Investigations of the dynamic ultimate strength of a ship’s hull girder during whipping

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Abstract

In the recent past, the whipping phenomenon has been extensively investigated by different researchers, but its consequence on the hull girder’s collapse is still unclear. The most common practice is to compute whipping as a linear dynamic response of the hull girder to slamming loads. The total bending moment is computed and compared to the hull girder’s ultimate capacity. This approach is often considered as conservative because it is trusted that the hull girder does not have time to collapse during a whipping event.

In order to investigate this dynamic ultimate strength and to compare this with the usual quasi-static ultimate capacity the hydrodynamic loading is strictly separated from the structural response and both linear (elastic) and nonlinear (elastic or elasto-plastic) structural response are considered. A simplified one degree of freedom model is used to compute the linear or non-linear dynamic response of the hull girder. Different stress-strain relation curves and different hydrodynamic loading sequences are considered in order to assess their influence on the final response. It is shown that a time sequence corresponding to a linear whipping response higher than the hull girder capacity does not necessarily lead to the hull girder collapse when a non-linear structural model is used.

Keywords

Container ship; Whipping; Ultimate strength.

Introduction

The hull girder ultimate strength is defined as the capacity of the hull girder to resist to external wave forces without complete collapse. This check is used by many classification societies and has been recently introduced in the IACS UR S11A (2015) dealing with longitudinal strength standard for container ships. The non-linear relationship between the external bending moment and the curvature of the hull girder is computed taking into account yielding and buckling behavior of each individual structure component of the ship section (Fig. 1). The hull girder ultimate capacity is defined as the maximum bending moment in this curve. The rule check consists in comparing the sum of the still water and the wave bending moments (including some partial safety factors) with the ultimate capacity. This check does not take into account any dynamic behavior of the hull girder: it is a pure static check.

Recent accidents on some container ships (MSC Napoli, MOL Comfort) suggest that the whipping phenomenon might be one of the causes for structural failure and the post-accident recommendations strongly request more thorough investigations of this phenomenon. At that time whipping was not taken into account in the classification society rules, but its effects were supposed to be covered by the partial safety factors. Since then many numerical methods have been developed to simulate the whipping response to slamming loads (el Moctar, 2011 - Malenica, 2012 - Tuitman, 2012). It is now possible to use direct computation to predict design bending moment including whipping, and some classification societies are making this mandatory for Ultra Large container Ships (Bureau Veritas, 2012). This design bending moment, which includes the dynamic response of the hull girder, is then compared to the ultimate capacity, exactly as it was done with the quasi-static wave bending moment. Recently DNV-GL (2015) has introduced a partial safety factor of 0.9, reducing the effectiveness of whipping during collapse. It is hard however to find any rational justification of this factor.

In order to follow the collapse behavior of a ship’s hull girder in waves, Kimura et al (2010) proposed a hydro-elasto-plastic model to study the dynamic collapse behavior. Iijima et al (2014) have used this model to study the post-ultimate strength collapse behavior of the hull girder under wave loads or whipping loads. They have used a simplified single degree of freedom model to simulate the hull girder bending. Their results are compared to model scale experiments. Their conclusion is that given the same amplitude of vertical bending moment, the collapse extent under normal wave loads is much larger than under impact loads.

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