Shells are very common elements of structures in nature e.g. walls of blood arteries or bones e.g. skull. They are also popular in building industry serving as walls of tunnels, tanks, cooling-draft towers or car chassis. The load bearing capacity of shells follows mainly from their specific geometry, however the material strength plays here also a crucial role. Given the variety of applications of shells, the materials that they are made of undergo numerous actions. The accelerating technological progress and the associated wider usage of shells in contemporary applications forced advances in material manufacturing. In this way multilayered laminates, composites and functionally graded materials (FGM) appeared, which are the subject of the present research project.

The composite shells, initially used in aeronautics, become in recent years more popular in other engineering applications such as: aviation and marine industry, production of sport equipment or home appliances and civil engineering. Functionally graded materials in turn are innovative alternative for laminates suffering from intrinsic discontinuity of thermo-mechanical properties which may cause delamination. Initially, in the 80's of 20th century, FGM shells were made of metal-ceramic assemblage and were used as parts of the outer lining of the space ships. In this way significant mechanical strength as well as the resistance to high temperatures were attained. Nowadays, FGM consist of metals such as: magnesium, aluminium, titanium, copper and ceramics , e.g. zircon or silicon carbide. Functionally graded materials may be found in some machine parts, in biomedical applications as implants and are used to manufacture sensors, optical fibres or elements of armour. The possible applications of composites and/or FGM are nowadays less limited and their usage in the existing structures determines their innovative character. Naturally therefore there emerges the need to formulate suitable computational models of shells made of these materials.

In this project we intend to formulate constitutive relations and to elaborate appropriate computational tools for nonlinear analysis of shells made of laminates and FGM. The key and current issue of mechanics of laminates is the failure analysis. This concept comprises two possibilities: the failure occurs at the onset of damage which is known as the First Ply Failure (FPF) or the failure takes place when all the layers at some point suffer from damage (Last Ply Failure, LPF). The choice of the failure model depends on the analyzed problem. Namely, in civil engineering problems it is forbidden to allow for uncontrolled progressive damage. On the other hand, analysis and observation of damage are the fundaments of formulation of new theories or practical designing guidelines. In the present project we plan to develop FPF and LPF failure models for laminates. What makes the project original is the application of the 6-parameter shell theory, in which the stress and strain measures and description of displacements and rotations are richer than those known from classical shell mechanics. The considered shell theory takes into account the material microstructure which is worldwide original. Moreover the range of rotations and displacements is not limited by the theory at all.

The computational models will be developed on the grounds of Finite Element Method (FEM) which nowadays is the main computational tool for engineers. The areas of application include civil engineering, fluid mechanics, aviation industry, electromagnetic actions or temperature loads. Indeed, it is today very difficult to find such a branch of engineering activity where FEM is not successful. It is the intention of the project to formulate 4-node shell finite elements within the framework of 6-parameter shell theory, that will allow for efficient i.e. fast and precise calculations and will reduce the time necessary for FEM calculation. Modern commercial FEM packages usually offer 4-node shell finite elements as the elements that cover majority of applications. The search for efficient elements with wide spectrum of applications and with the minimum number of limitations is practical and up-to-date.

Additionally, to improve FEM efficiency it is planned to implement modern procedures that allow for parallelization utilising multicore architecture of present computers which is also worldwide research problem.