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Practical demonstration of a large-scale active vibration isolation system

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ABSTRACT

Small experimental test-rigs are often used to investigate active vibration control concepts in the laboratory because of ease of construction and implementation. However, in marine applications, there is a large gap between this type of experiment and full-scale implementation onboard a ship. In this article a large-scale laboratory based active vibration control system is demonstrated. It involves a floating raft system attached to a hull-like structure by way of four hydraulic actuators, which are placed in parallel with eighteen passive resilient isolators. The flexible hull-like structure is supported on twenty six pneumatic springs to simulate a floating ship. A decentralized feedforward control strategy was implemented resulting in the reduction of vibration levels on the flexible hull-like receiving structure of up to 36 dB at some tonal excitation frequencies. The passive isolation results in broadband control and is most effective at higher frequencies.

1. Introduction

Active vibration control has been studied for many years, and is now a fairly mature research topic with several text books being written on the topic [1–3]. There have been some successful demonstrations of active control, for example the active control systems described in Refs. [4–8], but there are only a few current commercial systems, for example the active mount from Paulstra-vibrachoc [9]. Of particular interest to the authors of this paper is the active control of machinery vibrations in marine applications [10–16].

Active vibration control concepts are often investigated on small experimental test-rigs in the laboratory, but in marine applications, there is a large gap between this type of experiment and full-scale implementation onboard a ship. Since vibro-acoustic behavior of a ship structure is often of major interest, a large flexible structure is needed to emulate the hull, rather than rigid foundations found in many laboratory-based experimental test-rigs. There is thus a need to carry out large-scale laboratory experiments in controlled conditions to investigate some of the practical issues. This was the motivation for the work described in this article. Established control techniques were applied to a bespoke large-scale test-rig of a typical marine set-up involving a floating raft structure attached to a hull-like structure by resilient mounts. Four hydraulic actuators were used in a decentralized feedforward control system and some experiments were performed. The flexible hull-like structure is supported

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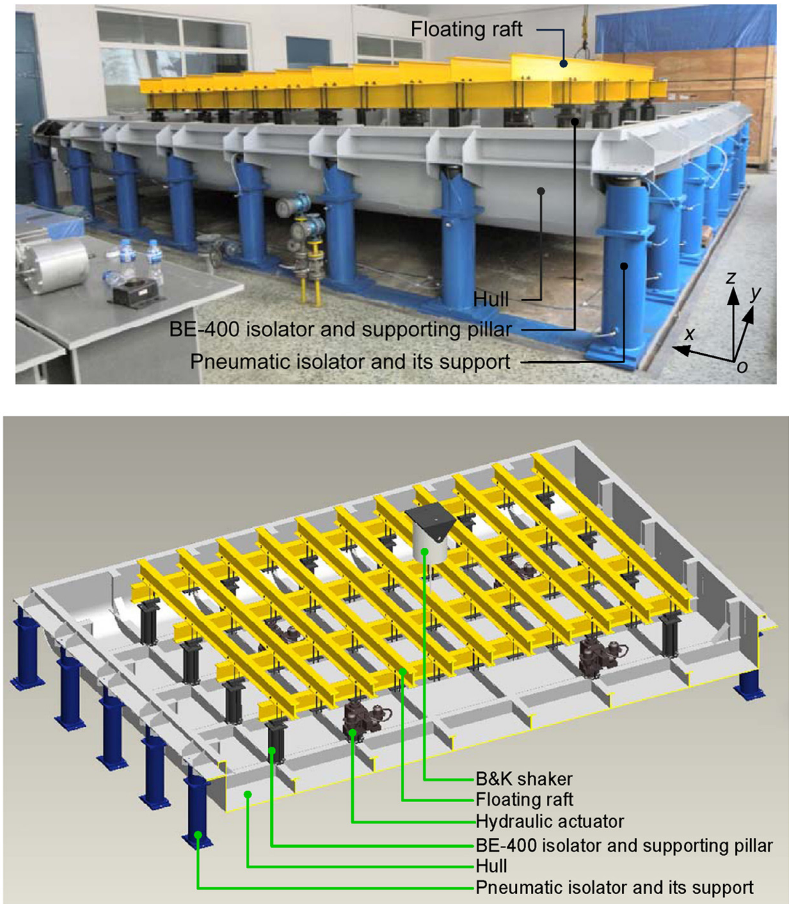
on pneumatic springs and the whole rig behaves dynamically as a section of a floating ship. Details of the experiments conducted and the results of these experiments are given in this article.

2. Description of the test-rig and the control system

A photograph of the experimental test-rig is shown in Fig. 1(a). It consists of a 6.2 m × 5.2 m × 0.4 m floating raft, constructed by 16 I-shaped steel beams, which are bolted together. It is supported on a flexible hull structure by 18 BE-400 type resilient isolators mounted on 18 steel pillars. The 7 m × 6 m × 0.7 m flexible hull structure is made from steel plates which are welded together and supported by 26 pneumatic isolators. The details of the test-rig are given in Table 1.

From modal testing, it was found that there were 25 modes below 150 Hz [17]. A Bruel and Kjaer (B&K) type 3628 shaker, positioned at the center of the floating raft as shown in Fig. 1(b), was used as a primary vibration source to excite the raft and simulate a primary uncontrolled vibration source. Note that this is an intermediate stage of experimentation. In the next

(a)



(b)

Fig. 1. Details of the active vibration isolation floating raft system connected to the hull structure. (a) Photograph of the experimental test-rig. (b) Schematic of the test-rig showing the primary B&K shaker and one of the hydraulic secondary actuators.

Table 1
Details of the experimental test-rig.

Floating raft	Dimensions	6.2 m × 5.2 m × 0.4 m
	Number of I-shaped beams	16
BE-400 resilient isolators	Number	18
	Vertical stiffness	1.61e6 N/m
Hull structure	Dimensions	7 m × 6 m × 0.7
	Weight	4.8 t
Pneumatic isolators	Number	26
	Vertical stiffness	2.3e4 N/m
	Horizontal stiffness	4.7e4 N/m