The proposed investigation deals with an analysis of phenomena occurring during mixing of different metallic materials (aluminum and magnesium alloys) in solid state. The mixing takes place during joining of metals by the friction stir welding (FSW). The basic concept of FSW is remarkably simple. A non-consumable, rotating tool with a cylindrical shoulder and a specially profiled pin is plunged into the joint line between two abutting or overlapping work pieces. As the tool traverses the joint, the rotation of the shoulder under the influence of an applied load heats the metal surrounding the joint and, with the rotating action of the pin, induces metal from each section to flow and mix with each other forming the weld. By its nature, the process is asymmetrical. The side of the weld for which the direction of material flow is the same as the tool traversing direction is called the "advancing side"; the other side, where the direction of material flow opposes the traverse direction is referred to as the "retreating side". The process comes about without melting of the joined pieces. The material flow around the tool pin has a complex character and is not fully understand yet, especially when two different metallic materials are mixed together. During this process the material is subjected to mechanical mixing and severe plastic deformation at elevated temperature. In addition, the metal mixing is accompanied by significant temperature gradient occurring across and beyond the stirring zone. This results in formation of complicated microstructure associated with plastic deformation, recovery and recrystallization as well as with phase transformations related to the dissolution or precipitation intermetallic compounds. Though the phenomena occurring during joining of materials of the same kind were intensively investigated and are fairly well comprehend, the process of mixing of dissimilar metals is far from understanding. This is due to differences in physical properties of the metals being joined such as thermal conductivity, melting point, density, crystal structure, etc.

The comprehensive study and characterization of mixing process of materials of different kind requires research in various scales – from macro to nano. That is why the proposed investigation will be conducted by means of either routine metallographic techniques or sophisticated electron scanning and transmission microscopies. In particular, phase transformations, deformation processes on micro scale, microtexture development and the material flow phenomena will be analyzed in detail. Hardness and tensile tests will be also carried out. The hardness tests will serve for the construction of hardness maps form the entire weldment sections as well as for hardness profiles across the joints at different depth form the surface of welded blanks. Tensile samples will be prepared from base and welded material. Tensile samples will be excised from the welded material in such a way that the tensile axis is perpendicular to the weld. Tensile tests on micro-samples, i.e. samples that are excised from particular weldment zones, will be also perform. Results from the experimental investigation will advance and validate a coupled thermal/flow numerical model that predicts the microstructural evolution and temperature behavior during the mixing process. This detailed and extensive research plan will enhance the understanding of the nature of solid-state joining of dissimilar metals.