Extended summary Project COSTGAS – Combustion System Development for the Next Generation Heavy Duty Gas Engines

COSTGAS is a project within heavy duty engine technology for CNG engines and is aimed to improve the existing gas engines for Euro VI. The goal of the project is to improve the maximum torque output from the engine by 10 % while increasing the efficiency of the engine by 10 % compared to current production engines.

During the project the goals were revised and the torque output was possible to increase by up to 20 %, which was set as a new goal. The improvements are intended to be implemented while observing the boundary conditions set by the Euro VI emissions regulations. This project covers the background and testing of different piston designs and the influence of swirl on the combustion characteristics. The project will also cover earlier developments within combustion systems as well as the fluid mechanics involved.

COSTGAS was performed within the program by the Swedish Energy Agency, “Samverkansprogram inom Energigasteknik 2013-2017” (Interaction program within energy gas technology). The financing has been put forward by AVL MTC AB and The Swedish Energy Agency. Scania CV is also a partner within this project. The changes to the engine proposed in this project are intended to increase the use of renewable fuels, for instance Biogas, in the commercial vehicle fleet.

In the project COSTGAS the focus lies on the development of the combustion system why variations of this have been tested on a research engine with careful monitoring of the combustion process. The main thesis of the project is to investigate the fluid mechanics and its influence on the combustion system, to investigate improvements in combustion duration and reduced exhaust gas emissions. The investigative tests will be performed through engine testing on a single cylinder research engine in a test cell.

The increased demands for Euro VI have led to a shift in technology towards stoichiometric combustion with EGR in order to meet emissions legislation. For the previous generation gas engines lean burn technology was used instead which requires improved fluid mechanics such as swirl to improve the combustion velocity for the otherwise slower combustion speed in these engines. For Euro VI engines, the same problem does occur when introducing cooled EGR, which for the later technology is used to reduce the thermal load and to mitigation of knock.

The use of EGR as a thermal damper does entail that the combustion speed is reduced which results in a poorer combustion quality, why it is critical to improve the combustion speed for stoichiometric Euro VI gas engines as well, through increased turbulence. Vice versa does an increase in turbulence also entail a potential of mixing in even larger amounts of EGR to be able to further increase the specific performance of the gas engine. This leads to an increase in torque output while keeping the thermal load on the engine down.

Apart from this thermal benefit for the engine ancillaries, an increase in EGR also leads to a reduction in thermal NO_x which is created under high combustion temperatures. More advantages of increased EGR is that the pumping losses during throttling of the engine can be reduced by increasing the manifold absolute pressure with this inert gas which does not affect the air/fuel ratio.

For the initial part of the project a literature survey investigated previous research within the field of gas engine piston shapes and combustion chamber layouts, but also the parameters which surround gas engines as an entity. Here the characteristics of the gaseous fuel and their mixing capabilities are of great importance, as it affects the gas management into the combustion chamber. These factors also affect how the fuel is combusted and at which speed.

For the chosen combustion system, the focus is on swirl, radial rotation around the piston axis, and on squish, the flow motion that occurs as the distance between the distance between the piston and combustion chamber roof is decreased around top dead center. Through an increase in squish length, the flow velocity down into the piston bowl is increased, which should thereby lead to an increase in gas motion and improved gas mixing. The literature survey does, however, show that a too high flow velocity around the spark plug may lead to problems with igniting the fuel as the initial flame may be snuffed out prior to igniting the air/fuel mixture. This entails that the parameters swirl and squish cannot be selected at random, but requires further investigation. By performing engine testing on a research engine in a single cylinder test cell, the combustion process can be more carefully monitored without the influence from other cylinders in the engine.

The testing method which has been chosen is engine testing with different variations of the pistons which has the best potential to reach the goals, as well as a variation of cylinder heads which can provide different levels of swirl in the combustion chamber. Through the variations in squish-to-bore ratio, squish as a function of the bore diameter, the parameter which aids the most optimal gas mixture for this kind of air motion-assisted engine is investigated. The level of swirl is investigated for both higher and lower levels compared to the baseline, in order to explore how the rotational speed of the combustion charge affects the combustion when varying squish. Vice versa it is also possible to investigate how squish alters the combustion when maintaining the swirl constant, in the testing matrix. This combustion concept will also be possible to implement for a lean-burn engine to further improve efficiency.

For a wide area of evaluation, the results of how the engine operated was chosen from an array of operating points based on the World Harmonized Steady State Cycle. This cycle specifies the engine speed and load based on the torque curve of the engine. The array was enlarged by three operating points in order to cover an even larger area of operating points, in respect to EGR-tolerance and combustion stability at both high and low engine loads.

The results from this project will be presented when the technical content can be released for publication. This will happen on the Swedish Energy Agency’s website, http://www.energimyndigheten.se/forskning-och-innovation/projektdatabas/