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FEM simulation of elasto-plastic tube indentation

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Paper provides the summary of the FEM simulation of elasto-plastic strains and stresses in the course of the local indentation of a steel pipe by a spherical indenter. The FEM calculation was performed according to the recommendation of API 579-1 / ASME FFS-1 2007 [1] for Level 3 dent assessment. Series of 65 FE calculations of the elasto-plastic state of the indented tubes was performed. The combination of three tube diameters *D* = 508, 920 and 1420 mm with the ratios between the diameter and the wall thickness *D/h* = 91, 76, 64, 51 and 37 resp. were used. The diameters of the spherical rigid indenters were 100 and 200 mm, the depth of the indent varied gradually from 75 to 150 mm. The residual stresses and strains in the vicinity of the dent after the relieving of load were determined together with the depth and length of the resulting dent.

The configuration of the experimental loading of the indented tube has two planes of symmetry see Fig. 1. FE simulation model was adjusted as 1/4 of the whole with appropriate symmetrical boundary conditions see Fig. 2. The FE model of tube was supported equally as in the experiment i.e. the support was modeled as the rigid plane with the inclination of 15 degrees. The contacts were defined between the tube and the rigid spherical indenter and between the tube and the rigid support. The loading was controlled by the displacement of the indenter. The elasto-plastic material properties were obtained from the tensile test curve of pipe material which was converted to True Stress – True (Logarithmic) Strain curve for the FE calculation purpose.

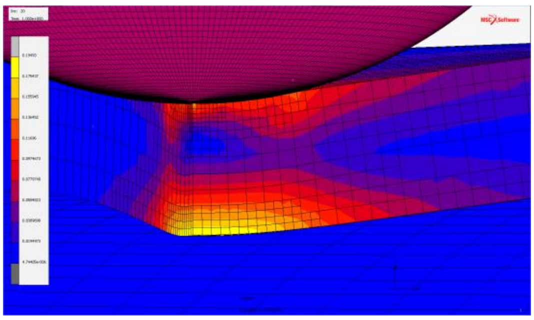

Fig. 1. Strain in contact region

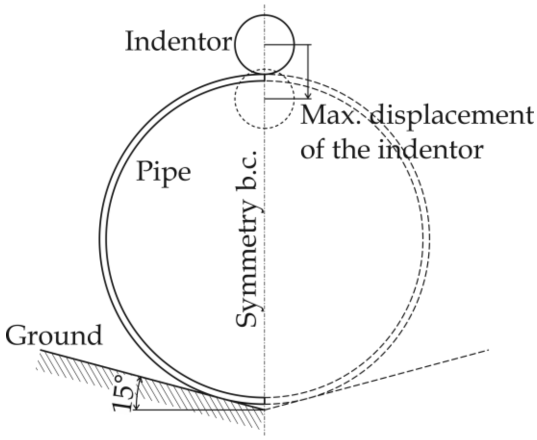

Fig. 2. FE 1/4 model of indentation

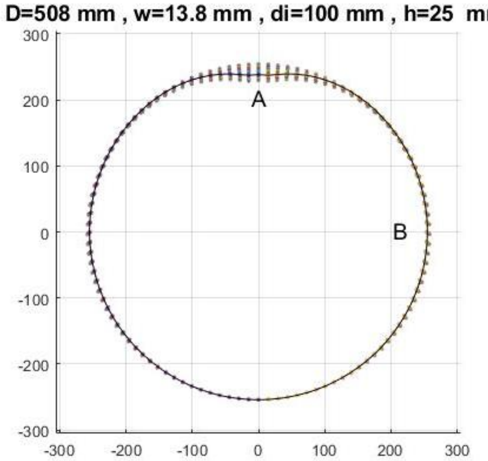

Fig. 3. Tube contour in course of indentation

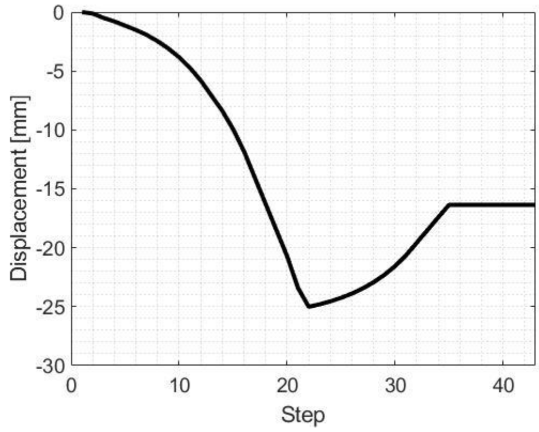

Fig. 4. Displacement of the point A

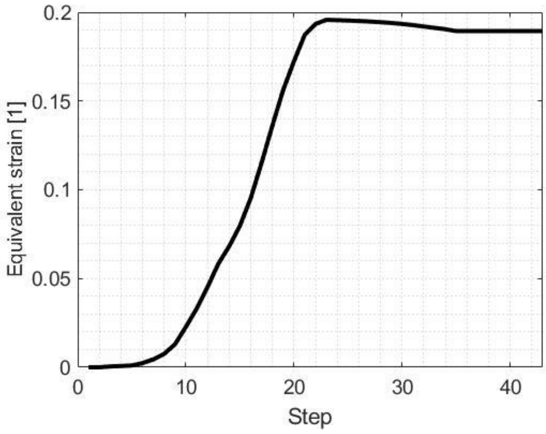

Fig. 5. Equivalent strain in point A

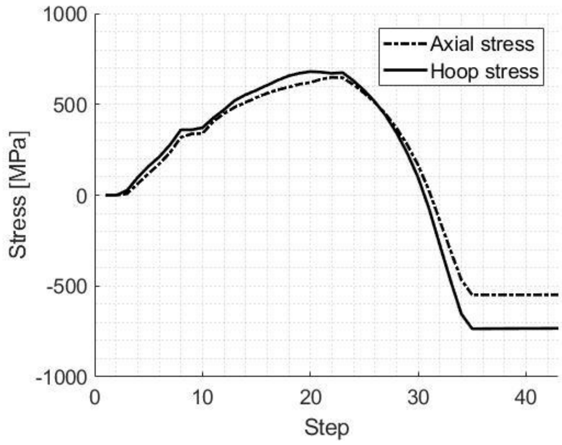

Fig. 6. Principal stresses in point A

FE mesh was created using 8-node hexahedron elements which allow the local adaptability of mesh that is necessary in large strains. Each single FE model from a series of 65 cases was created using a Python script which comprised the combinations of the tube diameter D, the wall thickness w, the indenter diameter di and the immersion depth of indenter h.

The evaluation of the FE results and the graphic processing were performed in Matlab. Some results for a particular case are shown in the Fig. 3 and 4 where the deformed contour of central cross-section is captured at the different steps of loading together with the displacement of the point A located inside the tube under the indenter. The successive equivalent strain and principal stresses at this point are shown in Fig. 5 and 6. The residual deformation of the tube and the residual strain and stresses are also apparent in these figures.

Acknowledgements

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References

[1] Osage, D.A., Janelle, J.L., A joint API/ASME fitness-for-service standard for pressurized equipment, Proceedings of the Pressure Vessels and Piping Conference, Illinois, 2008, pp. 777-791