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A New Numerical Model on Venting System of Liquid Cargo Tanks in FPSO

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ABSTRACT

This paper presents a newly developed numerical model on the dynamic behavior of the venting system of liquid cargo tanks in FPSO. Compared to the conventional models, which only consider the pressure drop, the present model considers more parameters and it may be applied to the cases with large pressure drops. Therefore, this model can simulate more popular cases with high accuracy. A finite element based method is adopted to numerically solve this model. Several cases with different working conditions are simulated. The effects of the working condition on the venting flux are analyzed.

KEY WORDS: FPSO; Liquid cargo tank; Venting system; Dynamics analysis; Finite element based method; Design optimizing

INTRODUCTION

The venting system of liquid cargo tanks is a necessary equipment of FPSO. This equipment balances the outlet pressure and the pressure of the vapor space of the tank, which always changes followed the changes of the gas-phase temperature, components and the volume of the liquid cargo during the operation of loading/unloading. For safety purpose, an accurate prediction of the venting flux as a function of pressure drop of the venting system should be carried out to make sure the pressure of the vapor space be less than the maximum designed value (China Classification Society, 1999) of the FPSO and the concentration of the vapor upon the liquid cargo exceed its explosion range. On the other hand, for the purpose of achieving highest economical efficiency, the designers and the operators also need to optimize the venting system to reduce its limitation on the loading/unloading rate (CONCAWE, 2002). All of these call for an accurate and robust model to simulate the venting rate of the venting system.

Compared to individual pipes, the pipe network in the venting system, including many accessorial components (e.g. valves and elbows), is much more complicated. Particularly, as the development of the oil/gas industries, FPSOs are designed to be larger and the venting system required, hence, becomes bigger. Furthermore, according to the regulation of the IMO (International Maritime Organization) on preventing the environmental pollution from liquid cargo tanks, the FPSOs are demanded to be equipped with a vapor emission control system to reduce the gas-phase pollution. This system clearly completes the pipe network of the venting system. A discussion of the effect of the vapor emission control system on the venting system can be found in Oldervik, Neeraas, Strem, Martens, and Meek-Hansen (2002). Therefore, an accurate simulation on this problem is not easy.

Conventionally, two models are commonly in use for this purpose. One is the Darcy formula recommended by the United States Coast Guard (USCG), the other one is suggested by the DNV (DNV, 2003). For detailed reviews, readers may be referred to Shi (1996) and Wang (2002). In nature, these two methods are consistent. They all establish the relationship between the pressure drop and the fluid velocity in the pipe network based on the principle of the incompressible fluid mechanics. However, a limitation of these models is that they show less accuracy in the cases where the pressure drop exceeds 10% of the inlet absolute pressure (Wang, 2002). But, for the venting system equipped with the vapor emission control system, which increases the pressure in vapor space of the liquid cargo tank and so results in a larger pressure drop (INTERTANKO,2001), the pressure drop is often larger then 10% of the inlet absolute pressure. Especially, for an integrated venting system which is commonly used according to state of the art of the FPSO, the pressure drop may be much larger than a sole venting system during the operation as indicated by Martens (2001). Therefore, these two models are difficult or may lead to larger error in calculating the venting rate of the venting system for a modern FPSO. Apart from the limitation of the pressure drop, another distinguished limitation of these models is that they are derived based on the assumption that the gas in the pipe network is incompressible and the fluid velocity in each individual pipe of the pipe network is constant. Under this assumption, the density of the mixed gases in the whole pipe network of the venting system is considered as a constant, ignoring the effect of the pressure and the temperature of the gas-phase in the pipe. In fact, the flux in the pipe network of the venting system is not stable during the venting procedure, as noted by Lin and Lai (2002). They are changed when the components of the working fluid (or gas-phase vapor), their temperatures and the pressures change (PRES-VAC, 2001; Gunner, 2002). Furthermore, because the flux is changed in pipe during venting, the flux of the working fluid affects the resistance coefficient of the pipe wall and, thus, the pressure drop and the density of the working