Reliability Analysis of Dynamic Stability in Waves

The assessment of a ship's intact stability is traditionally based on a semi-empirical deterministic concept that evaluates the characteristics of a ship's calm water restoring leverarm curves. Today the ship is considered safe with respect to dynamic stability if its calm water leverarm curves exhibit sufficient characteristics with respect to slope at zero heel (GM value), maximum leverarm, positive range of stability and area below the leverarm curve. The rule-based requirements to calm water leverarm curves are entirely based on experience obtained from vessels in operation and recorded accidents in the past. The rules therefore only leaves little room for evaluation and improvement of safety of a ship's dynamic stability. A few studies have evaluated the probability of ship stability loss in waves using Monte Carlo simulations. However, since this probability may be in the order of $10^{-4}$ per ship year such brute force Monte-Carlo simulations are not always feasible due to the required computational resources. Previous studies of dynamic stability of ships in waves typically focused on the capsizing event. In this study the objective is to establish a procedure that can identify "critical wave patterns" that most likely will lead to the occurrence of a considered adverse event. Examples of such adverse events are stability loss, loss of maneuverability, cargo damage, and seasickness. The adverse events related to dynamic stability are considered as a function of the roll angle, the roll velocity, and the roll acceleration. This study will therefore describe how considered adverse events can be combined into a single utility function that in its scale expresses different magnitudes of the criticality (or assessed consequences) of the adverse events. It will be illustrated how the distribution of the exceedance probability may be established by an estimation of the out-crossing rate of the "safe set" defined by the utility function. This out-crossing rate will be established using the so-called Madsen's Formula. A bi-product of this analysis is a set of short wave time series that at different exceedance levels may be used in a codified evaluation of a vessel's intact stability in waves.

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