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# A comparative study on the structural integrity of single and double side skin bulk carriers under collision damage

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**Abstract**

The primary aim of the present study is to investigate the collision resistance and residual strength of single side skin (SSS) and double side skin (DSS) bulk carriers subject to collision damage. The impact dynamics analyses were conducted using ANSYS LS-DYNA for the evaluation resistance forces, energy absorption and penetration depth for various collision scenarios. The struck vessels of Capsize SSS and DSS designs were assumed to be entirely standstill and the striking vessels of an Aframax-type oil tanker with different bulbous bow shapes were modeled as rigid bodies. The findings were compared, where possible, with existing analytical tools. Residual strength calculations on SSS and DSS vessels were computed corresponding to all considered collision damage scenarios. Traditional Smith's method was applied with the average stress — average strain relationships of elements based on derived semi - analytically. The effect of corrosion was also evaluated by Joint Bulker Project (JBP) Rules on the influence of plate and stiffener thickness. The safety of the vessels was determined as a ratio of the ultimate hull girder strength to bending moment in damaged condition. Finally, results and insights derived from the present work are summarized.


*Keywords:* SSS and DSS bulk carrier designs; Ship collisions; Rupture energy; Residual strength of uncorroded damaged ships; Residual strength of corroded damaged ships; Progressive collapse analysis; Safety strength assessment

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## 1. Introduction

A bulk carrier that experiences flooding of one or more cargo holds or machinery spaces is exposed to the risk of losing its stability and thus suffers the risk of sinking.

From 1980s to mid-1990s, over 150 bulk carriers have been reported lost with a loss of more than 1200 lives. Typically, the bulk carriers have a high number of lives lost in accidents, which shows that the consequences of bulk carrier casualties are more severe than other ship types [1]. A search in the database of Lloyd's Maritime Information Service (LMIS) has revealed that between January 1, 1991 and December 31, 2000, there were fewer accidents involving DSS bulk carriers compared to SSS bulk carriers. Only three accident records were retrieved and, notably, all three concerned combination-type vessels. The initiating event of each case was in contact with another object. Concern over the safety of bulk carriers has risen in recent years and has lead to a number of initiatives from various organizations. The IMO has bulk carrier safety as a priority issue in its work programme and bulk carrier safety is also the central priority of the International Association of Classification Societies (IACS). Recently, IACS announced new requirements to enhance the safety of bulk carriers. More than 3484 bulk carriers, with a capacity of up to 173 million DWT, are targeted by the new requirements from January 1, 2003. At the same time, Formal Safety Assessment (FSA) study of bulk carriers is also carried out by an international consortium, which is led by the Royal Institution of Naval Architects (RINA). The aim of the FSA study is to investigate whether the new survivability and structural requirements of SOLAS Chapter XII are sufficient for bulk carriers with double skin side construction.

There are two key advantages identified for the double skin side bulk carrier: the existence of redundancy in case of penetration of the outside shell from a low-to-moderate energy impact and, more importantly, the fact that primary structural members need no longer suffer from corrosive effects by being in direct contact with the cargo. Furthermore, the hull is protected from damage from cargo loading and offloading equipment. Therefore the damage to frames and plating that arise from such contact can be prevented. Double-sided structures have flat sides in the cargo holds and, as a result, the final stages of the cargo discharge process occur without grabs and pipes manoeuvering around awkward frames, etc. It is estimated that the steel weight increase in the cargo area of DSS bulk carrier by about 4% compared to a SSS bulk carrier for the same cargo hold volume and 3.5% for the same deadweight.

Double hull concept is one effective way to moderate the risk of cargo in collision accidents, even though it is not a whole solution. As long as the inner plating is intact, the cargo will not spill out immediately after an accident although the outer shell plating may have been seriously ruptured. On the other hand, if the cargo is still on board, there is still a possibility of vessel loss even if the inner shell plating remains intact immediately after collision damage. Such damage or loss can result from hull collapse due to a decrease of the accident-induced sectional forces including during salvage and rescue operations. In this case, it is necessary to compare the structural strength of DSS and SSS bulk carriers in both intact and damaged states.

The present study addresses the collision problem and the residual strength of SSS and DSS bulk carrier designs, where the same principle dimensions are analysed and compared for various collision scenarios. The dynamics numerical calculations on the collision resistance of SSS and DSS bulk carrier vessels are carried out by means of a non-linear