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NUMERICAL INVESTIGATION OF THE AIR FLOW IN A SIMPLIFIED UNDERHOOD ENVIRONMENT

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ABSTRACT–Thermal management plays a crucial role for the energy efficiency of electrified vehicles. Using numerical flow simulations, the air paths and temperature distributions in the underhood can be identified and optimised early in the development process. However, the numerical method needs to be verified in its accuracy for capturing the important flow features in the underhood. In this study, a numerical approach is developed that is robust with respect to spatial and temporal resolutions as well as to different turbulence models. The methodology is validated against experimental data from LDA measurements. The geometric configurations investigated are representative of electrified vehicles, with one or two front opening designs, two different fans, and with or without a blockage behind. The results showed that for one of the fan installations, although the major flow field structures were well captured, the locations of the peak velocities did not match the experiments. For the second fan, the CFD results agreed well with the measurements.

KEY WORDS : Vehicle thermal management, CFD, Cooling fan, Simplified underhood, BEV, HEV

NOMENCLATURE

$C_{u_i u_i}$: two-point correlation factor
k_{mod} : modeled turbulent kinetic energy, m^2/s^2
k_{res} : resolved turbulent kinetic energy, m^2/s^2
$k_{res,\%}$: percent of turbulent kinetic energy that is resolved
u_i : velocity components, m/s
R : outer fan radius, m
x, y, z : coordinates, m
y^+ : dimensionless wall distance
ε : turbulent dissipation rate, m^2/s^3
ω : specific dissipation rate, s^{-1}

SUBSCRIPTS

A, B : corresponding fan
RMS : root mean square

1. INTRODUCTION

From 2010 to 2019, the amount of electrified vehicles (EV) on the roads has globally increased from a few thousand to over seven million (Global EV Outlook 2020, 2020), and this number is expected to further increase. Energy efficiency is one of the main challenges when developing EVs, as it directly translates to the range that can be covered with one fully charged battery pack. Vehicle thermal management can notably contribute to a more energy efficient behaviour by providing a suitable thermal environment for the electric power components, as well as reduce losses in the cooling and cabin climate system. However, this requires, on top of a well dimensioned cooling system, a detailed knowledge about the flow distribution and physics in the underhood.

Performing measurements in the underhood of a complete passenger car is difficult due to the tight packaging in the underhood region, which results in a poor accessibility for most measurement equipment (Cogotti and Berneburg, 1991). As an alternative, Computational Fluid Dynamics (CFD) can be used to conduct such flow investigations, since it provides information about the flow field in all areas, even where measurement equipment cannot reach. Over the past decades, CFD has become an important part of industrial development processes and with more computational power, the flow around increasingly complex geometries can be simulated. However, the direct solution of the Navier-Stokes equations is still reserved for academic cases, with simple geometries and at low Reynolds numbers. For turbulent flows and the rotation of the axial cooling fan in industrial applications, numerical models must be employed, which require validation.

The simulation of the axial cooling fan is especially important, as it is crucial in determining the flow field further downstream in the vehicle's underhood. The most cost-efficient approach is the steady-state Multiple Reference Frame (MRF) method, which makes it popular amongst

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