Experimental and Numerical Studies on a Straight Exhaust Pipe

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ABSTRACT

In this study, radiated noise was investigated by experimental and numerical methods for a straight exhaust pipe. In experiment, a motorcycle of EZ 125cc (Kwang Yang Motor Co., Taiwan) was used with a straight circular pipe of diameter 2.3cm that replaced the original exhaust pipe. For temperature measurement, a K-type thermal couple with a data acquisition system (Advantech Inc.) of ADAM-5000 was used, a pressure sensor of PCB-111A21 (PCB Piezotronics Inc.) for pressure measurement, and a Pitot tube for flow speed measurement for different engine speeds ranging from 3000-5000rpm without loading. For sound pressure level (SPL) measurement, a microphone of B&K 4190 (Brüel & Kjær Inc.) and a multi-channel data acquisition system of B&K 3550 were used. The SPLs measured at several positions of 0.5m from the exhaust pipe exit for different directional angles (0°-90°) were recorded and compared with the numerical result. In numerical simulation, a high-resolution Euler solver was used and conducted on a parallel computation system with a cluster of 4 dual-CPU personal computers. The numerical result showed the flow field of blast wave diffraction and its incurred sound pressure distribution. It was found that there are two main sound lobes in numerical simulation. Moreover, the predicted SPL values reasonably agreed well the measured data.

Keywords: Blast wave, vortex ring, Euler equations, sound pressure level, radiated noise.

1. INTRODUCTION

Vehicles like cars and motorcycles have become a necessary traffic tool in a daily life. The accompanying problem associated with vehicles is the noise generated from exhaust pipe. Although the standard of noise control has been regulated to 96dB(A) for stationary noise for limousine and 90 dB(A) for motorcycles in Taiwan, and 76 dB(A) for accelerated noise for limousine and 75 dB(A) for motorcycles of engine volume 50cc-100cc. However, the lower noise than the noise associated with present motorcycles is preferable, in particular, during rush hours. Thus, there is still a need of efforts for studying the motorcycle noise, which is a stepping stone for studying the noise reduction problem by combining experimental and numerical simulation techniques.

Noise associated with an exhaust pipe of automotive internal engines can be classified into three kinds: turbulence noise, vibration noise and radiated noise. In this study, only radiated noise is considered. The sound sources of radiated noise mainly involved of shock wave, vortex ring and their interaction, since the exhaust gas emitted from an internal engine is a pulsating flow with blast waves. A blast wave is a so-called reverse “N” wave in a pressure profile which is a structure of two shock waves and expansion waves, causing the exhaust-flow’s nonlinearity and unsteadiness. Although linear acoustic theory has been developed and widely used, the generating mechanism of radiated noise from the exhaust pipe is still unclear. Due to the complicity of a real exhaust pipe of a motorcycle, a simplified exhaust pipe is considered to be a straight, circular pipe of 59cm in length and 23mm in diameter without a catalyst converter and an expansion chamber. Because the techniques of computational flow dynamics (CFD) and parallel computation were quickly developed and became almost matured, thus we investigate the noise problem by using the parallel CFD technique with experimental method.

In the past, there were many papers reported about the noise generated from an exhaust pipe. Due to the paper space, only some recent papers are mentioned here. Kim and Setoguchi investigated the downstream pressure variation of a shocked flow discharged from an open ended shock-tube with a circular baffle plate at the tube exit by using both experimental and numerical methods. Higashiyama and Iwamoto experimentally studied the noise generated by a pulsating flow downstream of a pipe end. Their data also showed the directivity of sound pressure. Endo et al. analyzed the noise relation between the directional angle and the rotation speed of a rotary valve in detail. They also compared the sound pressure distributions for different directional angles at various rotation speeds of the rotary valve. Chen and Liang investigated a planar blast/vortex interaction and its generated noise, and found four sounds generated for the blast/vortex interaction.