In recent years, a significant increase in the production of products made of polymeric materials and their composites has been observed. This increase is related to the low material and production costs of the products as well as the high strength in terms of density, high functionality and aesthetics of the material. The growing concern for the human environment leads to the search for material and technological solutions limiting material consumption in production and facilitating their subsequent disposal. Therefore, nowadays, the development of material engineering in the field of biodegradable polymeric materials of natural origin is very fast.

Interest in additive manufacturing has grown rapidly for a decade. These methods create a product using a computerized layering process that gradually builds one flat slice of a part (or layer) on top of another. This process allows to create a product with precise shapes and complex geometry in a relatively short time, which significantly reduces production costs. 3D printing has been used in various industries: medicine, aerospace, automotive and electronics. Often these products are subjected to significant mechanical loads, in some cases they are cyclical loads. Especially such cases occur in medical applications. Implants used as bone anastomoses due to their working environment (loaded skeletal sites - maxillofacial bones, tubular bones, etc.) are exposed to cyclical loads, during which there is a significant accumulation of defects, which leads to faster material destruction. In addition, changes in the properties of materials are often exacerbated by the water environment of their work, e.g. in the case of biomaterials: human body fluids, sweat, etc., and in construction materials: climatic conditions (precipitation, humidity, etc.). Increasingly, due to their complex structure, products for bone implants are manufactured by means of 3D printing from biodegradable polymer materials. Introducing personalized implants into the human body, made of materials that decompose automatically (without any negative impact on the body), not only affect the effectiveness of treatment, but also prevent reoperation. Understanding the required strengths under specific loading conditions is essential to any load variation. This is especially important for polymeric materials for which even loads below the yield point can fatigue the material, causing microcracks and ultimately failure. Given the rapidly evolving 3D printing industry and the interest in biodegradable materials, an understanding of the fatigue mechanisms for biodegradable composites is imperative to predict and prevent damage.

The aim of the project is to understand the phenomena and fatigue mechanisms of biodegradable polymer composites obtained by 3D printing. The project will aim to determine the synergistic effect of hydrolytic degradation (the effect of saline solution and temperature) and the applied load (static/cyclic) on the mechanical and fatigue properties of composites. In the first stage, composites based on two biodegradable and biocompatible polymers: polylactide (PLA) and poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) and their composites reinforced with hydroxyapatite and basalt fibers will be produced by means of 3D printing and injection molding. The materials will be subjected to cyclical loads and structural changes will be assessed at the various stages of fatigue and biodegradation. The main goal of the project will be to develop and adapt the innovative Lehr method for determining the approximate fatigue strength, on the basis of which a new model of cyclic fatigue will be developed. The registered real hysteresis loops and fatigue strength values will be implemented into the theoretical model, and the experimental data will be compared to the results from the numerical program, which will allow to verify the obtained results and exclude errors. In addition, images of the structure of fractures at individual stages of fatigue will be subject to comprehensive evaluation by computer image analysis methods for combining mechanical phenomena such as the ability to dissipate mechanical energy or dynamic creep with microstructure features. The analysis of changes in the molecular structure with the use of an X-ray diffractometer and a computer microtomograph of samples will be used to assess changes in the organization of the microstructure during fatigue tests. Moreover, the influence of the production technology on the mechanical properties of biodegradable polymer materials will be determined.

Previous literature reports clearly show that there is a gap in the information on fatigue of bio-based materials, moreover, information on fatigue of 3D-printed PHBV composites has not been published so far. Therefore, there is a need for experimental and computational fatigue testing to understand the mechanisms leading to material failure, which will greatly facilitate engineering design and increase material safety. In addition, the described phenomenon will allow for the improvement of 3D printing production technology. Taking up the research topic presented in the proposed project is justified by the need to develop knowledge about polymer materials and their composites, to find new solutions in terms of the production of new materials with special applications and to predict the life of the product.