Noise	Clarification of the Occurrence Mechanism of Discharge Noise Using an Exhaust Pulsation Simulation, and Countermeasures	Transportation Machinery
Noise		

Object Machine

Muffler for internal combustion engine

Observed Phenomena

In order to reduce the exhaust discharge noise generated from a muffler outlet, the diameter of a discharge tube (tail pipe) was reduced with an intention of decreasing the discharge noise. Contrary to our expectation, however, discharge noises increased (mainly higher harmonic components of air flow noise).

Cause Estimation

A conceivable cause for generating air flow noise is a fluid noise phenomenon at the discharge port. Specifically, it is considered that the cause of air flow noise is a vortex ring as a sound source that is induced by pulsating flow emitted from the discharge port.

Analysis and Data Processing

Based on a numerical analysis and experimental data obtained by using a high- speed pulsation generator (Fig.1) that simulates an internal combustion engine, a comparative verification was made. The computational fluid dynamics (CFD) employed a jet flow calculation model (Fig.2, Model B), which combines a compression fluid calculation model (Fig.2, Model A) that uses Navier-Stokes equation, the mass conservation law and the energy law as the governing equations, and the LES (Large Eddy Simulation) method as a turbulent flow model. Results of numerical analysis applied to fluid in the tube indicate the distribution of compression waves and expansion waves, and more particularly, inside the compression wave area, a complex distribution due to the influence of reflected waves is present (Fig.3). In the discharge jet flow space, expansion of spherical sound waves with the compression waves reaching the discharge port at the center is found, together with the formation of several vortex rings, which are visualized by calculations (Fig.4).

Countermeasures and Results

Enlarging the discharge port reduced air flow noises to a large extent. On the other hand, pulsation noises as the rotating speed-related order component increases, but the noise at the exhaust air discharge itself decreased as a whole (Fig.5).

Lesson

Assuming that noises at the air discharge consist mainly of two components; pulsation noises and air flow noises, then it is necessary to design exhaust system of mufflers in consideration always of the balancing of these two sound sources. That is, reduction of pulsation noises requires the reduction of the pressure in tube of the muffler, while flow speed of the discharge jet flow should be reduced for air flow noises. Each design method has something in common, but may be opposite in some cases. This example of discharge port diameter (Fig.6) is the latter.

References

Sakurai et al., Development of technology to estimate the exhaust system radiation sound due to exhaust pulsations; Proceedings of the Society of Automotive Engineers of Japan, Vol.36, No.2, p.71-76, (2005)
Kimura et al., Study on noises to occur from a high-speed pulsation jet flow; Proceedings of the Japan Society of Mechanical Engineers, edition B, Vol.67-664, p.57-64 (2001)

Keywords

Exhaust discharge noise, muffler, fluid noise, exhaust pulsation, internal combustion engine, CFD, LES

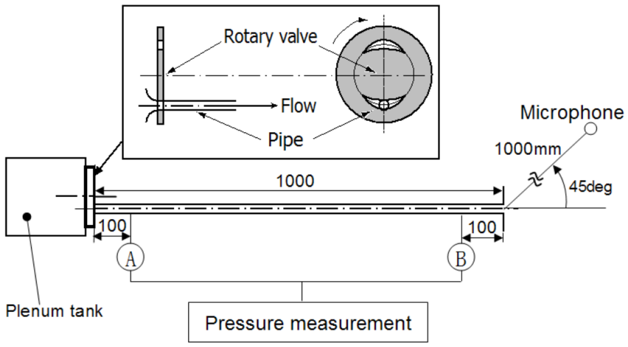

Fig.1 General overview of a high-speed pulsation generator

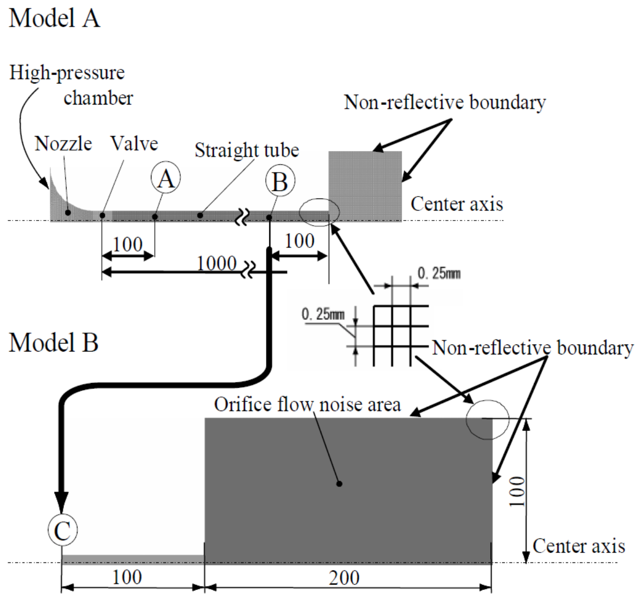

Fig.2 General overview of simulation models

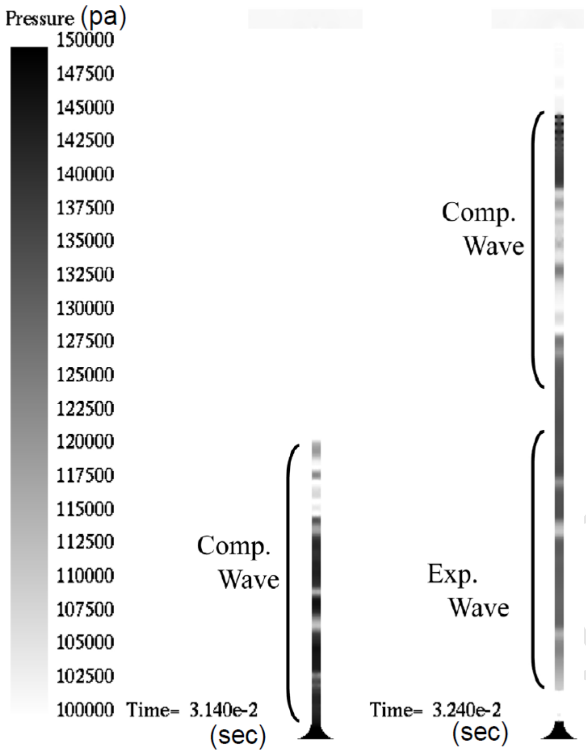

Fig.3 Distribution diagram of tube inside pressure

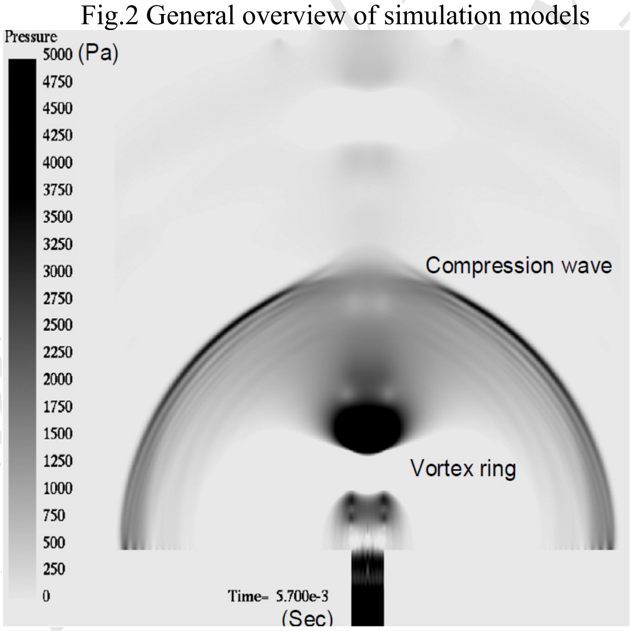

Fig.4 Distribution diagram of discharge jet flow pressure

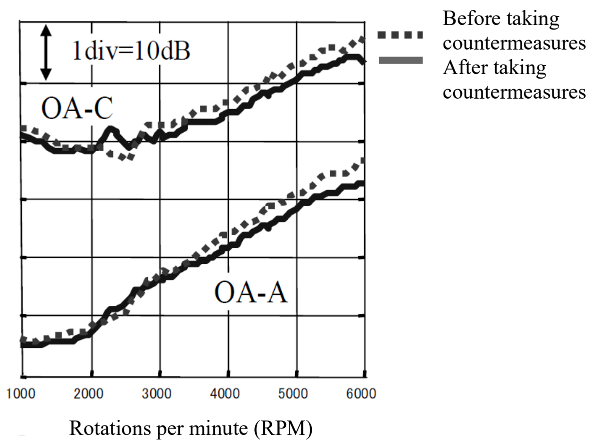

Fig.5 Changes in exhaust discharge sound due to modification of the muffler outlet port diameter

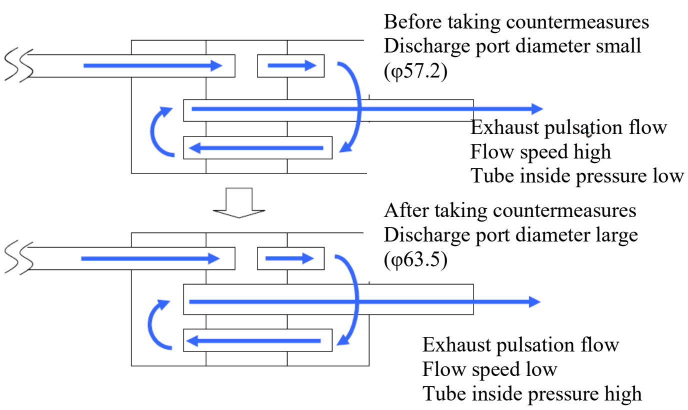

Fig.6 Changes in flow speed and tube inside pressure of exhaust pulsations due to modification of the muffler outlet port diameter