A Discussion of Deterministic vs. Probabilistic Method in Assessing Marine Pipeline Corrosions

Zahiranza Mustaffa, Pieter van Gelder, Han Vrijling

Hydraulic Structures and Probabilistic Design, Hydraulic Engineering Section
Civil Engineering and Geosciences, Delft University of Technology
Delft, The Netherlands

ABSTRACT

This paper provides comparisons between the deterministic and probabilistic methods through results obtained from a recent reported work. The study focuses on corrosions, a mechanism that leads to reduction in pipeline structural integrity. It has been shown in this paper that certain limitations in the deterministic method, through the failure pressure models, have been counter parted by results obtained from the probabilistic method. In addition to that, the paper summarizes some insights on the significance of fluid-structure interaction between the external flow and pipeline itself, in which this new discovery is very much relevant to be carried out in a probabilistic manner as well.

KEY WORDS: pipeline; corrosions; fluid structure interactions

INTRODUCTION

Marine pipelines, a complex system comprises a total length of thousands of kilometers, have been the most practical and low price means of transporting hydrocarbon (oil, gas, condensate, and their mixtures) in the offshore oil and gas industry. These pipelines are among one of the main factors contributing to marine environmental risks, exposing damages from material defects and pipe corrosion to ground erosion, tectonic movements on the bottom, and encountering ship anchors and bottom trawls. Depending on the cause and nature of the damage (cracks, ruptures, and others), a pipeline can become either a source of small and long-term leakage or an abrupt (even explosive) blowout of hydrocarbons near the bottom. Recent statistics data by the Offshore Environment shows that the average probability of accidents occurring on the underwater main pipelines of North America and Western Europe are $9.3 \times 10^{-4}$ and $6.4 \times 10^{-3}$, respectively. Corrosions in pipelines for instance, was the major cause of reportable incidents in North America and pipeline failures in the Gulf of Mexico. The corrosion-related cost to the transmission pipeline industry is approximately $5.4$ to $8.6$ billion annually.

The structural integrity of aging pipelines to withstand various operational, environmental and accidental loads has been a major concern to many parties. Therefore, the reliability of marine pipelines under various service conditions should be warily evaluated in order to protect the public, financial investment and environment from such failures.

Apart from the existing deterministic method used in structural design, there is a trend in the development of safety concepts as well as in economical approaches by implying more probabilistic concepts. This paper is aiming at providing comparisons between the deterministic and probabilistic methods when assessing risk in aging marine pipelines. An overview of deterministic method is presented at the beginning of the paper followed by a brief introduction to the probabilistic method. The application of the latter is shown through corrosion defects in a marine pipeline. A new insight on fluid-structure interactions is summarized at the end of the paper, in which the significance of uncertainties in pipeline hydrodynamics may be used to support the application of probabilistic method into the existing pipeline designs.

DETERMINISTIC METHOD

In structural design, the level of safety in each design component may be evaluated in several ways, as given in Table 1.

Level I method have been used as the common practice when designing a structure. It offers values of partial safety factors for the most common strength and load parameters, as shown in Figure 1(a). Some of the disadvantages of deterministic method as reported by Vrijling (2006) are (i) unknown how safe the structure is, (ii) no insight in contribution of different individual failure mechanisms, (iii) no insight in importance of different input parameters, (iv) uncertainties in variables cannot be taken into account and (v) uncertainties in the physical models cannot be taken into account.

Level II and III on the other hand, are formed by knowledge of probability and reliability theory concepts.