A Review of Strains to Internal Loads Conversion Methods in Full Scale Measurements

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Abstract

In full scale measurements as in model tests it is impossible to measure directly the hull girder loads. A conversion matrix usually combines the different strain or motion measurements and yields the different internal load values, at one or several locations. In this paper we show that all the different possible procedures to obtain the internal loads from strain measurements can be seen as variations of a single general procedure. First, a base of distortion modes is built using the structural model. Then a conversion matrix is used to project the measured values on the distortion modes base, and the internal loads are obtained by recombination of their modal values. These last two steps are often merged in a single conversion matrix, thus hiding the underlying analysis base. So the apparently different methods to convert strains into internal loads actually only differ in the choice of the deformation base that is used. The case of a real container ship instrumented with strain gauges is considered. Several types of distortion bases are considered and compared.

Keywords

Conversion matrix; Full scale measurements; Bending moment; Torsion moment

Introduction

The hull girder internal loads, such as bending moment and torsion moment, are very important design parameters. It is essential to measure them accurately during model tests and on real ships, for the validation of numerical models, design rules and classification rules. This is particularly true in the context of the ultra large container ships (ULCS) for which some dynamic hull girder vibration effects are expected and need to be properly modeled and accounted for.

However, in most cases the internal loads cannot be directly measured, and they are in fact evaluated from strains measurements. A conversion matrix is used to combine the different measurements to get the desired output quantities. The measured data can be of several natures such as motions, accelerations or strains. The required output data are usually quantities that cannot be directly measured such as sectional hull girder forces or even local stress where no sensor has been installed. The subsequent problem is the accuracy and the reliability of this procedure. The choice and later on the interpretation of the measured strains necessarily relies on some structural modeling, ranging from simple beam theory formula to complex 3D finite element method (FEM) models. In the case of the scaled model, this can be supplemented with some calibration tests, in which known forces and moments are applied while the associated strains are measured. But for a real ship it is almost impossible to perform full scale calibration tests, so the procedure fully relies on the structural models of the hull.

There are several procedures to obtain global results from local measurements. However all of them can be seen as variations of a single general procedure that relies on the choice of a base of distortion modes, built using the structural model. Many choices can be done for this base, ranging from the structural response to arbitrary load patterns (calibration tests), or the response to several design waves, to the natural vibration modes of the hull girder. A conversion matrix is used to project the measured values on the distortion modes base, and the outputs are obtained by recombination of their modal values. These last two steps are often merged in a single conversion matrix, thus hiding the underlying analysis base. So the apparently different methods to convert strains into internal loads actually only differ in the choice of the deformation base that is used.

Conversion matrix

Definition of the problem

Full scale measurements, as well as model tests, provide only some local measurements. This measured data are combined to get an evaluation of some output data that cannot be directly measured. The conversion matrix \( A \) is the one that converts the measured data \( X \) into the output \( F \) (Eq. 1).

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F = A \cdot X
\]  

(1)

There are many different manners to define the matrix \( A \). Usually a base of distortion modes is chosen, and the