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Decentralized active vibration control in cruise ships funnels

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ABSTRACT

A huge problem in cruise ships is related to undesired noise and vibrations generated by engines and exhaust stacks. Reduction or suppression of ship noise has traditionally been implemented by passive means, such as by the use of vibration isolation mounts, flexible pipe-work, and interior acoustic absorbing materials. However. while passive devices are effective mostly for attenuating high-frequency noise, they are generally ineffective to suppress low-frequency vibrations. The paper deals with the design of an active standalone device to suppress vibrations on cruise ships funnels. The device can work independently and, matched with others through a decentralized control, can dissipate most of the kinetic energy of the system, thus limiting the propagation of vibration and improving comfort on surroundings.

1. Introduction

There are many sources of noise within a ship structure. Among these are the propulsion systems, exhaust stacks, and various on board equipment. The principal noise source is the engine system. Fig. 1 shows a section of a cruise ship highlighting the engines room, the smokestacks, the chimney and the decks. Generally, there are five possible energy transmission paths associated to vibration diffusion, including the mounting system (consisting of the engine cradle, isolation mounts, raft, and foundation); the exhaust stack; the fuel intake and cooling system; the drive shaft and the airborne radiation of the engine (Akpan, 1999). Through these paths the energy exchanged causes the propagation of vibrations throughout the ship structure.

In general, passive and active control methods can be used to reduce acoustic noise and radiation. Passive noise control essentially reduces unwanted noise by utilizing the absorption property of materials. In this approach, sound absorbent materials are mounted on or around the primary source of noise or along the acoustic paths between the source and the receivers of noise. At low frequencies, however, passive control techniques are not effective because the long acoustic wavelength of the noise requires large volumes of the passive absorbers (Fuller and von Flotow, 1995).

Active vibration control involves the use of active systems to reduce the transmission of vibration (e.g., transmission of periodic vibration from the ship engine to its hull) (Kandasamy et al., 2016). Such an active system is used in practice to complement passive isolation. The active control of vibrations in ship structures is mainly related to: active vibration isolation of mounting system (Fuller et al., 1996); active control of noise in ducts and pipes (exhaust stack; fuel intake and cooling system) (Douglas and Olkin, 1993; L'Esperance et al., 1999); active control of vibration propagation in drive shafts (Pan and Hansen, 1993; Elliott, 1993) and active control of enclosed sound fields (airborne radiation of the engine) (Sutton et al., 1994; Elliot et al., 1990).

The paper fits into this field, deepening the problems relating to suppress vibrations on the ship structure by dissipating the energy coming from the funnels that are considered one of the main path of energy transmission (Fig. 2).

The paper is structured as follows. Section 2 introduces the motivation of the work and gives an overview of advantages of using inertial actuators to suppress vibration on funnels. Section 3 presents the layout of an innovative device designed to actively self damping vibrations, while Sections 4 and 5 describe the model and the design of the device. In Section 6 the damper is realized and tested to assess its performance in suppress vibration autonomously. Finally conclusions are drawn in Section 7.

2. Active control of funnels

Funnels are a main path of energy transmission throughout the ship. Their design is carried out considering to join them to the casing in some few points that are the nodes of vibration of main modes involved. Moreover, connections are realized by using isolators thus minimizing the energy transmitted to the ship. Nevertheless, its a matter of fact that, in practice, this approach does not work properly. Main causes are related to the high complexity of the system and the

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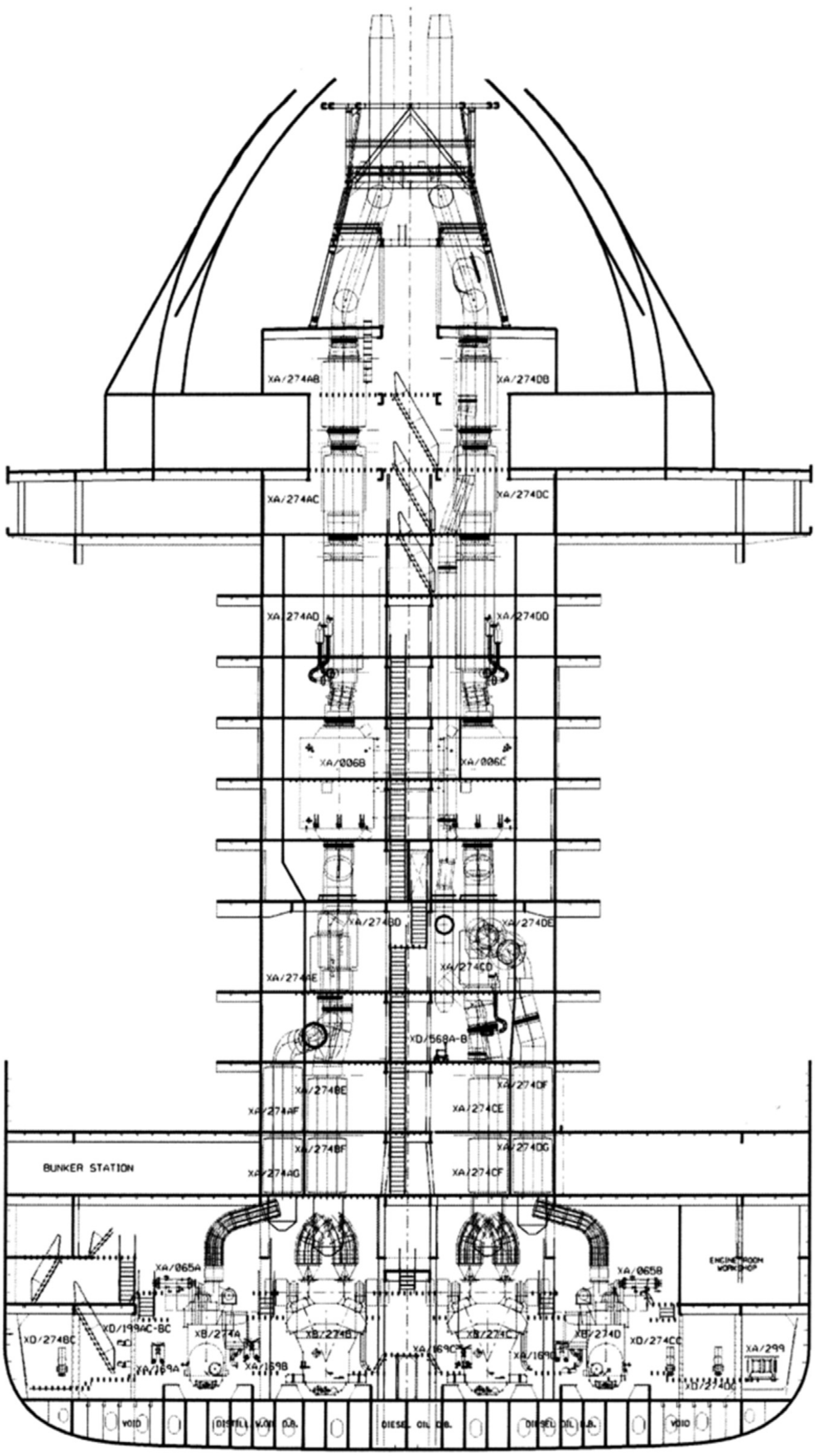

Fig. 1. Cross section of a cruise ship.

large number of modes of vibration, to the ineffective behavior of isolators at low frequency and, sometimes, to the difficulty of installing the supports exactly where expected due to the limited space available to perform the operation.

Fig. 3 shows the results of the finite element model of the funnels of a cruise ship. The 3 modal shapes are at 3.4 Hz, 16.0 and 21.9 Hz respectively. Connections are exactly in the nodes of vibration of the first mode, while for the others it happens that some of them are close to anti-nodes. As a result, the vibration cannot propagate in the first mode, while energy can be transmitted to the casing for the other two modes. Acceleration measured on the casing shows the corresponding peaks (Fig. 4).

Active control can profitably overcome these limitations by reducing vibration in the whole range of frequency. One of the most