Abstract

Traditionally, the hull girder ultimate strength analysis is performed under quasi-static conditions, where the maximum total vertical bending moment (VBM) of a ship, obtained from a long-term hydrodynamic analysis, is compared with the maximum VBM that the ship structure can withstand, determined from a progressive collapse analysis. In the last 10 years, the importance of whipping on the extreme hull girder loads has received much attention from designers and classification societies. The most common practice to evaluate the ultimate strength of a relatively “soft” floating structure is to compare the maximum dynamic VBM after a slamming event, which is derived from hydro-elastic calculations, with the quasi-static hull girder capacity. Some aspects regarding the current procedure remain unclear, like the capability of the current hydro-elastic methods to accurately predict the extreme dynamic response on the basis of a linear elastic structural model. Moreover, the whipping-induced stresses have a higher frequency than the ordinary wave-induced stresses; hence, the dynamic effects such as inertia and strain rate effects may provide additional strength reserves for the ship structure and should be investigated. Therefore, the aim of the research work presented in this paper was to investigate the dynamic ultimate strength of stiffened panels considering real loading scenarios, associated to wave loads and whipping response. The nonlinear finite element method was employed for a systematic analysis, in which both material and geometric nonlinearities are taken into account. Strain rate sensitivity was considered through the Cowper Symonds material model. Also, the influences of initial geometric imperfections, as well as modelling techniques were evaluated in the present study. Different combinations of in-plane biaxial loads and lateral pressure were defined to investigate the influence of dynamic effects on the ultimate capacity. The numerical results and some important insights developed from the present study are documented.

Keywords: dynamic capacity, ultimate strength, strain rate sensitivity, stiffened panels, whipping, ultra large container ship;

1. Introduction and motivation

Ships and offshore structures are operating in harsh ocean environment and are subjected to different physical phenomena including waves, large ship motions, slamming, spray, wind, etc. The collapse of hull girders is the most catastrophic failure event because it almost always generates the complete loss of the structure. Therefore, it is essential to ensure that the structure has sufficient strength to sustain an extreme loading situation.

Until middle of 20th century, the design criterion of ship strength was the conventional elastic bending analysis. The first attempt to evaluate the ultimate longitudinal strength of a ship's hull girder was performed by Caldwell (1965). According to Caldwell, the ultimate strength of a ship is the