The objective of the study / research hypothesis:

The scientific objective of this project is to analyse the stability and failure of compressed real thin-walled composite columns with complex closed cross sections and to describe the behaviour of these structures depending on the applied stacking sequence of laminate plies in the critical, post-critical and limit states as well as to describe composite damage mechanisms (including delamination phenomenon).

The research will be conducted in an interdisciplinary manner via experimental testing and non-linear numerical calculations by the finite element method. In addition, mechanical and limit properties of the manufactured composite material will be determined in compliance with relevant standards. The research will investigate the behaviour of thin-walled composite structures under axial compression over the full range of loading, including their behaviour at failure. Results obtained with the developed numerical models will be verified by experimental tests. The results of the research will contribute to the development and improvement of methods for analysing the non-linear stability and load-carrying capacity as well as design of thin-walled composite structures with closed cross-sections.

The research hypothesis is that the stability and post-buckling behaviour (including load-carrying capacity) of thin-walled composite structures depend on both the cross-sectional shape of the composite structure and the applied laminate stacking sequence. The orientation of laminate plies as well as the amplitude of initial geometrical imperfections (initial deflections) have a significant impact on the structural stability, post-buckling behaviour and failure load of such structures.

The applied research method / methodology:

This research project will involve the production of thin-walled composite structures with complex closed cross sections by autoclaving. The research will investigate the stability, post-buckling behaviour and load-carrying capacity of compressed composite structures depending on the applied laminate stacking sequence and initial geometrical imperfections. Experimental testing will involve carrying out static compression tests of the produced thin-walled composite columns with closed cross sections. Simultaneously, test parameters will be measured, such as load history, deflection perpendicular to the column walls (by laser deflection technique), displacement, strains (using resistance strain gauges), acoustic emission signal (by acoustic emission method), and deformation measurement using Aramis system and assessment of damage phenomenon (including delamination) using a high-speed camera and digital microscope. Real structures simply supported between the upper and the lower clamping head of a testing machine will be subjected to compression, and at the same time, they will be aligned using specially prepared centring elements. As part of the research project, the impact of laminate stacking sequence on the behaviour of an axially compressed structure in critical and limit state conditions will be determined. Parallel to the experimental tests, numerical calculations will be carried out by FEM in a way reflecting the experimental conditions. In the numerical simulations limit states will be described by the criteria of composite material damage implemented in the calculation program ABAQUS® (based on damage models such as Progressive Failure Analysis - PFA and Cohesive Zone Model - CZM). The material model used in the numerical calculations will be defined based on the experimentally determined mechanical and limit properties of the produced composite material. The developed numerical models will be validated by results of experimental tests conducted on real structures.

Impact of the expected results on the development of science, civilization and society:

The research tasks under the project are of interdisciplinary nature and cover the problems related to mechanics, stability and failure of thin-walled composite structures with closed cross-sections. The innovative character of the research primarily lies in producing composite samples with closed cross sections (design and development of both autoclave production technique for samples and necessary equipment) and experimental testing of manufactured samples with respect to their non-linear stability and load-carrying capacity (using numerical simulations to evaluate failure phenomenon, including delamination), considering the effect of different stacking sequences of laminate plies on the stability and limit states of structures under axial compression. In this research project the main focus is put on the description of limit states and failure of a composite material, which will directly affect the development of science by increasing the state of knowledge in the field of mechanics and failure of laminates (especially in the context of delamination). A measurable result of the planned experimental tests of stability and failure of thin-walled composite structures with closed cross sections will be a description of behaviour and failure of these structures depending on the applied laminate stacking sequence and initial geometrical imperfections. This will provide important information regarding the design of thin-walled composite elements in terms of shaping their optimal strength and stiffness properties in order to reduce the structure's sensitivity to critical and limit states, which is of particular importance in the aerospace and automotive industries where complex operating loads occur. An additional outcome of the implementation of the assumed research tasks will be a significant improvement of the research team members' skills in experimental testing and numerical simulations. It can be assumed that obtained research results will have a considerable impact on the development of such important fields of science as mechanics and failure of laminates.