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Ship Grounding over Rock and Shoal

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This paper focuses on the characteristics of bottom damage caused by different types of underwater obstructions, with an emphasis on the different deformation/failure modes for a simplified analysis of internal mechanics. The shape and size of the seabed obstruction are of crucial importance to the bottom damage. Most studies to date are concerned with *rock*-type, sharp obstruction. Very few focus on grounding over blunt obstructions with large contact surfaces, such as *shoals*. The governing mechanics involved in ship grounding are described and compared for sharp rock-like and blunt shoal-like obstructions. When a rock-type obstruction is considered, plate tearing is a dominant failure mode. In contrast, denting rather than tearing is more likely for bottom plating during grounding over a blunt-type obstruction. A simple method is proposed for assessing the strength of ship-bottom structures in grounding accidents over obstructions with large contact surfaces. The primary deformation modes for the major bottom structural members are the sliding deformation of longitudinal girders, the denting and crushing of transverse members, and the indentation of bottom plating. By assembling these modes, the total resistance and energy dissipation for a ship's bottom can be obtained. The effect of friction is included as a factor in the resistance from plasticity. Comparisons are conducted between simple methods for grounding over rock and shoal types. Coupled with the analysis of external dynamics, this method may be used whenever fast estimates for ship grounding are needed (e.g., in conjunction with crisis handling during emergency situations).

INTRODUCTION

Potential massive oil spills resulting from ship accidents, such as collision and grounding, constitute a serious threat to the conservation of marine environments. Although there have been significant advancements in both ship design and operation, the risk of collision or grounding is never eliminated. This is demonstrated by the continuous reports of collision and grounding incidents. One recent high-profile accident involved the *Selendang Ayu*, a cargo ship that ran aground and broke in two off Unalaska Island in 2004. It created the worst Alaskan oil spill since the *Exxon Valdez*. Along the Norwegian coast, the cargo ship *MS Server* grounded and split in half outside Fedje in 2007, as seen in Fig. 1.

In ship grounding analysis, besides the structural arrangement, the characteristics of the structural behavior are determined by the definition of the accident scenario, among which loading condition and seabed topology are of crucial importance. The grounding action may be in either the vertical or longitudinal direction, or a combination of these. The mechanics of vertical action is referred to as stranding (Amdahl and Kavlie, 1992). If the ship grounds with a forward speed, it is often referred to as powered grounding (Simonsen and Friis-Hansen, 2000). The mechanics involved in the grounding varies due to the variety of seabed topologies.

Three major types of seabed topologies—rock, shoal and reef—have been defined by Alsos and Amdahl (2007) for grounding analysis. It has been recognized that relatively flat seabeds and blunt obstructions are by far the most common, as stated in Amdahl et al. (1995) and Wang et al. (2000, 2002). However, most studies to date have been concerned with rock-type seabed obstructions. Such interest has been most likely inspired by the investigation of high-profile grounding accidents such as the *Exxon Valdez*. Consequently, plate cutting and tearing have been investigated extensively. Indeed, a sharp rock may cause earlier penetration of the bottom plating, resulting in unfavorable consequences such as compartment flooding. In contrast, the bottom plating may not fracture when moving over shoal-type seabed obstructions with large contact surfaces. In this situation, denting rather than tearing is a more likely deformation mode for the bottom plating. Such obstructions are more likely to damage a significant part of the ship's bottom, hence threatening the global hull bending resistance (Pedersen, 1994; Alsos and Amdahl, 2007). Fig. 2 shows an example of failure of the hull girder after running aground. This necessitates studies on the response of ship-bottom structures subjected to grounding over seabed obstructions with large contact surfaces.

It is generally understood that the process of ship grounding can be divided into external dynamics and internal mechanics. (See e.g. Wierzbicki et al., 1993; Simonsen and Wierzbicki, 1996.) This study focuses on internal mechanics. Only a steady-state grounding process is considered—i.e., the bottom penetra-

Fig. 1 Cargo ship *MS Server* after grounding outside Fedje, Norway

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