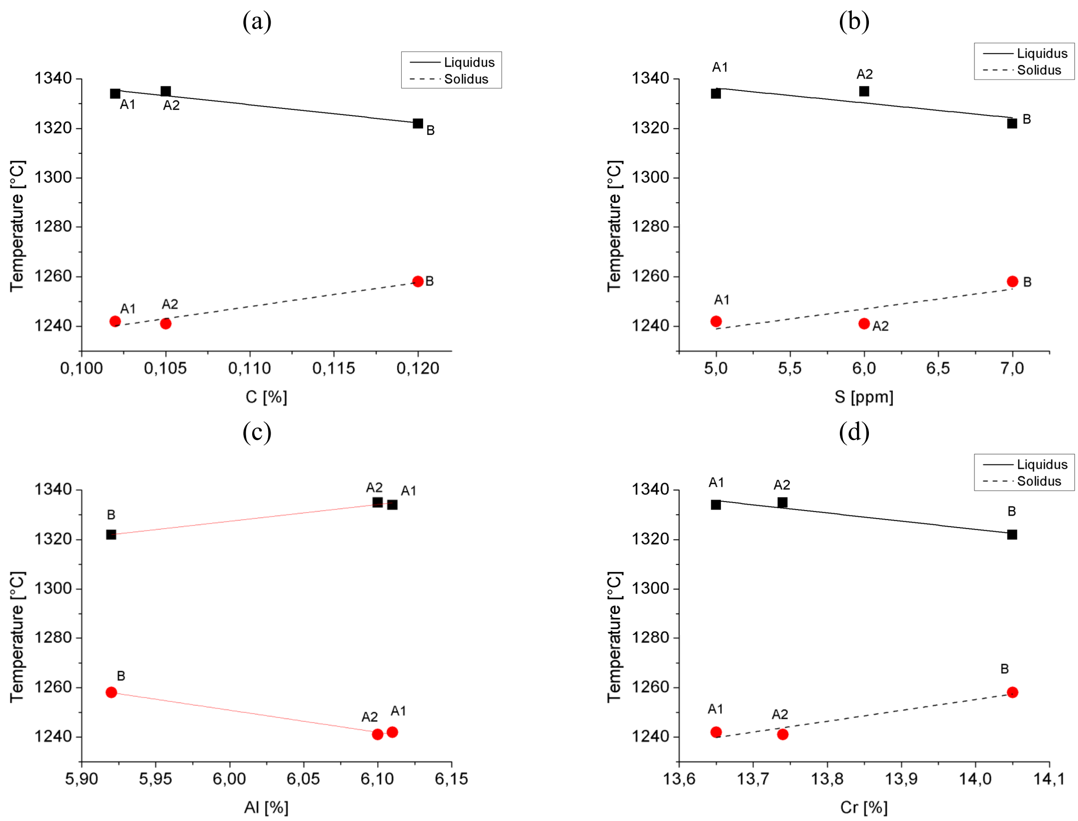


Fig. 3 - Different elements content in various alloys: (a) carbon, (b) sulphur, (c) aluminum, (d) chromium, (e) titanium, (f) iron, (g) boron, (h) molybdenum, (i) zirconium, (j) niobium and tantalum.



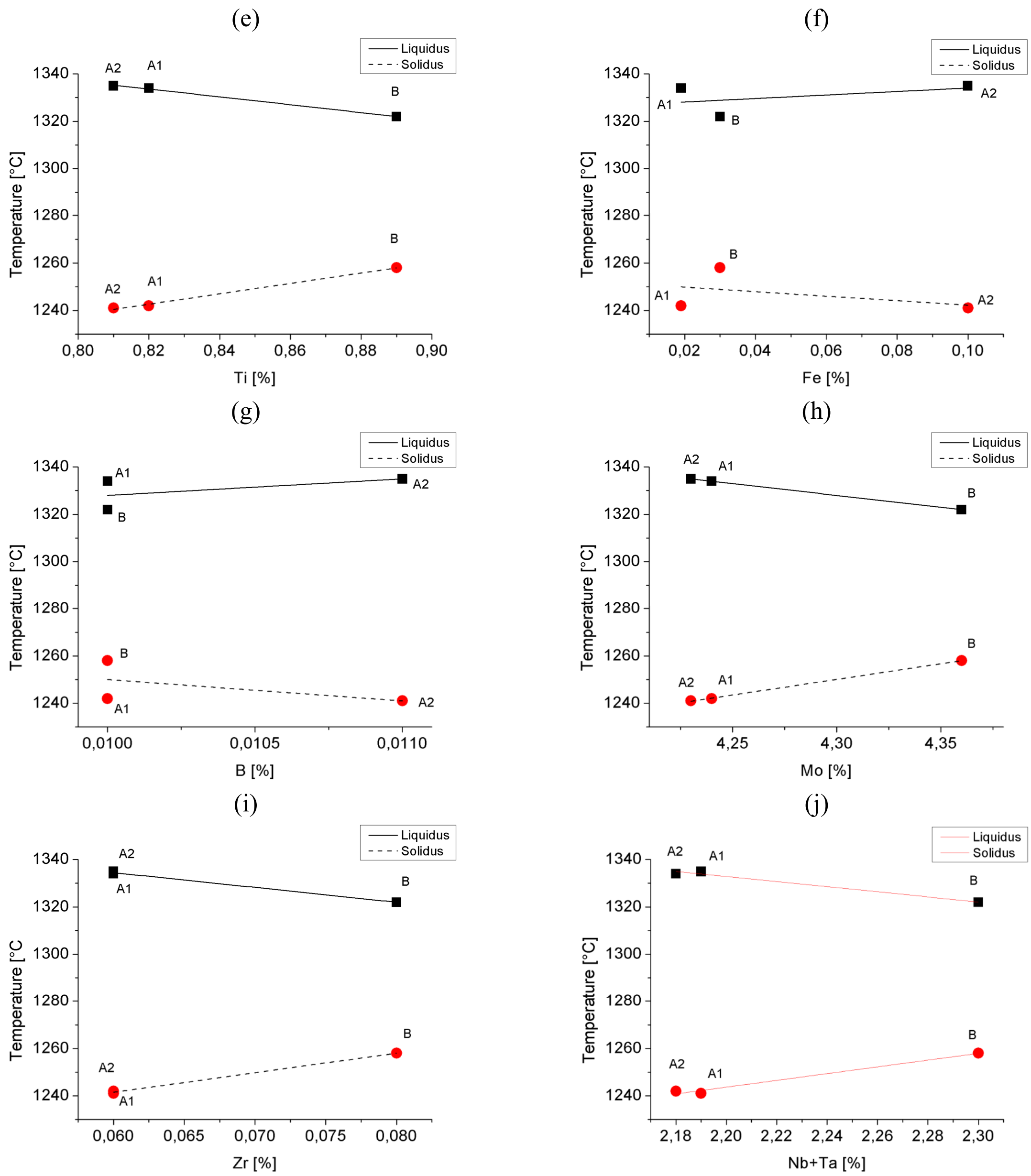
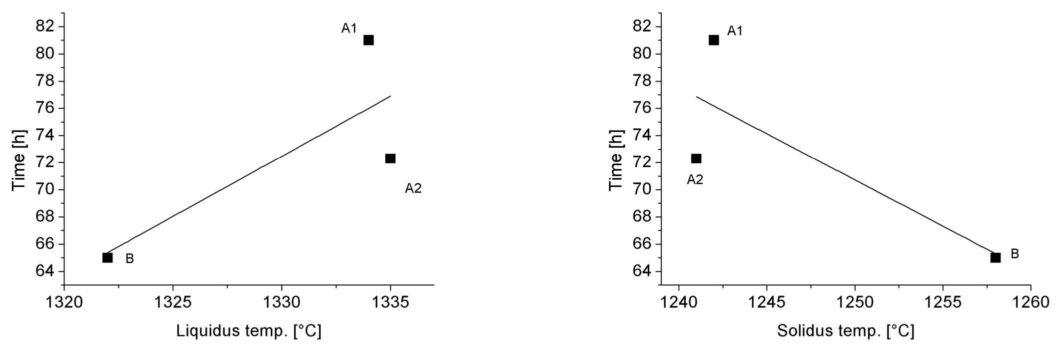


Fig. 4 - Impact of different elements on liquidus and solidus temperature: (a) carbon, (b) sulphur, (c) aluminium, (d) chromium, (e) titanium, (f) iron, (g) boron, (h) molybdenum, (i) zirconium, (j) niobium and tantalum.

(a) (b)



(c) (d)

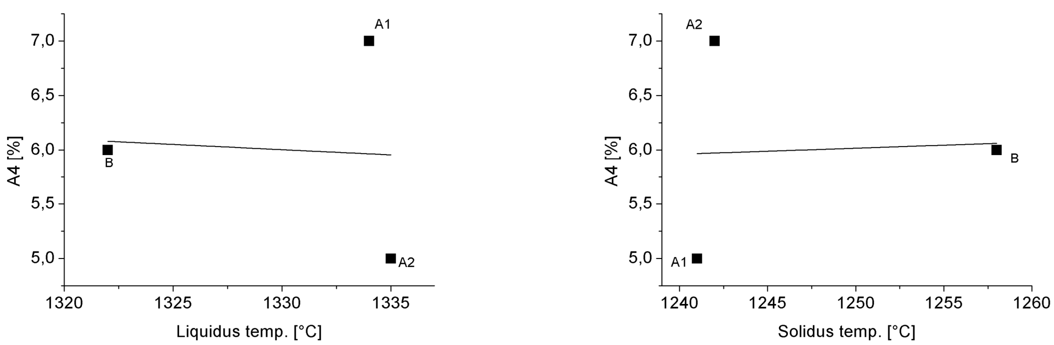


Fig. 5 - (a) Liquidus temperature effect on time to rapture, (b) Solidus temperature effect on time to rapture, (c) liquidus temperature effect on elongation, (d) solidus temperature effect on elongation.

CONCLUSION

Although examined alloys differ in chemical composition, each of them is compatible with the standard and the content of individual elements is within the required tolerance.

For most elements, their content is similar to content in the casting from a single supplier. The exceptions are S, Fe and B.

Alloys from a single supplier also are characterized by similar liquidus and solidus temperature values which is consistent with chemical composition of this melts.

Materials having different liquidus and solidus temperatures have different mechanical properties. However, to define this dependence, there is a need to increase amounts of data to be analyzed.

B alloy is characterized by higher carbon content, lower liquidus temperature and higher solidus temperature.

A1 and A2 alloys, which are characterized by higher liquidus and lower solidus temperature, have improved tensile strength at elevated temperature.

Lack of correlation between sample elongation and liquidus and solidus temperature.

ACKNOWLEDGMENTS

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