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Cooling Analysis of Super Precision and Large Stage for OLED

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ABSTRACT

As the OLED industry develops, display equipment is becoming larger. As a result, the stage required for display equipment is getting bigger. This enlargement led to increase in OLED production and industrial development. However, due to the large scale of the stage, other problems due to overheating and overheating caused by heavy load on the linear motor, which is mainly used in the stage, must be solved. In this study, a linear motor equipped with a cooling channel is modeled and the three - dimensional heat conduction flow analysis for this model is simulated using Fluent to analyze the cooling efficiency and cooling efficiency according to the cooling water flow rate. As a result, the cooling channel was effective and the cooling effect and efficiency were the best when the flow rate was about 5 ~ 10 L./min. In addition, the cooling effect is increased when the flow rate is increased, but the efficiency is significantly lowered when the flow rate is more than the predetermined value.

Key Words : Cooling Analysis, Cooling Channel, Linear Motor, OLED, Stage

1. Introduction

As the OLED industry develops, demand for OLEDs is increasing, and the related equipment is becoming larger. As a result, the stage required for display equipment is getting bigger. Many studies on stages of display devices have focused on precise measurement and control [1-6].

Moving a large stage requires more force than moving a conventional stage, so it is heavily loaded on a linear motor, which is widely used in a general stage, and the motor is overheated. This overheating leads to many problems such as the need for precise axial movement, affecting the display equipment that has to move in the control direction, affecting above the stage and damaging the substrate.

In this study, to solve the overheating problem, the cooling effect according to the cooling water flow rate is analyzed through the cooling channel analysis around the motor.

2. Analysis

This study is a three dimensional thermal conduction analysis by analyzing the cooling effect according to the flow rate in a linear motor attached to a linear stage used in a display inspection equipment moving in X and Y axis.

The heat conduction equation in three dimensions is as follows.

$$\mathrm{k}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)+Q=0 \tag{1}$$

In the case of heat transfer involving fluid (incompressible) flow, the governing equations are as follows.

$$\frac{\partial u_i}{\partial x_i}=0 \tag{2}$$

$$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_i}(\rho u_i u_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial \tau_{ij}}{\partial x_j} \tag{3}$$

$$\rho C_p\left(\frac{\partial T}{\partial t}+u_j\frac{\partial T}{\partial x_t}\right)=\mathrm{q}+\frac{\partial}{\partial x_j}\left(k\frac{\partial T}{\partial x_j}\right)+\tau_{ij}\frac{\partial u_i}{\partial x_j} \tag{4}$$

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where $\tau_{ij} = \frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \rho\overline{u_i u_j}\right]$

Figs. 1 and 2 are magnified views of the stage and linear motor for OLED, respectively. Fig. 3 shows a 3D modeling of a linear motor with magnet and magnet housing as well as cooling channels for analysis. The boundary conditions were 30 ° C for the heat source and 20 ° C for the cooling water as shown in Fig. 4. The flow rate (L / min) was converted to mass flow (kg / s) and analyzed. The analysis employs a commercial finite element method code ANSYS.

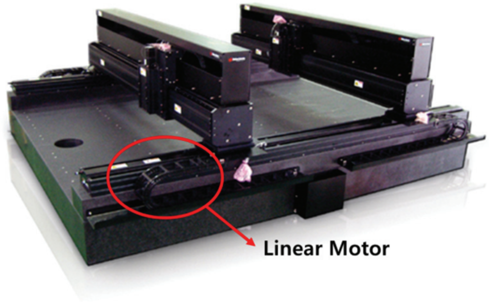

Fig. 1. General stage appearance for OLED.

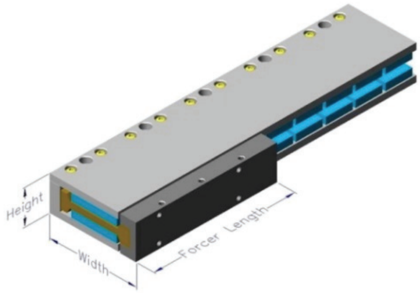

Fig. 2. Linear motor in stage.

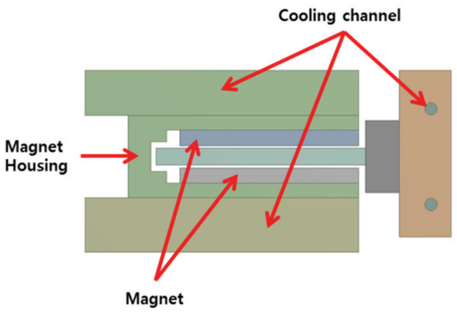

Fig. 3. Modeling of linear motor with magnet, magnet housing and cooling channels.

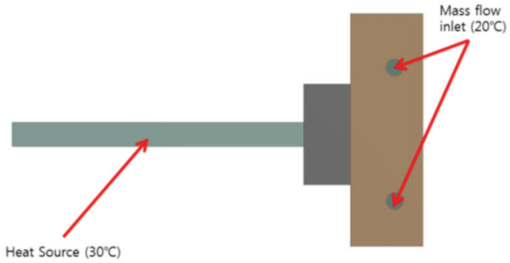

Fig. 4. Heat source and mass flow inlet for analysis.

Before proceeding with the analysis, the method of analysis was determined by comparing the results of the conduction and the natural convection, Fig. 5 shows the modeling of the thermal analysis using the thermal conductivity of air, and Fig. 6 is an enlarged view of the analytical modeling. Fig. 7 shows the modeling of the external air in box form for natural convection analysis, and Fig. 8 shows the inside of this air layer.

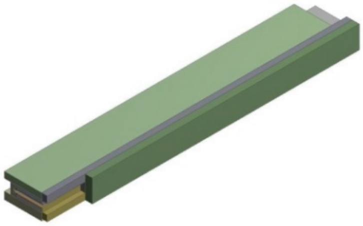

Fig. 5. Modeling for air thermal conductivity analysis.

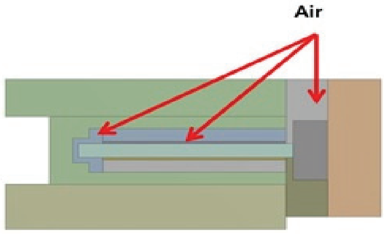

Fig. 6. Magnified view for analysis of air heat conduction.

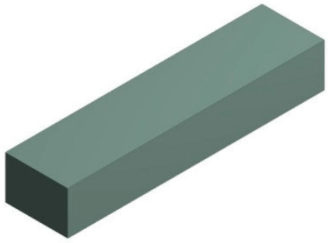

Fig. 7. Modeling for air natural convection analysis.

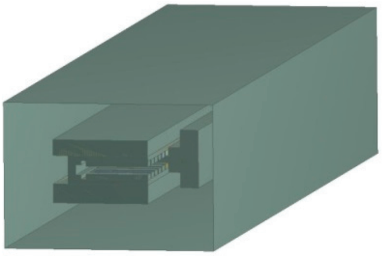

Fig. 8. Internal view for air natural convection analysis.

Figs. 9 and 10 show the Tetrahedrons Mesh for thermal conductivity analysis and natural convection analysis, respectively, Heat conduction analysis consists of 3,361,761 (flow rate 0L / min), 3,752,790 (flow rate 5 ~ 20L / min) node and natural convection analysis 1,185,565 nodes. Heat conduction analysis consists of 3,361,761 (flow rate 0L / min), 3,752,790 (flow rate 5 ~ 20L / min) node and natural convection analysis 1,185,565 nodes. Both interpretations proceeded when all the flow rate was 0 L/min, The temperature distribution and the maximum temperature were confirmed in the magnet and magnet housing required for this analysis.

Fig. 9. Mesh for air thermal conductivity analysis.

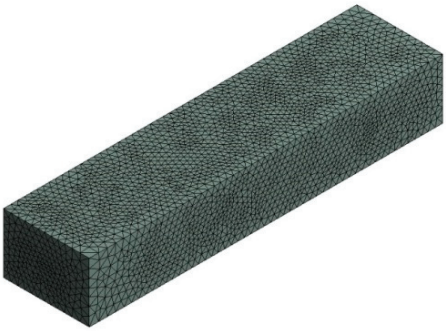

Fig. 10. Mesh for air natural convection analysis.

Fig. 11. Temperature distribution of magnet for air thermal conductivity analysis.

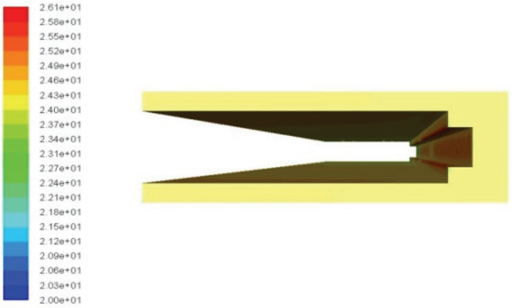

Fig. 12. Temperature distribution of magnet housing for air thermal conductivity analysis.

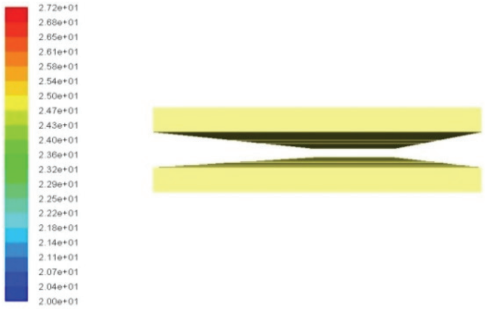

Fig. 13. Temperature distribution of magnet for air natural convection analysis.

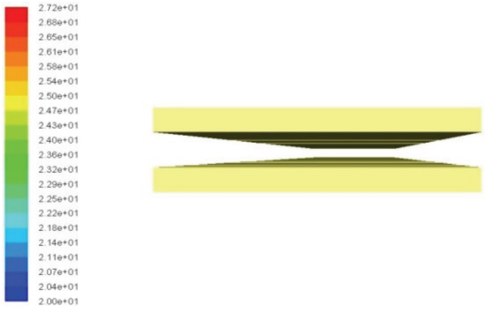

Fig. 14. Temperature distribution of magnet housing for air natural convection analysis.

As shown in Figs. 14 ~ 16, there is no big difference in temperature distribution, and Max Temperature is also the heat conduction (Magnet: 27.2 ℃, Magnet Housing: 26.1 ℃) and natural convection (Magnet: 25.3 ℃ Magnet Housing: 25.3 ℃). As the temperature difference is not so large, we proceeded with the analysis of the heat conduction which enables quick analysis.

3. Results

Cooling analysis for flow rate (0, 5, 10, 15, 20 L / min) was performed to analyze the cooling effect according to cooling water flow rate. Linear Motor Magnet and magnet housing were the main factors considered in the linear motor cooling analysis. Figs. 11 ~ 14 show the temperature distribution when the flow rate is 0L/min and 5L / min. In this figure, it can be seen that cooling effect occurs when the flow rate changes from 0L/min to 5L / min. It is seen from the graphs of Figs. 15 and 16 that as the flow rate increases, the cooling effect becomes better as the flow rate increases, but the cooling efficiency decreases.

Fig. 15. Temperature distribution of magnet for 0 L/min flow rate.

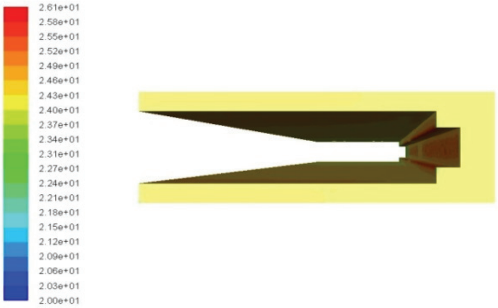

Fig. 16. Temperature distribution of magnet for 0 L/min flow rate.

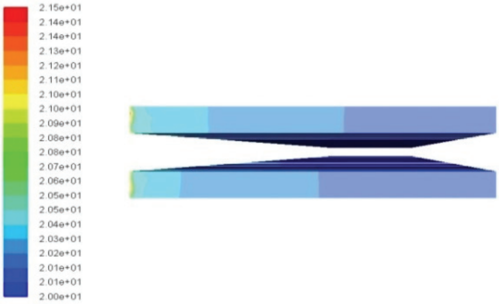

Fig. 17. Temperature distribution of magnet for 5 L/min flow rate.

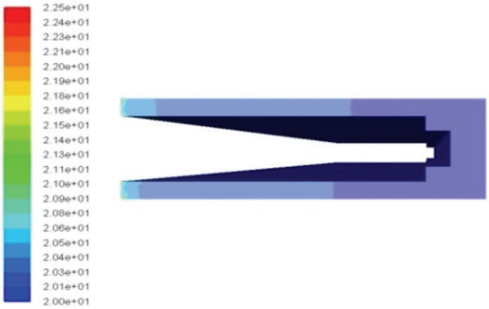

Fig. 18. Temperature distribution of magnet for 5 L/min flow rate.

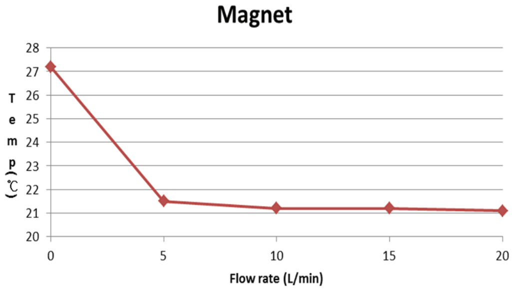

Fig. 19. Temperature distribution of magnet for air thermal conductivity analysis.

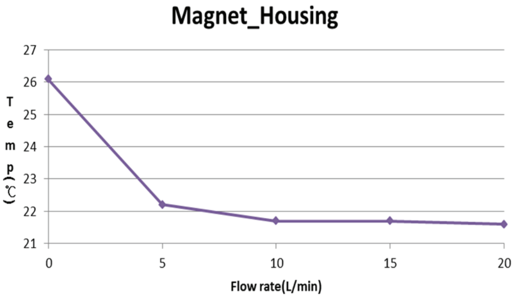

Fig. 20. Temperature distribution of magnet for air thermal conductivity analysis.

4. Conclusions

In this study, we simulated the cooling effect according to the flow rate (0, 5, 10, 15, 20 L / min) when using the cooling channel for the overheated linear motor. As a result, the following conclusions were obtained. If you use the cooling channel, you can get a considerable effect. If you use the cooling channel, you will be able to reduce the damage to the substrate due to heat control or damage to the substrate. In this system, it was confirmed that the optimum flow rate was 5 to 10 L / min. Finally, it was found that the cooling effect was improved as the flow rate increased. However, it was confirmed that it is effective to find the appropriate flow rate according to the desired temperature rather than to input a large amount of flow rate because the cooling efficiency is drastically decreased at a certain flow rate.

Acknowledgement

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