W02

An average small car engine consumes 5 liters of diesel per 100 km of driving. Now, let's consider a scenario where we have a car traveling at an average speed of 60 km/h. During this operation, the car's engine generates an average of 21 kW of heat. Diesel has an LHV of 35.8 MJ per liter.

The outer surface of an engine is located in an area where oil leakage can occur, and if the leaked oil comes into contact with a hot surface having a temperature above its autoignition temperature, it can ignite spontaneously, posing a fire hazard. To address this concern, engineers have designed an engine cover made of an aluminum plate with a thickness of 2 cm and a thermal conductivity of 237 W/mK.

The inner surface of the engine cover, which is exposed to hot air, maintains a temperature of 330 ^{o}C. To prevent fire risks in the event of an oil leak onto the engine cover, a layer of thermal barrier coating (TBC) with a thermal conductivity of 1.1 W/mK is applied to the outer surface of the engine cover.

For this analysis, we consider the engine's surface area to be 1.1 m^2. The application of the TBC acts as a thermal insulator, reducing the rate of heat transfer from the hot inner surface to the outer surface of the engine cover. This insulation layer helps in lowering the temperature of the outer surface, thereby minimizing the risk of oil autoignition and potential fire hazards.

By implementing this thermal barrier coating, engineers aim to enhance the safety and reliability of the engine while ensuring optimal performance even in challenging operating conditions.

a Give the definition of efficiency.

b What is the efficiency of the car engine? State the assumptions that are made.

c Provide a sketch of the thermal network. Include all known temperatures, resistances, and the direction of the flow of heat. Explain each component.

d Determine the heat flux through the wall of the engine.

e Would a TBC layer of 8 mm in thickness be sufficient to keep the engine cover surface below the autoignition temperature of 200 °C to prevent fire hazards?

f Determine the temperature at the interface between the aluminium and TBC layer.

g Give a sketch of the temperature profile inside the layers of the car engine.

Note: Clearly indicate the change in temperature in the axial direction, the change in slope at the interface. Lastly, indicate the numerical value of the temperature at the interface