International Journal of Naval Architecture and Ocean Engineering xxx (2017) 1–13

Contents lists available at ScienceDirect

International Journal of Naval Architecture and Ocean Engineering

journal homepage: http://www.journals.elsevier.com/international-journal-of-naval-architecture-and-ocean-engineering/

Dominant components of vibrational energy flow in stiffened panels analysed by the structural intensity technique

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ARTICLE INFO

Article history:
Received 9 August 2017
Received in revised form
24 October 2017
Accepted 18 November 2017
Available online xxx

Keywords:
Energy flow concept
Structural intensity
Vibration analysis
Stiffened panel
Finite element method

ABSTRACT

Stiffened panels are widely used in naval architecture and ocean engineering, and knowledge about their dynamic behaviour represents important issue in the design procedure. Ordinary vibration analysis consists of natural frequencies and mode shapes determination and can be extended to forced response assessment, while the Structural Intensity (SI) analysis, assessing magnitude and direction of vibrational energy flow provides information on dominant transmission paths and energy distribution including sink positions. In this paper, vibrational energy flow in stiffened panels under harmonic loading is analyzed by the SI technique employing the finite element method. Structural intensity formulation for plate and beam element is outlined, and developed system combining in-house code and general finite element tool is described. As confirmed within numerical examples, the developed tool enables separation of SI components, enabling generation of novel SI patterns and providing deeper insight in the vibrational energy flow in stiffened panels, comparing to existing works.

1. Introduction

Stiffened panels are primary constitutive elements in all fields of engineering, as for instance: aeronautical, civil, mechanical, naval, ocean, etc (Cho et al., 2014, 2015a). The most important engineering problems encountered with stiffened panels can be classified into three main groups: bending, stability and vibration (Troitsky, 1976). Stiffeners of different cross-sections are regularly used to increase panel loading capacity and to prevent buckling, but at the same time they influence system dynamic properties and should be properly taken into account in vibration analysis.

Ordinary procedure for vibration analysis of stiffened panels includes solving of eigenvalue problem, i.e. determination of natural frequencies and mode shapes, and their comparison with excitation frequencies if required. Also, sometimes it is necessary to check whether the obtained response satisfies prescribed criteria (in terms of displacement, velocity or acceleration) or not, and in that case forced vibration analysis in frequency or time domain is done (Cho et al., 2015b). In spite of variety of available methods for vibration analysis of stiffened plates, that can be classified into the analytical ones, semi-analytical and numerical methods, remedying of vibration problems (particularly in complex ship and offshore structures) is still rather complicated task. Moreover, vibration analysis of complex ship and offshore structures is usually based on trial and error approach, and can be rather time consuming, especially if advanced computational methods involving large modelling and computational efforts are used. Therefore, knowledge about source power, dominant transmission paths and vibrational energy dissipation, can be very helpful in vibration problem elimination. Such information can be obtained by the Structural Intensity (SI) analysis, which calculates vibrational energy flow from vibratory velocity and internal force of the structure. Hence, the SI analysis provides additional information and deeper physical insight into vibration characteristics of the structure. This subject is investigated for a long time, both experimentally (Noiseux, 1970; Pavic, 1976, 1987; Verheij, 1980; Saijyou and Yoshikawa, 1996; Pascal et al., 2006; Eck and Walsh, 2012) and numerically (Gavric and Pavic, 1993; Xu et al., 2004a,b,c; Tran et al., 2007; Cho et al., 2016; Petrone et al., 2016). The usual objective of both measuring and calculating the vibratory energy

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Peer review under responsibility of Society of Naval Architects of Korea.

https://doi.org/10.1016/j.ijnaoe.2017.11.003

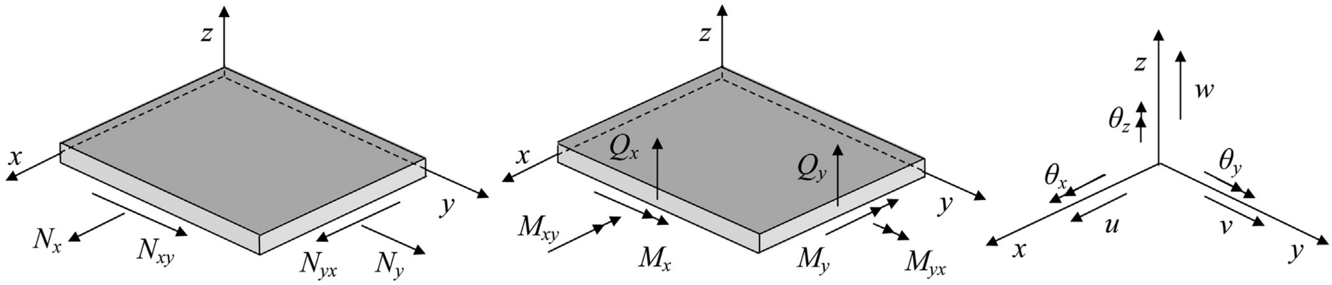

Fig. 1. Forces, moments and displacements for plate element.

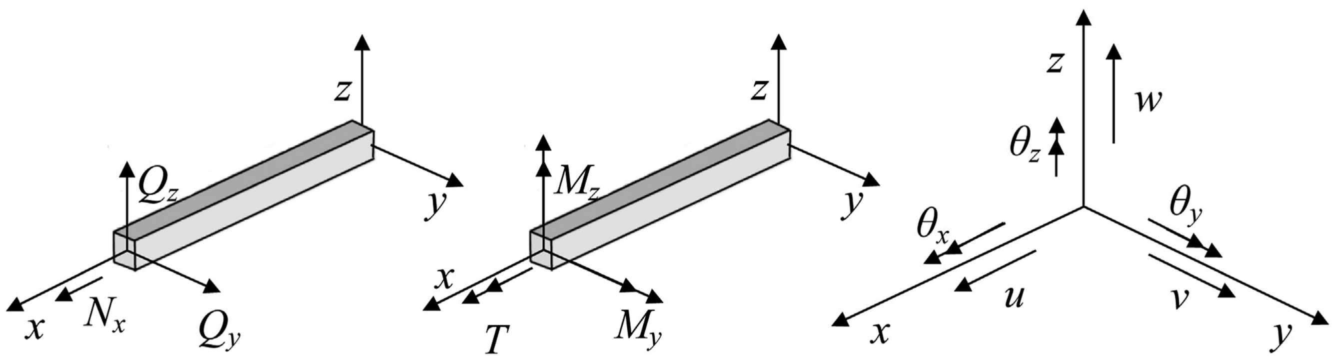

Fig. 2. Forces, moments and displacements for beam element.

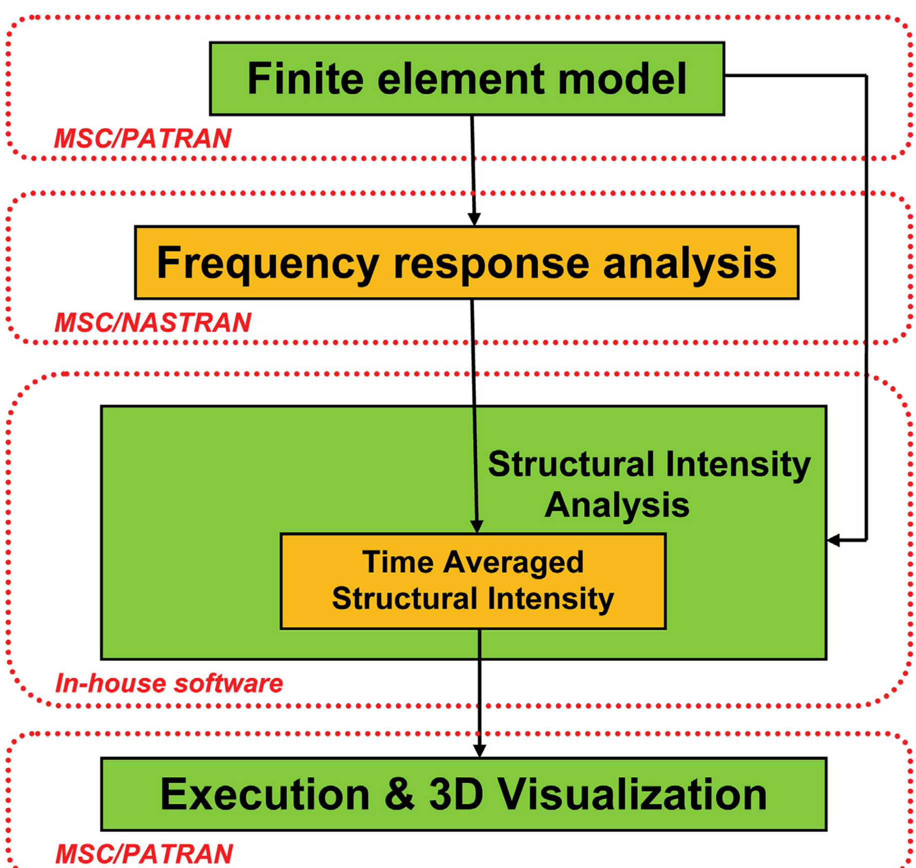

Fig. 3. Scheme of computational system for structural intensity analysis and visualization.

Please cite this article in press as: Cho, D.-S., et al., Dominant components of vibrational energy flow in stiffened panels analysed by the structural intensity technique, International Journal of Naval Architecture and Ocean Engineering (2017), https://doi.org/10.1016/j.ijnaoe.2017.11.003