High resolution central schemes for multi-dimensional non-linear acoustic simulation of silencers in internal combustion engines

F. Piscaglia *, A. Montorfano, G. Ferrari, G. Montenegro

Dip. di Energia, Politecnico di Milano, Via Lambruschini 4, I-20156 Milano, Italy

A R T I C L E   I N F O

Article history:
Received 11 October 2010
Received in revised form 8 December 2010
Accepted 13 December 2010

Keywords:
Computational Fluid Dynamics
CFD
Acoustic simulation
Central schemes
Numerical methods
Internal combustion engines

A B S T R A C T

Because of their small numerical viscosity even when very small time steps are enforced, central schemes look very suitable for acoustic simulations of silencers in internal combustion engines. In this work, a high resolution central scheme has been used with ad-hoc developed boundary conditions for the generation of different acoustic perturbations (white noise, sweep, impulse) in the OpenFOAM® technology. The temporal solution, carried out by a first-order integration of the conservation laws by the explicit Euler’s method, has been first transferred into the frequency domain using FFT and then it has been processed to evaluate the transfer function of different geometries of silencers for internal combustion engines. The results obtained from the simulations have been compared with experimental data.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Internal combustion engines are the source of mechanical, combustion and gas dynamic noise. In particular, gas dynamic or pulse noise is related to unsteady flows in the intake and exhaust systems and it is mainly caused by the cylinder gas exchange process. The level and quality of noise radiated from the open ends can be controlled by a different arrangement of pipe systems and silencers, to achieve the required vehicle sound characteristic. Generally numerical simulation codes are very useful during the design and optimization process of manifolds and mufflers, to quickly define a geometry that will be refined experimentally. The attenuation features of simple and complex acoustic filters can be predicted by 1D and multi-dimensional fluid dynamic/acoustic simulation codes with different levels of complexity. Nowadays nonlinear 1D and CFD fluid dynamic codes, based on the complete solution of the fundamental conservation equations, are widely used in acoustic simulation since they allow the prediction of silencer performance and radiated pulse noise when the duct system is connected to the engine source itself, subjected to finite amplitude pressure waves and significant mean-flow velocity. The aim of this paper is to define a reliable methodology to predict silencer performance that does not require the use of acoustic corrective lengths. First, results obtained by non-linear fully multi-dimensional acoustic simulations of silencers for internal combustion engines are presented. Simulations have been performed on three different geometries (two expansion chambers and a resonator) derived from automotive applications. An ad-hoc developed boundary condition developed in the OpenFOAM® technology to generate different kinds of acoustic perturbations was coupled with a high resolution numerical scheme. The resulting code, along with an accurate numerical setup considerably improved the accuracy of the results in a reasonable computational time.

* Corresponding author. Tel.: +39 02 2399 8620; fax: +39 02 2399 3863.
E-mail address: federico.piscaglia@polimi.it (F. Piscaglia).

0895-7177/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.