Heat Transfer in Large Two-Stroke Marine Diesel Engines

Heat transfer between the cylinder gas and the piston surface during combustion in large two-stroke uniflow scavenged marine diesel engines has been investigated in the present work. The piston surface experiences a severe thermal load during combustion due to the close proximity of the combustion zone to the surface. At the same time, cooling of the piston crown is relatively complicated. This can cause large thermal stresses in the piston crown and weakening of the material strength, which may be critical as it can lead to formation of cracks. Information about the piston surface heat transfer is thus important for the engine manufactures.

The piston surface heat transfer was studied in the event of impingement of hot combustion products on the piston during combustion, and an estimate was obtained of the peak heat flux level experienced on the piston surface. The investigation was carried out numerically by performing simulations with a CFD code of the heat transfer between gas and wall in a jet impingement configuration where a hot round turbulent gas jet impinged normally onto a wall under conditions approximating the in-cylinder conditions in the engine during combustion.

A jet impingement reference case was first established based on estimations of the incylinder conditions during combustion. Subsequently, variations of different jet impingement parameters were performed and the influence on the wall heat transfer was observed. In all the cases, the ratio between the jet inlet to wall distance, H, and the jet diameter at the inlet, D, was H/D = 2. The jet Reynolds number, Re, varied between 1.10×10^5 and 6.64×10^5. The resulting Nusselt numbers along the wall were calculated for dimensionless radial distances from the stagnation point, r/D, between 0 and 6. The maximum Nusselt number was located in the stagnation point in most of the investigated cases, and an analysis was performed of the variation of the stagnation point Nusselt number, Nu0, with the jet Reynolds number and the jet turbulence intensity at the jet inlet, TI. Based on the observed relations, a correlation between Nu0, Re and TI is suggested for high jet Reynolds number cases. A satisfactory validation of the correlation was not possible to perform due to insufficient available experimental data. A comparison of the correlation predictions to existing experimental data indicated however an overprediction of Nu0 in the magnitude of 50% – 100%. The overprediction is considered to be caused primarily by incorrect numerical model predictions. Based on the performed jet impingement heat transfer investigations, an estimate is provided of the peak convective piston surface heat flux level experienced in the considered large marine diesel engines. The contribution from thermal radiation to the piston surface heat flux was not investigated in the present work, but a coarse estimation of the magnitude was performed. The obtained estimations indicate a peak piston surface heat flux level in the interval from about 1 MW/m^2 and up to 9.5 MW/m^2 with the actual value probably being in the lower part of this interval. This is about the same magnitude as that previously reported for automotive size diesel engines. The obtained interval is relatively large, but a more accurate prediction is difficult to achieve with the applied method due to limited knowledge about the actual local in-cylinder conditions during combustion. Therefore, further research in this area is encouraged.

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