Effects of Initial Water Layer Thickness on Oil Leakage from Damaged DHTs

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ABSTRACT

The paper presents an experimental study on oil spilling from damaged double hull tanker (DHT). Only the grounding scenario is considered in the experiment. The effects of the initial thickness of the water layer in the ballast space on the oil leakage from a fixed damaged DHT in still water are focused. The dynamic process of the oil spilling is discussed based on the test data. The results reflect that the initial water layer in the ballast space significantly affects the oil leakage and thus may be considered in the design practices to improve the effectiveness of the DHT design.

KEY WORDS: Double hull tanker; thickness of water layer; model test; oil leakage

INTRODUCTION

Double hull tanker (DHT) design was regulated in 1992 by the International Maritime Organization (IMO) for the purpose of minimizing oil spills in the event of a casualty (Yamaguchi, 1992). It is widely accepted that the DHT is the most effective design to reduce the leakage from a damaged tanker due to collisions and groundings in the past twenty years. Questions have also been raised whether or not the DHT performed better than single hull designs at all incident scenarios. Due to this fact, many researchers have been and are carrying out experimental or numerical investigations on the effectiveness of the DHT in incidental scenarios.

It is understandable that different arrangements of the double hull affect effectiveness of the DHT on reducing oil leakage. For example, Karafiath (1992) discussed the effect of the internal hull arrangement ("I" versus "U" tank), Card (1975) analyzed the effects of the height of double bottom layers and Yamaguchi and Yamanouchi (1992) confirmed the effect of the width of two side layers. Researchers have also pointed out that the initial hydrodynamic environment of the DHT affects the effectiveness. Typical approaches include (1) configuring vacuum pressure in the ullage space of the oil tanks (e.g., Miyagawa, 1998) and (2) filling water in the ballast space (e.g., Yamaguchi and Yamanouchi, 1992). A good review on the structural design procedures and some innovative design concepts can be found in Paik (2003). In fact, the studies on the effect of the initial thickness of the water layer in the ballast space of the double hull benefit not only the design of the DHT, but also the prediction of the spilled oil during collision or grounding incidents which may cause the damage of the external hull leading to water inflow and filling the ballast space.

So far, the researches on the oil spilling/leakage from oil tankers mainly focus on the ultimate amount of the oil outflow or water inflow using the hydrostatic analyses or steady/quasi-steady analysis based on Bernoulli’s equation. Apart from the references mentioned above, Hart and Hancock (1992), Chang and Lin (1994), Yamaguchi and Yamanouchi (1995), Yamanouchi and Yamanouchi (1996), Daidola, Reyling and Ameer (1997) and Smaily and Mindaugas (2006) have contributed to this issue based on either direct numerical analysis or probabilistic methodology. However, the oil spilling is clearly a dynamic and unsteady procedure. The spilling affects the force on and the motion of the tanker, which in turn influence the oil spilling. Even in the cases where the tankers are fixed, numerical studies have confirmed the importance of the role of the turbulence and thus the significance of the dynamics on the spilling process (Yang, Lu and Yan, 2014). Nevertheless, the corresponding studies on the DHT have not yet found in literatures. Only a few papers focusing on the oil spilling process from a single-hull tankers can be found in the public domain, e.g., Tavakoli, Amdahl, Ashrafian and Leira (2008); Tavakoli, Amdahl and Leira (2009); Tavakoli, Amdahl and Leira (2010) and Tavakoli, Amdahl and Leira (2011) on the experimental studies and Lu, Gong, Yan, Wen and Wu (2010) performing both numerical and experimental investigation. These researches also confirmed the hydrodynamic features of the oil/water flow during the spilling process.

This paper focuses on the hydrodynamic mechanism of the oil spilling from a damaged DHT using model tests. As mentioned above, the whole spilling process may be affected by many factors, e.g., the sloshing of the oil tank, the viscosity of oil and the motion of the tanker, for simplicity, only a fixed DHT is considered in this study. The effect of the initial thickness of the water filling in the ballast space on the dynamic process of the oil spilling is discussed. As adopted by Tavakoli, Amdahl and Leira (2011), broken holes situated on the bottom of the DHT are used in the experiment to simulate the grounding scenarios.

ANALYSIS ON POREESS OF OIL LEAKAGE

Formation of initial water layer in double bottom