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Instabilities and transition in three-dimensional flows with rotation

INFLUENCE OF PISTON POSITION ON THE SCAVENGING AND SWIRLING FLOW IN TWO-STROKE DIESEL ENGINES

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1 Introduction

We study the effect of piston position on the in-cylinder swirling flow in a low speed large two-stroke marine diesel engine model. We are using Large Eddy Simulations in OpenFOAM, with three different models for the turbulent flow: a one equation model (OEM), a dynamic one equation model (DOEM) and Ta Phuoc Loc's model (TPLM). The simulated flows are grid-independent and they are computed in situations analogous to two different piston positions where the air intake ports are uncovered 100% and 50%, respectively. We find that the average flow inside the cylinder changes qualitatively with port closure from a Burgers vortex profile to a solid body rotation while the axial velocity changes from a wake-like profile to a jet-like profile. The numerical results are compared with measurements in a similar geometry [3] and we find a good agreement between simulations and measurements. Furthermore, we consider the unsteady flow and identify a dominant frequency in a power spectrum based on velocity which we show is due to precession of the vortex core, and compare with measurements of the unsteady flow obtained with Laser Doppler Anemometry.

2 Numerical methods

We study the swirling flow numerically using large eddy simulations [6, 5]. We apply three different models. The one equation eddy model where the kinetic energy k is solved while another scale is estimated [7, 1, 5, 4, 6], the dynamic k-equation eddy-viscosity model, where the model constants are recalculated during the simulation rather than to be pre-calculated [2, 5, 6] and the Ta Phouc Loc model, which is based on the velocity-vorticity (v-ω) formulation of the Navier-Stokes equations, where two spatial filters are used [8, 9].

3 Computational domain and results

The computational domain is shown in Fig. 1 (a). Flow enters uniformly at an oblique angle which ensures the overall in-cylinder swirling flow as shown in Fig. 1 (b) [3]. All the results are obtained by simulating the flow on a grid with 8 million cells.

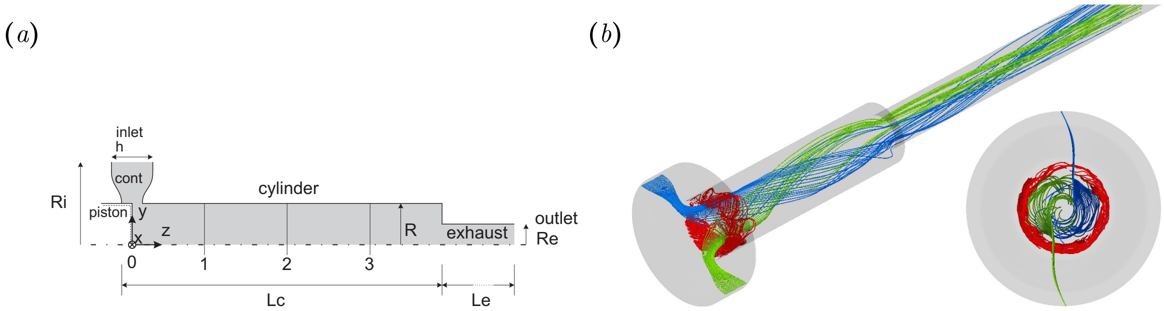

Figure 1: (a) Sketch of the cylindrical computational domain shown in grey shades, in the case where the piston covers the intake ports by 50%. Flow enters radially through the horizontal inlet section and exits through the vertical outlet. Notice that the exhaust is shortened in the figure. Data are extracted at the enumerated cross-sectional planes marked by z_i, and $R = 9.5$ cm. (b) Visualization of the three-dimensional time average streamlines (in blue and green colors) of the mean-field for the 100% open port case. Notice the 'braided' separation region shown by red streamlines and the modest pitch of the flow in the main cylinder. The small inset shows the swirling motion of the streamlines

Fig. 1 (*b*) shows the time average stream lines for the 100% open port case. The results shown in Fig. 2 demonstrate that the simulations capture the wake and jet like profiles of the axial velocity but both are not as pronounced as in the experimental results.

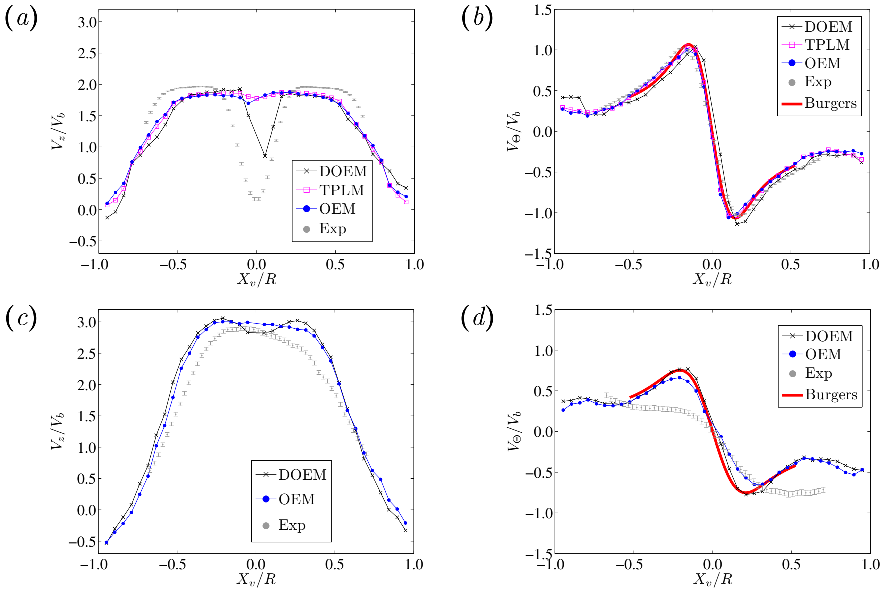

Figure 2: (*a*,*b*) Time averaged axial and tangential velocity profiles for the 100% open ports, (*c*,*d*) Time axial and tangential velocity profiles for the 50% open ports, at the axial position $z1/2R = 0.96$.

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