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Ultimate strength analysis of highly damaged plates

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ABSTRACT

This work deals with the ultimate compressive strength of highly damaged plating resulting from dropping objects, grounding or collision. Extensive static nonlinear finite element analyses are conducted, where several governing parameters are considered. The effect of dent depth as well as dent size is studied. Different dent shapes are considered in order to cover different possible damage scenarios. The toughness modulus is used to measure the capacity of the plate to withstand the applied load with permanent deformation. An expression to estimate the average reduction of ultimate strength of highly damaged steel plates, subjected to compressive loading as a function of the residual breadth ratio is also developed.

1. Introduction

As a result of ship grounding, collision or dropped objects, an indentation or large plastic deformation may occur with different shapes and sizes, which in turn may affect both local and global strength of the structure, (see Fig. 1, left).

For grounding, the damage is resulting from the interaction between the ship bottom and seabed, where most of the existing studies of ship grounding are concerned with the sharp rock type

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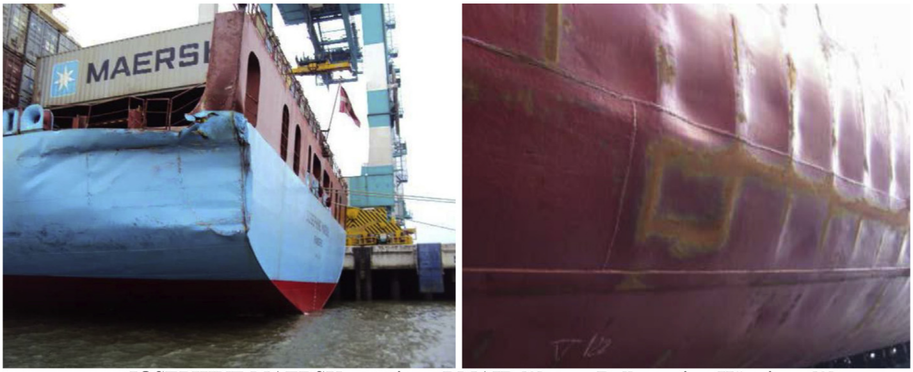

JOSEPHINE MAERSK container, DMAIB [2] Bulk carrier, Hänninen [3]

Fig. 1. Collision (left) and ice-contact (right) damage [2,3].

obstruction. The damages of hull structures after grounding are classified into five fundamental damage modes, which are: (a) the stretching mode of shell plating and local large deformation, (b) plate perforating model, (c) plate denting mode for main supporting members, (d) axial crushing mode for intersection of main supporting members and (e) plate tearing mode for plate in plane compressed by sharp body [1].

For collision, damage may occur due to interaction between two ships, ships and offshore structures, ship and quay side or a ship–ice contact (see Fig. 1, right). Normally the most affected structural areas are the side shell (plating, frames and stringers) and bow. Consequently, the damage locations and shapes are different around the ship hull and depend on the operational conditions and the geometry of the indentation object. In case of dropped objects, which normally happened on the ship deck or platforms, the indentation is formed due to falling down of an object i.e. containers or equipment.

Therefore, it is an important issue to assess the residual strength of permanently deformed structures caused by these damage scenarios in order to estimate the structural capacity, which in turn may affect the repair and maintenance planning.

For plate elements, one of the first studies regarding the effect of localised damage is of Dow and Smith [4], who presented a numerical study of the buckling and post-buckling behaviour of long rectangular plates under uniaxial longitudinal compressive load with localized initial deformation. It was concluded that the amplitude of the localized imperfection is a very important governing factor influencing the collapse of plates.

Cui and Mansour [5] stated that in addition to the amplitude, the initial imperfection shape (i.e. the number of half waves) has a significant effect on the ultimate strength. However, only those initial imperfections whose shapes are very similar to the final deformation shape, significantly affect the ultimate strength rather than other shapes.

Guedes Soares et al. [6] investigated the effect of localised imperfections on the ultimate compressive strength of unstiffened plates with aspect ratios ranging from one to three, and the effect of combining localized and global imperfections was studied. It was concluded that the final shape of the imperfections (local plus global) changes the effect of the localized imperfections on the ultimate compressive strength.

Nikolov and Andreev [6] studied the influence of symmetrical and asymmetrical imperfections in adjacent plates, on the collapse strength of plates. It was found that the symmetric imperfections result in a higher resistance to the loading and dependent on the plate slenderness. Moreover, the lower and upper bounds for this effect happened when the amplitude of the imperfections in adjacent plates was equal.

Saad-Eldeen et al. [7] analysed the initial and post-collapse plate deflections based on measurement records of the experiments of three corroded box girders subjected to pure vertical bending loading,