DESCRIPTION FOR THE GENERAL PUBLIC

Advanced superconducting materials consisting of a copper matrix with filaments are used in elements which work at extremely low temperatures. A discontinuous plastic flow phenomenon (DPF) and a stick-slip effect were observed in these materials during plastic deformation at near to 0K temperatures. The DPF is observed independently in a matrix and in filaments, whereas stick-slip effects occur in a matrix/ filaments interface.

Fundamental to superconductors is an influence of these phenomena on superconductivity. Therefore, experimental investigations of DPF mechanisms in a matrix, filaments, as well as investigations of stick-slip effects in a matrix/ filaments interface are essential from a scientific point of view. Moreover, an interaction of these phenomena should be considered. Experimental results will be crucial for building constitutive (mathematical) models of these effects and their coupling.

Tensile tests of superconductor specimens will be carried out at liquid helium (4.2K), liquid nitrogen (77K) and room temperatures. Test specimens consist of copper matrix with filaments (e.g. NbTi/Cu, Nb3Sn/Cu). Tensile tests will be carried out at cryogenic experimental set-up located at Cracow University of Technology. Before starting a tensile test, the cryogen flows from the dewar to the cryostat until the specimen with the sensors is immersed in the cryogenic medium. Thermal insulation system of the cryostat consists of insulation vacuum, radiation screens and styrodur blocks, which provide the thermodynamic stability to the cryogen. The experimental set-up is complex and not transparent – it does not allow to observe the sample directly. Therefore, rather complex instrumentation has to be used. This, in turn, implies application of high resolution and high quality data acquisition system. Thus, the instruments are linked to the data acquisition system. Elongation of the specimen, its temperature and the applied loads are monitored and stored. Moreover, a microstructure analysis of specimens will enable better understand a DPF and stick-slip effects. It will include microstructure analysis of matrix, filaments and matrix/ filaments interface, before as well as after tests at 4.2K, 77K and room temperature. It is worth pointing out, that the tracking of strain localization during DPF by means of an acoustic transducer is intended.

Based on experimental results, the multiscale constitutive model of a DPF will be proposed. It will be multiscale model which includes micro-, mezo- and macroscopic effects.

1. Microscopic scale: the analysis of plastic deformation mechanisms in crystal lattice, the mechanism of heat transport at very low temperatures which is based on the diffusion of phonon gas as well as the thermodynamic instability of lattice at temperatures close to absolute zero.
2. Mezoscopic scale: definition of representative volume element (RVE) containing microstructure with DPF effects.
3. Macroscopic scale: continuum mechanics modeling of materials with DPF effect, as well as smooth plastic flow, including dissipative phenomena such as macroscopic plastic slips in a matrix and filaments of superconductors.

Dissipative mechanism related to a stick-slip effect in a matrix/ filaments interface will be described by appropriate mathematical equations. Moreover, an attempt to describe the interaction between DPF and stick-slip effects will be undertaken.

Identification of DPF and stick-slip models parameters will be realized based on experimental results. A numerical model of DPF and stick-slip effects will be provided for superconductors, which consist of cooper matrix and filaments, and they are loaded below critical temperatures (T_0, T_1). It is worth pointing out, that models validation will be also prepared based on experimental results.

Experimental tests and mathematical description proposed by the author, allow better understand the DPF and stick-slip effects in superconductors, which consist of copper matrix and filaments, and they are loaded at near 0K temperatures. Such superconductors are most often used in superconducting magnets in particles accelerators, nuclear magnetic resonance spectroscopes, superconducting magnetic energy storages, thermonuclear reactors or superconducting power lines. It is worth pointing out, that low-temperature superconductors were used in the Alpha Magnetic Spectrometer, a particle physics experiment module that was mounted in 2011 on the International Space Station. It is designed to measure antimatter in cosmic rays and search for evidence of dark matter. The author believes that the constitutive model and based on it the numerical simulation of a DPF and a stick-slip effects will have influence on design process of superconducting elements. For instance, it seems crucial for preservation of their superconductivity during a work.