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# Simulation on progressive collapse behaviour of whole ship model under extreme waves using idealized structural unit method

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A B S T R A C T

To ensure the safety of navigating ship, working loads and structural load-carrying capacity are two important aspects. In the present paper, a total simulation system combing load calculation and structural collapse analysis is applied to simulate progressive collapse behaviour of a single-hull Kamsarmax type bulk carrier. A three dimensional singularity distribution method is adopted to calculate pressure distribution with time history. A mixed structural model, collapse part simulated by ISUM elements and remaining part by elastic FEM elements with relative coarse mesh, is proposed for collapse analysis. Progressive collapse behaviour obtained by ISUM is good agreement with that by nonlinear software package, MARC. However, the calculation time of ISUM analysis is about 1/70 of MARC analysis. The applicability to structure system, high accuracy and sufficient efficiency of ISUM had been demonstrated.



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## 1. Introduction

Ship's hull girder is a large floating structural system composed of plate panels and stiffeners, and it is subjected to both still water loads and wave loads. The structure may be collapsed if the structural capacity is less than the work loads (still water loads + wave loads) when the ship is subjected to extreme sea condition such as typhoon. The collapse of ship shall lead to not only loss of lives and properties but also environmental problem such as pollution due to spilled oil. So, the safety of navigating ship is paid more and more attention by international society recently. The working loads and hull girder capacity are two important aspects to ensure the safety of ship.

As for the extreme load estimation, strip method [1] or singularity distribution method [2] can be applied. Three-dimensional method has advantage in transferring load to structural model because the error can be reduced to minimum if the load calculation and structural analysis share the same model. Regarding evaluation of hull girder capacity, Nonlinear Finite Element Method (NFEM) [3], Idealized Structural Unit Method (ISUM) [4] and simple method such as Smith's method [5] are effective ones. Lots of simplifications are assumed for simple method so that its application shall be limited. For example, Smith's method [5] is applicable when a ship's hull is subjected to pure bending. In theory, NFEM can be adopted to solve any problem. Fine mesh is necessary in order to ensure the precision because material and geometrical nonlinearities have to be considered for such analysis. Magnitude effort as well as computation time will be cost for large-scaled structural system such as ship hull girder which seems quite difficult to perform actually. ISUM is an alternative method. Material and geometrical nonlinearities are idealized and included in the element so that larger structural unit can be regarded as one ISUM element [6]. Degrees of freedom can be reduced significantly for large-scaled structural system as well computation time is relatively shortened. That makes it possible to apply ISUM for progressive collapse analysis of ship hull girder [4].

In the past research on structural capacity, one frame space model or hold model is usually adopted imposing forced rotation on end cross-sections assuming that the cross-section remains plane. The bending moment is calculated by integrating the axial force multiplied by a lever in each element. The ultimate strength is defined as the maximum moment along the equilibrium path obtained by the above mentioned static analysis. The natural world is, however, not controlled by pathways or curvatures, but by pressure and/or force. Bending moment–curvature relationship obtained by forced displacement method or arc length method could be far from the reality after the working bending moment has exceeded the hull girder capacity, as pointed out by Lehmann [7] in his official discussion on the report of committee III.1 in ISSC 2006 [8].

Prof. Lehmann pointed out that snap-through may take place to Curve A beyond the ultimate hull girder strength (See Fig. 1). If static analysis imposing forced rotation is performed, equilibrium path may be Curve B. There is also possibility to act along Curve C and Curve D. To clarify what shall happen

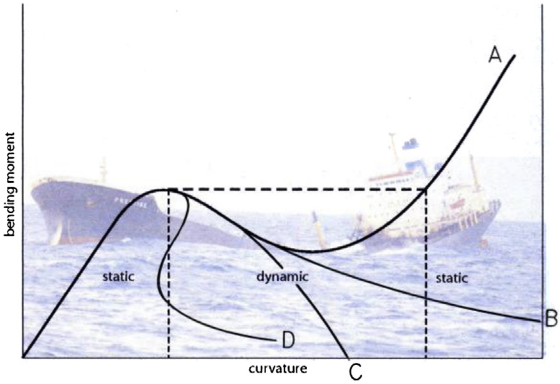


**Fig. 1.** Relationship between bending moment and curvature.