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Thermal Analysis of Thermal Conductivity of Headlamp Reflectors

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Abstract

Headlamps in cars are comparably small in size; however, they help in expanding the driver's view and alerting other cars and pedestrians of the car's presence. Additionally, they are an important part that affects the design of the car. we analyzed the temperature characteristics within headlamps according to specific thermal conductivity using finite element analysis. This was done in order to compare with the heat protection performance of headlamps, when heat protection elements are used to manufacture reflectors, according to the specific thermal conductivity of the heat protection elements. First we created a 2D cross-section of headlamp concept design and analyzed the temperature distribution from the bulb. Based on the results of the 2D analysis, we designed a headlamp reflector model to be used in an actual car and analyzed the lamp's temperature characteristics caused by the specific heat thermal conductivity. From the results of the analysis, we determined the thermal conductivity rate appropriate for lowering the internal temperature of the headlamp below 100°C.

Keywords: Headlamp, Reflector, Thermal conductivity

INTRODUCTION

Headlamps in cars are comparably small in size; however, they help in expanding the driver's view and alerting other cars and pedestrians of the car's presence. Additionally, they are an important part that affects the design of the car. Recently, in the car industry, there has been a trend toward developing light sources with excellent reliability, design, functionality, and energy efficiency. The core technologies of light sources have made the problem of heat protection an important issue. As electronic elements become more densely integrated, more heat is generated. This radiant heat output not only reduces the performance of these elements but also causes malfunctions in nearby devices and, furthermore, becomes a heat source for circuit boards and reflectors. As a result, there has been a rapidly increasing demand for heat protection. LED headlamps are exposed to an operating environment at a temperature level of 95°C due to heat from the car engine, heater, radiator, etc. Heat is also produced by the lamp itself within the sealed headlamp interior. Thus, not only is the LED element heated but also the amount of light it produces is reduced, and its lifespan is therefore shortened. [1-3]

A significant amount of research has been performed on headlamp heat protection, and a variety of methods are being used to cool headlamps. [4-5] Firstly, cooling methods using fins and fans can be used at a relatively low unit cost; however, the heat protection effect is low, and power is required to move the fans. Cooling methods using cold plates that use water have a relatively high cost, and electrical equipment faults can occur due to water leaks and moisture. Additionally, power is required to operate the pumps. Forced convection cooling methods are a modified form of conventional air cooling that avoid the problems of water cooling and allow air cooling techniques to be used effectively. Recently, heat conducting polymer composite materials have been used to improve heat protection performance.

In this study, we analyzed the temperature characteristics within headlamps according to specific thermal conductivity using finite element analysis. This was done in order to compare with the heat protection performance of headlamps, when heat protection elements are used to manufacture reflectors, according to the specific thermal conductivity of the heat protection elements. First we created a 2D cross-section of headlamp concept design and analyzed the temperature distribution from the bulb. Based on the results of the 2D analysis, we designed a headlamp reflector model to be used in an actual car and analyzed the lamp's temperature characteristics caused by the specific heat thermal conductivity. From the results of the analysis, we determined the thermal conductivity rate appropriate for lowering the internal temperature of the headlamp below 100°C.

ANALYSIS OF REFLECTOR'S 2D THERMAL FLOW

Modeling Analysis and Setting Conditions

Numerical analysis was performed to check the changes in temperature according to changes in the reflector's specific thermal conductivity. For a basic analysis, the headlamp was

simplified into a 2D cross-sectional form and analyzed thereafter. The headlamp was composed of a bulb, reflector, baffle, lens and housing, and for simplicity, the heat source was set as the bulb surface. The heat generated by the bulb was assumed to be entirely spread through radiant heat. The lamp's internal condition was taken to be air with an initial temperature of 20°C. The heat exchange between the lamp and lamp surface was set so that conduction, convection, and radiation were all occurring. The outside of the reflector was assumed to be insulated and therefore heat loss was ignored. Because the baffle protects the lens from radiant heat, and the reflector and baffle are both made from a reflective metal, a low emissivity object like a mirror was used. The combined effect was that light and heat were dispersed from the bulb to the lens. The lens was made of glass, and the refractive index was set at 1.5.

Fig. 1 shows the 2D cross-section of the headlamp structure and the conditions for the initial analysis. Table 1 lists each condition.

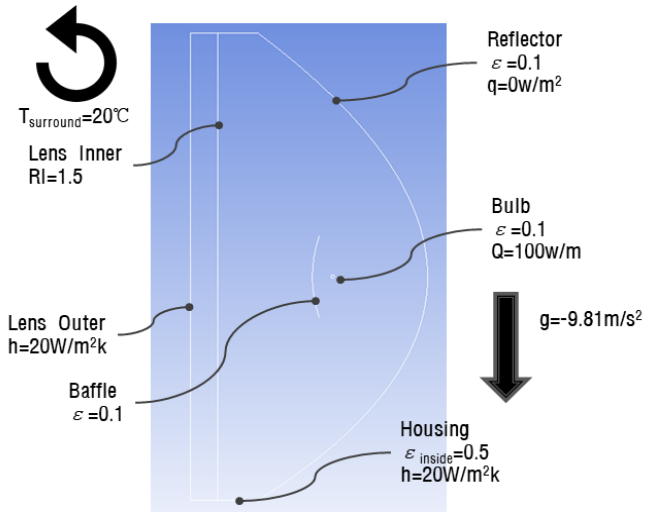


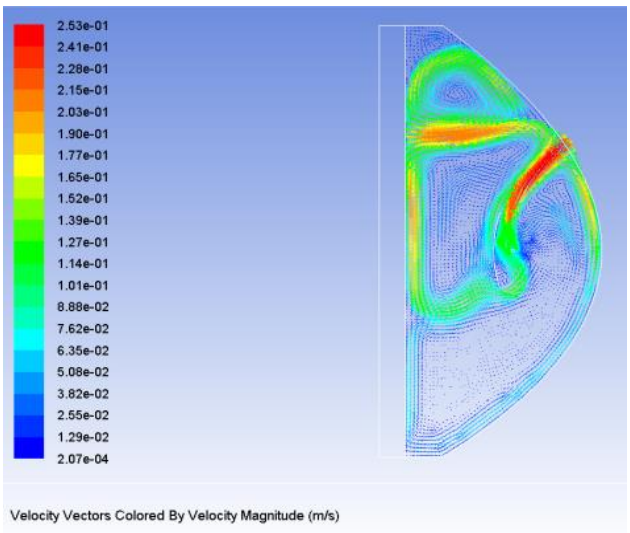
Figure 1: Structure of 2-Dimensional Sectional Headlamp and Initial Condition Setting

Table 1: Boundary conditions of 2-diensional model

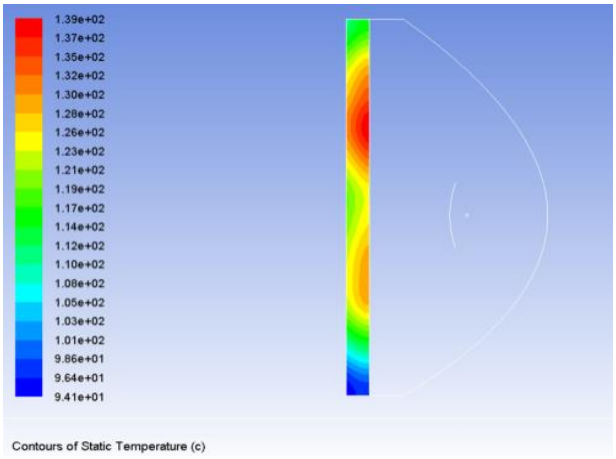
No.	Name	Condition
1	Bulb	100w/m
2	Convection	20w/m^{2}k
3	Lens Inner RI	1.5
4	Gravity	9.81m/s^2

Analysis of Temperature According to Changes in Reflector Heat Conduction

Fig. 2 shows the results of the analysis of the 2D cross-sectional structure. From the results of the headlamp analysis, when we compared the speed vector and reflector temperature distribution, it was confirmed that the top part of the bulb and baffle was at the maximum temperature. Fig. 3 shows the changes in temperature according to the headlamp height, and it can be seen that the temperature was highest at the top where the bulb is located. From this, it was confirmed that irregular temperature changes occurred according to changes in height.



(a) Result of velocity vector



(b) Result of temperature distribution

Figure 2: Results of analysis

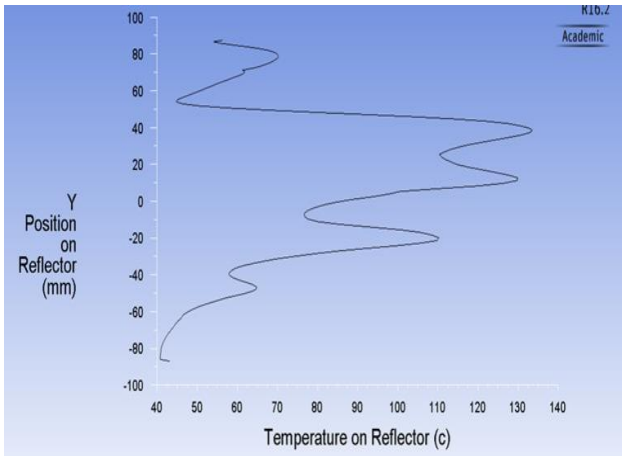


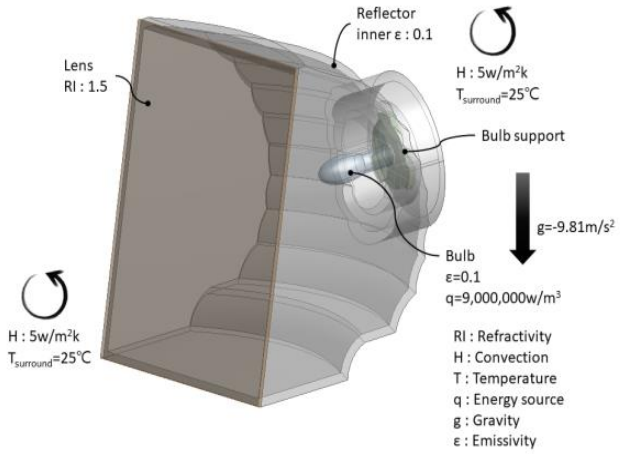
Figure 3: Temperature analysis results of headlamp reflector

3D THERMAL ANALYSIS OF REFLECTOR

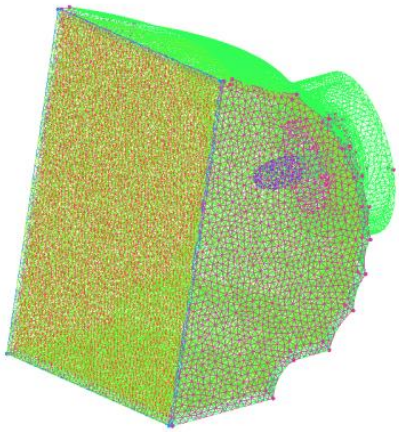
Analysis Conditions and Settings

Based on the results of the 2D analysis, we performed a 3D thermal analysis of the reflectors used in cars. Fig. 4 shows the headlamp used in an actual car for performing the 3D thermal flow analysis of the reflector. Based on this, we performed modeling considering the reflector's size and curvature. We modeled the bulb support to be the same as its actual shape. For the mesh, we used a Tetra mesh and created a total of 300,000 mesh elements. To analyze the reflector's radiation characteristics, we used a discrete ordinates radiation model under the assumption that all the heat generated by the bulb was spread as radiant heat. We included both visible rays (light) and infrared light in the radiation when performing the analysis, and the atmospheric temperature was set at 25°C, just as in the 2D analysis. The heat exchange of the lamp and its vicinity was set so that conduction, convection, and radiation all occurred. The reflector's specific thermal conductivity was set at 8 different levels: 0.18 W/mK, 0.5 W/mK and from 1 W/mK to 6 W/mK. The specific thermal conductivity of 0.18 W/mK was set in consideration of the properties of PBT material. The lens was designed with glass, and we used 1.5 as the refractive index of the glass. Fig. 5 shows the model created by the reflector and the mesh modeled for performing 3D thermal flows.

Figure 4: Selection of reflector model for thermal flow analysis



(a) condition of simulation



(b) Mesh

Figure 5: Structure of 3-Dimensional Sectional Headlamp and Initial Condition Setting

Table 2: Initial condition of 3-Dimensional model

No.	Name	emissivity	setting value
1	Bulb	0.1	9×10^7w/m^3
2	Reflector inner	0.1	
3	Air	Convection	5w/m^{2}k
		Temperature	25 ℃

Analysis of Results According to Changes in Reflector Thermal Conductivity

For the results of the analysis according to reflector thermal conductivity, we compared the reflector's maximum temperatures.

In the case where the thermal conductivity was set at the thermal conductivity of existing PBT resin, the maximum temperature of the reflector was 150.5°C; when the thermal

conductivity was 0.5 W/mK, the maximum temperature changed to 128.4°C. In addition, when the thermal conductivity was 1 W/mK, the temperature was 107.12°C; and when it was set at 2 W/mK, the temperature was 93.02°C. We observed that the maximum temperature values rapidly decreased from 0.18 W/mK to 2 W/mK, and at thermal conductivities above 2 W/mK, the extent to which the maximum temperature was reduced became smaller. Therefore, we conclude that a thermally conductive material with a specific thermal conductivity of 2 W/mK or more must be used to provide heat protection so that the reflector temperature can be kept below 100°C. Fig. 6 shows the maximum temperature according to specific thermal conductivity, and Fig. 7 shows the headlamp temperature distribution according to specific thermal conductivity.

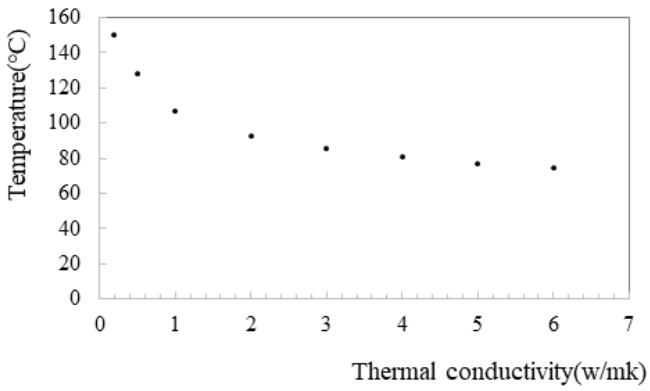
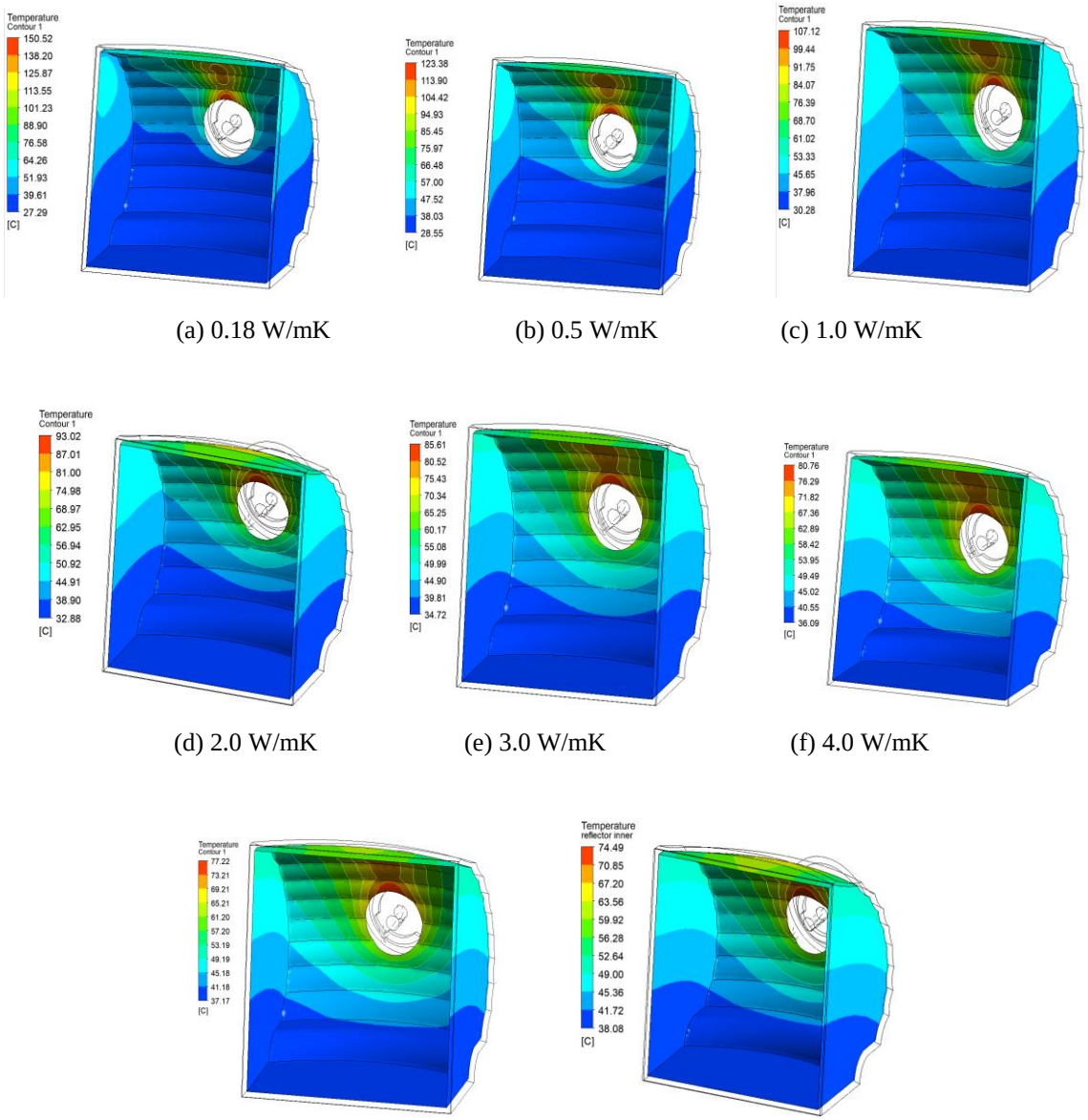


Figure 6: Temperature change due to reflector heat conduction



(a) 0.18 W/mK (b) 0.5 W/mK (c) 1.0 W/mK

(d) 2.0 W/mK (e) 3.0 W/mK (f) 4.0 W/mK

(g) 5.0 W/mK (h) 6.0 W/mK

Figure 7: Results of analysis temperature

CONCLUSION

In this research, we used finite element analysis to analyze the temperature characteristics of headlamps according to changes in the specific thermal conductivity of the reflectors used in the headlamps. Through a basic 2D analysis, we found that temperature changes occurred according to the height of the headlamp. Additionally, we designed the shape of the reflector for a model that is actually used in cars and observed the temperature changes according to changes in thermal conductivity. When the specific thermal conductivity of the existing material was used, we found that the headlamp's internal temperature was more than 100°C. From this, we were able to determine the thermal conductivity appropriate for keeping the heat temperature below 100°C.

ACKNOWLEDGEMENTS

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