1. Research project objectives/Research hypothesis.

Polymeric composite materials, due to their numerous advantages, have found a very wide application. However, due to their complex nature, they have drawbacks, which include poor resistance to transverse impact loadings. Low energy impact damage is the particularly serious problem, since it is barely visible on the impacted surface, whereas may cause remarkable internal damage, which lowers the composites' residual strength. According to the damage tolerance philosophy, composite components with existing damage are allowed to be operated if the damage does not weaken the structural integrity. Therefore, inspections using non-destructive testing (NDT) methods should be performed periodically in order to identify damage and monitor its growth. The most commonly applied NDT method for composite elements is ultrasonic testing (UT), which enables identifying damage size and location including the depth. However, possibilities of such inspections end at the step of diagnostics of the condition-based maintenance (CBM) program, whereas the step of prognostics (i.e. fault prediction) is not applicable. One of the major challenges posed to today's monitoring systems is development of a methodology enabling prediction of development of detected damage, and as a result, prevention of failure. **The research project objective** that the proposer plans to achieve is to develop a methodology enabling prediction of the residual life of composite structures based on data acquired from UT and numerical evaluation of structural degradation. The proposer poses **the hypothesis** that it is possible to extract reliable information about geometry of internal damage of a composite element by advanced processing of ultrasonic scans, which will be used as an input to numerical modelling for predicting the residual strength of the tested element.

2. Research project methodology.

Within the project, it is planned to make a complex study using a statistically representative set of specimens made of a carbon fibre and a glass fibre reinforced polymer. The specimens will be damaged using various scenarios of impacts, and tested using UT and X-ray computed tomography (XCT), as a reference method. Then, two algorithms of damage detection and three-dimensional (3D) reconstruction based on UT and on XCT scans will be developed using MATLAB®. The next step is a verification of damage reconstruction from UT scans by comparing it with the damage reconstructed from the reference XCT scans. Then, an algorithm of classification of damage types will be developed in order to extract data about regions being the matrix cracks and delamination in the reconstructed damage, as well as their arrangement with respect to the composite's layers. For the purpose of applying the extracted data as an input to numerical modelling, a methodology of conversion of the damage characteristics into a CAD model will be developed. In order to look broadly at the scientific problem undertaken in the project, the numerical modelling will be performed both for simulation and experimental data. Firstly, numerical analyses and predicting residual strength using compression after impact (CAI) tests will be performed based on prepared earlier numerical models of composite specimens and simulations of impacts. Afterwards, the same types of analyses will be performed based on the experimental data, i.e. the real damage extracted from UT scans. Moreover, the laboratory CAI tests of the impacted specimens will be performed in order to verify the developed methodology. Having the above discussed numerical results of structural degradation for both the simulation and experimental data and the results of the laboratory CAI tests, they will be comprehensively analysed and compared. Based on findings from the obtained results and comparative analysis, as well as taking into consideration the theoretical fundamentals of fracture mechanics of composite materials, a theoretical model describing the residual strength of composites with low velocity impact damage will be developed.

3. Expected impact of the research project on the development of science.

The effect of the project will be the new experimentally verified methodology of predicting the residual strength of composite structures based on ultrasonic scans and numerical simulations. A new approach based on reverse engineering will be developed, exploiting data extracted from ultrasonic scans acquired during NDT of composite elements in order to create a CAD model of this element reflecting its current condition, including existing damage. The results obtained from numerical analysis will bring information about the estimated residual strength of the tested composite element. Such the results will bring more information than the results obtained solely from UT, therefore the new methodology will bring better results in the CBM program of composites structures using UT compared to the results achievable so far. Namely, the developed methodology will allow going one step further, i.e. not only the diagnostics step but also prognostics step will be possible based on UT results. Moreover, it is planned to develop a theoretical model describing the residual strength of composites with low velocity impact damage, which will consider findings of the performed experiments and numerical simulations. Considering the planned development of the new damage identification algorithms and the new predicting approach, the proposed approach will provide a significant scientific input in the field of structural diagnostics, non-destructive testing and fracture mechanics of composite structures.