Popular science summary

Contemporary technology development leading to the creation of many modern devices is the reason for the constantly growing demand for modern materials exhibiting reduced weight while increasing strength and resistance to all kinds of external factors. In this area, metal sandwich composites have a lot to play, because they are designed taking into account the functionality of the components, their appropriate selection, expected restrictions in operation and the optimization of many of their features to meet the objective function assumed. Metallic layered structures allow to design the flow process in a more flexible way taking into account the functionality of individual layers. For the above-mentioned reasons, in the proposed project it is planned to conduct experimental and numerical analysis of mechanical properties and resistance to damage of selected two types of layered composites: aluminum with copper and titanium with copper. The main goal of the project is to recognize the physical mechanisms responsible for the process of plastic deformation induced by complex loadings. It is commonly know that just the complex loadings are the most effective and most faithful ways that may reflect the real working conditions of the material used for specific structural elements. The materials to be investigated will be tested in the as-received state and after deformation history induced deliberately by monotonic loading or low cycle fatigue processes. In order to effectively visualize changes in the stress state of the tested materials subjected to the loading history defined, the concept of yield surface will be used. It is defined as the geometrical place of points in the stress space corresponding to the same value of deformation. Two unique complementary testing systems will be used for the characterization of mechanical properties and damage evolution: a testing machine for simultaneous loading of thin-walled tubular specimens by means of axial force, torque and internal pressure, and a modern machine for material testing on cruciform specimens, ensuring the implementation of tests in a plane stress state resulting from simultaneous action of axial forces in two mutually perpendicular directions. This combination of testing machines guarantees the unique possibilities for material properties assessments. In addition, two optical systems will be used: digital image correlation (DIC) and electronic speckle pattern interferometry (ESPI), especially useful for identification specimen damage initiation and its further development, particularly in the field of cyclic loading. Parallel application of both optical systems in the case of tests on the cruciform testing machine will give the great opportunity to compare their capabilities in terms of accuracy of the results and resolution of methods. The ultrasonic technique will be used to assess the initiation of the dominant fracture in order to verify indications of the optical methods. An important component of the research will be results from tests in which a combination of monotonically increasing load with symmetrical cycles will be applied. This type of research will be carried out on both types of specimens. Some results of the preliminary tests on the tubular specimens show significant reductions in tensile strength as long as torsional cycles accompany it. Confirmation of this type of effect on the cruciform specimens may have potentially an important significance for future more effective design of different technological processes.

The last important element of the project will be the modeling of deformation and degradation mechanisms taking into account processes associated with local micro-plasticity. The finite element method coupled with the Chaboche model will be the starting point for simulation of the behaviour of the tested materials at low cycle fatigue. Determination of the optimal values of the thickness of bi-metal layers in the tested specimens, guaranteeing the maximum strength of the tested laminar composites will become a direct achievement of the analyzes performed.