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Numerical Analysis on the Thermal and Fluid in Air Conditioning Duct for Marine Offshore

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해양 구조물용 공조덕트 열유동에 관한 수치해석

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ABSTRACT

This study is about the distribution of heat transfer in air conditioning ducts used for marine vessels and oil drilling platforms. As the convective heat transfer coefficient increased, heat transfer was conducted dynamically to inside as it exited to the outlet of duct. The experiment was to determine if the amount of heat transfer generated at the duct exit increased as the convective heat transfer coefficient increased. When the convective heat transfer coefficient was low, the temperature of the duct showed a relatively high temperature difference between the outside and inside of the duct due to the temperature influence of the internal fluid. In case of temperature distribution generated the volume of the duct along the change of the convective heat transfer coefficient, the temperature descended as heat transfer was promoted and the convective heat transfer coefficient increased.

Key Words : Drilling Ship(시추선), Air Conditioning Duct(공조덕트), CFD(전산유체역학)

1. Introduction

Currently, air-conditioning ducts are normally installed for ventilation in the columns and pontoons, which act as the legs of a submersible semi-drilling rig among several marine plants.

For air-conditioning ducts used in marine and oil drilling ships, a light gauge watertight duct is widely employed, which is installed as a module type inside the columns, and a bellows section is formed at the surface in the longitudinal direction to enable a design with reinforced strength and lightweight.

As the strength of light gauge watertight air-conditioning duct is increased by the bellows section, the thickness of the air-conditioning duct can become relatively thin, thereby reducing the overall weight, which is suitable for efficient applications in marine and oil drilling ships. Thus,

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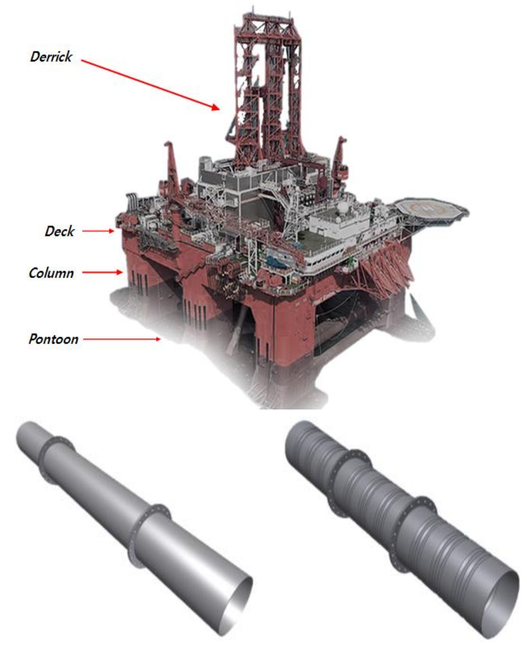


(a) Present (b) Development

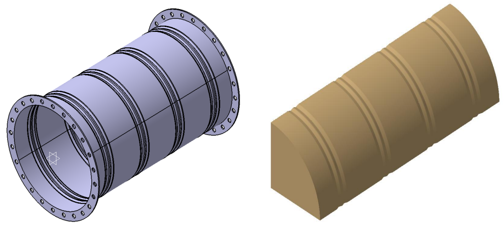
Fig. 1 Air conditioning duct for marine offshore

most major oil companies in Europe have attempted the light-weighting of newly built oil drilling ships[1-4].

As shown in Fig. 1, the air-conditioning ducts installed in the columns are made of simple flat-surface steel plates, and their ends are welded and connected. Thus, this study aims to perform the numerical analysis of the thermal and flow behaviors that occurred inside the air-conditioning duct.

2. Heat flow analysis method

This study was performed with a 550-mm-diameter air-conditioning duct, as shown in Fig. 2, and aimed to identify the effect of the bellows installed inside the duct on the flow field and heat transfer.



(a) 3D modeling (b) CFD modeling

Fig. 2 Analysis model

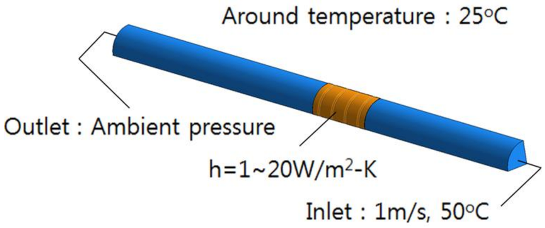


Fig. 3 Control volume shape for CFD analysis

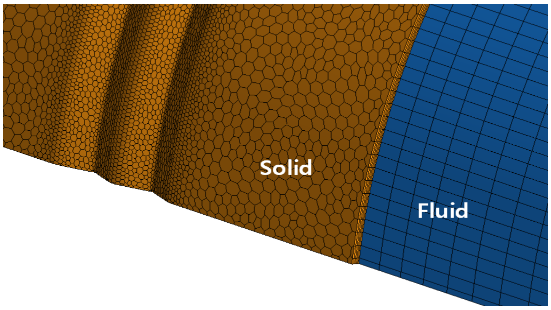


Fig. 4 Control volume for fluid and solid

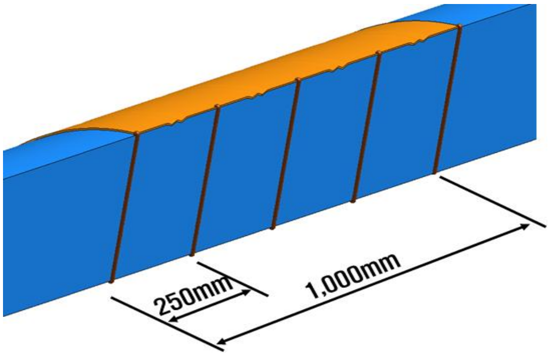


Fig. 5 Sensing positions at length and radial direction

Fig. 3 shows the boundary condition for performing the heat flow analysis on the air-conditioning duct. The inlet and outlet were extruded by five and seven times the hydraulic radius to ensure the stability of the flow.

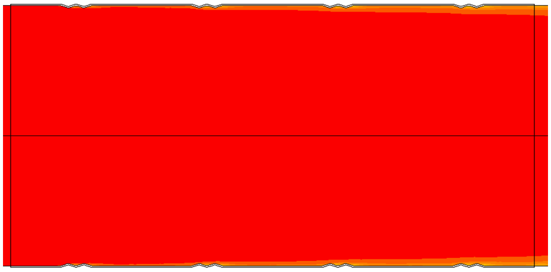
As shown in Fig. 3, a convective heat transfer coefficient was set to a variable outside the light gauge watertight duct. Here, the ambient temperature was assumed to be 25℃. In addition, an air inflow rate of 1m/s in the inlet and air temperature of 50℃ flowing through the duct were assumed. For the outlet, the atmospheric pressure was assumed[5-7].

Fig. 4 shows the controlled volume for heat flow analysis. The thickness of the duct in the solid area was 3 mm, and it consisted of five mesh-type layers.

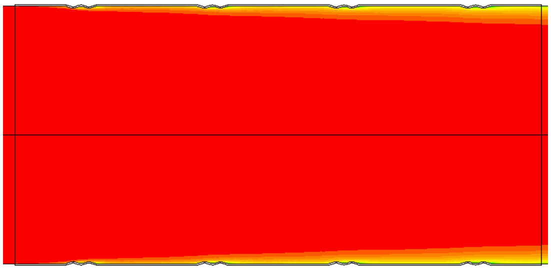
Fig. 5 shows the temperature distribution at five regions every 250 mm from the duct inlet from a virtual sensor to measure the inner temperature distribution in the radial direction with regard to the longitudinal direction of the light gauge watertight duct. The 250-mm region is the central position between the bellows.

3. Heat flow analysis results

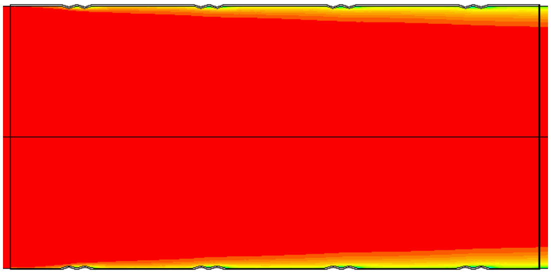
Fig. 6 shows the inner temperature distribution in the duct according to a change in the convective heat transfer coefficient that acted on the outside surface of the light gauge watertight duct. As shown in the figure, gradual cooling was verified inside the duct as heat transfer occurred at the duct surface, thereby generating heat exchange with the outside. As the convective heat transfer coefficient increased, heat transfer occurred actively as the air was discharged to the outlet in the duct. Fig. 7 shows the temperature distribution at each region according to a change in the convective heat transfer. In this figure, 0 in the X-axis refers to the center of the duct. Overall, the figure verified that the duct inside cooled faster as it was nearer to the outlet due to the heat exchange with the outside of the duct while passing through the duct.



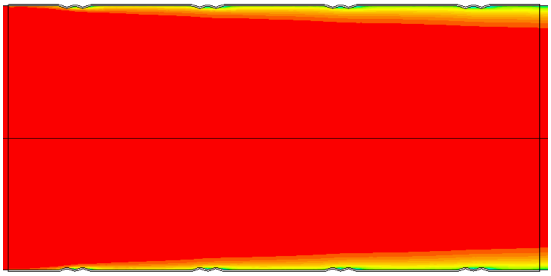
(a) h=1W/m2-K



(b) h=5W/m2-K



(c) h=10W/m2-K



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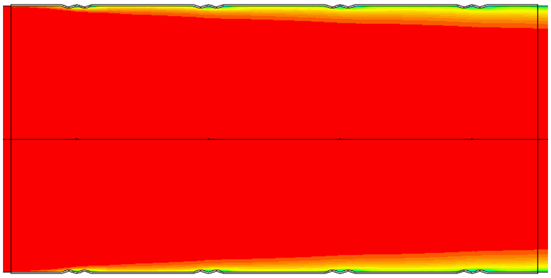

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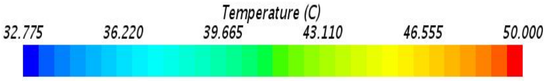
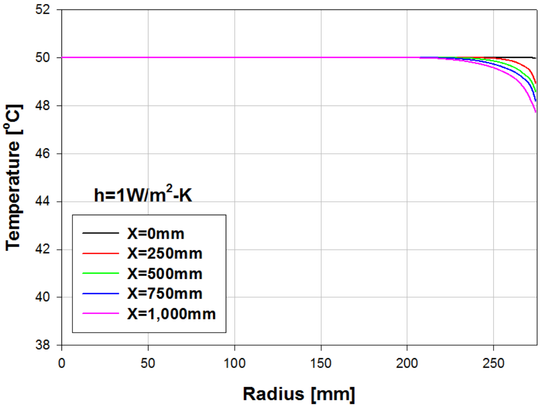
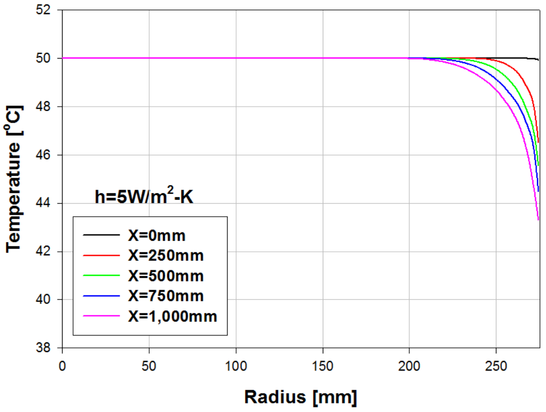


Fig. 6 Result of temperature distributions in Fluid region



(a) h=1W/m2-K



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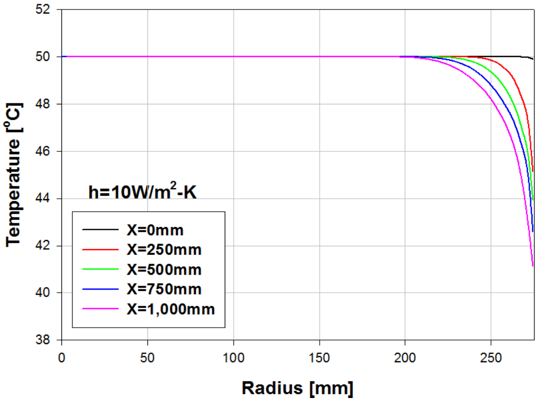

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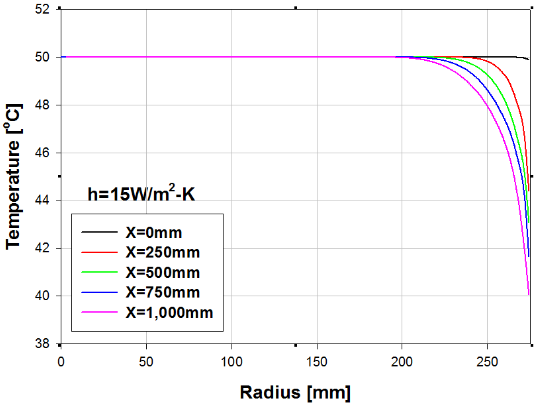

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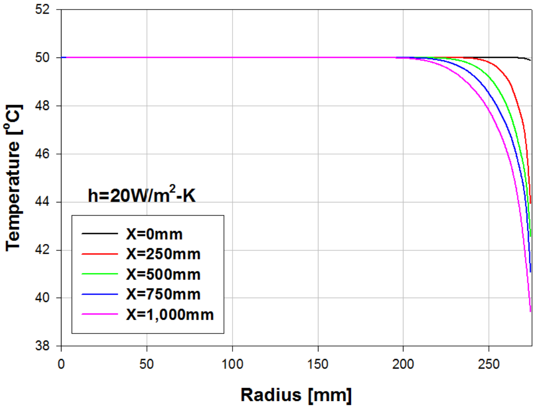


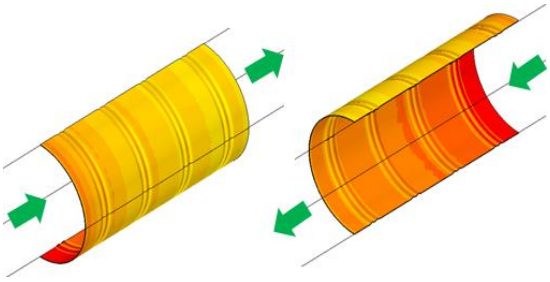
(e) h=20W/m2-K

Fig. 7 Comparison of temperature distributions at positions

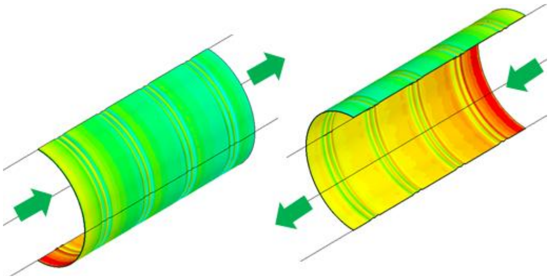
The figure also verified that heat transfer progressed deep inside the duct as heat exchange was facilitated with the increase in the convective heat transfer coefficient.

Fig. 8 shows the temperature distribution of the solid duct solid area. As shown in Fig. 8, heat transfer between the inside and outside of the duct slowed down when the convective heat transfer coefficient was lower, thereby exhibiting a relatively high temperature distribution due to the temperature effect of the inner fluid in the duct. In contrast, the figure result verified that the temperature in the duct surface became lower as heat exchange was facilitated with the increase in the convective heat transfer coefficient.

The temperature distribution on the inside and outside surfaces of the duct displayed that the inside surface had relatively higher temperature distribution due to the high temperature of the working fluid, whereas the outside surface showed a relatively lower temperature distribution due to the convective heat exchange with the outside.



(a) h=1W/m2-K



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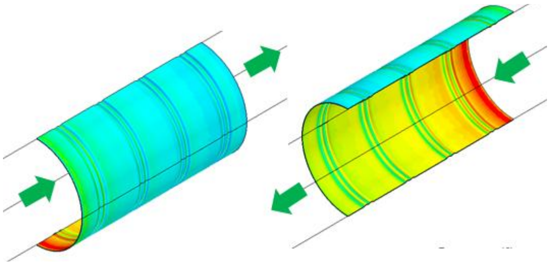

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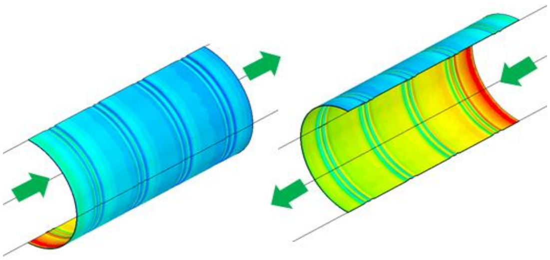

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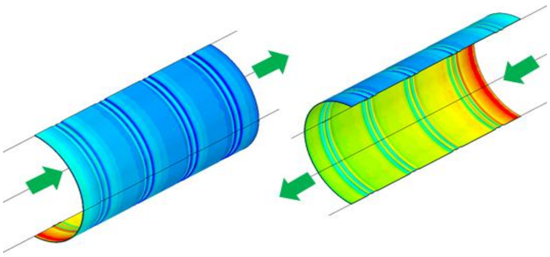

(e) h=20W/m2-K

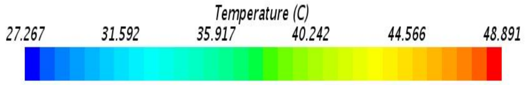

Fig. 8 Result of temperature distributions at solid region

The heat exchange inside the duct in the travel direction of the working fluid revealed that heat exchange was facilitated as air passed through the outlet, resulting in lower temperature distribution.

Fig. 9 shows the heat transfer that occurred in the duct. It verified that the increase in heat transfer occurred in the duct as the convective heat exchange coefficient increased. This was because heat exchange with the working fluid that flowed inside the duct was facilitated as the convective heat

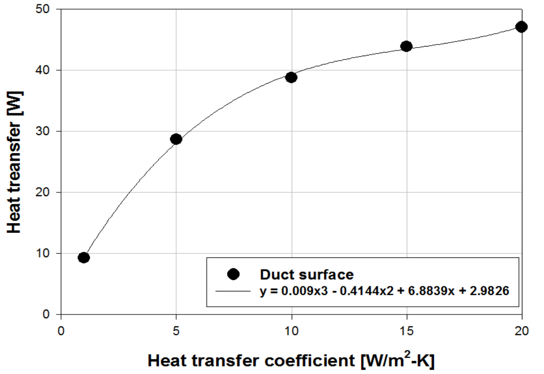

Fig. 9 Result of heat transfer distribution at duct surface

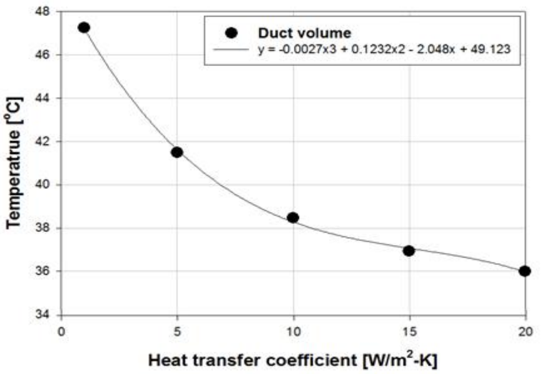

Fig. 10 Result of temperature distribution at duct

transfer coefficient acting on the outside surface of the duct increased.

Fig. 10 shows the temperature distribution that occurred in the duct volume according to a change in the convective heat transfer coefficient. The figure verified that the temperature dropped as the heat transfer was facilitated with the increase in the convective heat transfer coefficient.

4. Conclusions

This study conducted a heat transfer analysis of the air-conditioning ducts used in marine structures and derived the following conclusions.

1. As the convective heat transfer coefficient increased, heat transfer occurred actively as the air was discharged to the outlet in the duct. Thus, this verified that the increase in heat transfer occurred in the duct as the convective heat exchange coefficient increased.
2. Heat transfer between the inside and outside of the duct slowed down when the convective heat transfer coefficient was lower, thereby exhibiting a relatively high temperature distribution due to the temperature effect of the inner fluid in the duct.
3. The temperature distribution that occurred in the duct volume according to a change in the convective heat transfer coefficient showed that as the convective heat transfer coefficient increased, heat transfer was facilitated, thereby decreasing the temperature.

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