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Damage and Residual Strength of Double-Hull Tankers in Grounding

Jeom K. Paik* and Tak K. Lee
Research Institute of Mechanical Technology, Pusan National University, Pusan, Korea

ABSTRACT

This paper will discuss and analyze the mechanics of ships in grounding on rock. A raking damage estimate model in grounding of ships is proposed. The accuracy and applicability of the model are verified by a comparison of experimental results. The progressive collapse analysis of damaged hull sections, under vertical bending moments by use of the ALPS/ISUM computer code, is described. The procedure is applied to the grounding simulation of a double-hull tanker with a transverseless system.

NOMENCLATURE

A : length of stiffened panel
a : spacing between transverse stiffeners
A_s : cross-sectional area of a longitudinal stiffener
B : moulded breadth of ship in meters
b : spacing between longitudinal stiffeners
B_s : breadth of stiffened panel
$C_{1.5}$: experimental coefficient
C_a : added mass coefficient for surge
C_b : block coefficient of ship
C_f : dynamic frictional reduction factor
E_k : momentum of ship during grounding
f_s : safety factor
h_r : rock height above ship bottom
h_s : height of transverse stiffener
L : length of ship in meters
ℓ : raking length of ship bottom
ℓ_o : raking length at specified condition
m : mass of ship
M_{ps} : plastic moment of transverse stiffener
: $\sigma_o h_s t_s^2/4$
M_P : fully plastic bending moment of hull section
M_s : design still-water bending moment
M_t : total design bending moment
M_u : ultimate bending strength
M_w : maximum design wave-induced bending moment
n_s : number of transverse members
t_{eq} : equivalent plate thickness of stiffened plate
: $t+A_s/b$
t_s : thickness of transverse stiffener
V : ship speed in m/s
V_m : mean ship speed during grounding
: $V/2$
W : total work dissipated by raking damage of ship bottom
W_L : work component by raking damage of longitudinally stiffened plate
W_T : work component by raking damage of transverse members
Z_B : section modulus of hull section at bottom
Z_D : section modulus of hull section at deck
$\dot{\varepsilon}$: strain-rate
ε_x : axial tensile strain of transverse member
ε_r : critical rupture strain of member
θ : half-angle of wedge (*rad.*)
σ_o : static yield stress
σ_{od} : dynamic yield stress

INTRODUCTION

After the Exxon Valdez grounding in 1989, the U.S. Oil Pollution Act of 1990 (OPA90), requiring that all oil tankers operating in U.S. waters must have double hulls by the year 2015, was passed. Although the double-hull concept is not the absolute solution, it is one of the most effective ways of preventing oil pollution in grounding and collision accidents. In this respect, the International Maritime Organization (IMO) has established this requirement in waters throughout the world.

The present paper is concerned with the mechanics of grounding of double-hull tankers. Depending on grounding scenarios, oil spills will possibly occur even though the tanker has double hulls. In a high-energy grounding, both inner and outer bottom platings will be torn and cargo oils will spill out. In a low-energy grounding, the inner bottom platings may not have structural damage and oil spills will not occur immediately after the accident. However, the residual strength of the damaged hull section can decrease seriously and the applied loads may be amplified by waves and tides. If the hull girder is broken into two pieces due to lack of residual strength, more oil will be spilled and greater damage will be done to the marine environment.

In this regard, the structural design of double-hull tankers against grounding should be made on the basis of hull collapse as well as grounding damage.

The present paper has three parts. First, a semi-empirical model for estimation of the raking length of the double bottom due to grounding will be described. The amount of oil spills after grounding can be predicted by use of the estimated raking length. Second, the progressive collapse analysis method for the damaged hull section under vertical bending moments will be presented by using the ALPS/ISUM computer code developed by Paik (1993). The ultimate collapse strength of the tank section with grounding damage will be obtained and compared to the design bending moments. Finally, the present procedure is applied to grounding simulation of an AFRAMAX-sized double-hull tanker with a transverseless system. Some design considerations of a tanker against grounding are discussed.

*ISOPE Member.
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KEY WORDS: Double-hull tanker, grounding damage, residual strength.