

The Feasibility and Prospect of Strain-based Design to Pipelines in China

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ABSTRACT

With the sharply rising demand of oil and gas, the Chinese pipeline industry has been experiencing a rapid development in recent years. Pipelines in the areas of ground movement from slope instability, seismic sideslip, loess collapse, mining subsidence, frost heave and thaw settlement in discontinuous permafrost can experience displacement-controlled plastic strain. This paper describes the application of strain-based design of pipelines in China and introduces relevant codes, standards, and criteria of other countries. Some major issues in strain-based design such as geologic conditions, strain limits, mechanical performance, etc., are mentioned. The feasibility and prospect of strain-based design of pipelines in China is discussed with reference to the geologic conditions and the state of the Chinese pipeline industry.

KEY WORDS: pipeline; strain limit; strain-based design; ground movement; geologic conditions; West-East pipeline;

INTRODUCTION

Conventional pipeline design methods, which always limit the stress in pipe wall by a design factor on the specified minimum yield strength (SMYS), are stress-based. The actual safety factor in terms of the risk of failure is unknown in most cases. As the universal approach for pipeline designs, stress-based methods have been adopted by codes and widely used for many years. The stress-based methods could be insufficient for displacement-controlled or partly displacement-controlled loadings, such as ground movement, etc. The ground movement poses a significant challenge to design, construction, and operation of transmission pipelines and facilities. It induces large deformation of pipelines through events such as slope instability, seismic sideslip, loess collapse, subsidence, frost heave and thaw settlement in permafrost. To ensure pipeline safety and integrity and to maintain project economics, an alternative design methodology on the basis of strains is required. Strain-based design is a methodology based on limit states design principles and applies to design cases where displacement-controlled loads are the dominant design conditions. Application of strain-based design can achieve adequate pipeline safety and integrity, and reduce the cost of pipeline construction and operating and maintenance.

The development of strain-based design in China was launched for oil and gas pipelines in the areas of active ground movements. In areas

with ground movements, like slope instability, seismic sideslip, loess collapse, mine subsidence, discontinuous permafrost, pipeline strain must be estimated both for installation and for operation conditions. This paper describes the status and prospect of strain-based design method in China.

APPLICATION STATUS OF STRAIN-BASED DESIGN

Overview

Safe and conservative stress-based design methodologies, which are based on limiting the stress in the pipe wall, are widely used for pipeline design. In the last 10 years or more, pipeline design codes have experienced an important change when the limit states design philosophy was introduced. This philosophy explicitly recognizes that there are many ways pipeline could fail and that these modes may be more or less severe or more or less likely. The safety factors of these different modes can be based on the level of severity and likelihood of the occurrence, as well as the specific parameters that cause the limit state to be reached. With the development of new materials and modern welding and NDT technology which has removed the hazard of failure modes associated with brittle materials behavior, deformation failure modes and associated limit states involving large plastic strain or significant geometric distortion can be utilized. Consequently the non-linear analytical approaches for evaluation of each limit state became necessary.

Application Status of Strain-Based Design

The use of strain-based design in pipeline technology has been widely discussed during the last decade. An parlance of the types of provisions allow strain-based design while stress-based design method is not fit can be described as follow(ASME, 1995): "In situations where the pipeline experiences a predictable noncyclic displacement of its support (e.g., fault movement along the pipeline route or differential subsidence along the line) or pipe sag before support contact, the longitudinal and combined stress limits need not be used as a criterion for safety against excessive yielding, so long as the consequences of yielding are not detrimental to the integrity of the pipeline. The permissible maximum longitudinal strain depends upon the ductility of the material, any previously experienced plastic strain, and the buckling behavior of the