# Abstract

The dynamic development of the industry creates a demand for high-quality aluminum alloys that are used for important structural elements. Ecological aspects related to increasingly scarce natural resources are a particular challenge for modern materials engineering. Researchers turned their attention again to lightweight alloys, particularly aluminum-based alloys while highlighting the importance of newly developed chemical compositions. Despite numerous scientific articles, there is a lack of structured data on design and manufacturing rules determining the achievement of a specific structure depending on the chemical composition in newly developed aluminum alloys.

The aim of the work was to design the chemical compositions of the Al-(Cr,Cu,Zr,Ni)-Fe ternary alloys and Al-Ni-Fe-Y quaternary alloys to obtain amorphous, nanocrystalline, and structurally complex alloys. The research thesis assumes that, on parameters related to the Gibbs free energies, mixing enthalpy and mismatch entropy, along with the adjustment of technological parameters, it is possible to produce alloys with a complex atomic structure, however, the improvement of physical and chemical properties depends primarily on the chemical composition.

The research part was divided into three sections concerning the study of the structure and properties of the $Al_{65}(Cu,Zr,Cr,Ni)_{20}Fe_{15}$ and $Al_{71}(Cu,Zr,Cr,Ni)_{24}Fe_5$ as well as the structure and corrosion resistance of $Al_{79}Ni_5Fe_5Y_{11}$, $Al_{79}Ni_5Fe_{11}Y_5$, $Al_{79}Ni_{11}Fe_5Y_5$ and $Al_{79}Ni_7Fe_7Y_7$ alloys and the verification of thermodynamic parameters. Structural studies were performed using X-ray diffraction, neutron diffraction, light microscopy, scanning and transmission electron microscopy, and Mössbauer spectroscopy. The crystallization mechanisms were described based on differential scanning calorimetry. In order to verify the influence of complex intermetallic phases, tests of selected magnetic, electrochemical, and mechanical properties were carried out for the $Al_{65}(Cu,Zr,Cr,Ni)_{20}Fe_{15}$ and $Al_{71}(Cu,Zr,Cr,Ni)_{24}Fe_5$ alloys. Corrosion resistance studies by the potentiodynamic method were also performed for $Al_{79}Ni_5Fe_5Y_{11}$, $Al_{79}Ni_5Fe_{11}Y_5$, $Al_{79}Ni_{11}Fe_5Y_5$ and $Al_{79}Ni_7Fe_7Y_7$ alloys.

Based on the structural characterization, the presence of quasicrystalline phases was identified for the $Al_{65}Cu_{20}Fe_{15}$ ingot and high-pressure cast plates in copper molds: $Al_{65}Cu_{20}Fe_{15}$, $Al_{71}Cu_{24}Fe_5$, $Al_{71}Ni_{24}Fe_5$. In addition, the presence of the $Al_{65}Cr_{27}Fe_8$ phase with a complex structure was demonstrated for all Al-Cr-Fe alloys. The amorphous structure for

the $Al_{79}Ni_5Fe_5Y_{11}$ alloy was obtained at the casting temperature of 1400°C, while for the $Al_{79}Ni_{11}Fe_5Y_5$ alloy at 1200°C. The $Al_{79}Ni_5Fe_{11}Y_5$ and $Al_{79}Ni_7Fe_7Y_7$ alloys in the form of ribbons were characterized by a nanocrystalline structure. Based on studies using Mössbauer spectroscopy, it was determined that all the tested alloys were characterized by paramagnetic properties. On the basis of the obtained results, a significant influence of the chemical composition on the corrosion behaviour of the studied alloys was demonstrated. Additionally, a positive effect of phases with a complex structure on corrosion resistance was found, due to the higher polarization resistance and lower corrosion current density for the $Al_{71}Ni_{24}Fe_5$ and $Al_{71}Cu_{24}Fe_5$ alloys produced in the form of plates containing quasicrystalline phases.

In addition, the positive effect of the amorphous structure in Al-TMs-REEs alloys on corrosion resistance compared to alloys with a crystalline and nanocrystalline structure was proven. Among the $Al_{65}(Cr,Zr,Cu,Ni)_{20}Fe_{15}$ and $Al_{71}(Cr,Zr,Cu,Ni)_{24}Fe_5$ alloys, the highest average hardness was found in the alloys with the addition of chromium and nickel, while the lowest with zirconium and copper. The wear resistance of the $Al_{65}Cr_{20}Fe_{15}$, $Al_{71}Cr_{24}Fe_5$ and $Al_{71}Ni_{24}Fe_5$ alloys is similar to the single phase alloys with a complex structure described in the literature.

Based on thermodynamic calculations for Al-TMs alloys, the tendency of forming phases with a complex structure was determined for the Gibbs free energies of mixing and the formation of an amorphous structure directed towards positive values. The possibility of the occurrence of an amorphous structure was found for Al-Ni-Fe-Y alloys with the most positive mismatch entropy values together with negative enthalpy, using appropriate technological parameters, such as casting temperature. In addition, it was determined that there is a wide range of mixing enthalpies for which an amorphous structure can be obtained.