The Response of Buried Pipeline Subjected to Landslides

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ABSTRACT

In recent years, a number of projects have been funded in China to quantitatively evaluate the tensile and compressive strain limits of pipes and apply these limits to buried pipelines subjected to landslides. This paper covers the technical basis of strain-based design for pipelines subjected to landslides. First, finite element analyses (FEA) were conducted for a total of 594 cases covering a wide range of materials, ratios of pipe diameter to wall thickness, D/t and various internal pressures. By using the calculated data, parametric equations for strain limits of pipelines were developed. FEA analyses were also conducted for 8 cases of buried pipelines subjected to landslides. An approach for design of buried pipelines subjected to landslides using strain-based design was also proposed. It is believed that the above applications may lay the initial base of using the strain-based design method for buried pipeline subjected to landslides for pipelines in China.

KEY WORDS: Pipeline; strain-based design; strain limit; landslide.

INTRODUCTION

Background

With the rapid development of oil and gas pipeline industry, new trend is showing on pipelines for long-distance, large-diameter and high-operating-pressure. This requires the corresponding pipeline design guidelines and criteria to be adapted to these new situations. In the design step, not only the safety and reliability of pipeline but also its economic and efficient operation should be ensured. Most of the existing pipeline design codes are based on limiting stress criteria, which is considered acceptable for steel with a well defined yield point and a well defined ductility and strength. But the stress in pipelines may exceed the limit under some situations, such as earthquakes, landslides, and some displacement-controlled loading, such as that in laying of the submarine pipelines. In these situations, the strength design criteria based on stress is no longer valid.

Stress-based design criteria are based on the minimum yield stress for the pipeline, while strain-based design criteria are based on limit state design in displacement-controlled loading. If the safe operation can be ensured under displacement-controlled loading, the pipeline strain is allowed to exceed the specified yield strain. Although some plastic deformations occur in the pipeline, the pipeline is able to meet the operation requirements with higher operating capacity. Using stress-based design method supplemented with strain-based design method, the deformation capability of pipelines can be fully applied in security and economic design.

Limit state is a state beyond which the structure no longer satisfies the design requirements. Both Det Norske Veritas (DNV, 2000) and Canadian Standards Association (CSA, 2007) use limit state method for pipeline design. There is slightly difference in state limit classification between these codes. In DNV-OSF101 (2000), four kinds of state limits are recognized. They are serviceability limit state, ultimate limit state, fatigue limit state and accidental limit state. When limit state method is applied to the pipeline design, appropriate design criteria are presented in order to make less conservative and more flexibility for the designers.

There are many different classifications on loadings for the pipelines. Displacement-controlled loading can be defined specifically as a loading that can be reduced to zero by a change in the shape of the part of interest. On contrary, a load-control loading cannot be reduced to zero by a simple change in shape. Bigger strain may be allowed to displacement-controlled loading. The loading on a pipeline may generally be a combination of load and displacement controlled. The pressure loading is load controlled, while the soil motion around a pipeline usually causes displacement-controlled moments.

A number of natural gas and petroleum pipelines have been or will be constructed across ancient and currently active landslides in China. The pipelines studied in this paper cross numerous areas of active or potential active landslides that pose a threat to pipeline integrity. The interaction of the moving soil with the pipeline redistributes the axial force along the pipe, increasing tension in some locations and compression in others. It can also increase pipeline curvature, which induces tensile strain in half of the pipe cross-section, and compressive strain in the other half. If unmitigated, excessive tensile strain can lead to pipeline rupture. Large compressive strain may cause buckling, usually accompanied by formation of wrinkles that can rupture due to material fatigue or severe yielding.

Current Research and Development

The general framework for the application of strain-based design has been the subject of considerable researches during the past...