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A simple formula for insertion loss prediction of large acoustical enclosures using statistical energy analysis method

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ABSTRACT: *Insertion loss prediction of large acoustical enclosures using Statistical Energy Analysis (SEA) method is presented. The SEA model consists of three elements: sound field inside the enclosure, vibration energy of the enclosure panel, and sound field outside the enclosure. It is assumed that the space surrounding the enclosure is sufficiently large so that there is no energy flow from the outside to the wall panel or to air cavity inside the enclosure. The comparison of the predicted insertion loss to the measured data for typical large acoustical enclosures shows good agreements. It is found that if the critical frequency of the wall panel falls above the frequency region of interest, insertion loss is dominated by the sound transmission loss of the wall panel and averaged sound absorption coefficient inside the enclosure. However, if the critical frequency of the wall panel falls into the frequency region of interest, acoustic power from the sound radiation by the wall panel must be added to the acoustic power from transmission through the panel.*

KEY WORDS: Sound enclosure; Insertion loss; Statistical energy analysis (SEA); Sound radiation.

INTRODUCTION

Acoustical enclosures are very effective noise control measures for reducing high noise emitting from the sources like diesel engines, air compressors, etc. The performance of an acoustical enclosure is described by the Insertion Loss (*IL*) defined as the difference between acoustic powers with and without the enclosure. In a small acoustical enclosure at low frequencies, in which dimension of the enclosure is small compared with the wavelength, there exist no resonances inside the enclosure, and insertion loss is mainly determined by the stiffness of the wall panel (Vér, 2006). In a large acoustical enclosure, in which dimension of the enclosure is large compared with the wavelength, wall panels and interior air cavity exhibit a large number of resonances. In a large acoustical enclosure, sound field inside the enclosure and vibrations of the panel can be treated statistically using an averaging concept rather than deterministically using individual modal behaviors. In research vessels and naval ships where low noise is of prime concern, large enclosures are widely used to reduce high noise from diesel engines, in which size of enclosures often reaches more than 10 *meters*.

Insertion loss of the acoustical enclosures is determined from the coupled motion of the sound field and vibration of wall panels. Lee and NG (1998) studied insertion loss of the small enclosures whose sizes are less than 0.5 *m*. They solved coupled motion of air cavity and wall panel using an acoustic velocity potential and the finite element method. Lyon (1963) computed noise reduction of a small enclosure by assuming that the critical frequency of the wall lies above the first acoustic resonance of the enclosure. Al-Bassyiouni and Balachandran (2005) investigated sound transmission through a flexible panel into an en-

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Corresponding author: *Hyun-Sil Kim*, e-mail: *hskim@kimm.re.kr* closure, in which a spherical wave was generated outside the enclosure, and the largest dimension of the enclosure is 60.96*cm*. They proposed an active noise control scheme based on a structural-acoustics model, in which they used piezoelectric patches as actuators. Earlier works on active noise control in small enclosures are found in the papers by Sampath and Balachandran (1997; 1999) and Balachandran et al. (1996).

Vér (1973; 2006) and ISO (2000) described formulas to predict insertion loss for various sizes of enclosures, which is an extension of Lyon's work (1963). For large acoustical enclosures, Vér (1973) assumed a diffuse reverberant sound field and derived insertion loss from consideration of the power balance among several contributions like power dissipation by wall absorption, power loss through sound radiation of the wall panel, power dissipation through viscous damping effects, sound transmission to the exterior though openings and gaps, etc. Vér (1973) showed that the insertion loss of large acoustical enclosures is dominated by the sound transmission loss of the wall panel and averaged sound absorption coefficient inside the enclosure, if other effects such as leaks, silencer openings, flanking structure-borne noise path, and viscous dissipation of the wall panel are well controlled and negligible.

In ISO (2000), practical information about design and assembling enclosure panels is described. For instance, typical panel of a large acoustical enclosure consists of 1.5 *mm* steel sheet metal, 50 *mm* mineral wool for absorbent lining, and perforated plate covering with 30% opening at minimum.

The SEA method (Lyon and DeJong, 1995) is known as one of the most powerful tools in investigating the acoustical and vibratory motion of the structures at mid and high frequencies. Ming and Pan (2004) investigated insertion loss of an acoustic enclosure using the SEA method. However, their SEA formulation was incomplete, since they didn't include the full effect of structural-structural coupling between the component panels. Lei et al. (2011) improved Ming and Pan's SEA formulation, and used complicated expression for the transmission coefficient of finite flexible plate. They considered insertion loss of a small aluminum enclosure (1.15 *m* × 1.0 *m* × 0.868 *m*, thickness is 2.5 *mm*), and obtained good agreement with the measurements below critical frequency. Sgard and Nelisse (2010) presented a hybrid statistical energy analysis in predicting insertion loss of L-shape enclosure. They used the method of image sources in computing the sound field inside the enclosure. Although SEA based prediction methods are helpful in investigating the acoustical performance of enclosures, the formulations are rather complicated to be used by engineers who have no background knowledge in SEA

The aim of this paper is to present a simple formula for insertion loss prediction of large acoustical enclosures based on the SEA. We assume that the number of modes in the sound field and panel are sufficiently high enough to construct the SEA model, in which we can derive the power balance equations among subsystems systematically. We compare the predicted insertion loss to the measurements for two cases of large acoustical enclosures to confirm the accuracy of prediction.

INSERTION LOSS PREDICTION USING THE SEA

An example of large acoustical enclosures for marine diesel generators is shown in Fig. 1.

Fig. 1 An example of large acoustical enclosures for marine diesel generators.