Numerical Investigation on Noise Reduction Technique of Ship Elbow Pipes with Damping Materials

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ABSTRACT
Ship noise is an important standard of the comfortability of the ship. The low and middle frequency noise in ship piping becomes the main factor of shipboard cabin noise while the noise caused by marine main engines and propellers have been well controlled. Based on computational fluid dynamics (CFD) and Boundary Element Method (BEM), this paper analyzes the influence of inflow velocity, bending angle, cross-sectional shape and cross-sectional dimensions, on the noise of elbow pipes. The results show that the SPL frequency characteristics of elbow pipe outlet are similar at different inflow velocities. The SPL peak frequencies of elbow pipe outlet are close at different inflow velocities and the SPL of elbow pipe outlet increases as inflow velocity increases. The noise level increases as the bending angle increases, especially at low frequency. The noise level of circular section pipe is lower than that of square section pipe. When the quantity of flow is a constant, the noise level decreases as cross-directional dimensions increase. A damping material is attached to the elbow pipe for purpose of reducing the noise. The results indicate that the noise reduction effect of the damping material attached to elbow pipes is relatively effective.

KEY WORDS: ship piping, CFD, BEM, elbow pipe noise, noise reduction by damping materials.

INTRODUCTION
Ship noise is an important standard of the comfortability of the ship. The low and middle frequency noise in ship piping becomes the main factor of shipboard cabin noise while the noise caused by marine main engines and propellers have been well controlled. The controlling of piping noise are paid more and more attention because of International Maritime Organization (IMO) increasingly strict standards on shipboard cabin noise. Therefore it is very necessary to carry out research on prediction and control techniques of the noise of typical ship piping. At present, the main methods for calculating the piping noise are theoretical calculation, empirical formula, test method and CFD method. With the development of computer software and hardware technology, the CFD method has great improvement in the calculation accuracy and stability. Thus, in this paper, the CFD method is used to simulate the piping noise. Mori (2017) studied the aerodynamic sound characteristics of a T-shaped rectangular cross-sectional pipe. An experiment was set up to obtain the frequency spectra of SPL at the monitor point under several inflow velocity conditions. The results show that the characteristic of the generated aerodynamic sound in the pipe is strongly affected by acoustic characteristics of the pipe. Lee (2010) computed the inner flow field of air duct by the CFD method and converted the field information into the sound source, then calculated the radiation sound field based on BEM. The numerical predictions are shown to correlate reasonably well to the test measurements. Liu (2015) evaluated the noise of an elbow pipe based on a large eddy simulation and FW-H acoustic analogy. It is found that the frequency band of the sound pressure level of elbow pipe is wide and different pressures and velocities of the fluid have influence on the flow noise of the elbow pipe. Han (2019) analyzed the flow-induced noise generated by natural gas manifolds using LES and FW-H hybrid method. A noise experiment was carried out to validate the numerical model. The results show that the manifold noise is middle and low frequency noise, and the energy of manifold noise is mainly concentrated in the range of 50–1150 Hz. Ishihara (2008) studied the acoustic characteristics of the straight duct with some holes by experiment and BEM simulation. As a result, it is clarified that the noise reduction effect of holes is slightly effective. Zhang (2014) adopted Large Eddy Simulation model to solve for time varying pressure and velocity fields and used a hybrid LES/Lighthill’s acoustic analogy method to compute hydrodynamic noise of a 90° piping elbow. The sound sources were solved as volume sources in software ACTRAN. The result shows that a guide vane at the right location in the elbow can decrease SPL of a piping with a 90° elbow. Papaxanthos (2015) investigated noise produced by interaction of a low Mach number flow with fixed obstacles inserted in a rectangular duct. The CFD simulation was based on unsteady incompressible LES model and the total pressure was calculated via the Lighthill-Curle analogy. The predicted SPL was compared with experiment results showing good agreements. Yan (2019) analyzed the SPL distribution in standard orifice flowmeter by using the LES and FW-H acoustic analogy theory. The results show that the orifice flowmeter noise is a kind of broadband and mainly low-frequency noise. Chun (2014) combined the LES and FW-H acoustic analogy to simulate the flow distribution and calculate the flow-induced noise for an elbow pipe. The results of simulation were a little higher than experiment results because of the background noise. A kind of elbow with guiding plate was demonstrated to an effective method to reduce the aerodynamic noise. Lu (2009) engaged in establishing a methodology for evaluating the vibro-acoustic attenuation effect by using sandwich damping material on pipe flow.