Autogeneous coupled dynamic-acoustic effects are frequently observed in granular materials during flow (called ‘singing’ or ‘sonic’ granulates) when sheared at a sufficiently high rate (avalanches, debris flows, plug flows, earth-quake, dunes, confined silo flows). They are in particular pronounced during a dynamic (resonant) interaction between granular bodies and surrounding structures. The problem of autogeneous coupled dynamic-acoustic effects is in particular of major importance for surrounding structures that are frequently subjected to failures due to high dynamic amplitudes. In addition dynamic effects cause acoustic phenomena that disturb the surrounding environment and earth-quakes that are dangerous to other surrounding engineering structures and contribute to the fatigue of connections and joints. In spite of numerous experiments, the reasons of a spontaneous acoustic emission due to a vibration of granular materials, itself excited by a granular shear flow are still not recognized since the effects are strongly non-linear and non-stationary and combine complex granular flow dynamics with the shell dynamics and acoustics. A mathematical model for their description is missing.

The purpose of the 3-year experimental-theoretical research investigations is to understand the mechanism of the occurrence of autogeneous coupled dynamic-acoustic effects in granular materials during their dynamic interaction with surrounding structures. This mechanism will be described by means of advanced mathematical models at the grain level (based on the enahnced discrete element method (DEM)) and at the structure level (based on the finite element method (FEM)). THe calculations results will be checked by the experimental outcomes. Due to the fact that granular materials have a particular structure that is strongly discontinuous and heterogeneous, DEM is a suitable tool in understanding their mechanical behaviour at the grain level (micro-level) since it may directly reproduce the granular micro-structure. In order to describe a dynamic propagation of spontaneous coupled stress-acoustic waves, the mechanics of discontinuous bodies will be coupled with fluid mechanics that is a suitable tool to capture acoustic effects. Within fluid mechanics (by applying the computational fluid dynamics (CFD)), a model of laminar flow of viscous and compressible fluid will be used by taking mass and momentum into account in existing macro-voids of granular materials.

The model FEM, based on a micro-polar constitutive model for granular materials, is appropriate for describing dynamic effects at the structure level (macro-level) independently of the structure size since: a) it uses a constitutive model that captures the salient properties of granular materials, b) it provides mesh-independent results due to the presence of a characteristic length of micro-structure in the form of a mean grain diameter and 3) it uses a material point approach for the motion description that allows to avoid the excessive mesh distortion. The autogeneous dynamic-acoustic effects will be investigated in granular materials at the laboratory scale during their dynamic interaction with the surrounding structure in the form of a cylinders or prisms wherein they can be always repeatably reproduced. They will be investigated in real and artificial granular materials by using the most advanced dynamic measuring system of accelerations of structures and grains, natural frequency of the structure, air pressures, sound frequencies, sound intensity, horizontal wall pressures and wall frictional tractions. The experiments will be numerically analyzed by applying the coupled mechanical-acoustic DEM/CFD model and FEM model under 3D conditions.