Investigation of Boundary Condition Treatment in 1D/3D CFD Code Coupling for SI Engines Simulation

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Abstract

While moving towards the ultimately variable engine types and configurations, computational methods for the calculation of gas dynamics within the engine are becoming of growing importance. The gas exchange process includes a lot of phenomena that makes it difficult to be completely simulated with analytical models. Due to different effects that appear in the process, several techniques have been used for numerical study of the dynamic behavior of gases in intake and exhaust manifolds.

In the first case, one–dimensional models have been used inside pipes, joined to zero–dimensional models for cylinders, with the great advantage of a fast computational time, but requiring empirical constants to simulate more complicated phenomena. In the second place, three–dimensional models, calculating the flow field have been used in special zones, i.e. intake manifold, cylinders etc... One–dimensional (1D) gas dynamic codes, specifically for engines, have been steadily improving over the last two decades, despite the fact that limiting all the processes to one dimension, makes this process inherently inaccurate. To compensate for this weakness three dimensional (3D) CFD methods were introduced. These 3D-CFD simulation tools (e.g. KIVA) compute the flow field based on three dimensional Reynolds–averaged Navier–Stokes equations, giving a spatially resolved, realistic image of the processes inside an engine component.

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The object of this work is to investigate the effect of boundary condition treatment on 1D/3D code coupling for simulation of SI engines as a new modeling approach. To this end, an interactive coupling method between commercially available three-dimensional KIVA 3V code and a one–dimensional gas dynamic code has been introduced. In the current paper, underlying physics and numerics for the most effective method of treatment and implementing boundary conditions to achieve such a comprehensive model, along with the most proper averaging procedure adopted to 3D boundaries, among different methods and procedures has been investigated and introduced. In order to apply the new approach, a SI engine has been simulated. While treating the intake and exhaust ports and cylinders of an IC engine with 3D model, the rest of engine components are represented as a system of 1D components.