

Modification of metal surface topography and morphology to improve adhesion strength at the metal composite interface in fibre-metal laminates

Fibre-metal laminates are currently an interesting group of hybrid materials that consist of alternating layers of metal and polymer-fibre composite. Such a combination allows to obtain a new generation of materials with improved properties compared to the individual components constituting them. They are characterised by low density, high static and fatigue strength, but also high impact and corrosion resistance. In fibre metal laminates, the most commonly used materials are aluminium alloys in particular 2024-T3 or 7475-T6. Currently, titanium-based laminates are particularly popular due to their favourable properties, such as high increased fatigue strength, impact resistance and corrosion resistance.

However, modification of the metal surface remains an issue, in order to achieve adequate adhesion at the metal-composite interface. Because it plays a key role in the stress transfer between the metal and composite layers, and allows for high strength and quality of the joint. Therefore, the surface modification of aluminium and titanium in fibre metal laminates remains an extremely important and complex aspect. Literature data indicate that, in the case of titanium alloys, there is no single method that ensures high adhesion at the metal composite interface. On the other hand, an effective and widely used method of aluminium surface modification for fibre metal laminates is chromic acid anodisation (CAA), unfortunately the method is harmful to both human organisms and the environment.

The research objective of this study is to determine the relationship between the structure of the modified metal surface, using micro-arc oxidation process and application of sol-gel coatings, and the adhesion at the metal-composite interface in fibre metal laminates, including the analysis of interlaminar fracture resistance. In addition, the aim of the study is to comparatively assess the damage mechanisms on the metal-composite interface, depending on the micro-arc oxidation parameters used. The subject of verification will be fibre metal laminates based on aluminium and titanium alloys produced using the autoclave technique. Due to the fact that they exhibit the most favourable properties, especially when combined with a carbon composite. As a result, they can find a wide range of applications in the aerospace or automotive industries.

The effect of the research carried out in the proposed scope will be to obtain the characteristic topography and surface morphology of aluminium 2024-T3 and titanium GRADE 2 using micro-arc oxidation process, which can significantly improve adhesion on the metal-composite interface, compared to the currently used conventional electrochemical methods considered harmful (the methods used so far were insufficient and generated negative environmental impact). In addition, the work will result in the evaluation of the influence of the obtained metal structure on the adhesion strength at the metal-composite interface, as well as the analysis of the influence of morphology on the interaction with the epoxy composite.

The overall research plan includes a number of works related to the planned scope of work and research topics. The research plans to modify the surfaces of aluminium and titanium using different micro- arc oxidation process parameters and using eco-friendly sol-gel layers. Then, the structure, morphology and physicochemical properties of the modified metal surfaces will be analysed. Subsequently, the effect of the modified surface of the studied metals on the adhesion at the metal-composite interface will be verified and analysed. Verification of the adhesion strength will be carried out by testing interlaminar fracture resistance based on standards for composite materials. In addition, low-velocity dynamic impact tests are planned to be carried out. Subsequently, an analysis of the strength of the joint at the surface of the metal-composite interface will be carried out, in addition to a comparison of strength values, a detailed evaluation of the morphology of the metal surface in the failure area in terms of failure mechanisms will be carried out, depending on the different surface preparation methods.

The expected results of the planned research will bring a number of new aspects to the discipline of materials engineering by utilising the fundamental knowledge of surface science and metal surface layer formation. Development of the materials engineering discipline will focus on the development of fibre metal laminates with a modified metal surface layer. It is highly likely that the discipline of materials engineering will be expanded to include expertise in metal surface modification technologies, in particular surface modification of titanium alloys, in order to maximise adhesion at the surface of the metal-composite interface. By obtaining appropriate metal surface layer properties such as morphology, topography and physicochemical properties.