

## Finite Element Simulation for Shear Failure of Wrinkled Pipeline

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### ABSTRACT

Buried pipelines may be subjected to various complicated combinations of forces and deformations. This may result in localized curvature, strains, and associated deformations in the pipe wall. As a result, wrinkles may form. The wrinkled pipeline may then develop a fracture and even rupture in the pipe wall and lose its structural integrity if it is subjected to further sustained deformation. An NPS 10 field line pipe ruptured due to tearing in the pipe wall in the wrinkle region. It was felt that the wrinkle was subjected to shear deformation that resulted in tearing type rupture. Numerical study using non-linear finite element (FE) method was carried out to study the possible load-deformation history that may cause this type of failure. A detailed FE model was developed and analyzed to study the behavior of a wrinkled pipeline subjected to axial and shear deformation. The study shows that the combination of axial and shear deformations can introduce tearing type rupture in the wrinkle region the way the NPS10 field line pipe ruptured. This paper discusses the FE modeling technique and the results obtained from the FE analysis.

**KEY WORDS:** pipeline, wrinkle, shear deformation, rupture, laboratory tests, finite elements analysis

### INTRODUCTION

Field observations of buried pipelines indicate that it is not uncommon for geotechnical movements to impose large displacements on buried pipelines resulting in large localized deformations, strain, and curvature in the pipe wall. Such displacements may be associated with river crossings, unstable slopes, or regions of discontinuous permafrost. Often the deformation of the pipe wall results in local buckling and, in its post-buckling range of response, wrinkles develop rapidly and can be of significant magnitude. This can occur under loading conditions that may be idealized as combinations of variable internal pressure, compressive axial load, shear load, and moment.

The motivation for this investigation into failure mode in wrinkles under shear loading is due to the diagnosis and exposure of a rupture that occurred at the wrinkle location in a field NPS10 (line pipe with nominal diameter of 10 inch or 254 mm and actual outside diameter of 273.1 mm) line pipe with the actual diameter-to-thickness ratio of 48.7 oil/gas pipeline as shown in Fig. 1. Das et al. (2000, 2001) in their

other studies found that energy pipelines are highly ductile and do not usually fail in rupture if subjected to monotonically increasing axisymmetric compressive axial deformation. However, if the same pipeline is subjected to strain reversal because of variation of primarily loads, rupture can occur in the wrinkled region.

From the field inspection and the description of the load history, it is assumed that no strain reversals occurred in this field line pipe (Fig. 1). From physical inspection of the ruptured line pipe, it was felt that the pipe wall in the wrinkle region experienced a tearing type rupture due to application of shear (transverse) load above the wrinkle. However the real load combination was unknown. Thus, two full-scale laboratory tests on NPS12 pipe (pipe with nominal diameter of 12 inch or 305 mm and actual outside diameter of 323.9 mm) with D/t of 47.3 were undertaken to study the possible load combination that may have produced the rupture in the field NPS10 line pipe (Fig. 1). The 12 inch nominal diameter pipe with D/t of 47.3 was chosen because this was the closest match for the field line pipe among all the pipes those were available.



Fig. 1: Fracture in wrinkle in field NPS10 line pipe

These tests were conducted by applying axial and shear loads with two different boundary conditions. The second test was successful in producing a tearing type rupture in the wrinkle that looks similar to the one shown in Fig. 1. The deformed shape of first test specimen did not resemble with the field NPS10 line pipe. Since this kind of full-scale tests is expensive and time consuming, further study on this failure mode was undertaken using numerical method. A detailed non-linear FE model was developed to simulate the behavior that was observed from the second test in the laboratory. This paper discusses test