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Assessment of whipping and springing on a large container vessel

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ABSTRACT: *Wave induced vibrations increase the fatigue and extreme loading, but this is normally neglected in design. The industry view on this is changing. Wave induced vibrations are often divided into springing and whipping, and their relative contribution to fatigue and extreme loading varies depending on ship design. When it comes to displacement vessels, the contribution from whipping on fatigue and extreme loading is particularly high for certain container vessels. A large modern design container vessel with high bow flare angle and high service speed has been considered. The container vessel was equipped with a hull monitoring system from a recognized supplier of HMON systems. The vessel has been operating between Asia and Europe for a few years and valuable data has been collected. Also model tests have been carried out of this vessel to investigate fatigue and extreme loading, but model tests are often limited to head seas. For the full scale measurements, the correlation between stress data and wind data has been investigated. The wave and vibration damage are shown versus heading and Beaufort strength to indicate general trends. The wind data has also been compared to North Atlantic design environment. Even though it has been shown that the encountered wind data has been much less severe than in North Atlantic, the extreme loading defined by IACS URS11 is significantly exceeded when whipping is included. If whipping may contribute to collapse, then proper seamanship may be useful in order to limit the extreme loading. The vibration damage is also observed to be high from head to beam seas, and even present in stern seas, but fatigue damage in general is low on this East Asia to Europe trade.*

KEY WORDS: Vibration; Whipping; Springing; Fatigue; Extreme loading; Container; Full scale measurements.

INTRODUCTION

There are around 100,000 merchant ships over 100 *GT* trading internationally. They transport every kind of cargo, carrying over 90% of the world trade. The average age of the ships is 22 years. Losses from a severe accident of a vessel can be high not only when it comes to fatalities, damaged ship or cargo, but also with regard to the environmental pollution (IMO, 2012). Therefore, the shipping industry is one of the most heavily regulated industries, with internationally standards related to design approval, construction and operation including inspection. The regulation of the maritime industry is mainly related to the objective of ensuring safety, security and prevention of pollution from ships. One of the increasing concerns is related to the analysis of fatigue and ultimate strength of ship structures, which is related to maintenance and repair cost as well as safety,

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illustrated by the development of common structural rules for tankers and bulk carriers by IACS. However, there are still large uncertainties in prediction of fatigue lives, which is mainly caused by uncertainties in the actual environmental and operational profile, (Storhaug et al., 2010), as well as uncertainties associated with current calculations procedures used in design, where effects of some phenomena may be neglected at least explicitly, e.g. wave induced vibration, (Storhaug et al., 2003).

Wave-induced hull girder vibrations are normally described by the terms of springing and whipping. Springing is resonant vibrations, while whipping is transient vibrations, which increases rapidly due to wave-loads. Whipping is normally caused by an impact of loads from bottom slamming, bow flare slamming or stern slamming (or even from ice impacts, grounding and explosion which is less frequent). Full scale measurement onboard different vessel types shows that the effect of vibrations on the fatigue damage is comparable to the conventional wave loading effect. The whipping contributes to extreme loading which may also exceed the IACS URS 11 rule wave bending moment, (Moe et al., 2005; Storhaug et al., 2012).

The current paper considers an 8,600*TEU* container vessel, which is equipped with a hull monitoring system supplied by Light Structure AS (LS). The monitoring system is based on fiber optic sensors, which measure the strain in different key location of the hull structure. The system receives data from other ship systems available onboard, e.g. environmental, navigational and loading computer data. The vessel was considered in a previous research project where fatigue loading was studied based on one year of measurements. The setup and sensor location is explained in (Heggelund et al., 2011). The current paper investigates the correlation between stress data, wind heading and wind strength. The extreme loading are also assessed and compared to the stress from IACS URS11 rule wave bending (IACS, 2010).

VESSEL AND SENSORS CONSIDERED

An 8,600*TEU* container ship was built in 2009 to the DNV class notation "1A1 container carrier EO CSA-2", which implies direct hydrodynamic and structural analysis during the design phase. CSA-2 notation implies reduced risk of fatigue cracking compared to minimum industry standard for ships. This Post-Panamax vessel has been designed for 40 years target life in World Wide trade (WW). More characteristics of the ship are given in Table 1.

The vessel is equipped by a comprehensive hull monitoring system with 20 strain sensors for global and local hull response including a bow accelerometer. GPS, loading computer and wind sensor are among the sensors connected. Optical sensors give better performance and quality of the data compared to conventional strain sensors. They are smaller and more flexible in use than long-based strain sensors. Multiplexing signals are transferred with low noise and "cross talk" in fiber optic cable. More details about sensors and locations are listed in Tables 2 and 3. The system receives digitized information (wavelength of emitted light) from strain sensors and converts it to stress and corrects the stress for temperature effects. The obtained data is filtered to obtain different types of time series:

- Raw: unfiltered data (RAW).
- Dynamic: Responses with temperature/still water removed (above 0.01*Hz*) (DYN).
- Wave: wave frequency ship responses (from 0.01*Hz* to 0.3*Hz*) (WAV).
- Vibration: only vibration responses (above 0.45*Hz*) (VIB).

The times series are processed and used for several purposes like slamming event detections, warning of loading exceeding 80 and 100% of rule loading. From the time series Rainflow response spectra is also established and this is used for fatigue analysis. Statistical data are also produced and stored in statistics files for 5 minutes and 30 minutes intervals (stat5 and stat30). These statistical data have mainly been used in this paper. Some of this data is displayed on a monitor located on the bridge for decision support in bad weather.

An example of stress time series for deck sensor on port (DMP) and starboard (DMS) side amidships are shown in Fig. 1. This shows heavy whipping vibrations from bow flare impact. These whipping vibrations are superimposed on the wave loading and the contribution to the maximum stress is considerable. The small difference between the port and starboard sensors in this case suggest that the vessel encountered head seas during this short period.