Seismic Response of Floating Roof Storage Tanks Contact Pressure Analysis

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Abstract

Seismic response of liquid storage tank floating roofs involve phenomena that require dynamic nonlinear geometric and material behavior as well as surface to surface contact. Good engineering practice requires a practical analytical approach that captures the essential ingredients of structural behavior under earthquake excitation by making reasonable, conservative, and manageable approximations to the actual conditions. This paper discusses an approach used in Abaqus to calculate the stresses and deformations of a liquid storage tank floating roof under seismic loading. It represents a novel application of contact theory to achieve a solution to this problem. The method is validated by a fully coupled fluid-structure interaction (FSI) finite element analysis using actual earthquake ground accelerations. The method is supported by both the American Petroleum Institute (API) and the Petroleum Association of Japan (PAJ).

Introduction,

The large capacity liquid storage tank is an important facility for the storage of pre-production raw materials and partially or completely processed products for the petrochemical industry. These structures are primarily cylindrical in shape, with a very flexible bottom plate and either a fixed, floating, or combination of fixed and floating roofs. The underlying foundation for the tank can be asphalt, concrete, pre-designed or natural soil support, or crushed stone. These tanks are used to store many different types of hazardous and volatile liquids such as crude oil, naphtha, and gasoline.

The storage tank is a relatively simple welded or riveted structure but it responds to most loadings in a highly nonlinear manner. Beyond the basic hydrostatic loading of the contents, it can be subjected to large deflections and buckling from foundation settlement, wind, rain, snow, and seismic loading. These loads can induce localized plastic deformations in the tank bottom plate, shell walls, and roof.

The focus of this paper is the seismic liquid sloshing response of floating roof storage tanks (Figure 1). Seismic loading will induce both impulsive (fluid mass) and convective (liquid sloshing) loads on the tank walls. Simplified seismic design attempts to minimize the effects of these loadings which generate shearing and overturning forces on the tank. Primary mitigation methods of seismic effects rely on anchoring systems based on a seismic design spectrum. Earthquake loading is random and can be so powerful in magnitude that anchoring systems can and often fail. Inadequate design could result in loss of containment integrity or the more unusual "walking away" off the foundation and a phenomena known as "elephant foot buckling" (Cacciatore, 2004). Floating roof tanks are particularly vulnerable to

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