Numerical Simulation of Twin Nozzle Injectors

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Background

As compliance to all the recent stringent emission requirements can be achieved with gas fueled engines, it is expected that such engines will gain popularity among ship operators. Traditionally two different injectors are used to facilitate the necessary diesel fuel in a dual fuel engine; One for small quantity pilot injections and another for larger quantities injected during diesel mode operation. Injector manufacturers have looked upon how to omit the use of a second diesel injector. They regard twin nozzle injectors as a promising approach due to their potential ability to facilitate stable spray patterns independent of the fuel quantity delivered through the nozzle. If true, the small and large quantity diesel injector can be replaced by one injector that serves both purposes.

Motivation

It is believed that twin nozzles can improve mixture formation for the combustion process for diesel applications in general. NOx and soot formation is supposedly reduced through better fuel atomization and evaporation. A twin nozzle also liberates space in the cylinder head which may allow for more efficient valve sizes and combustion chamber geometries. Removal of one injector renders a decrease in CAPEX and OPEX as installation and maintenance costs are reduced.

Objective

Study internal nozzle flow and spray behaviour of a prototype nozzle provided by injection manufacturer L'Orange. Furthermore, investigate how this nozzle responds to different common rail and in-cylinder pressures.

Methods

- The commercial CFD code AVL Fire is utilized in this study.
- The high Reynolds number k-ε is chosen
- To predict cavitaion the nozzle flow is a three phase flow (fuel, air, vapour).
- The transient nature of the flow is affected by the needle movement. This effect is accounted for by moving the grid during the simulation to replicate the needle movement
- To predict caviation the nozzle flow is a three phase flow (fuel, air, vapour).
- The temperature in the computational domain is kept ambient. This is common when investigating fuel spray behaviour as the fuel is not allowed to combust or vapourize allowing measurements of the atomization process.

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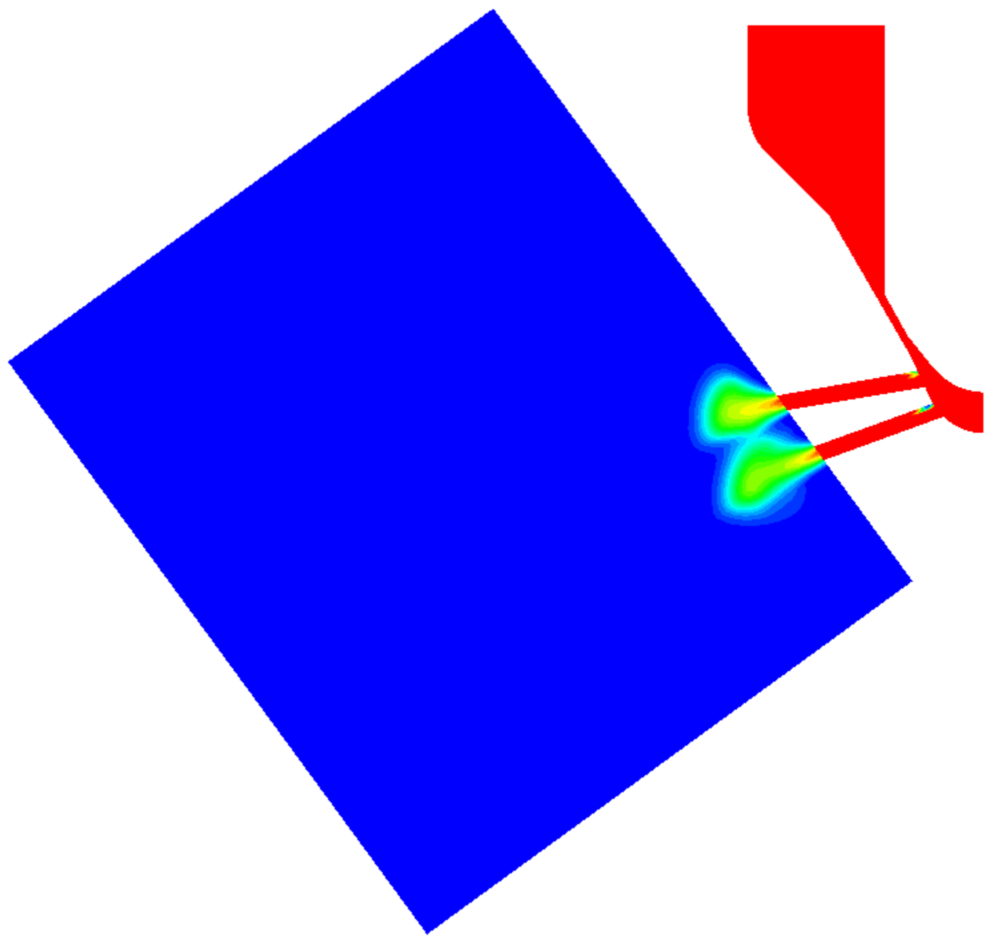
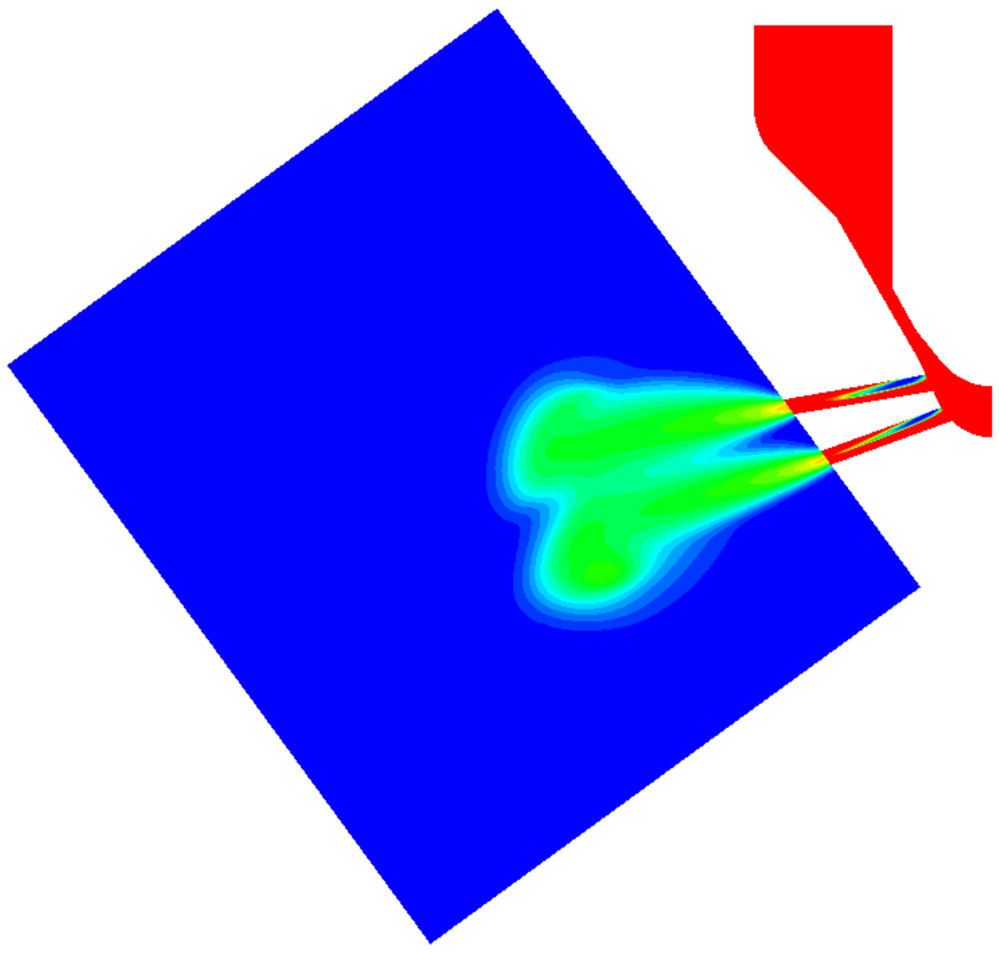
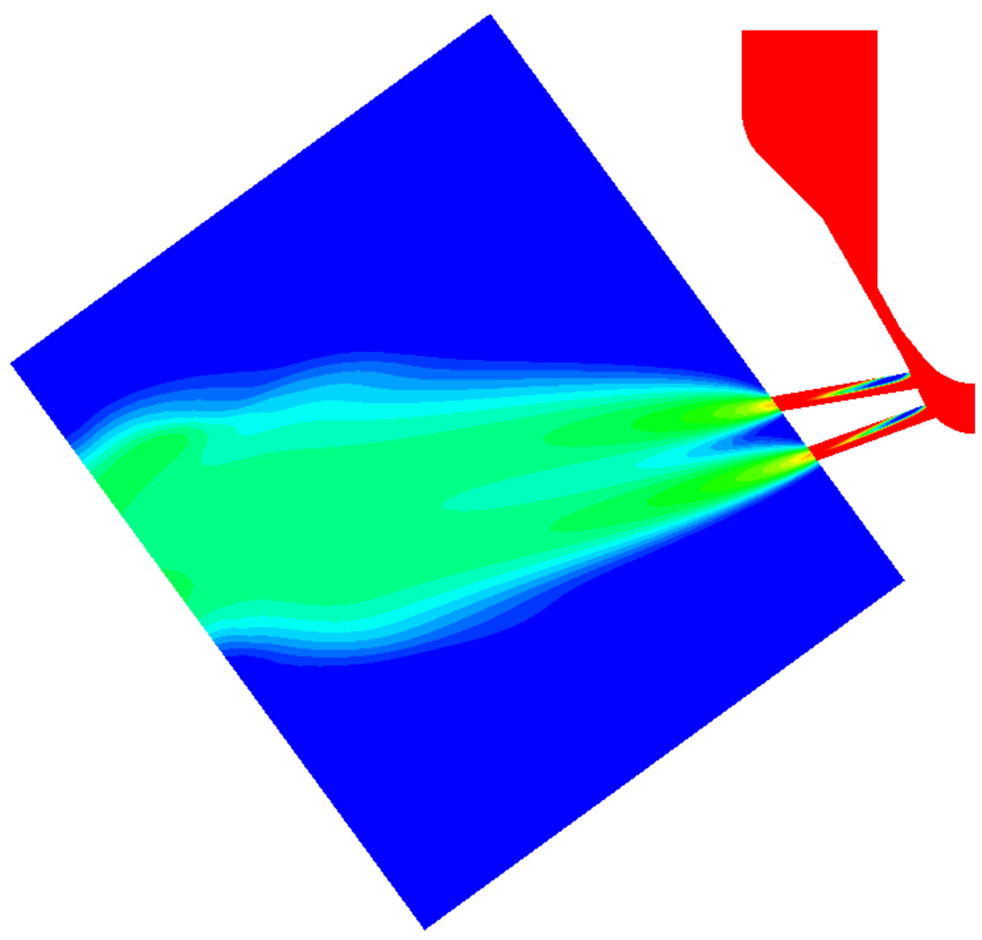
Visualization



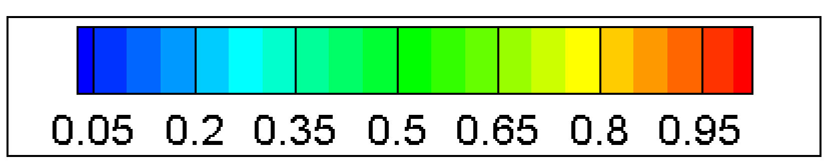
50 μs after injection start



200 μs after injection start



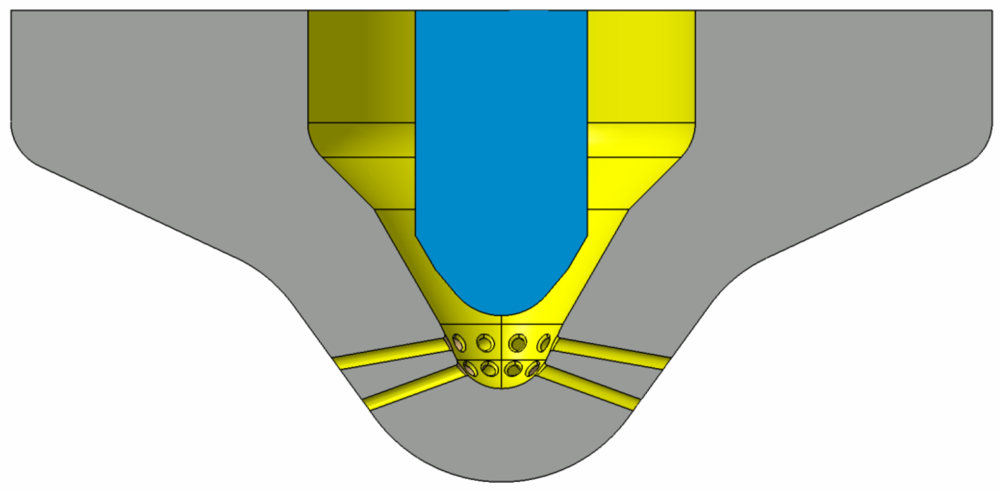
660 μs after injection start



Volume fraction of the diesel fuel phase

Modelling

The nozzle has 10 orifice pairs which are equispaced with 36 degrees between each of them. All orifices have constant diameter of 0.27mm. Due to symmetry it is sufficient to simulate only 18 degrees of the 360 degree nozzle. The grid is block-structured containing four blocks.



Results

Numerical simulations show:

The mass flow through the upper orifice outlet is greater than the lower. Hence is the pressure drop and normalized velocity through the upper injector hole also greater. The total cross sectional area of the orifices and the mass flow does not scale linearly with single nozzle orifices. For a single hole nozzle a orifice diameter of 0.38mm is needed to produce the same mass flow as a twin nozzle of 0.27mm.

Cavitation is present in the area of both injector hole inlets, though more severely in the upper. Cavitation intensifies as the rail pressure increases.

The flow in the bottom of the nozzle, called the SAC volume, is rotating. This recirculation area renders a higher turbulent kinetic energy for the flow through the lower injector hole.

Conclusion

The numerical model shows now obvious advantages compared to ordinary single hole nozzles. The present study is preliminary due to its absence of a spray-break up model. However, the calculated values can be used as initial boundary conditions for a spray calculation.

See full movie of spray visualization: