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Airflow Characteristics in Conveyor Type Damper for Hot Air Temperature Changes

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Abstract: The aim of this study was to present the characteristics of a hot airflow in a conveyor type dampers under the hot air temperature changes. The amount of space occupied by the damper was reduced by 50 %, and by efficiently managing the damper's airflow rate even in the face of extreme external conditions and constant air volume proportional control, a conveyor-type damper with a significant energy-saving effect has been explored. It was configured to control the degree to which it was opened by operating the folding conveyor drive mechanism, enabling the damper to modify airflow. In this study, the mass flow rate of heated air through the conveyor-type damper increased in proportion to the damper port's expansion. The mass flow rate of air decreased as the temperature of air intensified. In addition, the thermal energy of the air flowing in the conveyor-type damper improved in ratio to the increase in the damper opening. The findings indicate a 50 % reduction in the damper's occupied space, indicating a significant energy-saving impact of the conveyor-type damper. This is because the damper's air volume is effectively controlled even in the face of severe external conditions, as it is proportionately controlled throughout. The understanding of the properties of airflow for the hot temperature change is strengthened by this research. Furthermore, this study may provide useful direction for future research and industry optimization.

Keywords: air mass flow rate; air temperature; conveyor type damper; damper opening hydraulic; thermal energy

1 INTRODUCTION

The damper controls the air volume by adjusting the level of primary of the duct, but the control of the air volume is not easy because the air volume varies according to still pressure and the level of opening. A control of air volume is more difficult in the case of single-blade dampers because the air volume alterations non-linearly based on the degree of opening under the same static force [1, 2]. Local and international research on damper technologies tends to study multi-blade dampers to explain the nonlinearity issue. In addition, since multi-blade dampers cannot be easily made into round dampers, venturi-type dampers have been studied and reported [3]. Rectangular dampers or multi-blade louver dampers are common names for multi-blade control dampers. Based on the blade action—the direction in which the blades revolve within the control damper—these dampers are usually available in two different variants. Recently, blade-orifice dampers that has outstanding linearity as the blade is installed on the neck of the orifice have been studied, and their features has been compared with those of venturi type dampers [4, 5]. Yet, the air volume cannot be easily controlled in the case of blade-orifice type dampers since the density varies as the opening's degree is adjusted. In addition, as an important characteristic of a damper, the presentation of the damper is articulated by the flow coefficient, and a certain number of pressure drops are basically designed based on the stroke distance of the damper when manufacturing the damper. When the damper is opened rapidly, the opening begins, and the flow rate rapidly increases to the maximum flow rate. When the damper is opened linearly, the opening and the flow rate are proportional to each other at an equal ratio, and as the opening increases at an equal rate, the flow rate also increases at an equal rate as with the previous flow rate. The actual amount of pressure drops before and after the damper appear differently from the performance curve, and the amount of error is determined according to the design of the entire system. Therefore, the damper shows the error range of the damper designed with linear characteristics in the pressure drop ratio of the entire system of a typical linear device, and dampers should be designed and manufactured based on the pressure drop ratios of various systems. The damper coefficient is the ratio of the maximum air volume when the damper is fully opened to the system pressure drop before and after the damper. Looking at the report on the performance curve, parallel blade dampers are suitable for two-point control, and in the case of opposed blade dampers, the necessity to reduce damper errors with fine control is high because the ratio of the pressure drop at full opening to that at closing is large. Considering the characteristic that the ratio of the amount of pressure drop in the phase is large, there is a great need to reduce the error of the damper by fine control. In addition, the air flowing through the duct has a characteristic that the density, which is the physical property of the air, changes greatly according to the temperature changes of the air. Therefore, if an adjustment in the density in the air according to a change in a temperature of the air is not considered, the error of the damper will greatly increase. As such, by designing and manufacturing the dampers based on the characteristics of dampers and the design theory, the errors are reduced, and the precision is improved in the process of controlling the air volume by adjusting the degree of opening of the duct. However, since most of damper manufacturers are small and medium-sized enterprises (SMEs), research and development of dampers are insufficient, and since dampers are manufactured based on experience values in the state where the design theory values are lacking in the damper manufacturing process, the continuous air volume cannot be easily organized. Many errors occur in the process of controlling the air volume by adjusting the degree of opening of the duct. In addition, in the forced ventilation fans, the damper controls the intake flow of air by adjusting the opening/closing angle of the vane damper to supply combustion air to the boiler, heater, and dryer [5]. As the need for energy saving in mechanical devices such as boilers, heaters, and dryers has been increasing in recent years, dampers with high efficiency and low power consumption are studied for forced ventilation fans [6, 7]. Therefore, in order to reduce power consumption, forced ventilation fans are being developed to enable the adjustment of the air flow ratio based to the changes in external load conditions [8, 9]. The R&D of the forced ventilation fans as such is actively conducted because if such forced ventilation fans are used in boilers, heaters, dryers, etc., the air volume of the damper will be effectively controlled even when the external conditions change severely during operation so that the energy saving effect will be large [10, 11]. In addition, in order to reduce errors and improve precision when the damper is designed, the characteristics of the facility, the values of system loss characteristics, the values of pressure changes according to air flow changes, the performance curve values for the blower system action, the ratio of system pressure drop to the maximum air volume when the damper is fully opened, and the characteristic values of the density, which is the physical property of air, changing greatly depending on the air temperature changes should be considered accurately [12, 13]. Therefore, at the current level of domestic and foreign damper manufacturing technologies, study reports on dampers that considered all these variables are insufficient as it is difficult to satisfy all the variables with existing technologies. In this study, a blade folding damper that can satisfy all variables was developed. The purpose of this study was to describe the properties of a hot airflow for the hot air temperature of dampers at various authority levels. In this study, a blade folding damper that can satisfy all variables was developed. The blade folding damper occupies 50 % of the space that would be occupied by an existing damper and controls the constant air volume proportionally and effectively even when the external conditions change severely leading to a large energy saving effect.

2 METHOD AND DEVICE FOR EXPERIMENTATION

Fig. 1 explains the conveyor type damper experimental device. Fig. 1 represents the conveyor type damper is composed of the folding blade, a folding blade driving device, a blower fan, an inverter for controlling the air volume of the blower fan, a conveyor type damper rectifier grid, a blade folding damper opening proportional control device, and a hot air energy supply device with a gas burner.

The experimental device was configured so that the degree of opening of the conveyor type damper can be controlled by the driving of the folding blade driving device, to adjust the volume of air flowing with the conveyor type damper. To manage the amount of air passing by the damper, the blower was added with an inverter to regulate the fan's revolutions per minute. An experimental tool was configured in regulating the heat of the air go along in a conveyor type damper by supplying the hot air energy for the combustion gas of the gas burner. A flow velocity sensor was connected in the area of the duct outlet of the conveyor type damper to estimate the hot air flow velocity. A temperature sensor was installed in the section of the duct exit for temperature measurement of the air. In addition, hot air is introduced into the inlet of the duct of the conveyor type damper by the operation of the blower fan [14-17]. As such, the conveyor type damper experimental device was configured so that the air introduced into the inlet of the duct of the conveyor type damper passes over the rectifier grid so that the flow velocity of the air is uniform. An experimental device was configured so that the velocity of the air go along by the damper area is maintained to be uniform by the rectifier grid installed at the front end of the inside of the duct.

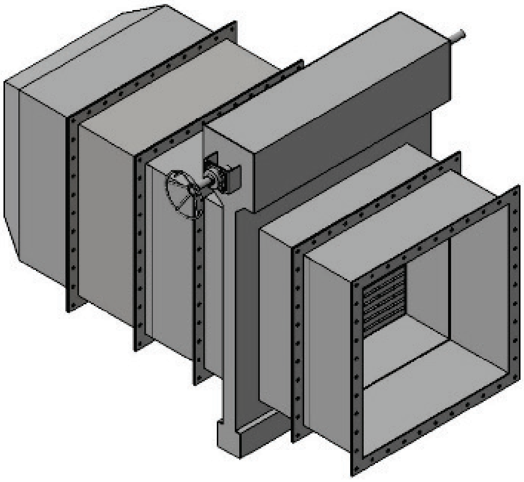
Figure 1 Experimental device of conveyor type damper

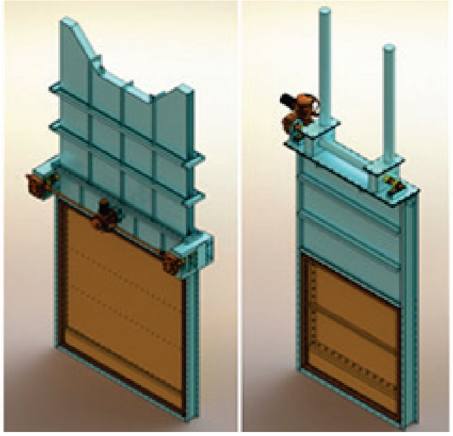
Figure 2 The folding blade drive unit with folding blades

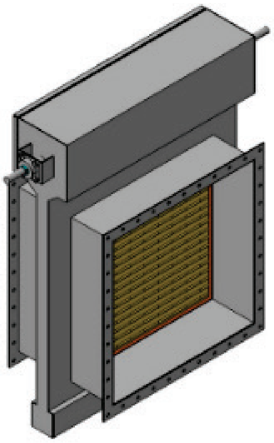
Figure 3 Drive system of blade folding damper

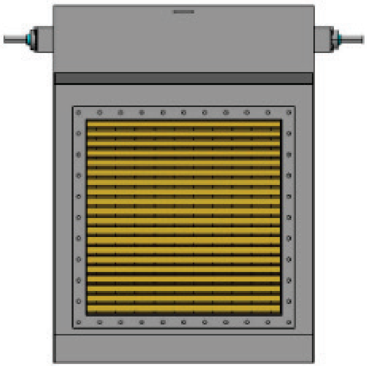
Figure 4 Front view of the drive system of conveyor type damper

Fig. 2 shows the driving device of the conveyor type damper. As shown, the driving device of the conveyor type damper was configured so that the folding blade proportionally adjusts the level of damper opening. The study was conducted on a conveyor type damper applicable in a constricted area shown in Fig. 3 and Fig. 4. Existing plate-type dampers occupy a huge area when the level of opening of the damper is augmented. In order to solve the problem of such structure, a blade folding damper experimental device should proportionally control the continuous air volume based on the level of opening of the damper. We configured a blade folding damper that enables precise quantitative regulation with horizontal movement of the fluid when the degree of opening of the damper changes and minimized the space in which the ascending and descending blade is accommodated so that the damper can be installed regardless of the space even when the installation place is small.

Fig. 5 presents the specifications of the foldable blade. As shown, the area of the folding blade is 50 mm, a total of foldable blades is 25, and the width is 2 mm. A weight of the foldable blades is 50 kg, and a driving rate of the foldable blades is 50 mm/c. An experimental device was configured so that the foldable blade driving shaft is driven at a torque of 19.12 kN·m.

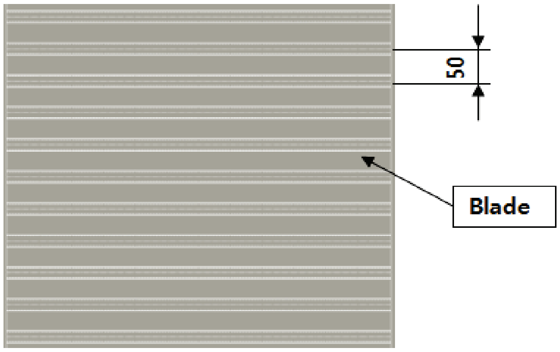

Figure 5 Size of foldable blade

2.2 Experimental Method

A slim foldable roll screen blade technology that will enable the application of dampers developed with new technologies with new concepts in cases where expensive products, high-function valves are used by installing slide dampers in narrow spaces in industrial facilities or the layout of industrial facilities are changed was experimentally studied. Whereas the existing dampers use individual blades or the integrated blade structure method like the slide dampers, in this study, an experimental device for a damper of a new concept in the foldable roll screen blade method was configured. In addition, according to study reports on the existing damper blades, it is hard to modify the continuous volume of the air that flows in the damper proportionally to a motionless weight and the level of opening. Tab. 1 presents the experimental variables and experimental situations for the study of the air volume characteristics according to the temperature change of the air going inside a duct of a conveyor type damper. The degree of damper opening was one of the experimental variables together with the air temperature, and changes in the hydraulic diameter. The degree of damper opening was uniformly allocated into 10 areas in the range of 10 to 100 %, and the experiment was performed at air temperatures of 280 K, 300 K, and 320 K. The hydraulic length was uniformly separated into five areas in the range of 0.07 to 1 m to conduct the experiment.

Table 1 Conditions and parameters for the experiment

Parameter	Value
The damper's opening degree	10-100 %
Temperature of air	280 K, 300 K, 320 K
Hydraulic diameter	0.18-0.95 m

3 RESULTS AND DISCUSSIONS

3.1 Mass and Thermal Energy Equilibrium of the Air Flowing in the Damper

Fig. 6 discussed the relationship of the theoretical air mass flow rate and the experimental hot air mass flow rate in the conveyor type damper. Eq. (1) represents the continuous equation for calculating the theoretical hot air mass flow rate.

$$m_{\mathrm{a\,th}} = \rho \cdot A \cdot V \tag{1}$$

In Eq. (1), ρ represents the density of hot air (kg/m^3), A represents the cross-sectional section of the conveyor type damper. The thickness of a conveyor type damper is 1 m and the length is 1m. Thus, the cross-sectional section of a conveyor type damper is 1 m^2. V signifies the flow speed (m/s) of the hot air running in the conveyor type damper. The temperatures of the hot air go along in the conveyor type damper were 280 K, 300 K, and 320 K when the hot air mass flow rate change experiment was performed with changes in the hot air temperature. In addition, the experiment was conducted in 10 equal sections while increasing the degree of damper opening by 10% from 0-100%. As shown in Fig. 6, a theoretical hot air mass flow rate and an experimental hot air mass flow frequency in the conveyor type damper matched well within a range of ±3%. Hence, the accurateness of the experimental results of the theoretical hot air mass flow rate and the experimental air mass go along are shown to be high. It is considered that the consistency of the experimental outcomes has been proved.

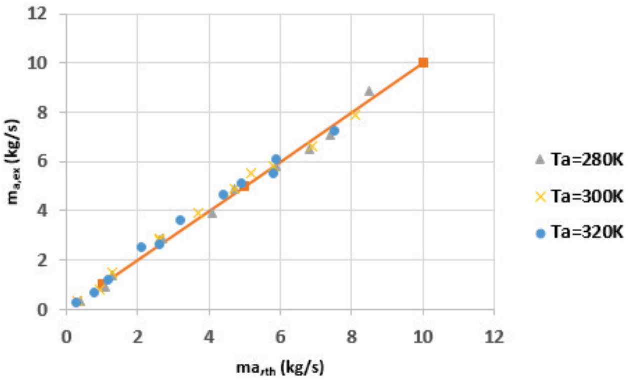

Figure 6 Comparison of theoretical hot air mass flow rate and experimental air mass flow rate

Fig. 7 represents the contrast of the theoretical hot air energy and experimental hot air energy of the air flowing in the conveyor type damper. Eq. (2) represents the theoretical thermal energy.

$$Q_{\mathrm{a\,th}} = m_{\mathrm{a\,th}} \cdot C_{\mathrm{p}} \cdot (T_2 - T_1) \tag{2}$$

In Eq. (2), C_p of air represents the specific heat of air (kJ/kgK). T_1 represents the primary temperature (K) of an air flowing in a blade folding damper. A primary temperature of the hot air for a calculation was set to 0 K, and the hot air energy at 0 K was set to 0 kJ. T_2 represents the temperature of the flowing air when hot air energy was applied. Three temperatures: 280 K, 300 K, and 320 K of the air flowing in the conveyor type damper were set to experiment changes in the hot air energy in response to temperature changes. In addition, the experiment was conducted in 10 equal sections while increasing the degree of damper opening by 10 % from 0-100 %. Fig. 7 shows the theoretical hot air energy and the experimental hot air energy of the air go along in the conveyor type damper were in decent arrangement within the range of ±3 %. As the hot air energy value rises, the accuracy of the experimental hot air energy develops. Therefore, the accuracy of the experimental hot air energy value of the air flowing in the conveyor type damper was high. It is considered that the consistency of the experimental outcomes has been confirmed.

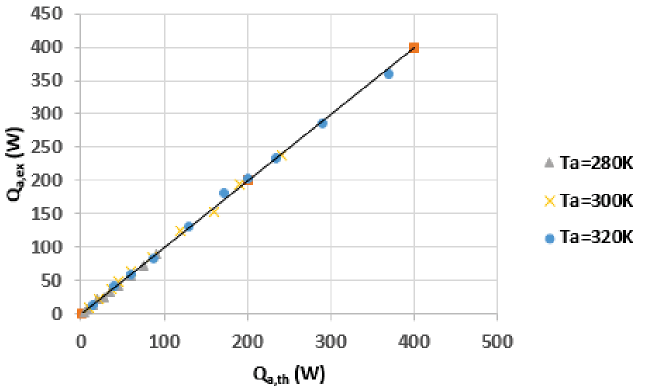

Figure 7 Comparison of theoretical hot air energy and experimental hot air energy of hot air flowing in the damper

3.2 Changes in the Temperature of the Air Flowing in the Damper and the Characteristics of the Air Volume according to Changes in Damper Opening

The variations in air mass flow rate about the conveyor type damper's damper opening level are shown in Fig. 8. In Fig. 8, D_o represents the degree of damper opening (%) of the blade folding damper. A degree of damper opening was controlled by configuring a conveyor type damper experimental device that can proportionally control the constant air volume. The experimental device was arranged so that the degree of damper opening could be adjusted, and the experiment was conducted in five equal sections while increasing the damper opening by 20 % from 0-100 %. In addition, three temperatures of the air flowing in the conveyor type damper: 280 K, 300 K, and 320 K were set to experiment changes in hot air energy in response to temperature changes. The mass flow rate of the air goes along in the conveyor type damper amplified in percentage to the increase in the degree of damper opening. It is believed that the mass flow rate of the hot air drops as the temperature of an air rises because when the hot air temperature increases, the density of the air decreases.

Fig. 9 shows a change in the air volume with respect to the adjustment in a degree of the damper opening of a conveyor type damper. In Fig. 9, D_o represents the level of damper opening (%) of a conveyor type damper. The degree of damper opening was controlled by configuring a conveyor type damper experimental device that can proportionally control the constant air volume. The experimental device was arranged so that the degree of damper opening could be adjusted, and the experiment was conducted in five equal sections while increasing the damper opening by 20 % from 0-100 %. In addition, three temperatures of the hot air go along in the conveyor type damper: 280 K, 300 K, and 320 K were set to experiment changes in the hot air energy in response to temperature changes. Furthermore, the volume of the hot air go along in the conveyor type damper amplified in percentage to a rise in a level of damper opening, and the air volume increases as the temperature of the air increases. It is believed that the air volume rises as the temperature of the air rises since as the temperature of the air rises, the density of the air drops. The hot air energy of the hot air rises proportionally as the volume of air flow increases following the increase in the degree of the damper opening. Also, it is considered that the hot air energy increases as the amount of heat retained in the air rises as the hot air temperature rises.

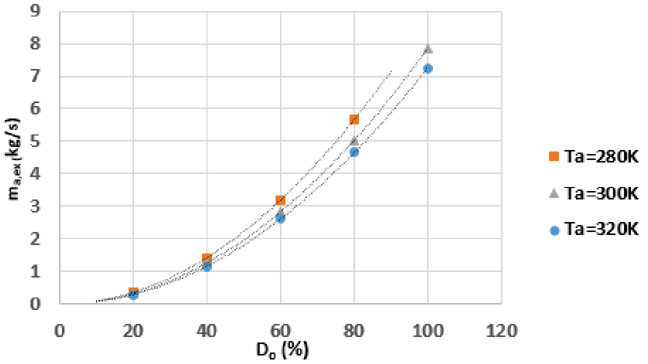

Figure 8 Modification of the air mass flow rate to adjust the damper opening

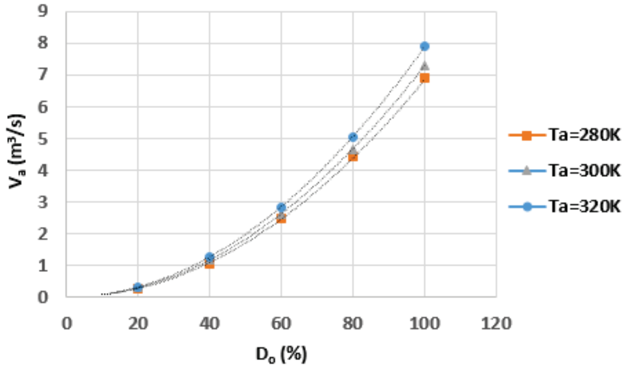

Figure 9 Change in hot air mass flow rate for change in damper opening

Fig. 10 appears a change in the hot air energy of the hot air for the adjustment in the degree of damper opening of the conveyor type blade folding damper. In Fig. 10, D_o represents the damper opening level (%) of the conveyor type damper. A damper opening was controlled by configuring a conveyor type damper experimental device that can proportionally control the constant air volume. The experimental device was arranged so that the degree of damper opening could be adjusted, and the experiment was conducted in five equal sections while increasing the damper opening by 20 % from 0-100 %. In addition, three temperatures of the hot air flowing in the conveyor type damper: 280 K, 300 K, and 320 K were set to experiment changes in the hot air energy in response to temperature changes. It is thought that the mass flow rate of the hot air drops as the temperature of the air rises because as the air temperature increases, the density of the hot air decreases. Fig. 10 shows hot air energy of a hot air flowing in the conveyor type damper augmented in ratio to the increase in the degree of damper opening and increases as the temperature of the hot air rises. It is considered that the hot air energy of the hot air rises proportionally as the mass flow rate of hot air increases as the degree of damper opening increases. Also, the hot air energy rises as the amount of heat retained in the air increases as the air temperature rises.

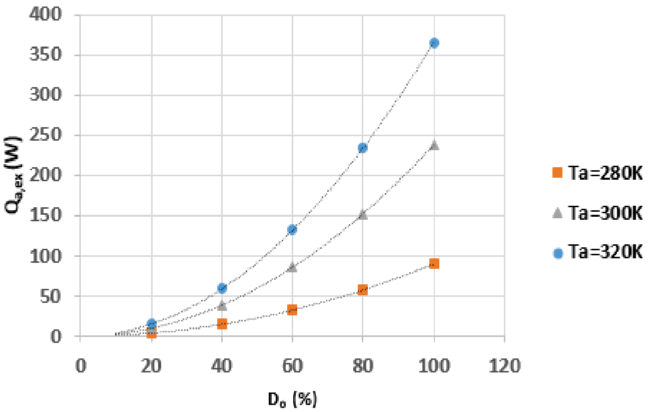

Figure 10 Modification of the hot air mass flow rate to adjust the damper opening

Fig. 11 represents a transformation in the Reynolds quantity for the changes in the hydraulic length of the conveyor type damper. Eq. (4) represents a hydraulic diameter.

$$D_\mathrm{h} = \frac{4A}{P} \tag{3}$$

where, P denotes the wetted perimeter of the conveyor type damper and Eq. (4) represents the Reynolds number.

$$Re = \frac{\rho \cdot V \cdot D_\mathrm{h}}{\mu} \tag{4}$$

where μ represents the viscosity coefficient of air (N/ms). The hydraulic diameter was experimented in five sections of 20 %, 40 %, 60 %, 80 %, and 100 % of the flow cross-sectional section of the damper. Thereafter, the hydraulic diameter was calculated using Eq. (3) for a flow cross-sectional section of a 5 sections. In addition, the Reynolds numbers according to changes in the hydraulic diameter at three temperatures of the air go along in a conveyor type damper: 280 K, 300 K, and 320 K. As shown in Fig. 11, following changes in the level of damper opening, the Reynolds number improved in percentage to the rise in hydraulic diameter. As an air temperature increased, the Reynolds number decreases. From these experimental results, it is considered that the Reynolds number of the air drops as the temperature of the air rises, because a density of an air decreases as a temperature of an air increases.

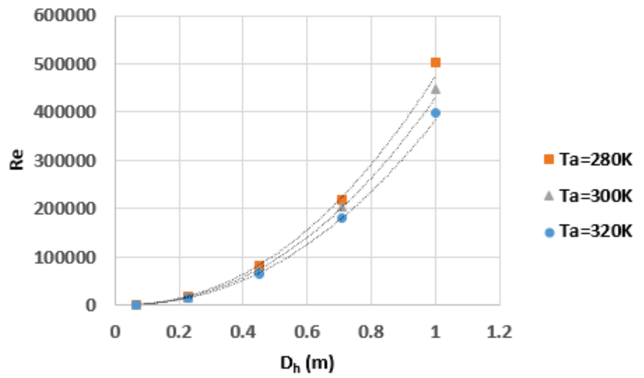

Figure 11 Change of Reynolds number of hot air with change of hydraulic diameter

Fig. 12 shows changes in hot air energy with respect to changes in the Reynolds number of the conveyor type damper. The Reynolds number was experimented in the range of 1000 to 400000. Changes in the hot air energy in response to temperature changes were experimented at three temperatures of the air go along in the conveyor type damper: 280 K, 300 K, and 320 K. Fig. 12 shows hot air energy of the air flowing in the conveyor type damper augmented in percentage to the rise in the Reynolds number. Furthermore, the increment of hot air energy increased greatly in proportion to the increase in the air temperature. Therefore, a thermal energy of a hot air flowing in the conveyor type damper is a variable greatly affected by the rise in the Reynolds quantity and the rise in the air temperature. Therefore, the results shows that the space occupied by the damper is reduced by 50 % thus the energy saving effect of the conveyor type damper were large because it proportionally controls the continuous air volume and effectively control the air volume of the damper even when changes in the external conditions are severe.

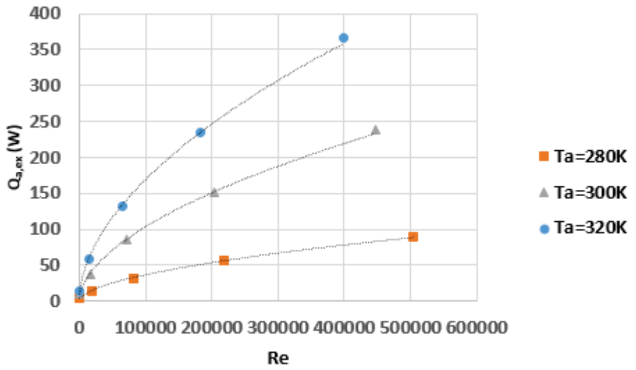

Figure 12 Changes in thermal energy concerning changes in the Reynolds number of the conveyor type damper number

4 CONCLUSION

An experimental study was conducted to find the adjustment in the mass flow rate of air and the adjustment in the hot air energy for the modifications in the temperature of the air passing through the conveyor-style damper varies together with the Reynolds number and damper opening degree. The following study results were derived. Within a ±3 % range, there was a good match between the conveyor type damper's theoretical and experimental air mass flow rates. There was a ±3 % discrepancy between the observed and predicted hot air energy of the air. As a result, it was demonstrated that the experimental effect values for the conveyor type damper's temperature changes and variations in damper opening level were highly accurate. Consequently, it was established that the experimental results of this investigation were consistent. The blade folding damper's mass flow rate of hot air is proportionally enhanced to an increase in the degree of damper opening and decreases as the temperature of the hot air increases.

The hot air energy of the hot air flowing in the conveyor type damper augmented in percentage to an increase in the degree of damper opening and increased as the temperature of the hot air increased. The hot air energy of the hot air flowing in the conveyor type damper augmented in percentage to an increase in the Reynolds number and the increment of the hot air energy increased greatly in proportion to the increase in the hot air temperature. The hot air energy of the hot air flowing in the conveyor type damper was greatly affected by the rise in the Reynolds number and the rise in the air temperature. From these research results, the space occupied by the conveyor type damper is reduced by 50 %, and that the energy saving outcome of a conveyor type damper is large because it proportionally controls the constant air volume and effectively control the air volume of the damper even when changes in the external conditions are severe.

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