

Additive manufacturing (AM), commonly known as 3D printing, is a modern production method for the fabrication of light and strong structures. It finds many successful applications, e.g., in dentistry, orthopaedics, mechanics, and robotics. The manufacturing process of 3D printed elements is not free of difficulties, like the possibility of creation of internal defects or deformation of the specimens due to the negative influence of high temperature during fabrication. Taking into account the wide usage of 3D printed elements and the possibility of damage existence, the advancement of non-destructive testing (NDT) methods is an interesting problem. In recent years, the rapid development of diagnostic techniques using ultrasonic waves is observed. It results from the ability of ultrasonics to determine the mechanical parameters of materials and to detect and visualize defects of different types. There are numerous works considering ultrasonic wave-based diagnostics of different structures (like concrete beams, steel plates, adhesive joints), however, the number of studies focused on the analysis of AM structures is limited, especially in composite elements. Some important aspects were not considered, like the influence of different kinds of damage or the determination of optimal parameters for guided wave measurements and data processing.

The aim of the proposed research is to **develop a diagnostic method for non-destructive damage detection and imaging in AM composite elements based on ultrasonic wave propagation**. The interaction of elastic waves with structural defects will be analyzed by advanced signal processing techniques and finite element method (FEM) simulations. The research is motivated by the current trend to arrange innovative, effective, and low time cost diagnostic methods. It is assumed that the measurement of propagating ultrasonic waves supported with advanced signal processing tools has the capability to detect and visualize geometric and material discontinuities in composite AM elements. As a result, the development of two-stage guided wave-based algorithm for non-destructive diagnostics of AM elements created from different materials will be obtained. Authorial approaches for the determination of optimal calculation parameters for the processing of wave signals based on wave energy and weighted root mean square (WRMS) will be prepared. FEM simulations of wave propagation will be performed to support the experimental investigations and minimize the time cost of measurements.

The project consists of a few related tasks. Initially, static compression, tensile, and bending tests will be conducted to determine the static material properties of intact composite AM elements. Measurements of ultrasonic wave signals will be used to determine the dynamic elastic constants based on dispersion curves. Both sets of parameters' values (static and dynamic) will be compared. Different types of specimens made of various filaments will be analyzed. Several degrees of porosity such as different directions of fabrication will be considered. The main part of the investigations will be focused on the development of two-step algorithm for the detection of defects in plate elements. The first step will be damage identification, which will give only information about the presence of a defect. The second step will be damage imaging, which is desired to provide a detailed visualization of defects. The signals will be processed using WRMS calculations. The optimal values of the calculation parameters will be determined. Additionally, modelling of elastic wave propagation in composite AM elements will be conducted using FEM. The signals collected during the numerical simulation will be treated the same way as the experimental data.

The proposed project creates an opportunity to perform a number of original experiments that can lead to widening a knowledge on the application of ultrasonic waves for the characterization of composite AM materials. The results will be useful for non-destructive diagnostics of these types of materials, what is an essential issue when considering the case of detection of unintended, mainly invisible internal defects. From a wider perspective, the results can potentially improve the safety of real-life structural elements in dentistry, orthopaedics, robotics, mechanics, and many more branches of industry. The proposed algorithms for guided wave-based damage detection and imaging will enable to control the state of AM structures during production, such as throughout the exploitation.