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Title of Seminar 1: Uncertainty quantification in the homogenization method of composites

Abstract: The seminar introduces the participants into two major homogenization methods of particulate and fibrous composite materials, namely analytical and numerical. These two methods based upon the deformation energy of the so-called Representative Volume Elements are contrasted with each other and discussed on the examples of polymer-based engineering composites. Further, the basic elements of uncertainty quantification are introduced in the context of discrete and continuous distributions of random variables and fields. Their application in homogenization-based analysis of particulate and fibrous composites leading to uncertainty quantification for effective material tensors is demonstrated. Statistical scattering of material properties is discussed together with a specific interface imperfections for both classes of composites. An impact of the stochastic interphase in fibrous and particulate composites is demonstrated also using three concurrent probabilistic numerical techniques, namely Monte-Carlo simulation, semi-analytical as well as the iterative generalized stochastic perturbation technique implemented in the Finite Element Method program. Some ABAQUS simulations concerning hyper-elastic behavior of the elastomers reinforced with the carbon black particles is also discussed in the probabilistic context.

Title of Seminar 2: Probabilistic entropies in structural dynamics

Abstract: This seminar is devoted to an introduction of probabilistic entropy and distance. Their applicability and significance in uncertainty quantification and reliability assessment for linear and nonlinear structural dynamics are discussed. An implementation and application of the Finite Element Method together with some numerical difference approaches is demonstrated. The FEM examples include the studies delivered in two commercial systems – ROBOT and ABAQUS. Numerical analysis includes first of all a comparison of the basic probabilistic characteristics of the dynamic response of the Newmark method with the Hilber-Hughes-Taylor approach. The basic sources in uncertainty quantification are geometrical features of different structures, their geometrical imperfections, and of course also environmental actions on the slender structures. Determination of the Shannon entropy in this context together with the additional computational implementation in the system MAPLE will be shown. A collection of different relative entropy models and their significance in the dynamic reliability analysis would be demonstrated from both mathematical and numerical point of view. Some fundamental engineering case studies related to steel cables, frames, plates, masts and towers will be discussed in detail, where a contrast of the traditional reliability indices with these coming from relative entropy apparatus will be demonstrated.

Course title: Uncertainty Quantification & Structural Reliability.

This course starts with a demonstration and interpretation of the basic probabilistic moments and characteristics, different types of uncertainty in engineering problems resulting from both engineering laboratory experiments and inherent in mathematical models and numerical simulations. Continuous and discrete definitions of positional statistics, and also a listing of different probability density functions is delivered. Mathematical issues inherent in probabilistic integrals are demonstrated using the computer algebra system MAPLE. The basic algorithm of the Monte-Carlo simulation is demonstrated in this system and also with the use of Python programming environment. Probabilistic convergence of the basic statistics in some specific engineering problems is demonstrated numerically; short overview of some numerical accelerators is attached. These issues are contrasted with the basic methodology typical for a family of the perturbation methods of the first, second and general order. The role of the perturbation order and convergence of the method is discussed, especially in the context of both linearization and iterative approach to the basic moments calculation. Some engineering examples for all these three methods are attached and discussed in detail. Next, a definition of the First and the Second Order Reliability Methods (FORM and SORM) would be provided together with some engineering illustrations. This apparatus would be enriched with the definitions and interpretation of probabilistic entropy and distance. Different mathematical models would be recalled and their engineering applications, i.e. in beam, plates, shells and spatial structures will be demonstrated. Application and usefulness of the probabilistic distance to the reliability assessment will be shown for linear, nonlinear and coupled multi-physics problems of computational mechanics and physics (including fire risk and safety analysis). This course would be completed with random time series approximations of the ageing processes of certain engineering materials and structures. Some numerical simulations will display an impact of the experimentally-driven ageing processes on popular engineering structures.