Abstract of dissertation by Dipl. Ing. Sascha Nolte

A Method of Simulating the Temperature and Flow Distribution in Lighting Devices

Lighting devices are one of the most important safety components of an automobile. If these devices are operated incorrectly or fail, vehicle occupants or other road-users may be put at risk. It must therefore be ensured that the device works properly at all times. The generally prevailing cost situation forces the manufacturers of such devices to implement an ongoing process of improvement in the development and manufacturing of their products. Ever-shorter development times demand methods of detecting and removing risks and failures at an early stage of development. To reduce manufacturing costs, it is necessary to work with the most cost-effective material which meets the specified requirements. However, it is not always possible to change materials during the production phase, which means that feasibility must be clarified at an early point in the development process. Nowadays, these tasks can be accomplished by a wide variety of simulation programs, which use CAD data and suitable general conditions as a basis for calculating the load on devices and components or their materials at an early point in the development process.

This dissertation is intended to contribute to simulating the temperature and flow distribution in lighting devices as close to reality as possible, and to discovering possible problems at an early stage of development. For this, a method is developed which helps to simulate the mechanisms of heat transfer occurring in such a system. It is based on a commercial ***C****omputational* ***F****luid* ***D****ynamics* program.

The vast majority of lighting devices produce light by means of thermal radiators. The shortcoming of these light sources is that only a small part of the electrical power input is turned into visible radiation. The rest leaves the bulb as heat, with the largest share of this heat being transported as heat radiation.

A realistic simulation of the temperature distribution in these devices is possible only if the simulation model and the general conditions represent reality as closely as possible. The difficulty encountered here is the limited size of the simulation model, because this size directly influences the duration of the simulation. The model should therefore be reduced to the essentials. In relation to this, an important point is how the edges of the simulation model are described. Here, a distinction must be made between two system boundaries: One is the external boundary at which the system is coupled with the environment and at which conditions affecting the system from outside are taken into consideration. In the dissertation, this boundary was realized with the aid of heat transfer coefficients for the different conditions.

The second, or internal, system boundary is the light source. This is where the electrical energy input is converted into heat and distributed in the system via the corresponding heat transport mechanisms. A further problem results, since the model of the light source should be designed such that the size of the entire model remains as small as possible. For this purpose, the heat flows emitted by the light source were determined and were combined in a minimized model for the general condition.

Radiation is the central issue of the entire system under examination. The lighting device is designed for optimum distribution of this radiation. As well as visible radiation, heat radiation is also transported in the same way. This can lead to components in the radiation path of system heating up. However, in the case of the implemented models for simulation of heat transport by radiation, most CFD programs differ greatly from reality, with the models for directed reflected radiation being particularly inadequate. This makes it necessary to expand the calculation of radiation. For this, the results of a ***C**omputer **A**ided **L**ighting* program were integrated into the simulation model in such a way that in the areas particularly strongly subjected to load by radiation, the radiation model better represents real processes.

Suitable measuring technology is essential for the validation of the simulation method drawn up. To measure the temperature distribution in the system, the widespread methods of contacting temperature measurement using thermocouples and contactless measurement using a thermal imaging system were used. The use of suitable systems for visualizing the flow distribution in the lighting system proves to be more difficult. Due to the low velocity of flow, the use of contacting measuring systems does not make sense. Even the well-known contactless measuring systems reach their limits here. Despite this, within the framework of this dissertation it was possible to gain initial information about the behavior of the flow.

The concluding comparison of the measuring results with the results of simulation shows that reality can be modeled successfully and that temperatures and flows match quite well in the critical ranges. However, the results also show that the simulation model must be improved for certain problems.