International Journal of Automotive Technology (2024) 25:469–479
https://doi.org/10.1007/s12239-024-00037-3

ELECTRIC, FUEL CELL, AND HYBRID VEHICLE, FUELS AND LUBRICANTS, HEAT TRANSFER, FLUID AND THERMAL ENGINEERING, VISION AND SENSORS

Development of an Algorithm for Predicting the Heat Resistance Temperature of Automotive Lamps

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Received: 15 September 2023 / Revised: 21 November 2023 / Accepted: 24 November 2023 / Published online: 13 February 2024

Abstract
Heat generated from the bulb of an automotive lamp is transferred to the lamp reflector and lens through a heat-transfer mechanism. If the heat transferred to the reflector and lens exceeds the heat resistance limit of the materials used in their production, the materials deform. Therefore, lamp designers must design lamps within a limited range. If the lamp fails the heat resistance test after the design and pilot model production, the design process must be restarted. Redesigning requires significant time and costs. Therefore, a temperature-prediction algorithm for a single-function lamp during the initial design stage was developed in a previous study. In this study, a multifunction temperature-prediction algorithm with two or more heat sources was developed to predict the temperature of lamps of various shapes. The focus length based on the parabolic shape of the bulb installation surface and corner slope values near the lens were used to reflect the actual shape of the lamp. The introduction of the effective area improved the accuracy of the temperature prediction for the upper surface, which was strongly influenced by convection. The performance of the developed algorithm was evaluated by comparison with the computational fluid dynamics (CFD) results of an actual lamp model. Consequently, it was confirmed that the newly developed best prediction algorithm can be effectively applied to new automotive lamp designs.

Keywords Automotive lamp · Reflector · Lens · Heat resistance temperature · CFD · Temperature prediction algorithm

List of Symbols

A	Lamp's surface area, mm^2
α	Thermal diffusion coefficient, m^2/s
β	Thermal expansion coefficient, $m/(m \cdot K)$
δ	Weights for correlation
ε	Emissivity
F_{i-j}	View factor
f	Focus distance, mm
H	Applied height for focus surface, mm
h_i	Distances from bulb installation to intersection line, mm
$\overline{h}$	Average convective heat transfer coefficient, $\mathrm{W/m^2 \cdot K}$
k	Thermal conductivity, $\mathrm{W/m \cdot K}$
L_{ch}	Characteristic length, mm
$\overline{Nu}$	Average Nusselt number
Q_{cond}	Conduction heat transfer rate, W
$Q_{n.\mathrm{conv}}$	Natural heat transfer rate, W
Q_{rad}	Radiation heat transfer rate, W
Q_{trans}	Transmittance heat transfer rate, W
Ra	Rayleigh number
σ	Stefan–Boltzmann constant
T_s	Surface temperature, °C
T_{fluid}	Fluid temperature, °C
T_{surr}	Surrounding temperature, °C
T_{bulk}	Bulk temperature, °C
T_{bulb}	Bulb temperature, °C
θ	Slope between planes, °
τ	Transmittance
V	Volume, mm^3
ν	Kinematic viscosity, $\mathrm{m^2/s}$

Subscripts

Al	Aluminum
Box	Simple box model
CFD	Computational fluid dynamics
dn	Down surface
Installation	Bulb installation surface of lamp

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