Appendix and Attachments

Contents

Appendix 1. DNV-RP-F111 Advanced Approach

To reduce the conservatism of the simplified approach as described in section 2.3, an advanced model is proposed in DNV-RP-F111 Appendix A, ref. /1/. The main aspects of the advanced approach are described in this appendix.

This approach utilizes nonlinear static and dynamic FE-analysis to estimate the dent depth from trawl gear impact taking the following effects into account:

- Local deformation of the pipe steel wall
- Local deformation of the coating
- Local deformation of other parts (e.g. protection structure for direct electrical heating DEH cables)
- Global deformation of the pipeline
- Pipe inertia effects inclusive hydrodynamic added mass
- Deformation of trawl gear
- Friction between pipeline and soil
- Soil deflection

The advanced approach covers the types of pipelines not covered by the simplified approach, e.g.:

- Flexible pipes
- Pipelines with other coatings
- Several types of electrical cable protection structures
- Other types not covered by the simplified approach

Model Assembly

The principles of the dynamic analysis model for trawl board impact on a pipeline are illustrated in Figure 1.

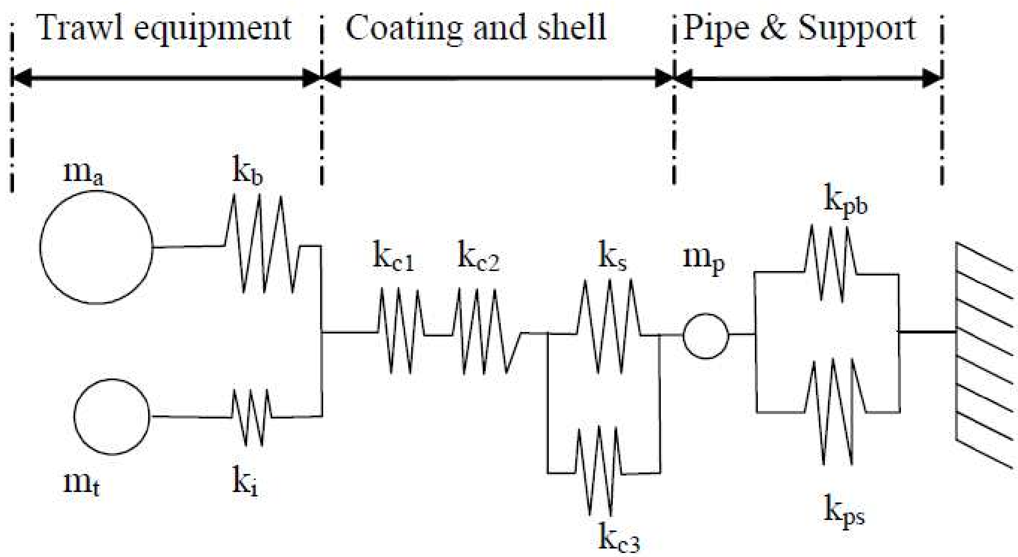


Figure 1: Analysis model for trawl board impact on a pipeline, ref. /1/.

Components of the analysis model are:

m_a	hydrodynamic added mass
m_t	steel mass of trawl gear
k_b	out of plane bending board stiffness
k_i	in plane stiffness of trawl board
k_{c1}	stiffness of protective cover for DEH cable
k_{c2}	stiffness of coating
k_{c3}	stiffness due to shear deformations of the coating distributing the impact force over a larger area
k_s	shell stiffness of the steel pipe
m_p	effective mass of the pipe including the hydrodynamic added mass
k_{pb}	effective bending stiffness of the pipeline
k_{ps}	effective soil stiffness

The effective velocity and masses applied in the analysis can be obtained from advanced analysis of the trawl gear impact phase, but conservatively the values given in section 2.3 may be applied. For clump weights, the hydrodynamic added mass m_a and the steel mass m_t are both added to the in plane stiffness k_i.

In general, the interaction phase between trawl gear and pipeline is time dependent and varies with the type of gear involved and tow direction relative to the pipeline, but since the scope of this project is to investigate the expected indentation of the pipeline, no further studies are done in this area.

The shape of the trawl gear interacting with the pipeline influences the contact area, which have a significant influence on the relation between impact force and expected dent. Different shapes of the element representing the trawl gear are discussed in section 2.1.

A typical analysis procedure is outlined in Figure 2.

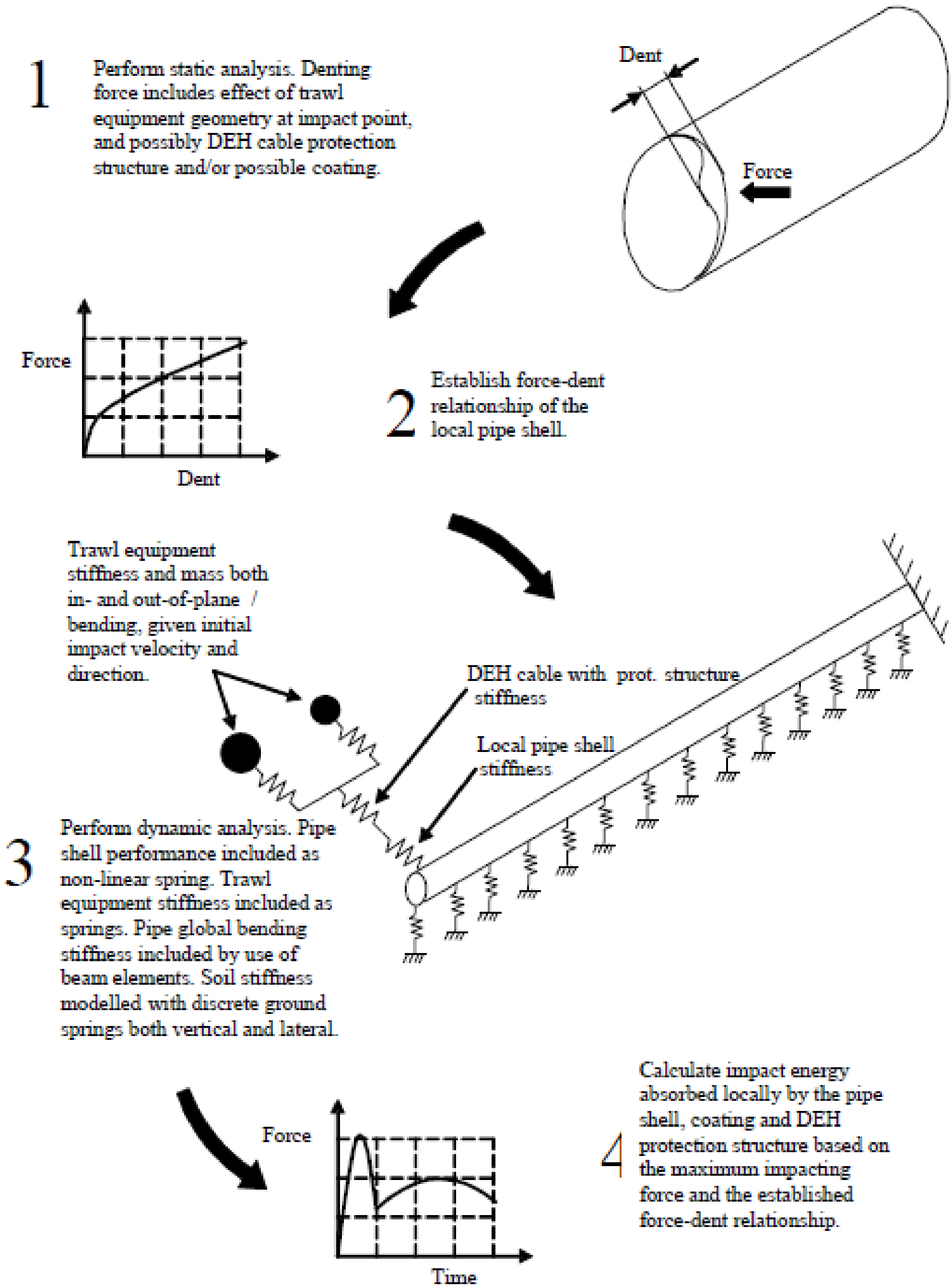


Figure 2: Typical impact analysis procedure for the advanced approach, ref. /1/.

Appendix 2. Impact Analysis with Incompatible Elements

As described in the report an impact analysis is carried out with the solid section meshed with the incompatible element C3D8I. The analysis involves a 16” bare steel pipe with *D/t*=25 as used during the pre-study in section 7.3. The result of the analysis is a failed convergence error at approximately 0.025 second after first impact. Figure 3 illustrates the deformed geometry at the impact area taken from the last frame before failure. Studying the status file from the analysis the error is linked to node 36905 as pointed out in Figure 3. The error spells “Excessive distortion of element number 36905”.

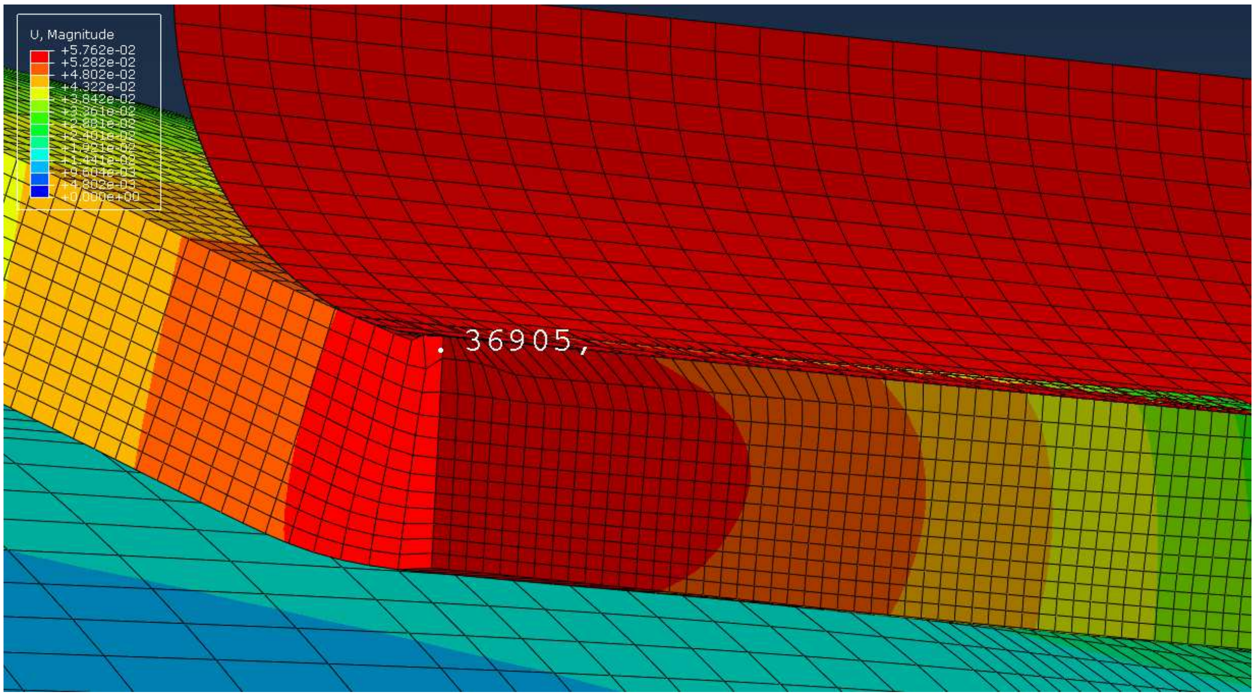


Figure 3: The deformed geometry from the last frame before failure plotted with deformations. Node no. 36905 is pointed out right at the intersection between the two symmetry planes.

Studying the Abaqus documentation it is stated to use the incompatible elements with caution in applications involving large compressive strains, ref. /13/. Studying Figure 3 it is obvious that element 36905 has deformed excessively. To quantify the actual straining of the element the maximum absolute principal strains are plotted in Figure 4, and with a maximum magnitude of 72.66 it is clear that excessive straining or distortion is present.

From this study it is concluded that the incompatible element is unsuitable for these impact simulations with large straining.

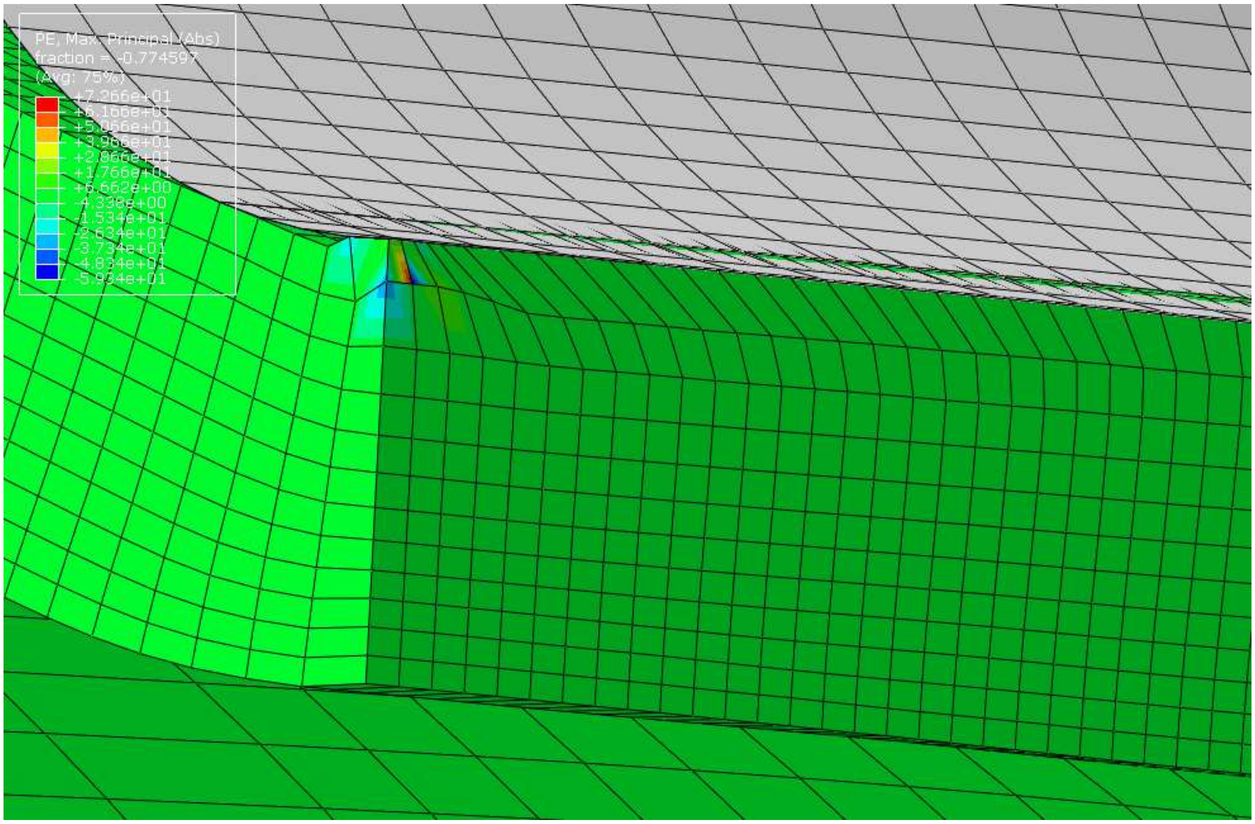
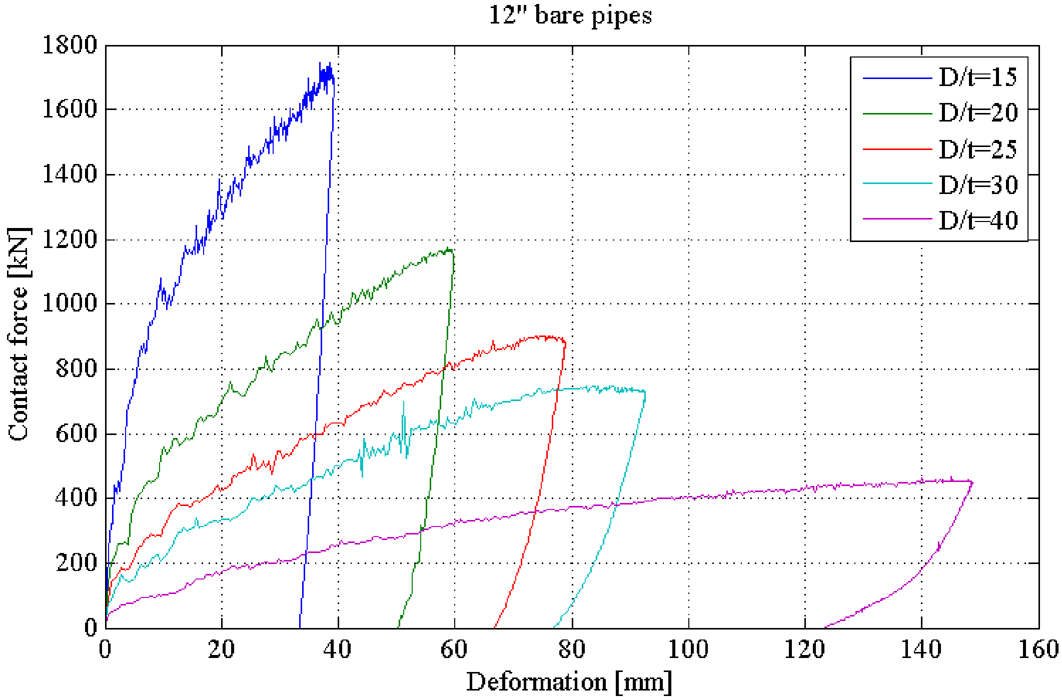


Figure 4: Maximum absolute principal strains.

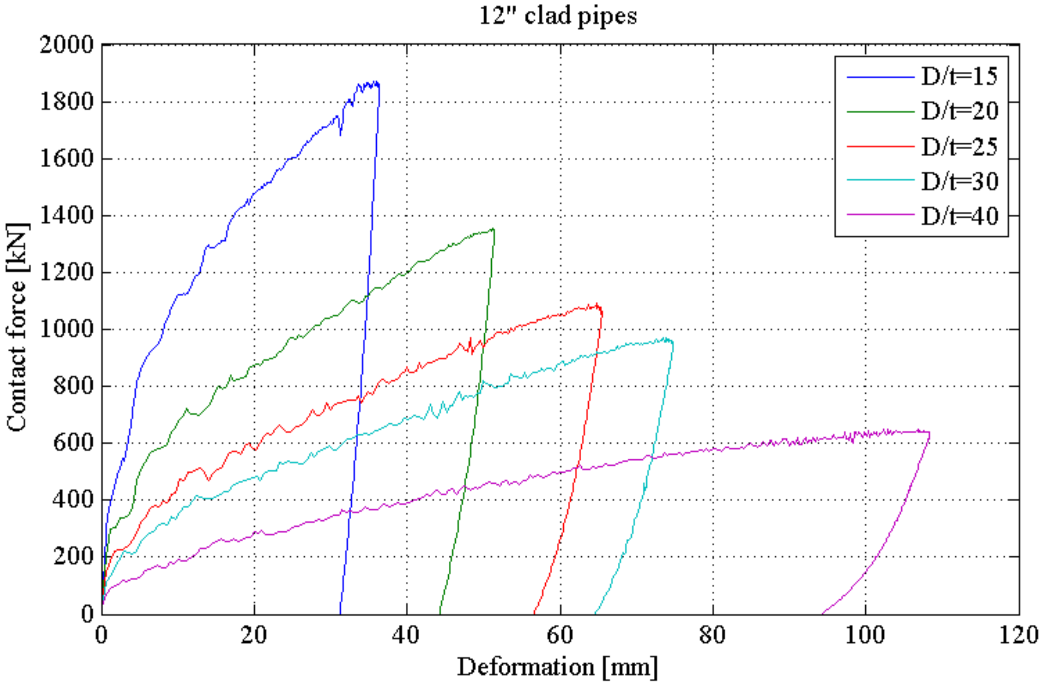
Appendix 3. Contact Force-Displacement curves

All contact force-displacement curves are given in this section.

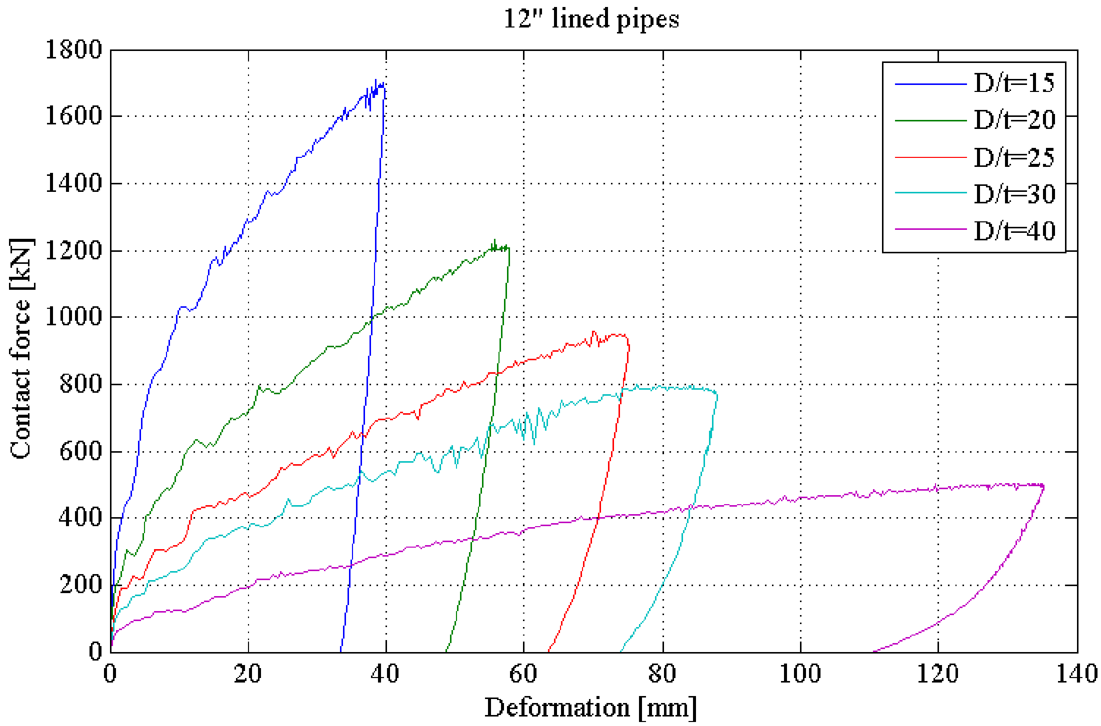
12” Bare Pipes



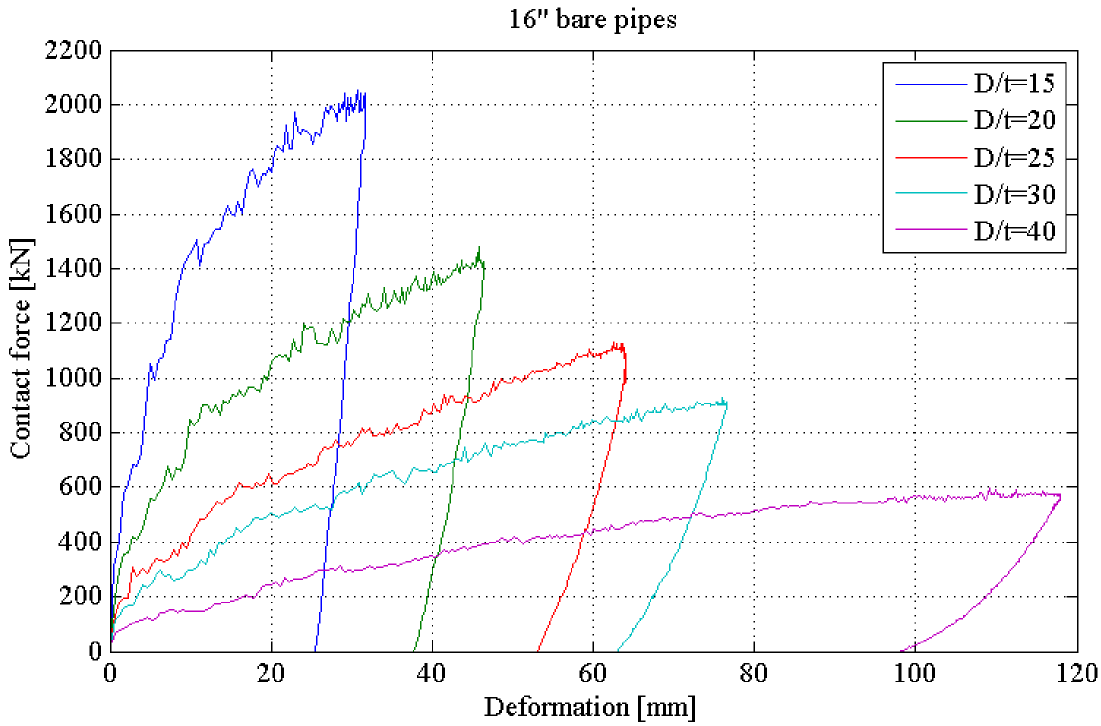
12” Clad Pipes



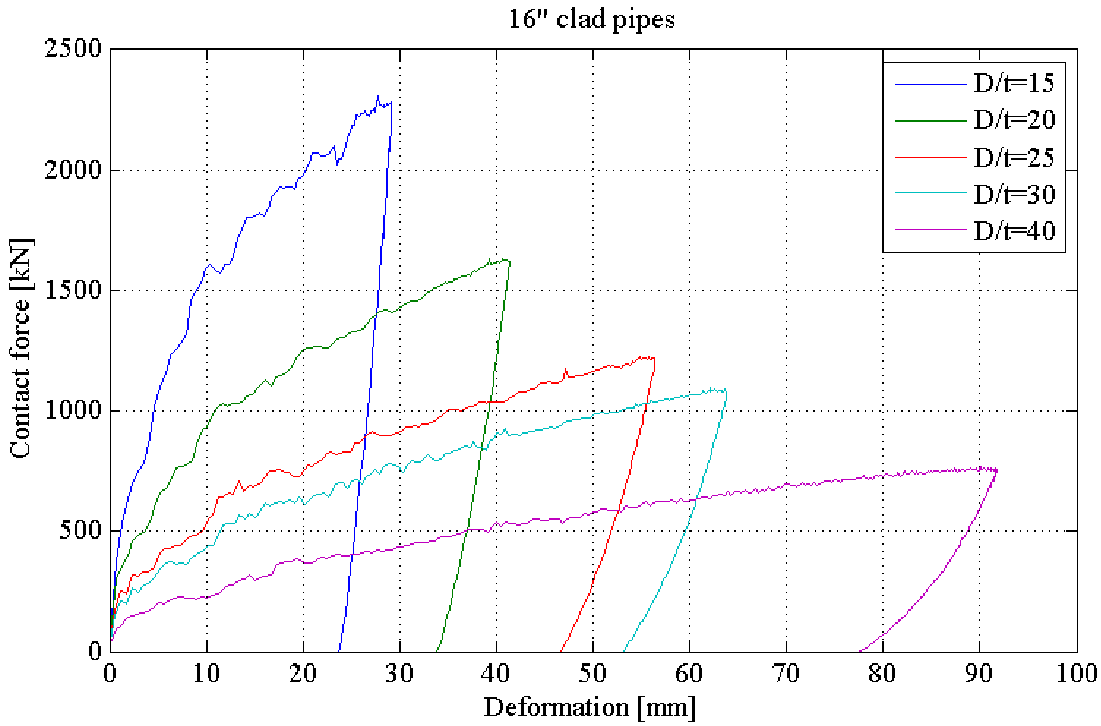
12" Lined Pipes



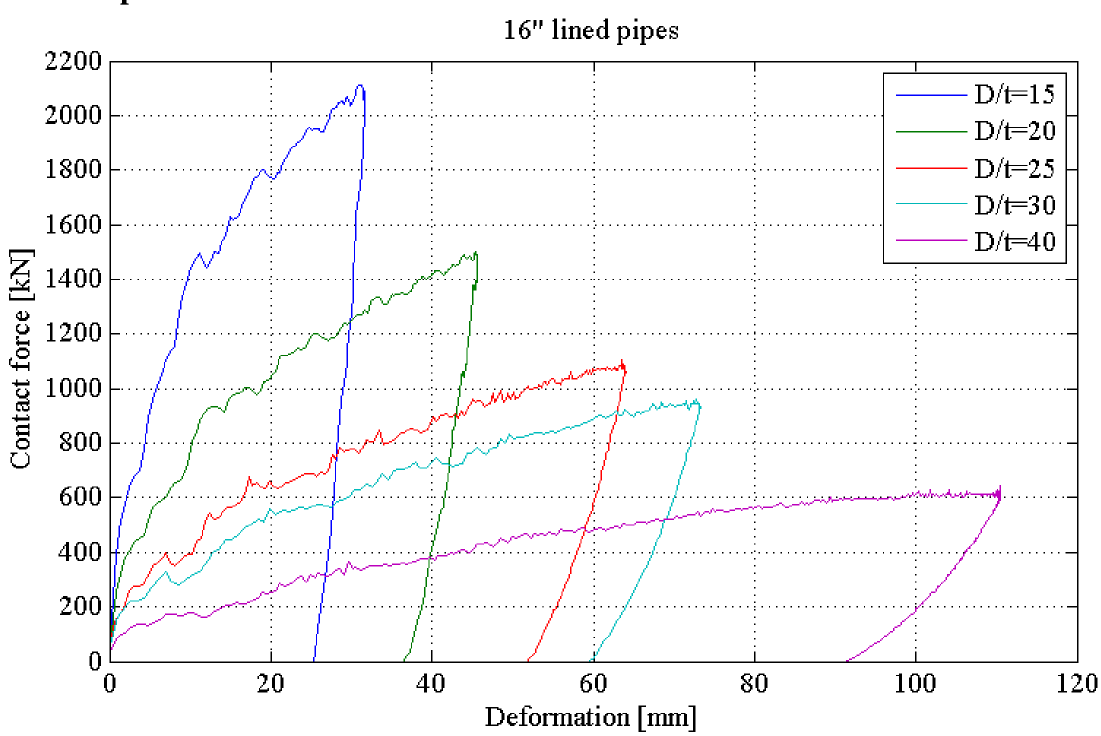
16" Bare Pipes



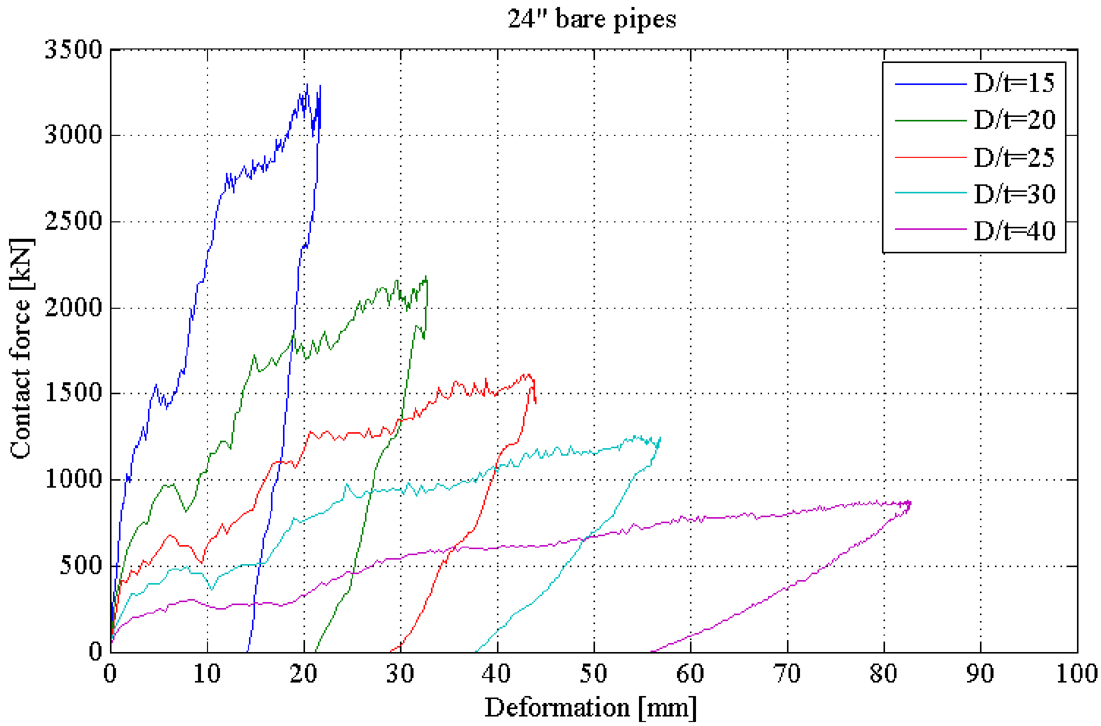
16” Clad Pipes



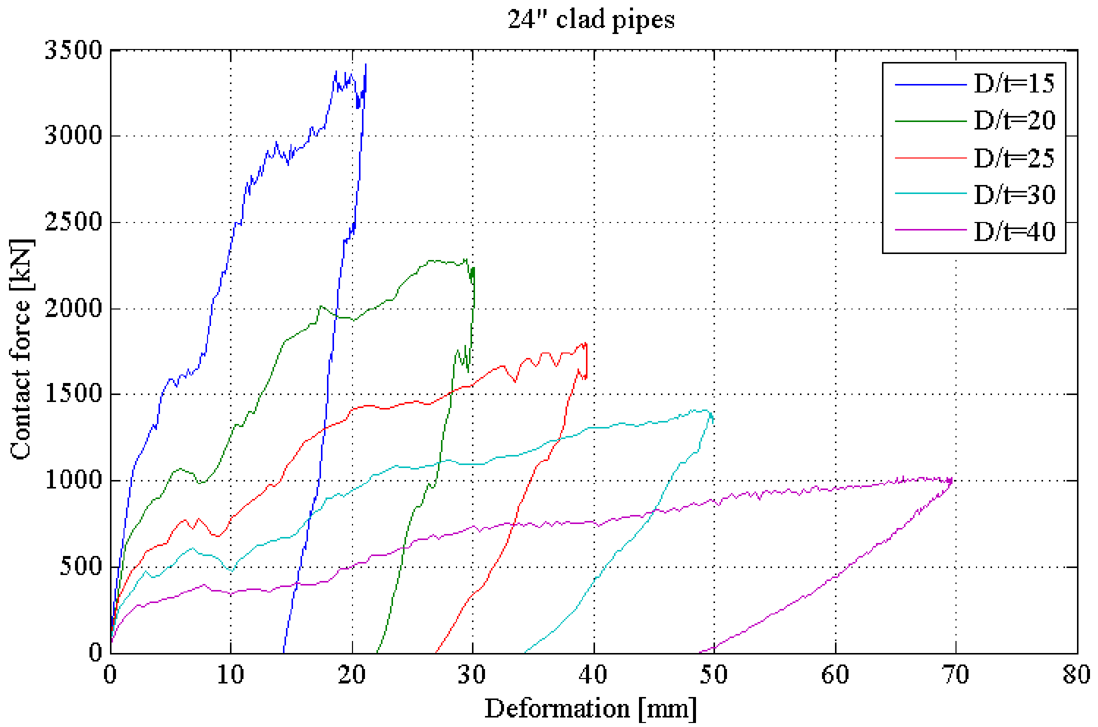
16” Lined Pipes



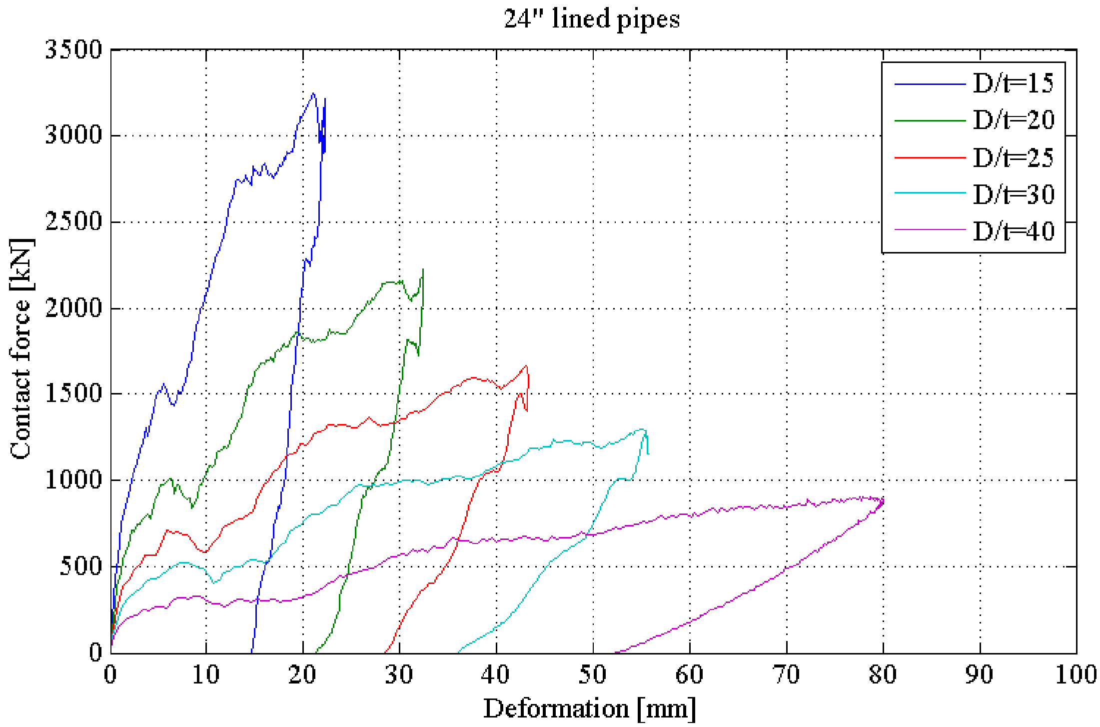
24” Bare Pipes



24” Clad Pipes



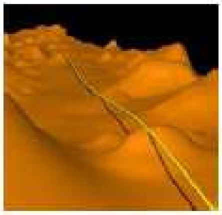
24” Lined Pipes



Attachment 1. Project Description

PROPOSAL FOR SPECIALIZATION PROJECT / MASTER THESIS

"TRAWL GEAR IMPACT ON PIPELINES"




Description of task

Heavy trawl gear is towed on the seabed and collision between submarine pipelines and trawl gear is eminent. DNV has established a good method for assessing the damage for such incidents for conventional pipelines. The use of more exotic materials such as cladded and lined pipeline is not covered by this methodology. A study is proposed to look into the differences by using FE-analysis in 3D modelling the clad layer and liner. The aim is to develop a relation between force applied and expected dent.

Industry relevance

Trawl impact is one of the design criteria applied for subsea pipelines. If the dents caused by trawl impact are considered too large mitigating actions like rock dumping or trenching may have to be used. Such mitigating actions are very costly and it is therefore of great interest for the industry to estimate the effect of trawl impact as accurately as possible – also for the "exotic" materials.

Practicalities

The proposal is considered most relevant for students with a background within structural engineering (naval, civil or mechanical) and experience with steel as material and FE-analysis. The successful candidate will be supported by one of DNV's principals within the area. Office space and facilities may be made available in the DNV offices according to agreement.

DNV Pipeline Technology and Operations Technology

The Well, Pipeline & Subsea unit at DNV Høvik consists of 150 enthusiastic and highly skilled engineers, and is the main hub for the DNV subsea activities. Our Pipeline Technology and Operations Technology units consists of 40 highly skilled engineers, with 1-30 years experience from the offshore industry.

With our unique cutting edge competence we have in close cooperation with the industry developed the DNV Pipeline standard and DNV Recommended Practices on which the design of ~70% of the world's subsea oil and gas pipelines are based. We deliver pipeline services ranging from early phase studies, through design, installation and the entire operational phase. We are also performing R&D and are running numerous Joint Industry Projects with the industry to solve the industry's challenges and shape the future.

DNV Technical Advisory Ship and Offshore
Department Well Pipeline & Subsea

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