Silos are engineering structures commonly used in the construction, chemical and agricultural industries for storing various types of materials. They are often built as a lightweight structures made of corrugated steel sheets, supported along the silo circumference by thin-walled columns. Although, their common occurrence, some problems still exists, such as granular material shearing phenomenon in the area adjacent to the wall, that have not been comprehensively analysed. The corrugations have a significant impact, in particular during the flow, on the effective wall friction coefficient and as a result, on the loads acting on the silo construction. Generally, two types of granular material actions on the silo structure can be distinguished. In the first one, bulk material, located inside the silo, acts on it in the static manner. Therefore, loads transferred from the material to the structure are easy to estimate with analytical solutions known for years. The second type of action occurs during the silo flow when granular material in motion causes dynamic and difficult to estimate loads acting on the wall. The magnitude of the transferred forces depends significantly on the phenomena occurring in the contact zone (in the so-called granular material/corrugated structure interface). In case of an effective wall friction coefficient determination procedure, current standards recommend an appropriate analysis of the bulk solid/wall contact regime or propose simplified approach and assume the constant coefficient for all surfaces, regardless of their geometry.

The purpose of the experimental-numerical research is to understand the mechanism inside the contact zone between granular material and corrugated wall during the silo flow. The analysis of the contacting regimes phenomena, especially the shear zone formation, will allow us to determine the dependence between effective wall friction coefficient and wall's corrugation profile. To achieve our objectives, experiments and numerical analysis will be performed, with the use of modern and advanced devices and methods. In the case of experimental part, laboratory scale set-up for the silo flow investigation will be constructed (partially with the 3D printing technology). 3D printer will allow us to create an exchangeable silo side walls of different corrugation profiles (e.g. various profile heights). Moreover, photographic documentation of the granular material during the silo flow experiments will be made. It will allow us to perform digital image correlation (DIC) analysis. This technique will let us analyse the motion of the granulates in the contact zone based on the material deformation. Pressure sensors of our own original project will be used in order to quantify the magnitude of loads transferred from the bulk material to the silo walls on both horizontal and vertical directions. Unfortunately, due to discontinuous and heterogeneous changes of a granular material structure, it is difficult to obtain numerous flow characteristics in the laboratory experiments. Therefore, a numerical analysis will be performed by means of modern and constantly developed discrete element method (DEM). DEM is a tool, specifically designed for bulk material investigation, which allows us to reproduce said material's microstructure, taking behaviour of the distinct grains into account. In the numerical investigation, some modern techniques will be used, e.g. microscopic photography which will allow us to reproduce real grain shapes of granular material during computations.

The research project is composed of two essential parts: laboratory experiments and numerical analysis. In the first stage, the influence of the 3D printed wall's corrugation profile (e.g. from smooth to very folded surfaces) on the silo flow will be investigated. Based on the measurements of normal and tangential pressures acting on the wall and DIC analysis of granular material motion and deformation, the relation between the effective wall friction coefficient and walls corrugation profile will be determined. Moreover, laboratory outcomes will be used to validate the numerical model. A comprehensive analysis of the bulk material behaviour in the area adjacent to the wall with the exact location of the shear zone will be possible due to the usage of numerical calculations. Parameters, such as grain rotations and displacements or forces between the particles and walls will be investigated. The results obtained with the numerical analysis will be used for determination of the shear zone exact location and its characteristics.

Research outcomes will be essential for designing procedures concerning the silo structures commonly used in many industry sectors. The shear zone formation phenomenon between two regimes will be defined and, as a consequence, the effective wall friction coefficient between granular material and corrugated structure will be reliably determined. As a result of our research, guidelines for quantifying the loads acting on corrugated walls during the silo flow will be introduced. The recommendations will positively affect the newly designed structures and improve their safety.