Application of three-dimensional quantitative fractography for analysis of structural materials fatigue life under multiaxial loading, taking into account creep pre-deformation and elevated temperature

The aim of the project is to develop a method of identifying the conditions of damage and cracking in a complex loading condition, also at elevated temperature, taking into account the effect of the initial creep deformation of the material. The project will fulfill the existing gaps in the literature based on the "entire fracture surface" and “crack initiation surface topography” methods. The basis for its development will be the results of experimental tests carried out for two different materials: aircraft aluminum alloy EN AW-2024 and high-temperature resistance boiler steel 1.4923. As part of the first phase of the project, previously obtained experimental results will be developed for (i) starting material subjected to monotonic, creep and fatigue loads; (ii) a material pre-creep at elevated temperature until a specified strain level is reached in terms of monotonic and fatigue loadings. The effect of initial deformation will be taken into account in the analyzes of the behavior of the material under the influence of uni- and multi-axial cyclical loadings. The second phase of the project will consist of measurements and analysis of the fracture surface topography in order to link the crack surface behavior with the methods of loading and fatigue life using fractographic parameters. An important element of the research will be the microscopic analysis of the fracture surface of the specimens, as well as the analysis of the evolution of the material's microstructure. It will help to determine the mechanisms of damage accumulation and cracking of the material under different loading conditions and with different history of initial deformation. Figure 1 shows selected components of the research provided for in the project.

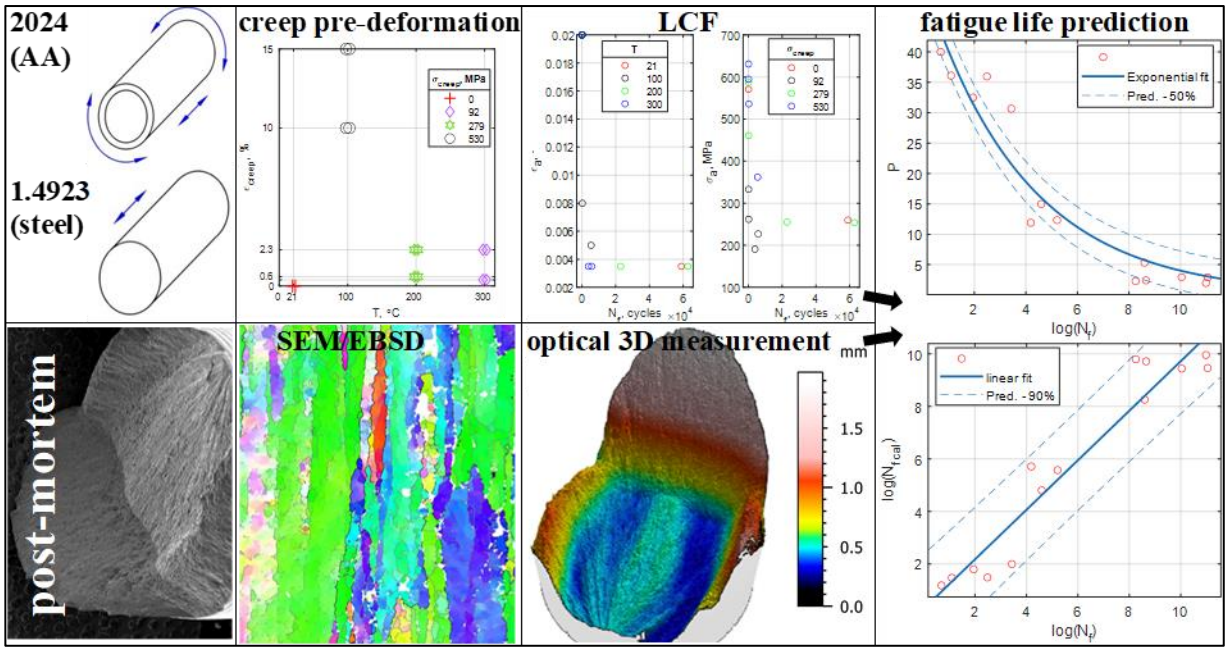

Fig. 1. Scheme of tests on the example of a EN AW-2024 aluminum alloy specimen.

The innovativeness of research consists of two main aspects. The first concerns the recognition of the influence of the initial creep deformation on the cyclic properties of the material under the influence of proportional and non-proportional loads at room and elevated temperatures. The second aspect is related to the "post-failure" tests for fracture surfaces and the presentation of the parameter depending on the method of loadings that led to failure. Combining both of these aspects will allow to present an original model that takes into account the impact of damage on fatigue life, both in simple and complex load cases. The influence of creep predeformation on the cyclical behavior of the material under different loadings and temperature conditions is not well recognized, and certainly significant. Advanced and original tools for quantitative fractographic analysis allow the introduction of new parameters to the description of phenomena related to fatigue and fracture mechanics. This may contribute to ensuring the proper maintenance times of a structure, thereby reducing the costs of its exploitation and improving the safety of its use.