EGR Mixing

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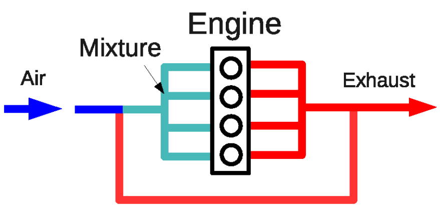
Abstract

This project deals with turbulent mixing processes occurring in internal combustion engines, when applying exhaust gas recirculation (EGR). One of the practical problems when applying EGR is the non-uniformity of the mixture among and inside the cylinders deteriorating the engine and emission performance.

Background

Emission legislation has become more and more strict throughout the last decades. This is problematic for engine manufacturers, who have to introduce new techniques in order to comply with these regulations. Most problematic for Diesel engines are the NOx emissions. NOx is formed at high combustion temperatures. One way to reduce the peak combustion temperatures is to lower the oxygen concentration of the combustion gas. This is done by EGR. A portion of the exhaust gases is recirculated and mixed with the intake air.



EGR working principle.

The issue that this project is addressing is the mixture non-uniformity of the exhaust gases and the intake air, which has shown to have negative effects on the engine and emission performance.

Method

Since the distribution of EGR is difficult to measure, the aim of the project is to compute it by CFD. Computing the turbulent flow and the turbulent mixing process is, however, not a trivial task. Different model approaches, RANS and LES, are therefore applied. The shortcomings and advantages of these approaches are assessed, first in simplified geometries with stationary and pulsating inflow conditions, then in realistic geometries with boundary conditions from GT-Power simulations. Furthermore, the sensitivity of the results to the boundary conditions shall be evaluated.

The GT-power simulations are preformed by another Ph.D.-student inside the center, Simon Reifarth, who is also performing experimental measurements of the EGR distribution. It will be tried to validate the results in close cooperation.

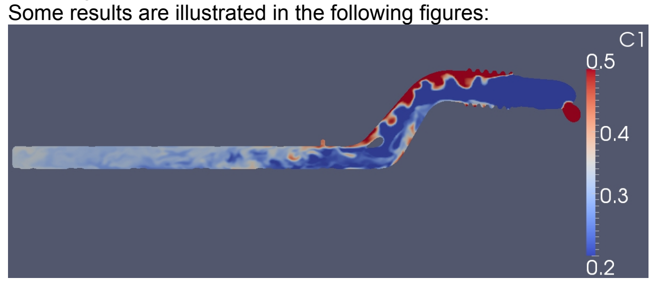
T-junction

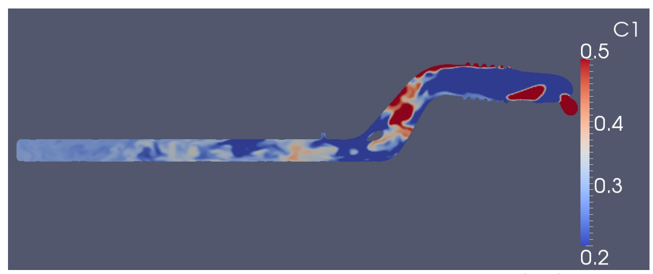
As a first approach, mixing processes were studied in a T-junction with stationary and pulsating inflow conditions. The main results in stationary flow are that RANS predicts fundamentally different flow structures from the LES computations. Dean vortices that occur due to the flow curvature are broken up by high turbulence intensities occurring downstream of the junction. The flow instabilities due to high velocity gradients are the main mechanism promoting turbulent mixing. When applying pulsating inflow conditions, these instabilities are amplified, if the pulsation frequencies are in the same order as the natural instability frequencies. Since RANS models the scales of these instabilities, these resonance effects cannot be predicted by RANS.

Scania manifold

Computations on a 6-cylinder Diesel engine manifold provided by Scania were performed applying RANS and LES. In this first study generic boundary conditions were applied with both stationary and pulsating EGR flow.

Some results are illustrated in the following figures:





Instantaneous concentration, top: stationary EGR flow, bottom pulsating EGR flow

Instantaneous concentration differences of up to 10 % are found in the flow into the cylinders. Pulsations are important for the mixture formations and are travelling down the fairly far downstream without being diffused.

Conclusions

The studies on the engine manifold show that the effect of pulsating boundary conditions is important. Moreover, it has been found that the smoothing effect of URANS does not seem to be adequate for accurate mixing computations for cases, where turbulence is governing the mixing.

Future computations will therefore focus on LES computations with boundary conditions from GT-Power and/or experiments.

The results summarized here have been presented in the licentiate thesis ‘On the computation of Turbulent Mixing Processes with application to EGR in IC-engines including the two conference articles:

‘LES of the turbulent mixing process in a T-junction with stationary and pulsating inflow conditions’, presented at ISAIF10, and

‘Computation of mixing processes related to EGR’, presented at TSFP7.