Wet Damping Estimation of the Scaled Segmented Hull Model Using the Random Decrement Technique

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ABSTRACT

Damping is one of the most uncertain factors in structural dynamic problems, and plays a very important role in resonance phenomena such as springing. This paper presents the wet damping estimation of a segmented hull model using a random decrement technique together with continuous wavelet transform. The 16 sea states were grouped together based on the speed of the ship to determine the possible influence of the ship speed on the damping ratio. The measured time histories of the vertical bending moment for each tested sea state were processed using the random decrement technique to derive the free decay signal, from which the damping ratios were estimated. In addition, the autocorrelation functions of the filtered signal were calculated and a comparison was made with the free decay signal obtained from the random decrement technique. The wet damping ratios for each sea state group, as well as precise wet natural frequencies, were estimated using a continuous wavelet transform. The wet natural frequencies derived from the measured signal did not show any significant discrepancy compared to those obtained using the wet hammering test, whereas a significant discrepancy was observed with the damping ratio. The discrepancy of the damping ratio between in calm and moving water might be due to the viscous effects caused by the dramatically different flow patterns and relative velocity between the vibrating structure and surrounding fluid particles.

INTRODUCTION

As modern merchant ships are increasing in size and speed, more attention is being paid to the global vibratory response of the ship structure under a wave load. The vibratory response of large, flexible ships can be categorized into two types, i.e., springing and whipping. The former is the steady-state resonant vibration of a flexible hull and the latter is transient vibration excited by an impulsive slamming load. The slamming load is defined as an impulsive load acting either on the bottom, flare, or stern of the hull when the bow or the stern of the ship plunges into a wave. In general, the springing phenomenon is more relevant to the fatigue strength of the ship structure whereas the whipping phenomenon is more ultimate relevant to the dynamic behavior of the ship structure, even though the cross relationship, e.g., the effect of whipping on fatigue is not negligible. Although two different vibratory responses have different effects on the structure, both cause additional fatigue damage to the ship structure on top of the wave-induced portion because both phenomena induce stress fluctuations near the fatigue prone area of the ship structure.

The additional fatigue damage induced by the above-mentioned hydroelasticity effect needs to be considered during the design stage to avoid unexpected premature fatigue failure at the critical location inside the hull structure. The influence of the hydroelasticity effect on the fatigue damage can be determined in two ways. The first is an experimental approach and the other is the numerical approach. In the experimental approach, a scaled, segmented model is tested in the model basin and the vertical bending moments and shear forces at the junction are measured and analyzed (Storhaug, 2007). This is considered to be the most reliable method because the model test itself can consider all possible complicated physical phenomena, including highly nonlinear slamming events as well as higher order springing excitations. On the other hand, from model fabrication and calibration up to the sea state selection, the test procedure is not straightforward so that care needs to be taken in carrying out the experiment. Numerical analysis has become mature enough to replace the experimental approach, even though the versatility is still limited by some nonlinear effects that are difficult to consider (Price et al., 1982, Malenica et al., 2003, Hirdaris et al., 2003, Kim et al., 2009). For an accurate prediction of the additional fatigue damage by numerical analysis, damping is considered to be of prime importance because both springing and whipping are the dynamic behavior of the flexible hull at the natural frequencies of the hull. The damping identification of a vibrating structure, including other modal parameters such as the natural frequencies and mode shapes, has been a key research topic in many engineering fields and the two key techniques are deeply entangled with this, the random decrement technique and wavelet transform. The random decrement technique was originally developed by Cole (1968, 1971), to identify the dynamic characteristics and in-service damage detection of the space structure from the measured response only. He detected the damage of a structure based on the envelope change in the autocorrelation function of the measured signal. Ibrahim and Mikuleick (1977) later introduced the concept of the auto and cross random decrement signature and enabled the identification of mode shapes and natural frequencies of a multi-DOF system. Vaidy et al. (1982) proved mathematically that a random decrement signature is related to the auto and cross correlation.