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Abstract of the doctoral thesis

"Diffraction study of deformation process for selected groups of grains and different phases in polycrystalline materials"

In this work the stress measurement methodology for polycrystalline material using time-of-flight neutron diffraction technique was developed. The experiments were conducted mainly on the EPSILON-MSD diffractometer at the Join Institute for Nuclear Research in Dubna (Russia). This instrument allows to perform measurements of crystal lattice deformations simultaneously in 9 different directions of scattering vector. In order to efficiently process a large amount of measurement data, several programs for the analysis of the experimental results were prepared. Measurements were carried out *in situ* during mechanical and thermal loading of the samples. In order to minimize the systematic error, the stress increments were determined on the basis of the relative lattice strains. The research concerned two materials: Al/SiC_p composite obtained by powder sintering, where the volume fraction of silicon carbide was 17,8%, and hot-rolled magnesium alloy AZ31. The neutron diffraction time-of-flight technique enabled to determine the stresses in each phase of the composite and to apply the crystallite groups method in the case of a magnesium alloy samples. For the composite sample, *in situ* measurements were carried out during the compression test, and also the results of previous experiment performed at different temperatures were used and analysed. Measurements in magnesium alloy were made for the compression test in the rolling direction and the normal direction. The neutron diffraction measurements performed at Neutron Physics Laboratory (NPI, Řež near Prague, Czech Republic) during the tensile test in the rolling direction were also analysed in this work. An important achievement of the work is the development of a methodology for selective stress analysis for two phases and for different crystallite orientations based on measurements carried out in many directions and with the use of different hkl reflections.

The first part of the work concerns the analysis of the results of measurements carried out for the Al/SiC_p composite. The phenomenon of residual stress formation between the SiC grains and the Al alloy matrix during cooling, corresponding to the composite production conditions, was investigated. These stresses result from a significant difference in the thermal expansion coefficients of both phases. The thermal stresses in the phases were correctly predicted by the thermomechanical self-consistent model (TMSC). *In situ* measurements during the compression test of the Al/SiC_p composite allowed for the examination of stress changes in individual phases. It has been shown that in the elastic range, the deviatoric stresses localised on the SiC grains are much greater than theses localised in the aluminium matrix. The difference between the loading of the silicon carbide as compared to the loading of the Al matrix increased significantly when the aluminium was plastically deformed. There

was also relaxation of thermal stresses during plastic deformation, the average values of which for each phase is hydrostatic. The stress relaxation phenomenon was explained using a developed thermomechanical self-consistent model (DTMSC).

The second part of the work concerns the research performed in order to explain the strong anisotropy of the response of textured samples made of magnesium alloy (AZ31) to the applied external load. Despite the isotropic elasticity constants of the crystallites, the elastoplastic behaviour of the samples depended on the direction and nature of the applied load. The samples were cut from hot-rolled magnesium having a strong crystallographic texture with a dominant basal component (0001). The measurements showed a higher yield point and greater hardening of the material during compression in the normal direction compared to compression or tension in the rolling direction. Moreover, during the compression test in the rolling direction, a twinning phenomenon occurred leading to a characteristic plateau range on the macroscopic stress-strain relationship.

To explain such a characteristic behaviour of magnesium samples, the measurement method of crystallite groups was used, which allowed to investigate the stresses localised at grains with different crystal lattice orientations. The different loadings of the sample in combination with the strong texture resulted in very different behaviour of the crystallites. There are 4 groups of grains: hard, intermediate, soft and grains for which twinning occurs. For these groups, there are different sequences of activity of the slip and twinning systems. The evolutions of stress tensor components for individual groups of grains, depending on their orientations, were measured using *in situ* diffraction measurements during compression and tensile tests. The knowledge of the stress tensor allowed for the determination of the shear resolved stresses (RSS) on all slip systems and the twinning system, along with their uncertainties. On the basis of changes in these stresses during the tests, the critical resolved shear stresses (CRSS) needed to activate the slip and twinning systems were determined. The uncertainty analysis of the determined values was also carried out.

The measured CRSS values were used as input to the elastoplastic self-consistent (EPSC) model. This reduced the number of parameters that must be optimized to fit the model results to the experimentally determined lattice strains. As a result, the calculations became more unambiguous and allowed to verify the assumptions concerning the process of twins formation and the interaction between the grains. The model parameters determined in this study were also verified for a set of samples subjected to compression in various directions. In this work, for the first time, an analysis was carried out to determine all CRSS values, together with uncertainties, directly from the experiment and without model assumptions.