ABSTRACT

Verification of constitutive models of elasto-plasticity using FEM and DIC

In the PhD thesis, the basic models of metal elasto-plasticity within the theory of small and large deformations were verified by comparing the results of experimental studies carried out using the Aramis digital image correlation system with the results of calculations: analytical within the strength of materials and the theory of thin-walled bars and numerical using the finite element method program Abaqus/Standard.

Chapter 1 informs about the purpose and scope of the work and contains some basic information about the tools used and the issues studied.

Chapter 2 discusses the constitutive models used. An elastic-plastic model of an isotropic material was adopted, having a linear character in the elastic range, and a flow law in the plastic range associated with the Huber-Mises plasticity criterion with isotropic or kinematic hardening. The theories of small and large deformations implemented in the Abaqus system as part of the so-called geometrically linear and non-linear analysis were used.

Chapter 3 describes the material tests carried out and their results. Static tensile tests and alternating stretching and unloading tests of standard samples were carried out using an electromechanical strain gauge and an digital image correlation system. A total of 16 tests of three different types were carried out, the development of strains and plastic zones was analyzed using the Aramis system, the values of selected material constants were calculated according to several different self-developed algorithms, and an extensive statistical study of the obtained results was made using three estimators (arithmetic mean, weighted mean and median). In addition, a visual assessment was made based on the inspection of the tested elements and a small number of hardness tests using the Rockwell and Brinell methods was conducted.

Chapter 4 describes the verification of constitutive models on the example of stretching an asymmetrically perforated flat bar. One static test was carried out with the use of the optical image correlation system and the appropriate plane stress model was analyzed in the Abaqus program.

Chapter 5 describes the verification of constitutive models on the example of compression of short sections of perforated thin-walled bars with an open cross-section of the Ω type. 106 compression tests were carried out on samples of 8 different heights, including 63 tests

with rigid attachment of the pressure plates to the testing machine and 43 tests with hinged attachment. As part of the analytical calculations, in the elastic range, the theory of thin-walled bars and mathematical buckling were used, and in the inelastic range, two alternative parabolic curves were adopted; calculations were also made according to the applicable thin-walled steel structure design standard with some additional assumptions. Numerical calculations were made according to the shells theory, assuming various: material models in the plastic range (isotropic or kinematic hardening and various constitutive relations of plasticity), boundary conditions (ends fixed or rotational in relation to various points, full or one-sided constraints) and imperfections (absent, sway and/or bow).

Chapter 6 contains a summary and conclusions as well as suggestions for further research issues that are a continuation or development of the research described in the thesis.

Keywords: elasticity, plasticity, elasto-plasticity, plasticity of metals, theory of small strains, theory of large deformations, plastic flow, Huber-Mises yield criterion, isotropic hardening, kinematic hardening, digital image correlation, optical image correlation, finite element method, experimental research, theory of thin-walled bars, buckling, plane stress, theory of shells, imperfections, thin-walled perforated bars, thin-walled bars with very low slenderness.