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Publishable summary

A combustion chamber thermal insulation applying the thermal swing effect delivers a significant potential to reduce wall heat loss and increase thermal efficiency.

Research focused on different methods for reducing heat losses through heat insulation of the internal combustion engines went back to the 1980s. The idea behind a low heat rejection engine consists into obtaining a high wall temperature inside the combustion chamber to reduce the heat transfer from the gas to the wall. This has been obtained by introducing low thermal conductivity and high heat capacity materials. However, the downside of this method is represented by a much higher average surface temperature inside the combustion chamber even during the intake and compression phases, deteriorating the volumetric efficiency of the engine and reducing the ignition delay. Resulting in higher fuel consumption and pollution due to the higher gas viscosity which slows the mixture formation during injection.

Literatures of research from 2010 on conclude that the material properties and surface structure are key parameter. A porosity in a range of 20-30 % delivers an optimal trade-off between thermal conductivity and heat capacity and a coating thickness around 200 µm is recommended to enable thermal swing. Further, a smooth coating surface is required that is not deteriorating the mixture formation resulting in a poor combustion. Nevertheless, it is also known from various literature that only limited benefits could be demonstrated through engine investigations so far and establishing thermal barrier coatings for series production is not realized yet.

A numerical analysis approach by means of 3D-CFD combustion and 1D thermal conduction simulations is established in this project to understand the heat loss reduction potential of the applied piston coating. First a 3D-CFD combustion simulation is performed to determine the heat transfer to the piston surface. Second, the heat flux inside the piston material is solved through a 1D thermal conduction model of the piston considering a sandwich-insulation coating of a metal-ceramic layer. The model is able to capture thermal swing resulting in a heat loss reduction of 12 % over the piston body.

Experimental investigations are performed on a HD single cylinder engine to approve the potential of thermal insulations with respect to lower wall heat losses and improved thermal efficiency. Therefore, a coated piston and coated cylinder head (flame deck, valves, exhaust ports) are investigated. The results showed a significant potential enabling an overall reduced wall heat transfer of 14 % leading to a thermal efficiency increase of 1.8 %. It turned out that the used prototype coating of the cylinder head is not durable and requires further development. Nevertheless, the prototype coating contributes to an additional heat loss reduction, and it is expected that a durable flame deck coating delivers further improvements.

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Project partners:

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