Technische Universiteit Delft

Offshore & Dredging Engineering

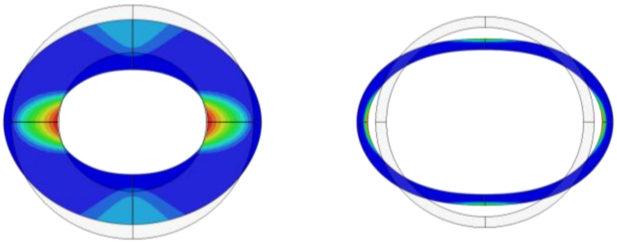
Local buckling and collapse of thick walled pipe

Heerema Marine Contractors B.V. is an offshore contractor who specializes in the installation and removal of a range of offshore facilities. This includes the installation of submarine pipelines in access of 1500 [m] water depth. Higher water depths and possible corrosion allowance drive the pipeline designs to increase wall thickness. A good understanding of the challenges of thick walled pipeline behaviour during installation can be of great benefit for Heerema Marine Contractors. This thesis will focus on the buckling behaviour during J-lay of steel submarine pipelines with a D/t ratio lower than 20 (from here on referred to as thick walled).

During design the DNV formulas for collapse and local buckling are used. Existing research shows conservatism in the pure collapse DNV formula for thick walled pipe. The thesis will consist of two parts. The first part of the thesis will focus on the collapse behaviour of empty thick walled pipe under external pressure. A 2D followed by a 3D FE analysis is conducted in ABAQUS and validated using existing papers and experimental test results. The analysis also covers an extensive sensitivity analysis with regard to geometrical imperfections and different material models.

The second part of the thesis will discuss the combined loading case of the pipeline as encountered in the sagbend during installation. Preliminary research already indicates possible conservatism in the DNV Load Controlled Criteria (LCC) formula for buckling of thick walled pipe in this scenario. Having a good understanding of the limit state of the pipe during installation can be beneficial since it can lead to a higher allowable bending moment during installation or a lower wall thickness in design. Normally the effective tension is neglected in the LCC check. The effective tension, as well as the end cap pressure, will be accounted for in this part of the thesis. A 3D FE model is constructed to incorporate the additional axial force.

Since material failure becomes more dominant, elastic collapse is not the governing failure mechanism for thick walled pipe. Therefore the plastic behaviour of the material becomes more influential. A realistic load path might be of interest. To generate the load paths for the sagbend loading including bending moment and tension, static Flexcom (FEM pipelay) analyses will be used where the vessel is sailed towards the touchdown point. With these load paths the FE analysis in ABAQUS is conducted, again with the same extensive sensitivity analysis as for the collapse limit state. The effect of each parameter and the collapse/buckle behaviour of thick walled pipe in the sagbend including effective axial tension are discussed. Results for the collapse limit state shows significant and increasing conservatism of DNV formula for D/t <15. Because maximum strains achieved at collapse increase, the stress/strain behaviour of the material becomes increasingly influential. It is concluded that hardening plays a role at D/t < 12.5, and for higher D/t ratio's the behaviour in the elastic region is influential. The failure mechanism observed changes from elastic instability to a more plastic mechanism, with plastic hinges being formed. The mechanism observed is fundamentally different from the basis of the DNV formula.



Results for the combined sagbend loading case shows a good performance of the LCC formula for most of the load cases. Conservatism is only observed for cases in which the pressure unity of the LCC formula exceeds 0.55. Although small, the effect of adding tension is increasing the bending capacity, contrary to the LCC formula. It is also observed that the performance of the LCC formula outside of its current scope of 15<D/t<45 is good down to D/t 5. Based on these FE analyses It is therefore recommended that the range of the LCC formula is reconsidered to be extended for lower D/t values.

Student
Steven Huiskes
December 8th, 2016

Sponsor
Heerema Marine Contractors B.V.

Thesis committee
Prof.dr. A. Metrikine
Ir. C. Keijdener
Dr.ir. K.N. van Dalen
Ir. H. Smienk
Dr.ir. E. Karjadi