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Development of a unified 3D numerical simulation model for horizontal Xe short arc lamp

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1. Introduction

Xenon short arc lamps using arc discharge are often used as light sources of a digital cinema projector. These lamps are used in horizontal operating position. At this position, the plasma flow accompanying the arc discharge is raised due to buoyancy. Correspondingly, the distribution of the temperature and that of the inner wall blackening of the bulb made of quartz glass occur uneven. The inner wall blackening of the bulb is caused by the adhesion of the evaporated tungsten of the electrodes to the bulb. As a result, explosion due to the local heating of the bulb or early illuminance reduction may occur. For this reason, the shapes of the electrodes and the bulb affecting the plasma flow must be designed appropriately. However, due to the structure of the lamp, various experimental measurements are difficult. Thus, in addition to such measurements, it is desired to quantitatively elucidate the phenomena using numerical simulation, though there have been a few reports using this method.

In this presentation, the influence of buoyancy in the horizontal operating position was evaluated using a unified 3D numerical simulation model of a Xenon short arc lamp. Results of this investigation on the distribution of the temperature and that of the inner wall blackening of the bulb are reported.

2. Simulation model

The main simulation model in this presentation is the electromagnetic and thermal fluid 2D numerical simulation model of a Xenon short arc lamp[1)]. In the unified 3D simulation model, the sub model of radiative heat transfer, gravity, and tungsten evaporation, including transportation and adhesion are taken into account in the main model.

3. Results and discussion

Figure 1 shows the temperature distribution of electrodes, bulb, and that of the gas including tungsten vapor at 1 minute after the start of operation in the vertical cross section through the lamp central axis. In addition, it shows the velocity vector of the gas including tungsten vapor. Although these actual values are higher than the showed ranges, these contour ranges are defined as shown in the figure 1 in order to make the overall distributions of the temperature and gas vector easy to see. In the temperature distribution, the arc plasma is formed to draw a slight rising between the electrodes. The hot plasma spot is generated in front of the cathode tip and heat further spreads to the radial direction as heat approaches the anode. Also, higher temperature gases are gathered to the upper area. The average gas temperature in the half upper area is about 1.3 times higher than that of the half lower area. In the velocity vector distribution, a cathode jet is formed from the front of the cathode tip towards the anode tip. The plasma flow in the upper central axis of the lamp goes along the tapered part of the anode and reaches the inner wall of the bulb. However, the plasma flow in the lower central axis of the lamp, after reaching the anode tip, goes slightly along the tapered part of the anode tip and deflects upward due to buoyancy. Figure 2 shows the mole fraction distribution of the tungsten vapor in the same cross section with the time same as in figure 1. The mole fraction of the tungsten vapor on the front of the anode tip is the highest and most of the tungsten vapor adhered to the inner wall of the bulb near the anode. This part is in good agreement with the blackening part seen in the horizontally operated lamp in the actual equipment.

Therefore, it seems that this model is shown to be useful for examining the temperature distribution and blackening part of the lamp in the horizontal operation.

In the future, we will be using this model to study the influence of electrode shape as well as other factors on the above mentioned phenomena.

Reference

1) S. Maenaka, S. Tashiro, A. B. Murphy, K. Fujita, M. Tanaka : Evaluation of Radiation Characteristics of Xe Short Arc lamp by Numerical Simulation, Journal of smart processing, 6-1 (2017) 40-45

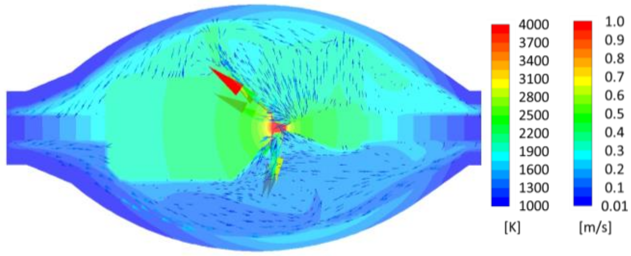

Figure 1. Distribution of temperature and velocity.

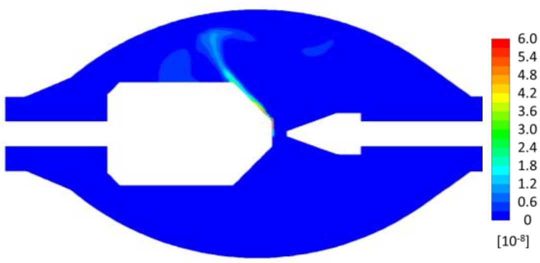

Figure 2. Distribution of mole fraction of tungsten vapor.