Influence of tantalum content controlled by constant Al/Ti ratio on partitioning of alloying elements, morphology of precipitates and mechanical properties in model superalloys based on IN740 after multistage heat treatment

Superalloys are a group of nickel-based alloys that are intended to work at high temperatures. Retaining high mechanical properties at temperatures exceeding 80% of melting point is unachievable for currently known materials. The intensive development of “modern” ceramic materials, fibre-strengthened composites or polymers do not weaken the superalloy’s strong position. This is thanks to their unique combination of properties under exploitation: resistance to corrosive environment (carbonising, oxidising or sulphating); creep resistance and also metallurgical stability. Nickel-based alloys receive their unique properties as a result of a complex chemical composition and multistage heat treatment.

Inconel 740 belongs to superalloys designed to work in new generation coal-fired power plants working under **ultra-supercritical parameters**. Regulations related to environmental protection, namely restricting the emission of harmful gases, require increasing the unit’s efficiency by increasing temperatures and vapour pressure. The performance properties of the Inconel 740 alloy result from the numerous alloying elements, including chromium and cobalt, which give high temperature corrosion resistance, guaranteeing the possibility of operation in harsh service conditions for over 100000 hours. Providing resistance to hot corrosion is no less important as high mechanical properties at elevated temperature. The mechanical properties of the Inconel 740 superalloy are affected by solid solution strengthening resulting from the difference of atomic radius of nickel and alloying elements, and also strengthening via γ' precipitates. The second of these mechanisms is key in the context of shaping the properties of the alloy because the volume fraction and morphology of the γ' precipitates can be changed even through small modifications of the alloy chemical composition and heat treatment.

The intermetallic γ' phase possesses the stoichiometric formula Ni_3Al. Its large volume fraction in the superalloy can substantially affect the high mechanical properties both at ambient and elevated (service) temperatures. The γ' phase volume fraction in nickel based superalloys does not substantially decrease at temperatures around 1000˚C, which determines its work range. The intermetallic γ' phase is an ordered phase, namely the atoms occupy specific positions. This translates directly into the strength-temperature relationship. Unlike other, even the most modern engineering materials, the increase in strength at elevated temperature is a unique feature of nickel superalloys. The second possibility of controlling the superalloys structure is multistage heat treatment consisting of solution and aging. The high content of the γ' phase results directly mainly in the content of Al, Ti, and Ta, while the preferred morphology of the precipitates is shaped during heat treatment.

The Inconel 740 contains about 15% of γ' phase in the delivery condition. Taking into account the high resistance to corrosion, it is reasonable to undertake research aimed at improving the mechanical properties. The achievement of the abovementioned objective can be accomplished by the strengthening of the γ matrix, increasing of the volume fraction of carbides and the intermetallic phase γ'. **Tantalum as the only of the currently known elements can participate in each of these types of strengthening, thus indicating the need to study its effect in complex multi-component nickel alloys.** Due to the high price of this element, it is necessary to precisely specify its impact at various concentrations of other elements included in the main strengthening phase γ '.

The currently available literature lacks a sufficient number of works focusing on the influence of tantalum on the microstructure and mechanical properties of superalloys with different Al/Ti ratio. Considering the huge influence of Ta on almost all microstructural components, it's important to consider this interaction more detail. <u>The project manager wants to clarify at what ratio of Al / Ti ratio and Ta concentration it is possible to achieve a synergistic effect on microstructure and mechanical properties</u>. The project manager plans to undertake fully innovative activities in this direction. **The implementation of the designated research objective assumes the use of basic and advanced research techniques allowing for comprehensive studies of microstructure and mechanical properties.**