Among construction materials, the search for those with high strength-to-density ratio and good ductility is still an objective of the research in many laboratories in the world. It was observed that multiphase steels, which have the features of composites, are very promising and are characterized by high values of the mentioned parameters. These steels benefit from the best features due to the mix of phases they are made of. Recent research showed that there is still a huge possibility to improve mechanical properties of multiphase steels by control of their heterogeneous microstructures. Contradictory effects in the multiphase microstructure somehow limit improvement of steel properties. From one side microstructure with hard constituents in soft matrix has excellent strength and good global formability. On the other hand, large differences between properties of the components decrease local formability, which is very important in some applications. It is expected that design of microstructures with smoother gradients of properties will lead to superior local formability of steels. Therefore, our objective was to develop models, which will be able to predict distributions of various features of microstructure and calculated gradients of properties.

Conventional deterministic models calculate average values of parameters and are not able to predict distributions of various parameters. The aim of the proposed project is to create a modelling methodology, which will use stochastic internal variables and will account for the random character of some metallurgical phenomena. Such model will enable effective prediction of distribution of microstructural features and mechanical properties in the multiphase materials resulting from the production. Results of simulation based on this model will lead to optimal metal processing and that way overall properties of steel could be improved significantly. In our earlier project we have developed a solution of the evolution equation for hot deformation assuming stochastic character of the dislocation density and grain size. However, the properties of products are shaped by phase transformations during cooling after hot forming. Therefore, the present project is focused on a stochastic model for phase transformations. The model will account for the random character of the nucleation of the new phase and will solve differential equations of growth for the stochastic variables. A particular attention will be paid to the mathematical background for both these aspects. Where possible, an attempt to determine mathematically strict conditions, which ensure existence and uniqueness of the solution, will be made. This knowledge will be later used as a benchmark in numerical simulations. We hope that exact, mathematically strict solutions for these equations can be calculated. Simply, not always computer simulation reflects real solution of the equations, because errors of computation can quickly accumulate leading to a completely different picture. Knowledge about analytic solutions will be helpful in avoiding such pitfalls and choice of most suitable numerical methods.

Developed model will be identified and validated by comparison with experimental data. Searching for a correlation between distribution of microstructural parameters and mechanical properties of product will be an objective of the second part of the project. Statistically Similar Representative Volume Elements (SSRVE) of the microstructure will be designed on the basis of histograms of microstructural parameters calculated by the stochastic model. SSRVEs will be subjected to deformation (finite element simulation) and gradients of properties will be calculated. Two practical applications of the model will be considered. The first will be simulation of typical industrial processes and application of the model to design optimal technological parameters. The second will be connected with accounting for the uncertainty of the input from sensors in the industrial processes and prediction of the product properties with certain probability.

A numerical tool and methodology for its creation based on the stochastic analysis of the phase transformations will be the main output of the project. It is expected that this tool will supply a new knowledge on control of heterogeneous microstructure during phase transformations and will be a useful support of research on development of new steels.