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NUMERICAL MODELING OF STEEL WELDED SUPPORTING ELEMENTS

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Abstract: *The paper is focused on the numerical modeling of steel welded supporting elements and their verification using experiment. Currently, for the stress-strain analysis of the elements in supporting structures it is possible to use many commercial software systems, based on the finite element method - FEM. It is important to check and compare the results of FEM analysis with the results of physical verification test, in which the real behavior of the bearing element can be observed. The results of the comparison can be used for calibration of the computational model. The article deals with the physical test of steel supporting elements, whose main purpose is obtaining the material, geometry and strength characteristics of the fillet and butt welds. The main aim was at defining the tested samples numerical models for using FEM analysis and for the commercial software ANSYS. The tension test was performed during the experiment, wherein the totals load value and the corresponding deformation of the specimens under the load was monitored. Obtained data were used for the calibration of numerical models of test samples and they are necessary for further strain analysis of steel supporting elements.*

Keywords: Numerical modeling, Experiment, Steel structure, FEM, Fillet weld, Butt weld.

1. Introduction

Numerical modeling is increasingly promoting into design practice. Using powerful computers and efficient software systems can provide valuable results, which serve to increase the reliability of the proposed support systems and elements (Kotes & Vican, 2013). Complex mathematical procedures take into account physical and geometric nonlinearities of the structure (Janas et al., 2016). An important tool for mathematical modeling is particularly the Finite Element Method - FEM, whose principle is to discretize continuum to a certain (finite) number of elements and the determination of calculated parameters in individual nodes.

Numerical modeling finds its application in all sorts of areas of engineering. There are publications that analyze problems of mathematical modeling of structures based on thin-walled cold-rolled cross-section (Flodr et al., 2014) or round timber bolted joints with steel plates (Lokaj & Klajmonova, 2014). The results of numerical modeling have usually limited use without the experimental verification or without the load tests (Cajka & Krejsa, 2014). Test results may lead to calibration and validation of mathematical model, which should ensure compliance of the numerical model and the actual behavior of the investigated structure. Valuable results of mathematical modeling are also conditional on defining the material models, which are often associated with laboratory-obtained material properties (Major & Major, 2010). Some particular and selected problems of numerical modeling are aimed at ultimate limit state and probability-based studies (Kala, 2015; Kotrasova et al., 2015; Protivinsky & Krejsa, 2015; M Kralik & Kralik, 2013).

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The stress analysis of welds has got also the considerable attention in the past. In (Hobbacher, 1993) it was defined stress intensity factor of welded joint for typical structural details, among others for cruciform joint fillet weld. In (Lazzarin & Tovo, 1998) the authors discuss the derivation of the so called notch stress intensity factors for welded joints, using which can be accurately described stress distributions in the toe neighborhood of weld toes.

With the development of commercial computing systems there have been emerging works which aim at describing the state of stress in the welds through FEM analysis. In (Meneghetti & Guzzella, 2014) is described the approach for a determination of the notch stress intensity factor in welded joints using three-dimensional finite element models (SOLID 45) in software system ANSYS. In (Cerit et al., 2010) authors focused on modeling of fillet welded cylindrical joints under tension and torsion loading with regard to the fatigue resistance (Krejsa, 2013, 2014). The work (Anca et al., 2011) deals with the mechanical analysis with the simulation of fusion welding by the Finite Element Method, where the implemented models include a moving heat source, temperature dependence of thermophysical properties, elastoplasticity and non-steady state heat transfer. Using software systems MSC Marc and ANSYS is possible to simulate and model the welding process and the rise of residual stresses (Barsoum & Lundback, 2009).

Application of the finite element method to predict thermal, material and mechanical effects of welding are comprehensively described in (Lindgren, 2006). Real behavior of welds in terms of stress analysis can be examined through physical tests. Publication (Kanvindea et al., 2009) contains the results from twenty-four cruciform weld experiments and complementary finite element simulations to study the effect of the weld root notch on strength and ductility of fillet welds. In (Lee et al., 2015) the real stress state in steel butt welds subjected to cyclic mechanical loading is evaluated. From the above summary of publications aimed at mathematical modeling of structures, focusing on the problems of welded oriented problems is obvious that this is a very current topic.

The further interpretation is dedicated to problems of mathematical modeling of welded bearing elements in steel structures. Some works focused on numerical modelling of a steel fillet welded joints based on experimental verification have been published (Krejsa et al., 2015). This article focuses on numerical modelling of different types of steel welded bearing elements - fillet welded lap joint and double V butt welded joints.

2. Numerical modelling of special designed specimens

Three types of specimens were designed to investigate the state of stress in fillet of butt welds. Specimens were designed to reflect the fact that the stiffness of connected elements has to be higher than the stiffness of the welded joints (see Fig. 1 to Fig. 3). It can therefore be assumed that the stress-strain diagram will reflect the behavior of strains and stresses in welds. It has to be noted also that for comparison of the behavior of the weld sample in Fig. 3 was made special specimen with the same geometrical parameters, which is not welded, but is formed by only the base material.

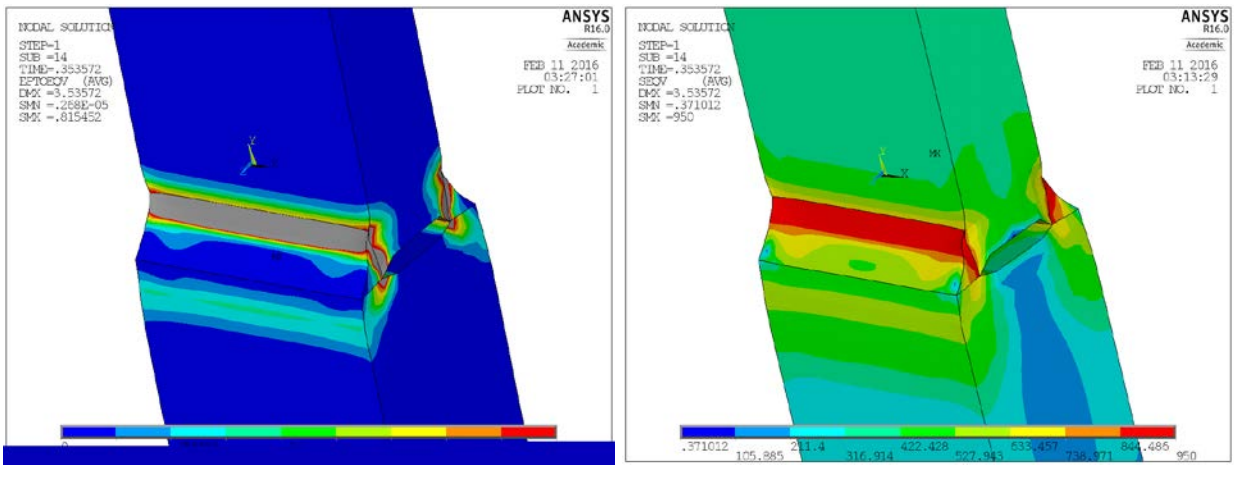

Fig. 1: Resulting total strain (left) and von Mises stress (right) in numerical model of fillet welded lap joint with densest FEM mesh and for the maximal achieved strength in tested sample

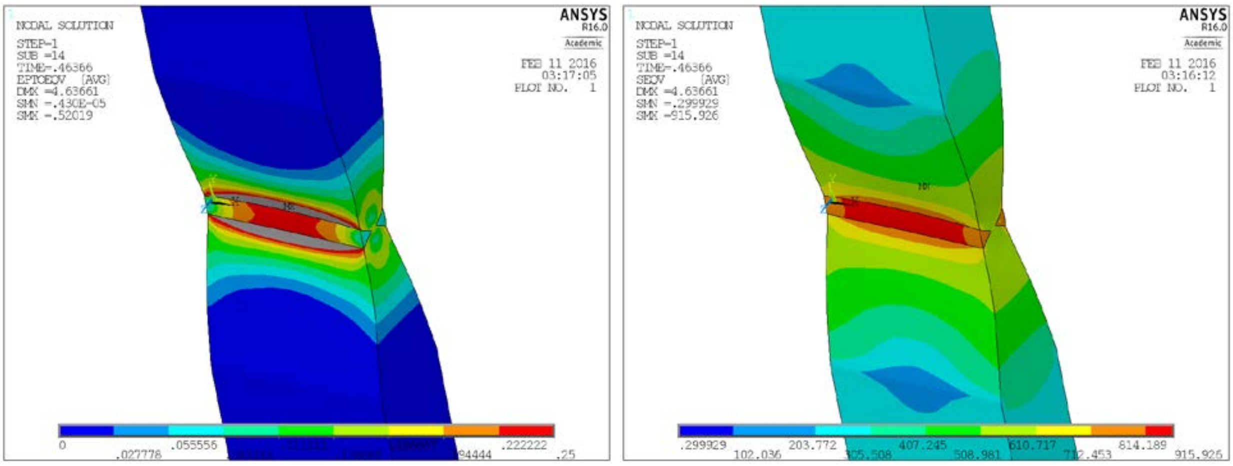

Fig. 2: Resulting total strain (left) and von Mises stress (right) in numerical model of double V butt welded joint with densest FEM mesh and for the maximal achieved strength in tested sample

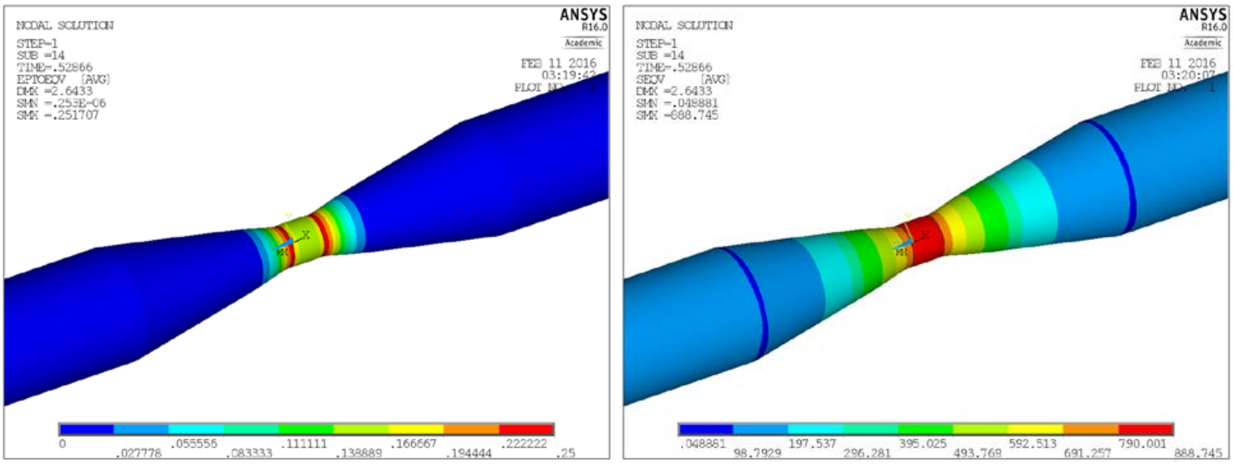

Fig. 3: Resulting total strain (left) and von Mises stress (right) in rotationally symmetric double U butt welded joint with densest FEM mesh and for the maximal achieved strength

The 20-node isoparametric SOLID186 finite elements and the ANSYS software were used. For each of the model were performed three variants of FEM mesh density (size of elements was 3 mm, 2 mm and 1 mm). For each model and FEM mesh density were performed compare/sensitivity stress-strain analysis based on bilinear and multilinear stress-strain diagrams of basic steel material and weld material. These diagrams were verified using measurement data from experiments. Resulting total strain and von Misses stress for numerical models with the densest FEM mesh and for maximal achieved strength in tested samples is possible to see for all three types of tested and modeled specimens in Figs. 1 to 3.

3. Conclusions

The article described experimental tests and numerical analysis in the program system ANSYS focused on steel fillet and butt welded supporting elements. On the basis of these experiments there were obtained parameters of a real stress-strain relations that will be used as input data for further works in the area of modeling of specific types of welded components, which can be used in steel structures of buildings.

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