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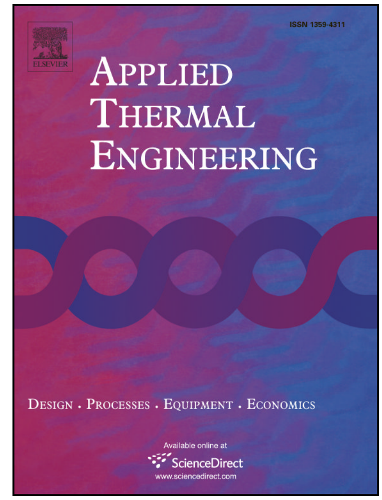

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Lumped Parameter Network Simulation of a Loop Heat Pipe for Energy Management Systems in Full Electric Vehicles

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Abstract

Loop heat pipes (LHP) and other two-phase passive thermal devices, such as heat pipe loops (HPL), represent a very attractive solution for the energy management of systems characterized by a distributed presence of heating and cooling zones and by the needs of fast start-up, reliability, low cost and lightness. Even if the usual application for these devices is in the space sector, there could be a potential significant application for the automotive industry, for the development of embedded thermal networks for full electric vehicles (FEV), in order for example to recover the waste heat for cabin heating and cooling or to improve the aerodynamic efficiency. In the present investigation, the possibility to implement a new thermal control for an electric vehicle comprising from heat pumps (HP) and LHP, is here evaluated. In more detail, a 1-D lumped parameter model (LPM) that is able to predict the transient behaviour of a LHP in response of varying boundary and initial conditions, is developed and validated against literature experimental data. A novel methodology for treating numerically the condenser is proposed and validated for three different working fluids. An extensive parametric analysis is also conducted, showing the robustness of the thermal solution for different conditions and proving the possibility of using the proposed numerical code both for feasibility studies and for optimization purposes. A feasibility study utilizing the proposed model is also conducted and the results indicate that an array of LHPs can effectively transport heat from the motor section of the vehicle to the underbody, reducing significantly the aerodynamic losses.

Keywords: Loop Heat Pipe; Lumped Parameter; Electric Vehicle; Thermal Management

Nomenclature

A	Exchange surface (m^2)	R_d	Distributed hydraulic resistance (bar s/kg)
c_p	Specific heat (J/kg K)	R_{pwvo}	Thermal resistance primary wick/vapour grooves (K/W)
g	Gravity (m/s^2)	R_{pw2}	Thermal resistance primary wick/inlet bayonet (K/W)
H	Total enthalpy (J)	R_{vowall}	Thermal resistance vapour grooves/wall (K/W)
h	Specific enthalpy (J/kg)	R_{wallpw}	Thermal resistance wall/primary wick (K/W)
h_c	Convection coefficient (W/K m^2)	r	Radius (m)
h_{LV}	Specific enthalpy of vaporisation (J/kg)	$\bar{r}$	Medium pore radius (m)
k	Thermal conductivity (W/m K)	T	Temperature (K)
k_c	Constant for pressure losses in a turn	T_{sat}	Saturation temperature (K)
k_g	Adiabatic index	t	Time (s)
L	Length (m)	$thick_{ev}$	Evaporator wall thickness (m)
m	Mass (kg)	u	Specific internal energy (J/kg)
$\dot{m}$	Mass flow rate (kg/s)	V	Volume (m^3)