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NUMERICAL ANALYSIS OF DIFFERENT WELD GEOMETRIES OF LAP WELDED JOINT IN AMMONIA TRANSPORT TANKS

NUMERIČKA ANALIZA ZAVARENIH SPOJEVA RAZLIČITIH GEOMETRIJA U SLUČAJU PREKLOPNOG SPOJA NA CISTERNI ZA TRANSPORT AMONIJAKA

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- finite element method
- ammonia transport tank
- lap joint
- P460NL2 steel

Ključne reči
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- cisterna za amonijak
- preklopni spoj
- čelik P460NL2

Abstract

Presented is a comparison of stress and strain distribution in lap welded joints of different geometries, which are part of a pressure vessel used as an ammonia transport tank. For this purpose, two numerical models are developed using finite element method (FEM). The models are subjected to tensile load and the obtained stress and strain results are compared in order to determine how the difference in welded joint dimensions affects the behaviour of the weld as a whole. It is concluded that in this case, the differences in distribution and stress/strain values are negligible, as expected due to very similar mechanical properties of the materials used.

Izvod

U ovom radu je prikazano poređenje raspodele napona i deformacija u preklopnim zavarenim spojevima različite geometrije posude pod pritiskom za transport amonijaka. U tu svrhu su razvijena dva numerička modela zasnovana na metodi konačnih elemenata (MKE). Modeli su opterećeni na zatezanje i dobijeni rezultati napona i deformacije su upoređeni kako bi se utvrdilo u kolikoj meri razlike u dimenziji zavarenog spoja utiču na njegovo ponašanje. Zaključuje se da su razlike u raspodeli i veličinama napona/deformacija zanemarljive u ovom slučaju, usled veoma sličnih mehaničkih osobina primenjenih materijala.

INTRODUCTION

The aim of this research is to determine how the geometry of a welded joint affects the stress and strain distribution around it, in the case of a lap joint connecting the mantle and lid of an ammonia transport tank. The welded joint in question is made up of two P460NL2 steel plates that are welded with EPP2NiMo2 electrode. Steel P460NL2 belongs to a group of steels that are typically used in the manufacture of pressure vessels, /1/. The behaviour of welded joints in ammonia transport pressure vessels is of great importance, due to the numerous risks associated within, /2/.

Lap joints are used in the manufacture of various structures, typically made of metal, wood and plastic. Their applications also include the welding of fuel tanks and other vessels used for transport, /3/. While they are not the most desirable solution for ammonia transport tanks, attempts are being made to determine how their effectiveness in this particular field could be improved. Lap joints are typically used in smaller pressure vessels, since their geometry can lead to stress concentration in the area around the welds. For this reason, butt joints are preferred, although lap joints have the advantage of providing a better contact between the welded plates.

The focus of this paper is on comparing welded joint geometries, i.e. the extent to which it penetrates the parent material in terms of stress and strain distribution, and concentration. For this purpose, numerical models are made and subjected to analysis via finite element method.

MATERIALS AND METHOD

Steel P460NL2 is typically used in the manufacture of pressure vessels due to its increased yield strength and better ductility compared to typical structural steels. It should be noted that the yield strength of materials used for such vessels should not exceed 460 MPa in order to maintain a sufficient amount of plastic reserve (high-strength steels tend to have much less plasticity, which is unfavourable in the case when cracks occur). For this purpose, the P460NL2 is one of the best choices. Mechanical properties of the parent material and weld metal adopted, as the numerical analysis parameters are shown in Table 1.

Table 1. Mechanical properties of parent materials and weld metal.

Material	R_e (MPa)	R_m (MPa)	Young modulus (GPa)	Poisson's ratio (-)	Elongation (%)
EPP2NiMo2	450	650	210	0.3	20
P460NL2	480	690	200	0.3	22

The numerical simulation is performed in ABAQUS software using finite element method. This method is based on representing a physical model with a number of smaller elements with simple geometry and corresponding load and boundary conditions. Such elements are connected via nodes, and the calculation is performed for each node locally, followed by the determination of global displacement and strain fields, from which the stresses within the model can be calculated, /4, 5/.

Two models are made, with varying welded joint geometries, where in the case of the second model, the welded joint penetrated much deeper into the parent materials. The purpose is to determine if this difference in material distribution of the pressure vessel would result in significant difference in terms of stress and strain distribution and concentration. The geometry of both models can be seen in Fig. 1 below, with all of the relevant dimensions.

Two boundary conditions are defined for both models: the first model involves the fixing of the vertical edge of the thinner plate (the mantle), whereas the second model prevents the movement of the mantle plate's upper edge along the vertical (Y) axis, in order to avoid the occurrence of unrealistic deformation along that direction. The loading is defined as tension along the right vertical edge (the lid), with a magnitude of 200 MPa. Both the load and the boundary conditions can be seen in Fig. 2, for the first model, and are identical in the case of the second one. Shown in Fig. 3 is the mesh used for the calculation.

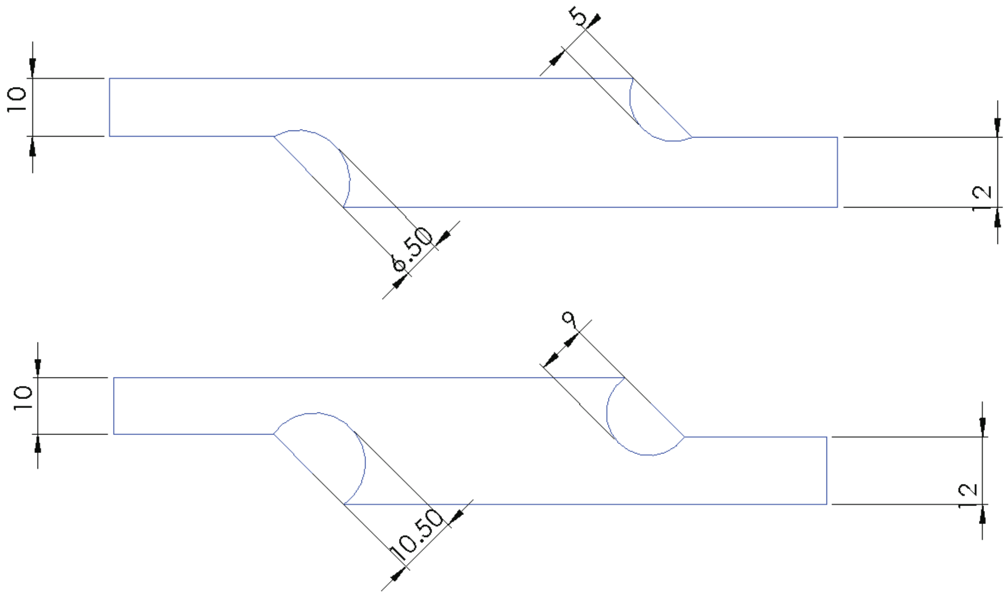

Figure 1. Geometry of the two numerical models with different welded joint dimensions.

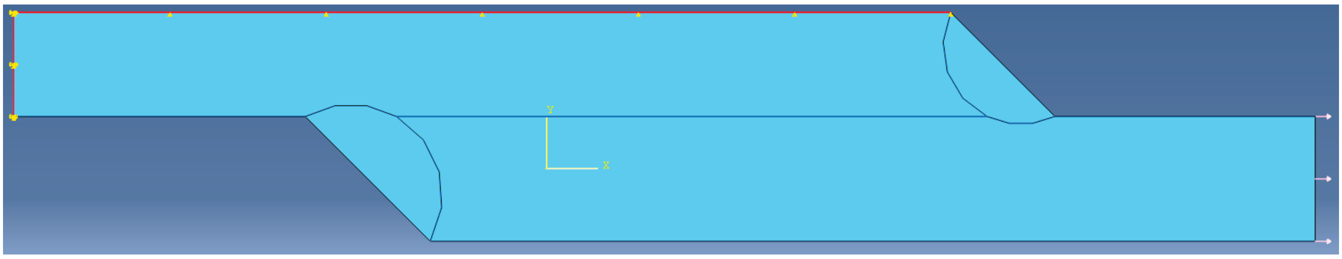

Figure 2. Loads and boundary conditions of the models.

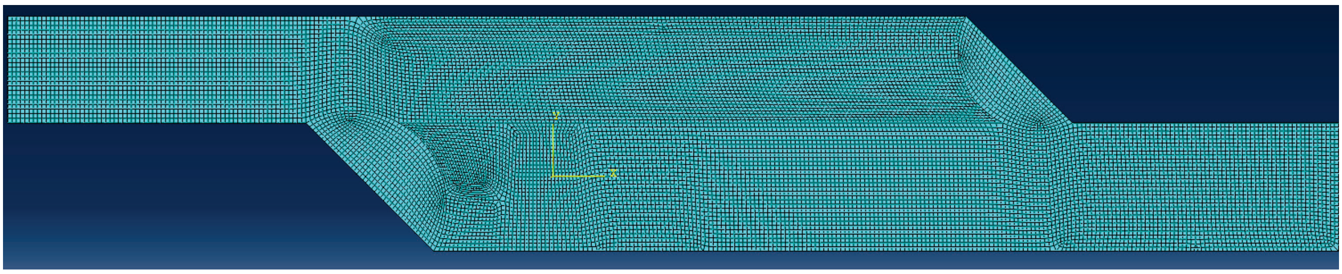

Figure 3. Finite element mesh.

RESULTS

In this section of the paper, the results of the numerical analysis are presented. Figures 4 and 5 show stress and strain distributions for both models, with and without the weld penetration into the parent materials.

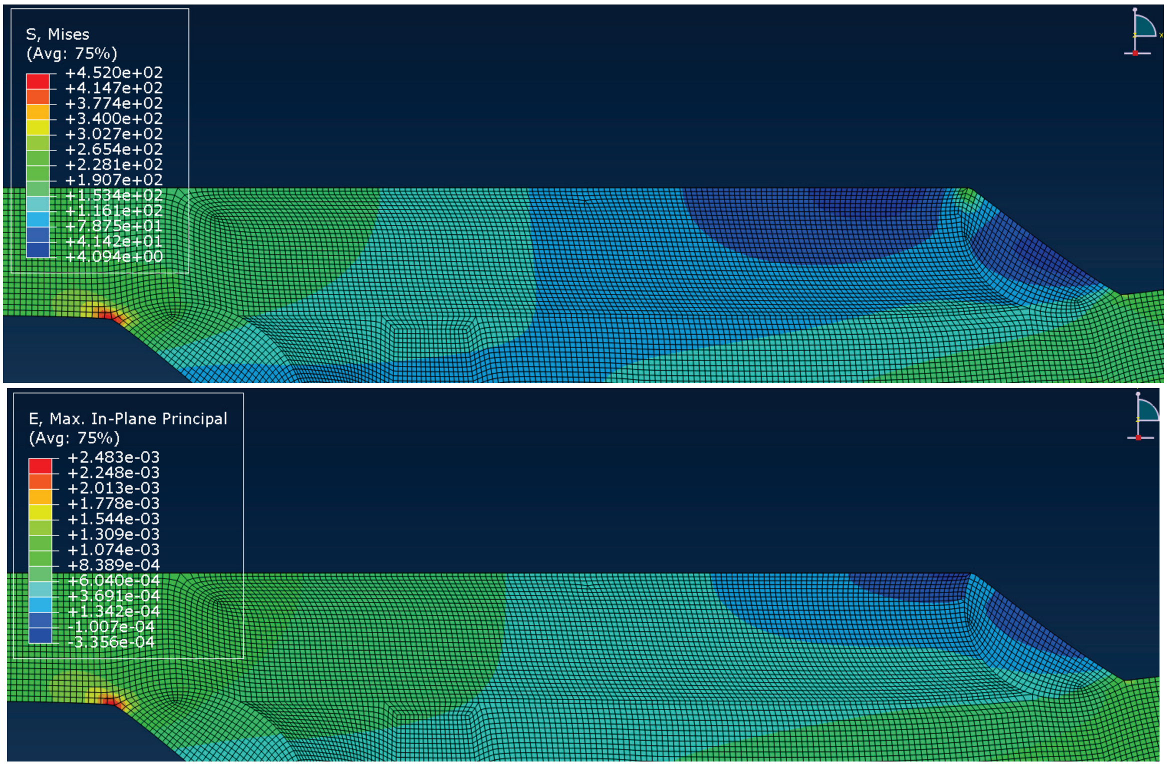

Figure 4. Stress and strain in the first model (without penetration).

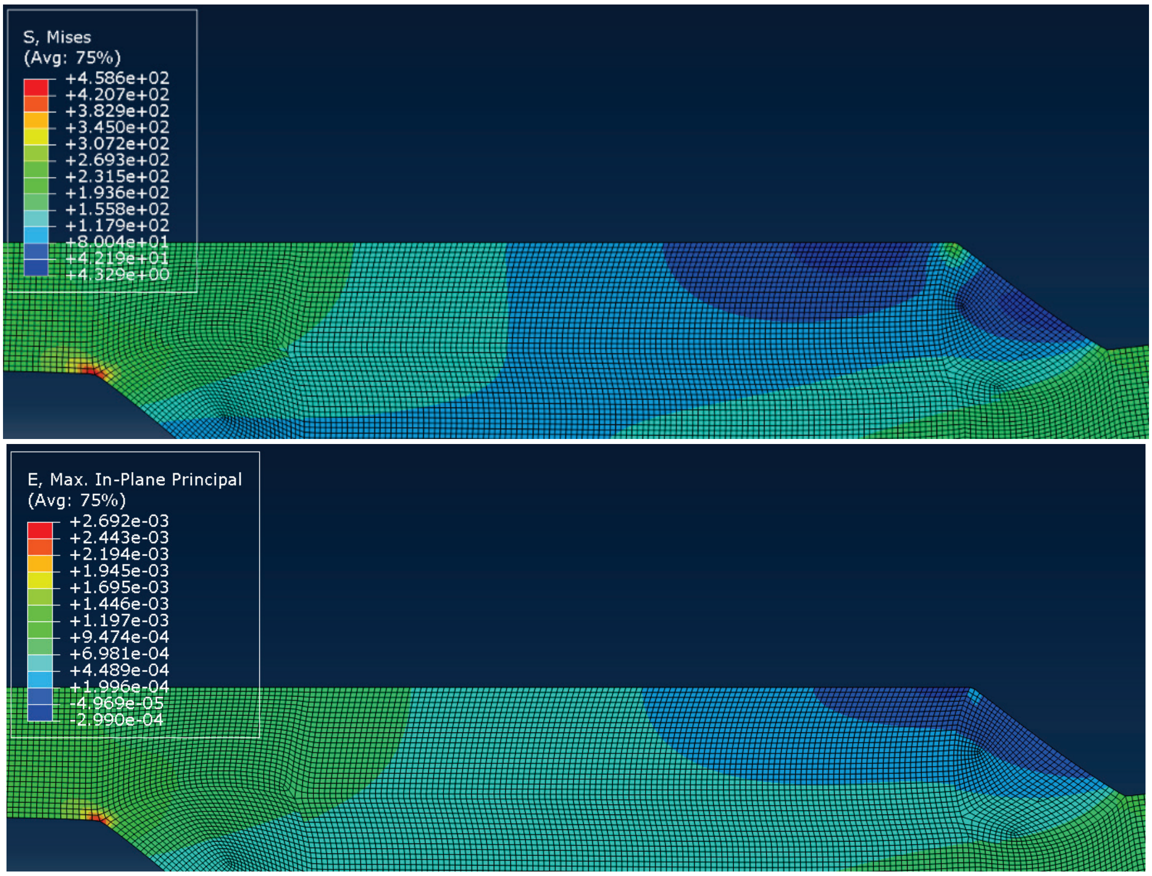

Figure 5. Stress and strain in the second model (with penetration).

DISCUSSION AND CONCLUSIONS

As can be seen from the results presented above, the highest stress values for both models are located above the left welded joint (border between the welded joint and the mantle) with values of 452 MPa and 459 MPa (without and with penetration, respectively). The strain in both cases is also of similar value, reaching 0.248 in the first model, and 0.269 in the second one. Insignificant small plastic strain is expected due to the fact that maximal stresses are concentrated in a rather small area and that their values are barely above the yield strength of the parent material (P460NL2).

The results also indicate the main weakness of lap joints in terms of stress concentration, as the stress and strain values are noticeably higher in areas where the geometry changes. For the applied load, there was no significant difference in stress/strain distribution due to the lack/presence of penetration in the welded joint. The difference in stresses is only 1.5%, whereas the strain in the second case is 7.8% higher than in the first case.

Further research into this subject should involve the comparison between lap- and corresponding butt joints, typically used in these vessels, in order to determine the differences in stress distribution and concentration.

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