PERFORMANCE ANALYSIS OF FINED PIPE IN AIR SAMPLING SMOKE DETECTION SYSTEM AT REFRIGERATED WAREHOUSE

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ABSTRACT

Refrigerated warehouse is temperature-controlled environment that contain a wide range of frozen foods and dry items. However, in situation of fire, fire is rapidly spread coupled with a dry environment and high airflow by air condition system. Therefore, to minimize damage and loss in refrigerated warehouse, a fire must be detect at a very early stage. Generally, air sampling fire detection system is widely used in refrigerated warehouse. The air sampling fire detection system sampled cold air with smoke via pipe network located the underside of the ceiling. The cold air flows into laser-smoke detector chamber installed at outdoor. However, temperature of the detector chamber falls below the dew point by cold air, condensation and frosting occur and cause malfunction. Therefore, in order to prevent condensation and frosting, aluminum fin and pipes are designed to raise the temperature above the dew point. Especially, the average temperature and humidity of summer in Korea is 30℃ and 70%. Thus, the dew temperature at summer is about 21 ℃.

In this study, numerical analysis is performed to investigate heat transfer characteristics according to the number of fins. The number of fins are varying 0, 2, 4 and 8 respectively. The inlet temperature of air is – 19 ℃. The pipe diameter is 10 mm and 2.5mm thickness. The geometry of fin is 22.5mm length, 1mm thickness. Also, the fin efficiency of finned pipe is compared to the bare pipe. As a result, temperature of outlet air are -3.14 ℃, -1.35 ℃, 0.1 ℃ and 2.16 ℃ and fin efficiency are increases 0.34, 0.37 and 0.41, according to the number of fins are varying 0, 2, 4 and 8 respectively. The condensation occurs when temperature is lower than dew temperature.

Therefore, to satisfy the outlet temperature above the dew point, the number of fins and pipes must be increased, but the number of fins cannot be increased further due to machining and installation problems. Therefore, to increase the temperature of the outlet over the dew point, an additional heating method is required.

INTRODUCTION

Fire detection time in tall and large volume spaces directly relates to the concentration of smoke within the space. Especially, the ceiling height of warehouse is usually higher than 10 m and risk of fire is high. Generally, the fire detection system use passive detector installed in ceiling. However, in refrigerated warehouse, high air flows and low temperature air is generated by blast chillier unit will impede operation of passive detectors. Moreover, the fire is rapidly spread coupled with a dry environment and high airflow by air condition system. Therefore, in order to minimize damage and loss due to fire, the air sampling fire detection system is preferentially installed. [1] The air sampling fire detection system sampled air via pipe network into smoke detector chamber where installed at outdoor of refrigerated warehouse.

However, the cold air flow into the detector chamber directly, the temperature of the detector chamber falls below the dew point by cold air. Therefore, condensation and frosting occur at outside of detector chamber.

This condensation and frosting cause malfunction. Therefore, in order to prevent condensation and frosting, the temperature of air in pipe must be raised to a temperature higher than the dew point. So, aluminum fin and pipes are designed to raise the temperature above the dew point.

Therefore, in this study, numerical analysis is performed to design the effective fin and pipe according to the number of fins. In order to the design the effective fin and pipe, the performance of fin and pipe is analyzed.

NOMENCLATURE

A	Total heat transfer surface area, m^2
A_f	Fin surface area, m^2
T	Temperature, ℃
RH	Relative humidity, %
R	Radius
X, Y, Z	Cartesian axial coordinate

Greek symbols

η_f	Fin efficiency

Subscripts

ave	Average
f	Fin
in	Inlet
out	Outlet
w	Wall

GEOMETY AND BOUNDARY CONDITIONS

In this study, to design the effective fin and pipe according to the number of fins, the numerical analysis is performed four cases along the number of fins as no fin, two, four, and eight respectively. Figure 1. represents the schematic of air sampling smoke detection system with fin pipe. The finned pipe used in this study has a simpler form than the existing fin-tube because it is used in a harsh environment for fire and has high reliability.

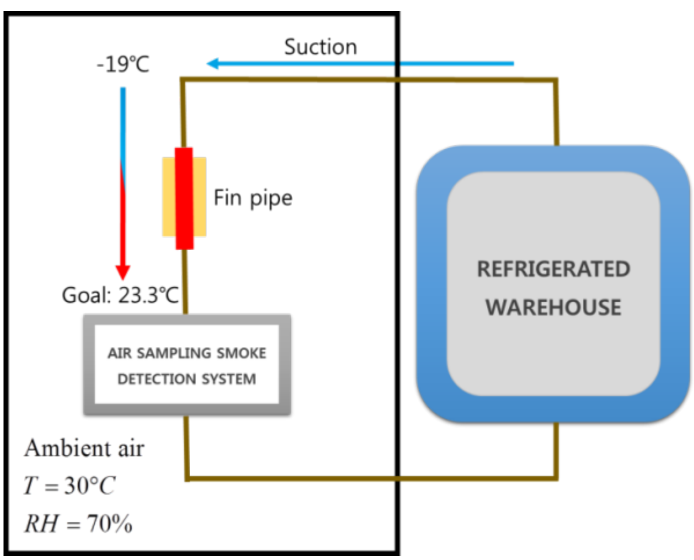

Figure 1 Schematic of air sampling smoke detection system with fin pipe

Figure 2. represents the geometry of numerical domain. The numerical domain of fin pipe consists of aluminium fin, aluminium pipe, PVC pipe and PVC case. The number of fins at each case are 0, 2, 4, and 8 respectively.

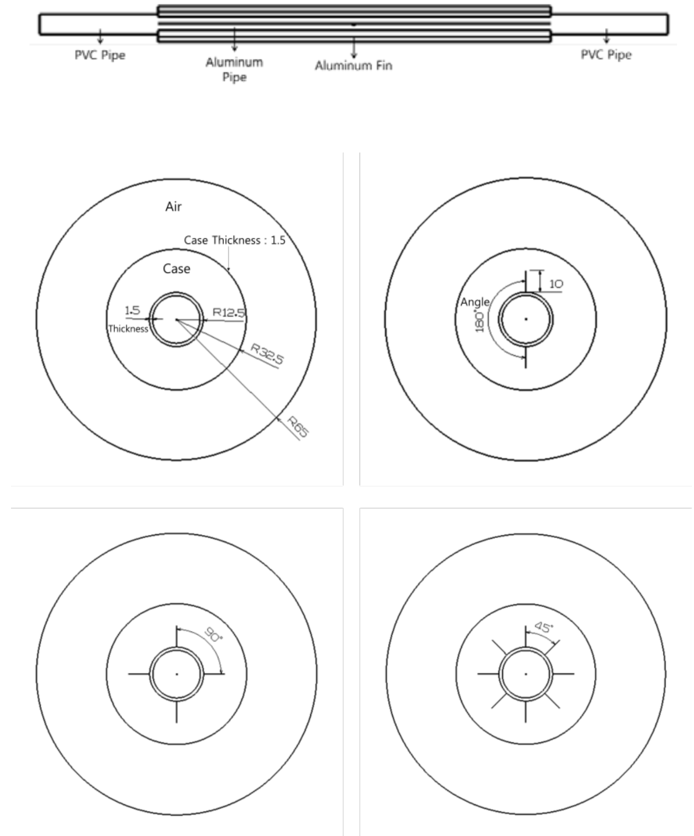

Figure 2 The geometry of numerical domain [Unit: mm]

Figure 3. represents the boundary conditions of numerical domain. The inlet, outlet and each wall conditions set up as shown in the table 1.

The material properties of PVC are as follows, density is 900 kg/m^3, specific heat is 2093 j/kg k. and thermal conductivity is 0.25 w/m k. The properties of aluminium are as follow, density is 2719, specific heat is 871, and thermal conductivity is 202.4 w/m k. Also, the properties of air are use data base of ANSYS FLUENT 17. The density of air use ideal gas.

Table 1 Boundary Conditions

Name	Boundary condition	Value	
Inlet	Velocity inlet	0.796 m/s	303.15 k
Outlet	Pressure outlet	0 Pa	303.15 k
Outlet2	Pressure outlet	0 Pa	303.15 k
PVC_Pipe	Wall	No-Slip	PVC
AL_Pipe	Wall	No-Slip	Aluminium
AL_Fin	Wall	No-Slip	Aluminium
Case	Wall	No-Slip	PVC

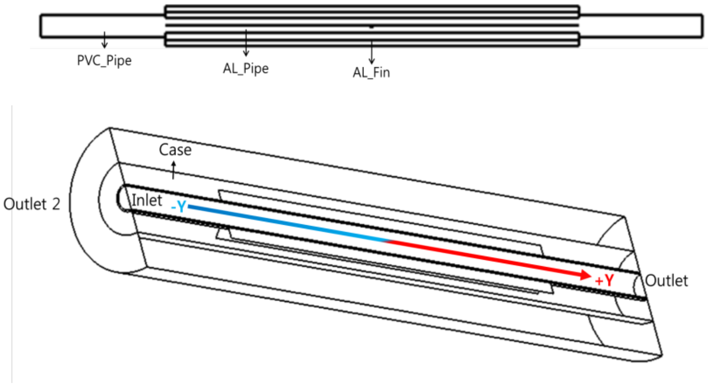

Figure 3 The boundary conditions of numerical domain

NUMERICAL DETAIL

The ANSYS FLUENT 17 is used for numerical analysis. To investigate of temperature rise at air from refrigerated warehouse by fin pipe, heat transfer and buoyancy are calculated in steady state. The computational grid was consisting of hexa-hedral mesh by ANSYS ICEM 14.5. The laminar viscous model is used. The standard wall function is used to near wall treatment. The SIMPLE scheme is used to discretization of pressure-velocity coupling. The second order upwind scheme is used for mass, momentum, and energy. The convergence criterion for numerical study residuals was set up 10^{-6} for mass continuity and energy. The solution time of each case was about 10 min on a personal computer with 8-node 3.4GH processor.

RESULT AND DISCUSSION

Figure 4. represents the temperature in the center of pipe along the length direction. The temperature of the air inside the pipe rises sharply from -0.25 m which is the starting point of the fin-tube. As the number of pins increases by two, the temperature of the outlet increases by about two degrees. The buoyancy driven is mainly affect flow near the fin. It is known that the critical Re for turbulent regime in open channel exceeds 1000.The maximum velocities near the fin are 0.271, 0.273, 0.282, 0.293, and 0.296 m/s according to the number of fins varying 0, 2, 4, 6 and 8 respectively. The Reynolds number are 295, 297, 307, 319 and 322 respectively. Therefore, every flow is laminar flow and it means that laminar viscous model in this research is good agreement. In this study, to prevent dew in detector chamber, the outlet temperature should rise above the dew point temperature of 21 °C. However, even if the number of fins increases, the outlet temperature are -3.14, -1.35, 0.10 and 2.16 °C according to the number of fins are increasing as 0, 2, 4, 6 and 8 respectively. The variation of are temperature are decrease along the distance from the inlet to outlet. Because, the laminar flow is dominant at heat transfer at fin surface to air. Also, the conduction is mainly affected by the temperature between the two materials which are temperature of fin and air.

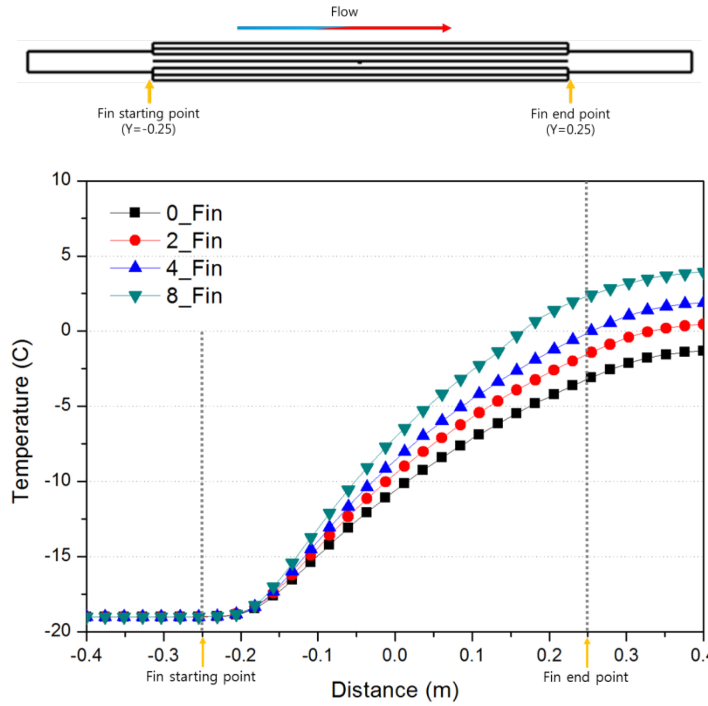

Figure 4 The temperature in the center of pipe along the length direction

Therefore, to satisfy the outlet temperature above the dew point, the number of fins and pipes must be increased, but the number of pins cannot be increased further due to machining and installation problems. Therefore, to increase the temperature of the outlet beyond the dew point of 21 °C, An additional heating method is required.

Table 2 is Fin efficiency and temperature. The fin efficiency is the ratio of the mean temperature difference from surface to fluid divided by the temperature difference from fin to fluid at the base or root of the fin. The fin efficiency is calculated by equation (1). [2]

$$\eta_f = \frac{T_f - T_{ave}}{T_w - T_{ave}} \qquad (1)$$

Where T_f is the mean temperature of fin, given by equation (2), and Tw is ambient temperature assumed summer as 30 °C

$$T_f = \frac{\int_{A_f} T_f dA}{\int_{A_f} dA} \qquad (2)$$

Where T_{ave} is the average temperature of air fluid calculated by equation (3).

$$T_{ave} = (T_{in} + T_{out})/2 \qquad (3)$$

The fin efficiency increase 0.34, 0.37 and 0.41 according to the number of fins are increasing as 0, 2, 4, 6 and 8 respectively. The efficiency increases along the number of fins, because temperature of fin increase more than variation of temperature in inlet and outlet. Also, the fin efficiency increase about 3% along the area of fin increasing twice.

Table 2 Fin efficiency, heat flux and temperature

	0Fin	2Fin	4Fin	8Fin
T_f [℃]	-	2.35	4.24	6.79
T_{out} [℃]	-3.14	-1.35	0.10	2.16
T_{in} [℃]	-21.00	-21.00	-21.00	-21.00
T_{ave} [℃]	-12.07	-11.17	-10.45	-9.41
T_w [℃]	28.00	28.00	28.00	28.00
Efficiency	-	0.34	0.37	0.41
Heat flux [W/m^2]	-	-126.03	-117.53	-98.87
Area [m^2]		0.01	0.02	0.04

CONCLUSION

In this study, numerical analysis is performed to analyze the temperature of the air and performance of fin and pipe. The temperatures of outlet and fin efficiency are increasing along the area of fin increase twice. In this study, the goal of outlet temperature should rise above the dew point temperature of summer at Korea. However, even if the number of fins increases, the maximum temperature inside the pipe past the fin pipe is lower than the dew point temperature. Thus, condensation may occur in detector chamber and it may cause malfunction. Therefore, additional heating method such as forced convection and heat tape is required. Also, since the fin efficiency is directly influenced by area of fin, the area of fin and efficiency is considering for efficient fin pipe design.

ACKNOWLEDGMENTS

This research was supported by the Chung-Ang University industry Academic Cooperation Foundation of Alllite life company Grants in 2017

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[2] GU, Lingdong, et al. Airside heat transfer and pressure loss characteristics of bare and finned tube heat exchangers used for aero engine cooling considering variable air properties. International Journal of Heat and Mass Transfer, 2017, 108: 1839-1849.