ABSTRACT

For current containership designs, a new material class with a minimum yield strength of 460 N/mm², called YP47 steel, is considered. In connection with big plate thicknesses and high static and dynamic loads at the upper hull girder area, e.g., the coaming and the coaming top plate, brittle fracture is a factor that has to be deeply investigated. This paper describes development of a safety concept based on a brittle fracture avoidance strategy using fracture mechanics methods. Finally, this safety concept results in toughness and quality requirements, which are practically applicable in shipbuilding industry. Effects of different influence parameters are discussed, such as design temperature, fracture toughness, initial defect size, and shape of load spectra. Furthermore, prospective inspection and assessment strategies are presented.

KEY WORDS: High tensile steel; fracture assessment; two criteria approach; cyclic crack growth; toughness requirements; inspection strategy.

INTRODUCTION

Mainly driven by economy of scale, the size especially of containerships increased during the past years. This development is accompanied by using steels of increased plate thickness up to 85 and even 100 mm in some cases and higher yield strength exceeding 390 N/mm².

Currently, a new material class with a nominal yield strength of 460 N/mm², called YP47 steel, is considered for latest containership designs. This development is mainly driven to reduce the plate thickness to gain the benefit of thinner plate thickness and to reduce welding work. It is the challenge for classification societies to consider all points of view and to ensure a safe application of this new material.

Actually plate thickness up to 80 mm is designated in conjunction with this material. By utilizing the higher static load carrying capacity of the material, it is intended to achieve a limitation of the plate thickness. Otherwise, utilization of high permissible static loads results also in high dynamic loads. As a typical example where the application of YP47 steel comes into consideration, a 13,000 TEU containership is shown in Fig. 1.

The main area of application for YP47 steel is the upper hull girder area, e.g., the coaming and the coaming top plate of large containerships. The characteristic high tensile loads in this area in combination with large plate thicknesses and high strength steel rise the possibility of brittle fracture. It is well known that fracture toughness decreases with increasing plate thickness, especially for steels of simultaneously increased material strength. In comparison to mild steels, the so-called thickness influence becomes already effective at smaller plate thicknesses, Sandström et al. (2005).

Fig. 1: Finite element model of a 13,000 TEU containership

To ensure safe operation during the lifetime of the ship, it was necessary to establish a safety concept for the new material class of YP47 steel. Based on fracture mechanics calculations, this safety concept finally results in toughness and quality requirements suitable for practical application in the shipbuilding industry.

Beside the danger of brittle fracture, the danger of fatigue damages also rises for YP47 steel. This is mainly due to high cyclic loads and pronounced fatigue sensitivity of welded joints of thick high strength steel. But this paper is focused exclusively on the avoidance of brittle fracture.

SAFETY CONCEPT

Basically, within a safety concept for the avoidance of brittle fracture, the priority can be the avoidance of crack initiation or to the guarantee of crack arrest. The supplementary rules for application of YP47 steel of Germanischer Lloyd (2009) are based on a crack initiation concept. This means that the initiation of a brittle crack is excluded for the given boundary conditions. Due to uncertainties regarding crack arrest behavior, especially in ship structures under realistic boundary conditions, crack arrest is considered as a second line of defense only. Nevertheless, recommendations for a crack arrest design are given.