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Instability of damaged pipes retrofitted by a liner

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Background:
Underground piping systems have a large variety of applications ranging from oil, gas and petrochemical industries to water distribution networks. Presence of defects, particularly cracks, in underground pipes may severely undermine structural stability and makes restoration of the shell's structural integrity inevitable. Replacement of the damaged sections of the pipeline as the most direct restoration approach is costly, hard to execute due to difficulty in physically accessing the damaged sections, and often leads to prolonged interruption in the service. In light of these difficulties, alternative approaches have been proposed in recent years for retrofitting the damaged thin-walled structures by engagement between an inserted, expandable liner and the existing pipe (e.g. Underground Solutions' Duraliner™).

Objective:
The objective of this project is to examine the stability of the repaired pipelines and to provide a more in-depth understanding of the validity and practicality of the relining process materials and techniques and their limitations. We explored the instability of a cracked thin shell cylinder reinforced with an elastic liner subjected to pure axial compression and also combined axial compression and internal pressure.

Method:
Finite element models of cracked cylindrical shells with elastic liners for various crack lengths and orientations were developed using a special meshing scheme to accurately capture the crack tip stress intensity. Eigenvalue buckling analysis was used to assess the critical loading and buckling modes.

Results:
Through our extensive parametric studies, we studied the correlations between buckling response and reinforcement parameters such as the relative thickness and stiffness of the liner and shell layers and damage parameters such as crack size and orientation.

Conclusions:
While elastic reinforcement significantly improves buckling characteristics of the structure compared to the unreinforced case, there is significant differences in buckling behavior depending on crack size, orientation and the material properties of the shell structure and liner. We find that internal pressure may stabilize against local buckling by suppression at the lower internal pressure zones or, may precipitate local buckling of the reinforced cylindrical shells due to stress concentration at higher internal pressure zones depending upon the elastic and geometric properties of the structure.