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The measured contribution of whipping and springing on the fatigue and extreme loading of container vessels

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ABSTRACT: *Whipping/springing research started in the 50'ies. In the 60'ies inland water vessels design rules became stricter due to whipping/springing. The research during the 70-90'ies may be regarded as academic. In 2000 a large ore carrier was strengthened due to severe cracking from North Atlantic operation, and whipping/springing contributed to half of the fatigue damage. Measurement campaigns on blunt and slender vessels were initiated. A few blunt ships were designed to account for whipping/springing. Based on the measurements, the focus shifted from fatigue to extreme loading. In 2005 model tests of a 4,400 TEU container vessel included extreme whipping scenarios. In 2007 the 4400 TEU vessel MSC Napoli broke in two under similar conditions. In 2009 model tests of an 8,600 TEU container vessel container vessel included extreme whipping scenarios. In 2013 the 8,100 TEU vessel MOL COMFORT broke in two under similar conditions. Several classification societies have published voluntary guidelines, which have been used to include whipping/springing in the design of several container vessels. This paper covers results from model tests and full scale measurements used as background for the DNV Legacy guideline. Uncertainties are discussed and recommendations are given in order to obtain useful data. Whipping/springing is no longer academic.*

KEY WORDS: Springing; Whipping; Fatigue; Extreme loading; Container vessels; Model tests; Full scale measurements; Hull monitoring; Collapse strength; IACS URS 11.

INTRODUCTION AND BACKGROUND

Background

Ship designs are continuously developing. During the last centuries steel has replaced wood, welding has replaced riveting, sizes have grown and high tensile steel has been introduced. Containers were developed in the 60'ies, and the first real container vessels were delivered in the 70'ies. Economy of scale has driven development further. Panamax vessels have a capacity of up to 5,000 *TEU* (twenty feet equivalent unit = about 2.5 × 2.5 × 6.2 *m*). A capacity of 6,000 *TEU* on Post-Panamax vessels was exceeded in year 2000. The Ultra Large Container Ships (ULCS) exceed 10,000 *TEU*, and the largest on order in 2013 has a capacity of 18,800 *TEU*. With development new concerns arise. Hull girder bending and buckling becomes dimensioning for large vessels. Use of high tensile steel increased the concern for fatigue damage. The open deck structure requires thick plates which make brittle fracture an issue (again). Whipping and springing affecting both fatigue and extreme loading became a concern during the last decade mainly on the Post Panamax vessels, which have higher design speed and bow flare angles.

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The concern is often raised by accidents. There are four container vessels, Nepthun Sapphire, MSC Carla, MSC Napoli and MOL Comfort, which broke in two in year 1973, 1997, 2007 and 2013, respectively (Storhaug, 2014). For the latter two, the investigations points to whipping as a contributing cause (MAIB, 2008; Japan, 2013). For the two first accidents in 1973 and 1997, whipping has not been addressed as part of the cause, not meaning that it did not contribute. The contributing causes for these four accidents differ. The two recent accidents have placed whipping high on the agenda, and the industry needs answers to questions like:

- How to deal with whipping in design of new vessels?
- How to deal with whipping for existing vessels in operation?

The first question relates to ship design rules. IACS have no requirements yet. A few classification societies have however voluntary public guidelines, e.g. ABS, BV and DNVGL (ABS, 2010; BV, 2012; DNV, 2013; GL, 2013), or internal guidelines. They are not harmonized and refer to different approaches for how to assess it. This may be perceived as problematic for the designers, yards and owners. It is believed that all of them are strict enough, but some may be more costly than others. The current paper will illustrate the philosophy of the DNV Legacy guideline.

The second question comes from operators, managers and owners. The recommendation is here to assess the vessel as if it was new and account for the effect of whipping and springing according to the guidelines from the classification societies. If the vessel does not fulfil the requirements, then hull monitoring is recommended.

General

Whipping is sudden hull girder vibration caused by wave impacts, while springing is resonant hull girder vibration from oscillating wave excitation coinciding with the lowest natural frequency. The vertical 2-node vibration mode is dominating. Whipping is strongly nonlinear, while springing can be linear and nonlinear. These vibrations occur frequently in head seas, at high speed and in high or steep sea states. Damping, limiting the springing level, is higher for the container vessels than for blunt vessels. The slender bow shape of container vessels give less bow reflection; known to excite second order springing on blunt vessels. For these reasons, springing tends to be less important for container vessels, and whipping tends to dominate. Due to the damping of about 1.5-3%, the whipping vibrations decay slowly. Combined with springing, this may give the perception of continuous vibrations in head seas. A stress record from full scale measurements of an 8,600 *TEU* vessel is displayed in Fig. 1. The strain sensor is located in deck on starboard side amidships. Although the stress record may be perceived as springing, it may include small whipping impacts. The stress level does not contain significant wave frequency stress. In Fig. 2 a similar stress record is shown. This is taken 6 *hours* later, and it displays whipping impacts in sagging (negative). Both the wave and whipping stress are significant and one order of magnitude higher than in Fig. 1. The maximum dynamic stress is observed in hogging one and a half wave cycle after the first whipping impact.

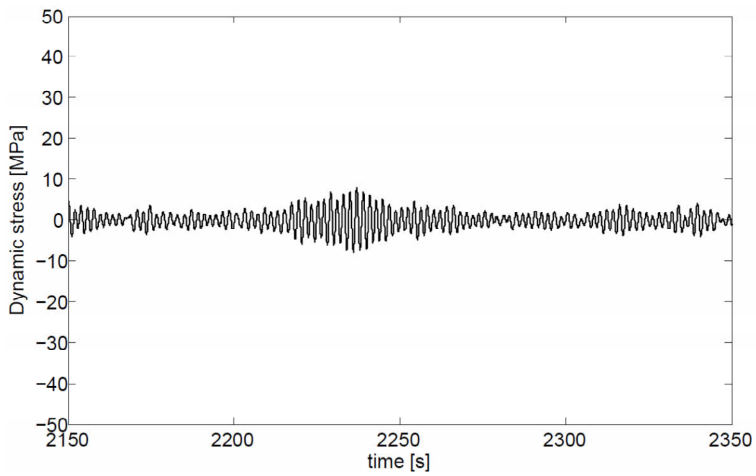

Fig. 1 Nominal stress in deck on starboard side amidships from full scale measurements of an 8,600 *TEU*. Mean stress have been removed. Hogging is positive. Time 30th of December 2011 at 01:00 *UTC*.