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# INVESTIGATION OF ALUMINUM-TITANIUM ALLOYS PRODUCTION AND LABOR SAFETY IN METAL SMELTING PROCESS

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Preliminary Note – Prethodno priopćenje

The labor protection requirements for the smelting process of aluminum alloys and the human safety condition are provided in this work. Also it includes the metallographic analysis results of aluminum-titanium alloys. ThixometPro software was used for analysis' performance and Thermo-Calc program used for the phase diagrams drawing of triple systems.

*Keywords:* aluminum-titanium alloys, labor protection, microstructure, phase diagrams, non-metallic inclusions

## INTRODUCTION

The development of the modern aviation industry is associated with a creation of economical and ecological clean gas turbine engines with reduced fuel consumption, increased service life and reliability. The key role in solving this problem is played by the use of modern lightweight heat-resistant materials with high performance characteristics.

The special requirements are imposed on heat-resistant alloys intended for a manufacture of blades, disks, guide devices and housing elements of compressor and turbine, since these parts are subjected to high thermal and power loads.

Aluminum-titanium alloys are widely used as structural materials because of their high thermal conductivity, forging property, corrosion resistance and ductility. These alloy building with molybdenum and nickel leads to a formation of strong and refractory intermetallic compounds. Due to this, the volume fractions of the strengthening phases are obtained in the alloys.

The Nickel is selected as the alloying elements in the article. The analytical review showed that the double systems Al-Ti, Al-Ni, and Ni-Ti are sufficiently studied. The data of the state diagrams of the triple systems Al-Ti-Ni are not contained in the references.

The phase diagrams drawing of the systems to be carried out by mean of use the Thermo-Calc program

In order to start smelting aluminum, first of all it is necessary to know the requirements for labor protection. Since there may be explosions during the melting of aluminum-titanium alloys due to a melting difference of titanium and Aluminum [1-3].

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At the present time, non-ferrous metals and alloys are mainly smelted in electric furnaces. The most common types of injuries are burns and electric shock. Therefore, the main safety measures in the melting shops are aimed at preventing measures.

The safety regulations include the following: the tilting furnaces with a drive must have tilt limiters, self-braking devices and a lock for automatic activation of the turning mechanism. The furnace tilt control panels must be installed in such places that the smelter can see the metal stream coming from the furnace and the crane operator involved in the casting. The shields and control panels should be equipped with light and sound signaling device.

The furnaces with water cooling systems are equipped with locking devices that cut off the power supply when the water supply is insufficient or stopped. The funnels for draining cooling water are located in such places that the water jets are visible from the workplace of the smelter.

The titanium melting and other refractory metals in arc furnaces is associated with a risk of explosions when the a water-cooled crucible wall burns through due to the water decomposition on the hot metal surface and the high pressure increase of a hydrogen and water vapor mixture. This danger is further increased due to a hydrogen-oxygen mixture formation when the tightness of the melting furnace is violated. In order to avoid burns, large melting furnaces are placed in reinforced concrete or steel armored chambers.

It is necessary to install the check valves in the drain lines of the mold and the electrode holder in order to prevent air penetration into working space of the furnace when the jacket is burned. Also a water cooling system in arc furnaces must be interlocked with devices that turn off the power supply when the water pressure drops or its flow stops in any of the system components during melting.

The majority cases where the cause of burns is the release of metal during the charge loading into the furnace or when pouring the mold. Therefore, the main measure to fight this type of injury is the elimination of metal emissions. These emissions occur mainly when loading a wet, non-dried charge into molten metal or pouring the metal into a cold metal mold, which has a working surface with a layer of condensed moisture. Consequently, a wet charge loading into the furnace without first drying it is prohibited. It is also forbidden to pour into unheated metal molds. The safe working methods rules do not allow loading scrap into liquid metal with closed cavities. The reason of metal release can also be intense steam release during the loading an alloying element with a low boiling point into the liquid metal. Such an element must be input as a hardener [4-6].

The working conditions have a decisive influence on the level of injuries. The creating favorable (comfortable) working conditions in the foundry and casting shops involve maintaining an optimal temperature, a necessary humidity, a low dust concentration and harmful emissions, a low noise and vibration levels, and adequate lighting in the premises and workplaces. In order to maintain such conditions, it is necessary to remove excess heat or heat the working areas / premises, clean the air from dust and harmful emissions, muffle noise and vibrations, and keep proper cleanliness and hygiene.

As a result of the measures taken recently, there is less untreated wastewater, the dustiness of the atmosphere and the content of harmful substances in it are reduced. An environmental assessment of enterprises and structures has been launched.

The provisions of the law and the requirements for nature protection are directly related to foundry and casting production, which often has a harmful effect on a state of air basin and environment. A large number of different materials are used for the production of castings in foundries and these materials interacting with liquid metals emit a large number of different gases (Carbon monoxide, Sulfur dioxide, Ammonia, Chlorine, flue gases, water vapor, gases formed during the deconstruction of binders), vapors (metals, chlorides, fluorides) and dust (Silica, Zinc and Magnesium oxides, Coke particles, lime and other materials). Some released substances are toxic. The concentration of such substances in the workplace often significantly exceeds the permissible norms. The reduction of harmful emissions concentration in the workshops is usually carried out by releasing polluted air into the atmosphere by mean of scattering them over large areas near the enterprise. Often, polluted air is not cleaned and treated in order to neutralize harmful emissions.

A heat radiation, a noise, a vibration, and electromagnetic fields can have a harmful effect on the environment.

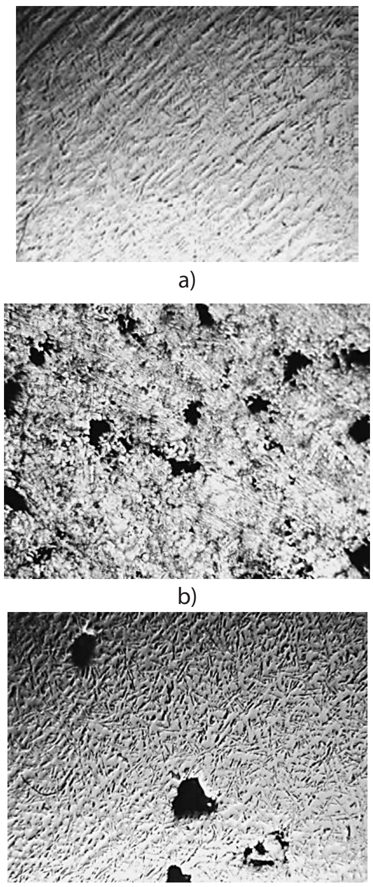
For the last recent years, many preventive measures have been taken in the foundry production to improve sanitary and hygienic working conditions and improve ambient environment. The effective cleaning systems for cupola gases have been developed, installations for cleaning flue gases from chloride vapors have been implemented, new non-toxic binders have been developed and introduced, and metal molds have been widely used. However, the sanitary and hygienic conditions in a number of foundries are still unsatisfactory.

Due to imperfect technology, outdated equipment, low efficiency of ventilation systems, improper treatment systems, dust and gas pollution of air in foundries so the permissible standards are often exceeded. Also within the foundry equipment designing and manufacturing, not enough attention is paid to sealing issues, and no provision is made for the capture and neutralization of harmful emissions.

## EXPERIMENTAL, DISCUSSION, RESULTS

The purpose of this study was to determine non-metallic inclusions and the $Al_3Ti$ phase in aluminum-titanium alloys.

The quantitative metallographic structure analysis of the studied samples was performed using Thixomet Pro software. The Figure 1 shows the structures of the studied samples.



a)

b)

c)

**Figure 1** Microstructure of studied samples: a) alloy of the Al-Ni-Ti system before processing; b) alloy of the Al-Ni-Ti system after processing; c) alloy of the Al-Ni-Ti with non-metallic inclusions.

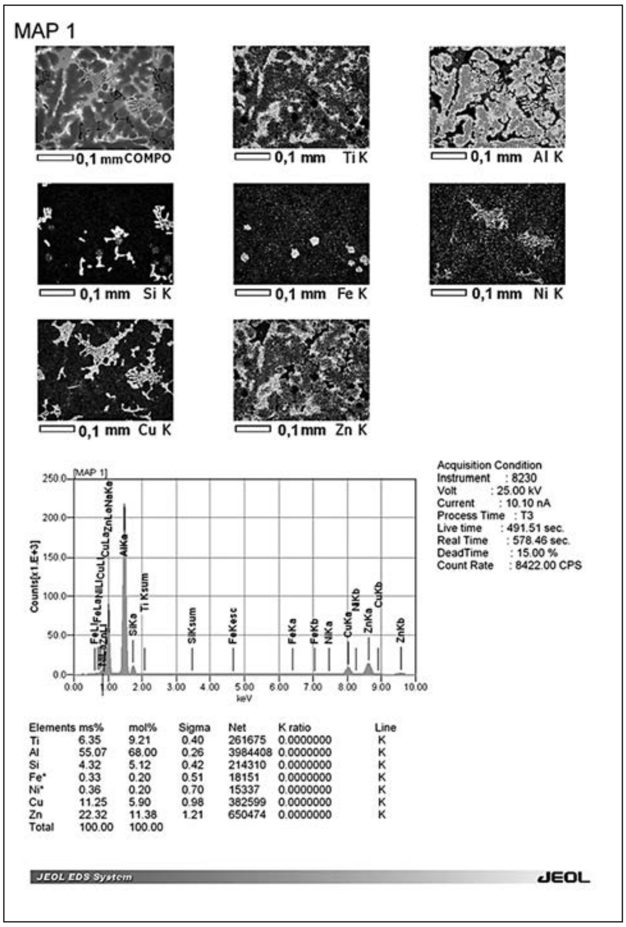



**Figure 2** Distribution of elements

Titanium aluminides and alloys based on them retain high strength at elevated temperatures, and their elastic modulus decreases less intensively with increasing temperature than that of non-intermetallic titanium alloys. The self-diffusion coefficient in aluminides is lower by several orders of magnitude than in alloys with disordered solid solutions based on α-and   - modifications of titanium at comparable temperatures, which provides increased creep resistance (Figure 2). Having a relatively low density (due to the high Al content), Titanium aluminides have serious advantages in specific strength over traditional Titanium and "heavy" (with a density of up to 8,55 g/cm$^3$) Nickel alloys. In addition, Titanium aluminides have an increased resistance to oxidation due to the formation of a dense oxide film on their surface, consisting of $Al_2O_3$, $TiO_2$, which prevents the diffusion of oxygen [7, 8].

The survey was carried out on the D8 Advance (Bruker) device, α-Cu, the voltage on the tube is 40 kV, the current is 40 ma. The processing of the obtained diffractogram data and calculation of interplane distances were carried out using the EVA software. The samples were decoded and the phases were searched using the Search / match program using the PDF-2 powder Diffractometric Database (Table 1).

The phase composition of the obtained ingots was determined by X-ray diffraction analysis, the results of which showed that in the cast state all compositions are

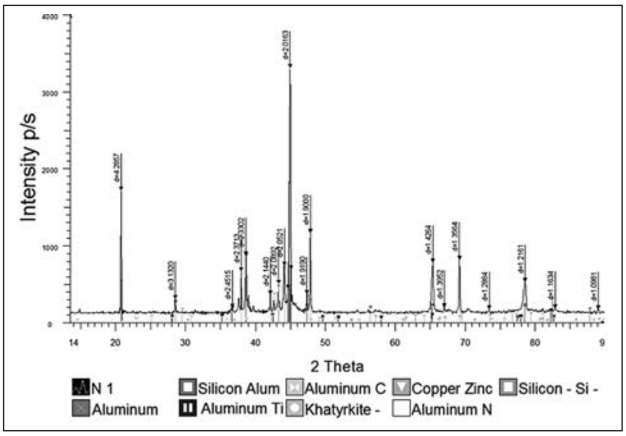



**Figure 3** Diffraction spectra of the studied compositions

Table 1 **Data from the diffraction spectrum**

| Compound Name | Formula | S-Q |
|---|---|---|
| Aluminum | Al | 32,1 |
| Aluminum Titanium | Al0,64Ti0,36 | 22,1 |
| Silicon Aluminum | Al9Si | 15,5 |
| Silicon Chromium Iron | CrFe8Si | 12,5 |
| Aluminum Copper | Cu9Al4 | 12,4 |
| Aluminum Nickel | AlNi3 | 5,3 |

represented by β - and O-phases and a trace amount of α2-phase (Figure 3). The rare-earth oxides $Y_2O_3$, $Gd_2O_3$ and $Sc_2O_3$ were found in the compositions $K_1$ (with Y), $K_2$ (with Gd), and $K_3$ (with Sc).

Even with a visual analysis, the differences in the structure of the studied samples are evident. Figure 4 shows an example of a quantitative analysis of the $Al_3Ti$ phase.

During the phase study, a proportion of the area occupied by the $Al_3Ti$ phase was estimated.

The polythermal sections were constructed using the ThermoCalc program, which are shown in Figure 5.

The figure includes the sections which also show a formation of the $Al_3Ti$ phase, which strengthens the alloy, and will expand the range of use of this alloy.

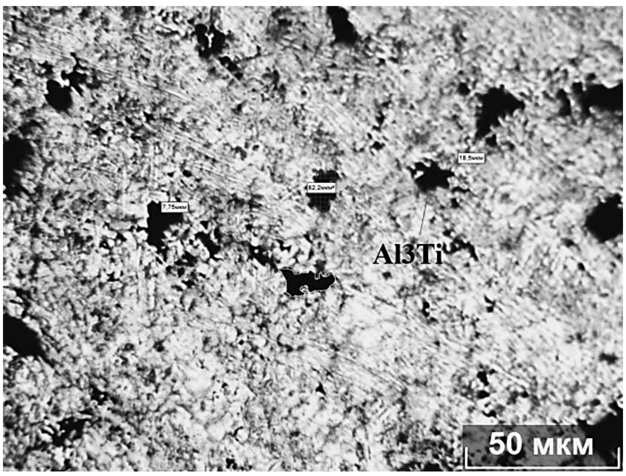



**Figure 4** Example of using Thixomet Pro software for $Al_3Ti$ phase analysis.

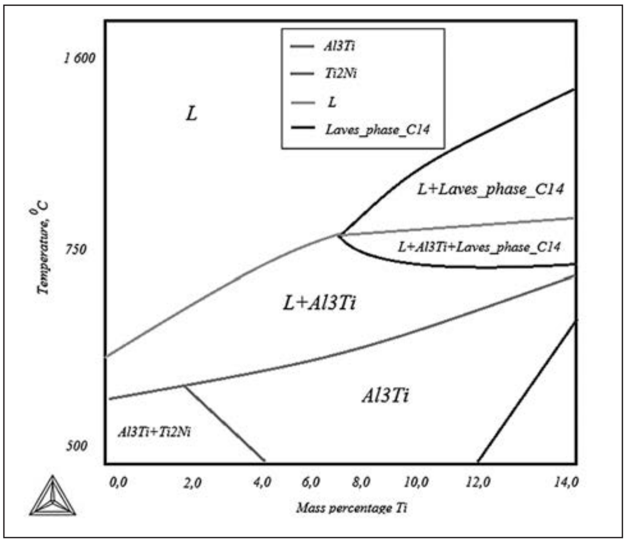



**Figure 5** The polythermal sections of the Al-Ni-Ti alloy system

## CONCLUSION

According to the results of the review, it was found that the most promising materials for GTE blades are intermetallides based on the Ti–Al system.

The analysis of the working conditions of GTE blades was carried out, from which the materials requirements for blades were formulated.

The modern methods of developing alloys require large time and economic resources. Therefore, the method of physical and chemical analysis was used in this work.

This method of alloy synthesis provides a possibility to reduce the time which required to create new multicomponent intermetallic alloys by an average of 4-5 times less, reduce labor costs by 20-30 times less, and save 10-20 times the scarcity of expensive materials compared to empirical methods.

Based on the analysis of the state diagrams of Ti–Al–E systems, the main alloying elements and the areas of their variation for intermetallic alloys are selected.

After analyzing the triple diagrams for temperature sections, the alloying elements were determined at which the phase regions narrow and expand. Based on this, the most promising alloying elements were identified: Ni, Nb, Cu, Ta, Co, Mn, V.

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**Note:** The responsible for English language is Tskhay Natalya, Karaganda Kazakhstan