Springing response due to bidirectional wave excitation

Springing is a two-node high frequency resonant vibration of the hull induced by unsteady wave pressure field on the hull. The excitation force may be rather complex - any wave activity (or their combination) in the Ocean matching the two-node natural hull vibration frequency. With some ship designs the hull natural frequency may get low enough that the corresponding level of excitation energy becomes large. Springing vibration negatively influences the fatigue life of the ship but, paradoxically, it still doesn't get much attention of the technical society. Usually, non-linear hydroelastic theories deal with the unidirectional wave excitation. This is quite standard. The problem is how to include more than one directional wave systems described by a wave spectrum with arbitrary heading. The main objective of the present work has been to account for the additional second-order springing excitation coming from interacting directional waves. The modification has been implemented in the Second Order Strip Theory (SOST) computer programme developed by Jensen and Pedersen, 1981; Jensen and Dogliani, 1996, based on the relative motion strip theory (Gerritsma and Beukelmann, 1964). The quadratic strip theory is an efficient tool for load calculation that has been validated and proven to give satisfactory results in the range of rigid body wave-induced loads. The present results from the linear analysis show very good agreement with other computer programmes for wave-induced loads calculation. Compared to the results of the full-scale measurements they agree quite satisfactory, too. Some differences inevitably appear between the different codes since they are not consistent in calculation of hydrodynamic coefficients, diffraction potential etc. On the contrary, the results from different non-linear (second order) high frequency springing analyses with unidirectional wave excitation are much more scattered. Some of the reasons are different level of wave excitation accounted in the different Executive Summary theories, inclusion of additional hydrodynamic phenomena e.g. slamming in the time-domain procedures, the structural damping coefficient uncertainty or some purely numerical details in the programme execution. Comparison with full-scale measurements clearly shows that in some cases all the presented computer programmes strongly underestimate the level of springing stresses in the hull. Not only a discrepancy with full-scale measurements exists, but worse is that no tendency in the measurement trend is captured. An important source of high frequency springing excitation is undoubtedly missing. The full-scale measurements that are presented in the thesis and have been used for the validation are unique because, to the author's knowledge, this is the first time that the wave data were collected simultaneously with stress records on the deck of the ship. This is highly appreciated because one can use the precise input and not only the most probable sea state statistics. The actual picture of the sea waves leads to the conclusion that the sea surface is rarely unidirectional and that two main wave directions usually can distinguish. This could be explained by existence of wind waves and swell in the ocean, or sudden change in wind direction that could create a wave system from the new direction while the energy is still not dissipated in the old waves. The new excitation coming from second order interaction between the two considered wave systems is included. The improvement of the agreement between the calculated and measured high frequency springing response is high while there was almost no change in rigid body response. This thesis should, hopefully, contribute to the better understanding of the springing response and it's excitation, recommend the way to include this new and very important excitation source and, finally, it should highlight the need to consider springing loads already in predesign stage at least for some types of ships and loading conditions.

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