FAILURE ANALYSIS OF UPHEAVAL BUCKLING IN A PIPELINE USING NON-LINEAR FE ANALYSIS

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ABSTRACT

FE models can be efficiently used in root-cause failure analyses, for example, when attempting to reproduce the conditions responsible for a known mode of failure. This can be important in order to determine whether a failure was caused by normal operating conditions within the design envelope or by other external factors.

In this failure analysis case study, a buried pipeline was observed to experience an upheaval buckling failure after operating for several years without any visible issues. Following excavation of the failed section, a large wrinkle was found at the inner curve of the bend that had come out of the ground. An analysis was completed to determine what operating and environmental conditions could have caused this failure.

A beam-element model was first set up to study the global behaviour of the pipeline as a result of applied operating pressure and temperature loads, as well as soil-based restraints and forces.

To obtain more detailed results in the area near the failure, a submodel was also created in an FEA program. The boundary conditions for this submodel included displacements or internal forces which were calculated using the global beam model. An elastoplastic Ramberg-Osgood material curve was used for modelling the material.

A series of sensitivity tests was performed to determine under what conditions it might be possible for the pipeline to undergo the required displacement for upheaval buckling to occur. The effects of changes to the operating conditions and soil properties were tested. It was found that the vertical displacements in the pipeline were highly sensitive to modifications to the assumed soil conditions.

Excessive water in the surrounding soil would affect the restraining vertical force on the pipeline, and would also introduce an upwards buoyant force which would act on the pipeline. Sensitivity tests showed that only 50 meters of waterlogged soil around the failed bend was required in the model to cause upheaval buckling and wrinkling in the pipeline wall to occur.