World Academy of Science, Engineering and Technology
International Journal of Transport and Vehicle Engineering
Vol:14, No:04, 2020

Investigation of Software Integration for Simulations of Buoyancy-Driven Heat Transfer in a Vehicle Underhood during Thermal Soak

Authors : R. Yuan, S. Sivasankaran, N. Dutta, K. Ebrahimi

Abstract : This paper investigates the software capability and computer-aided engineering (CAE) method of modelling transient heat transfer process occurred in the vehicle underhood region during vehicle thermal soak phase. The heat retention from the soak period will be beneficial to the cold start with reduced friction loss for the second 14°C worldwide harmonized light-duty vehicle test procedure (WLTP) cycle, therefore provides benefits on both CO_2 emission reduction and fuel economy. When vehicle undergoes soak stage, the airflow and the associated convective heat transfer around and inside the engine bay is driven by the buoyancy effect. This effect along with thermal radiation and conduction are the key factors to the thermal simulation of the engine bay to obtain the accurate fluids and metal temperature cool-down trajectories and to predict the temperatures at the end of the soak period. Method development has been investigated in this study on a light-duty passenger vehicle using coupled aerodynamic-heat transfer thermal transient modelling method for the full vehicle under 9 hours of thermal soak. The 3D underhood flow dynamics were solved inherently transient by the Lattice-Boltzmann Method (LBM) method using the PowerFlow software. This was further coupled with heat transfer modelling using the PowerTHERM software provided by Exa Corporation. The particle-based LBM method was capable of accurately handling extremely complicated transient flow behavior on complex surface geometries. The detailed thermal modelling, including heat conduction, radiation, and buoyancy-driven heat convection, were integrated solved by PowerTHERM. The 9 hours cool-down period was simulated and compared with the vehicle testing data of the key fluid (coolant, oil) and metal temperatures. The developed CAE method was able to predict the cool-down behaviour of the key fluids and components in agreement with the experimental data and also visualised the air leakage paths and thermal retention around the engine bay. The cool-down trajectories of the key components obtained for the 9 hours thermal soak period provide vital information and a basis for the further development of reduced-order modelling studies in future work. This allows a fast-running model to be developed and be further imbedded with the holistic study of vehicle energy modelling and thermal management. It is also found that the buoyancy effect plays an important part at the first stage of the 9 hours soak and the flow development during this stage is vital to accurately predict the heat transfer coefficients for the heat retention modelling. The developed method has demonstrated the software integration for simulating buoyancy-driven heat transfer in a vehicle underhood region during thermal soak with satisfying accuracy and efficient computing time. The CAE method developed will allow integration of the design of engine encapsulations for improving fuel consumption and reducing CO_2 emissions in a timely and robust manner, aiding the development of low-carbon transport technologies.

Keywords : ATCT/WLTC driving cycle, buoyancy-driven heat transfer, CAE method, heat retention, underhood modeling, vehicle thermal soak
Conference Title : ICVTM 2020 : International Conference on Vehicle Thermal Management
Conference Location : Lisbon, Portugal
Conference Dates : April 16-17, 2020