Application of Large Eddy Simulation technique for the Calculation of Internal Combustion Engine Flows

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Computational Fluid Dynamics is widely used in today's I.C. engine simulations and with the aid of advanced combustion models and spray models CFD has been proven to reproduce experimental trends and engine operating characteristics very well when compared with experimental data. Further improvements could be made to current prediction capabilities by improving turbulence modelling as combustion characteristics depend on flow, turbulence and swirl conditions which exist at the start of combustion. Large Eddy Simulation technique in this regard is a better and more accurate modelling technique compared to RANS based techniques. LES will also allow the possibility of predicting cycle-to-cycle variations in engine flow condition. In this project, work has been undertaken to implement LES capabilities to calculate flow characteristics in engine configurations. The well-known KIVA-4 engine computational code is being used for this work.

KIVA - 4 is the latest of RANS based CFD flow solvers of KIVA series, capable of simulating three-dimensional, multispecies gaseous flows under steady and transient conditions. KIVA solves the governing equations in an Arbitrary Lagrangian Eularian framework and has the ability to handle unstructured meshes with moving boundaries.

During the present work, the Large Eddy Simulation capability has been implemented in the KIVA 4 code and comprehensively validated against experimental flow measurements. An eddy viscosity model based on the sub-grid scale kinetic energy has been implemented where a separate transport equation is solved for the sub-grid kinetic energy. As validation test cases, the performance of the improved formulation has been tested in a backward facing step problem and an axisymmetric engine configuration. Calculated mean and rms velocity profiles were compared against measurements and found good agreements. In addition, the results were compared with KIVA-RANS predictions and the present improvements appear to be quite impressive. The model sensitivity has further been investigated in different mesh configurations with unstructured hexahedron elements. The validated model was then applied to simulate the full cycle motored flow in a Ricardo E6 engine and to visualize the in-cylinder flow structures.