NUMERICAL ANALYSIS ON THE COOLING PASSAGES OPTIMIZATION OF TURBO BLOWERS

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ABSTRACT

Turbo blowers are used for various industrial facilities and equipment such as agricultural machines, gas supply machines, etc. Recently, with the growing capacity and reduced size of turbo blowers, the thermal management of various packaged electric components has emerged as a challenging issue. Based on this recognition, this study aimed to estimate the required cooling flow and temperature distribution in the initial design phase of 200 HP turbo blowers. The results of this study show that it is possible to achieve cooling performance for the 200 HP turbo blowers by using an adequate partition wall, fan, and filter.

Keywords: turbo blower, cooling passage, thermal management, CFD.

INTRODUCTION

Industrial fluid machines are used to supply air or gas after compression, and are classified into fan, blower and compressor depending on compression ratios. Among them, the blower is a fluid machine widely used for processing, for example, for aeration tanks at a wastewater disposal plant, the transport of powder materials in the chemical and cement industries, desulfurization facilities and cooling equipment at a power plant, the manufacturing process and transfer lines of the semiconductor/LCD industries, etc.

A turbo blower is primarily used where high pressure is required for various industrial equipment or devices such as farming machines, vacuum cleaners, gas supply facilities, air mixers, air-floating systems, etc. [1] A turbo blower offers many advantages. For example, it can be operated for a wide area with high efficiency, and used semi-permanently. An industrial turbo blower, which is usually designed to have high capacity, is used extensively for power plants, waste disposal facilities, ventilation facilities, etc.

Technological development efforts are still underway to make turbo blowers more efficient, quieter and smaller. Large-sized turbo blowers used for domestic power facilities or plants in the 1900s were mostly imported ones [2, 3], but since the first domestic development of a turbo compressor in 2003, significant advancement has been seen, including the manufacturing of mid-sized low-pressure turbo blowers solely based on domestic technology, entry into the domestic and overseas markets, etc. [4, 5] More diverse products are newly being developed now, responding to the needs of consumers.

Jeong, *et al.* [6] proposed the optimal design of the impeller of a turbo blower, and estimated the pressure at the outlet by varying the radius of the hub, the radius of the shroud, the height of the outlet, and the number of blades.

Park *et al.* [7] conducted a study on the change of voltage ratio and efficiency according to the thickness of the impeller blade hub and tip. In their study, it was shown that changes of the blade thickness at the outlet of an impeller result in changes of slip coefficients.

Yang [8] examined the impacts that the inlet shape of a turbo blower and the gap or overlapping space of impeller and inlet section have on the performance of a turbo blower, in the study titled “Experimental Study on the Effect of Performance for Turbo Blower with Inlet Shape”. In this study, a method for designing and producing an ideal inlet shape of a serial-type centrifugal turbo blower with low-specific speed and high-pressure ratio was presented.

Seo *et al.* [9] conducted the study titled, “Aerodynamic Characteristics Analysis of Small Two-Stage Turbo Blower Using CFD,” where they found that the secondary flow is generated in the impeller and guide vanes in each stage of a small two-stage turbo blower, and the flow discharged from the impeller of stage 1 flows into the inlet of stage 2 through the guide vanes, producing the largest loss. It was also found that a reverse flow is caused in the gap between the impeller outlet and the casing, resulting in the secondary flow on the lower part of the impeller disk and the upper casing. The authors explained that this is how the performance of a turbo blower is undermined.

In their study, “A Study on the Noise Property and Its Reduction of the FCEV Blower,” Oh *et al.* [10] showed that the main sources of the noise of a blower are mechanical noise, and the peak noise caused by blade-passage frequency, not broadband noise, and therefore, it was concluded that reducing mechanical noise would be the most effective way to achieve noise reduction.

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Also, in their study, "Pressure Characteristics according to the Duct Shape of a Turbo Blower Connected in Serial," Park *et al.* [11] analysed the pressure characteristics of a turbo blower according to the shape of the inlet guide and duct based on the numerical analysis method. With respect to the efficiency and the pressure difference at the inlet and outlet according to the shape of the inlet guide, it was shown that an elongated shape was more effective. They also found that in the case of a turbo blower connected in serial, the pressure loss was minimized when the radius of curvature of the duct connecting the inlet and outlet was longest.

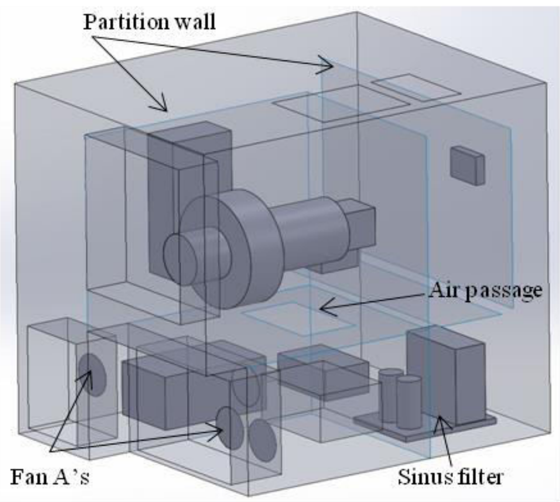
Meanwhile, Kim *et al.* [12] demonstrated that the bump foil bearing has a high load-bearing capacity through injury tests and load-bearing tests.

As shown above, most of the previous studies were conducted in connection with the performance enhancement of a turbo blower. However, as the power of turbo blowers grows, thermal management has emerged as an important issue recently, particularly with respect to packaging various electric components. Based on this recognition, this study aimed to estimate the required cooling flow and temperature distribution in the initial design phase of a 200 HP turbo blower.

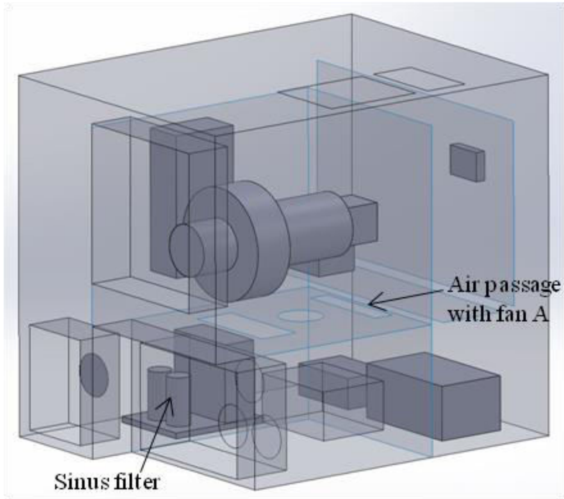
Numerical method and conditions

Table-1 shows the specifications of models considered in this study. In total, five models were considered by changing cooling passage, filter, the type or number of fans, exhaust fan, etc. The characteristics of each model are shown in Figure-1. First of all, Model 1, which was used as the reference model, adopted the locations of the partition wall, air passage and

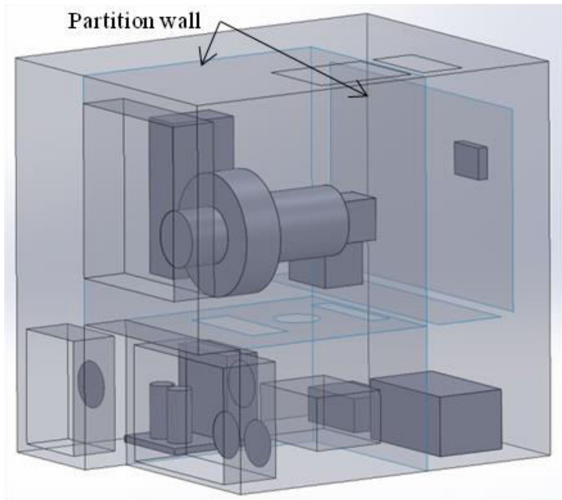
Electrical/electronic components of an existing turbo blower. In the case of Model 2, the locations of air passage and electric/electronic components were changed, and Fan A was additionally installed on the air passage. Model 3-1 is identical to Model 2 except for the shape of a



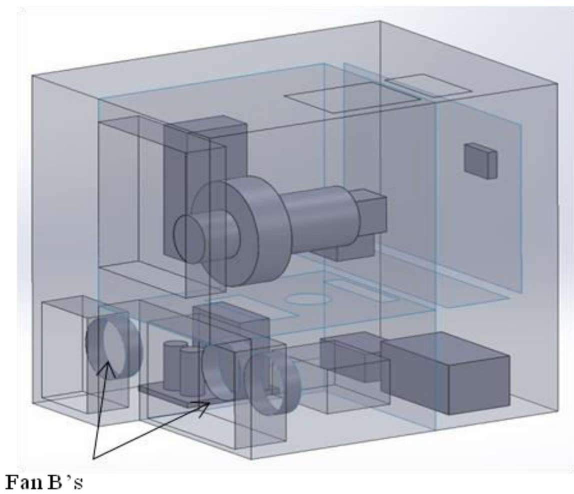
(a) Model 1



(b) Model 2



(c) Model 3-1



(d) Model 3-3

Figure-1. Schematic of analysis models.

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Table-1. Model specifications.

	Cooling passage type	Filter	Fan	No. of fans	Exhaust fan
Model 1	A	Dual filter	A	4	No
Model 2	B	Dual filter	A	5	No
Model 3-1	C	Dual filter	A	5	No
Model 3-2	C	Single filter	A	5	No
Model 3-3	C	Single filter	B	3	No

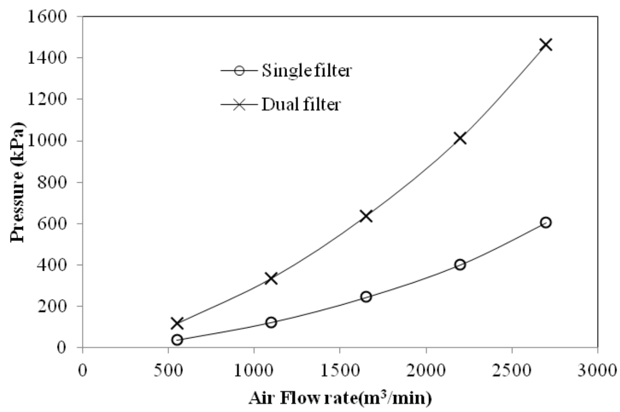

Figure-2. Variation of differential pressure with flow rate for the non-woven fabric filter.

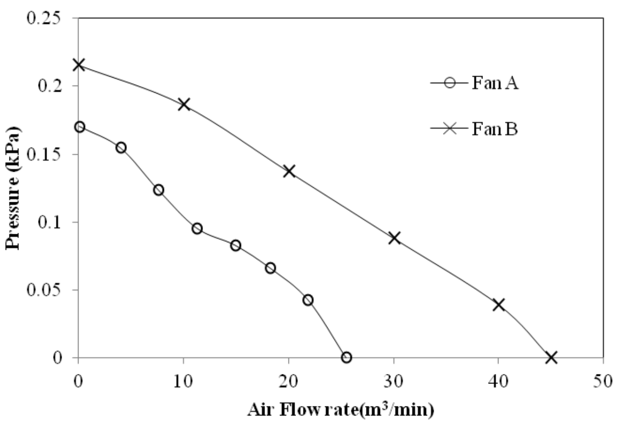

Figure-3. Performance curves of fans.

Table-2. Input conditions for numerical analysis.

	Inverter	Sinus filter	Controller
Q(W/m^3)	1300	5000	2500

partition wall, and Model 3-3 is identical to Model 3-1 except for the type of a fan.

Figure-2 shows the pressure changes according to air flow rates for Filter A and Filter B. In the thermal radiation analysis, the filters were assumed to be porous media, and the pressure drop characteristics were considered. Also shown in Figure-2 is the performance curve of fans, which is the result of a one-dimensional analysis based on performance curves, rather than a three-dimensional direct analysis. Table-2 shows the amount of released heat applied in the numerical analysis. As the sinus filter has the largest calorific value among the electric/electronic components, determining its location is the most important issue.

RESULTS AND DISCUSSIONS

Internal temperature variations according to cooling passage

First, using Model 1 and Model 2, the impacts that the change of the internal flow path of a turbo blower or the location of electric/electronic components has on heat release performance were examined. Figure-4 shows the air flow patterns of Models 1 and 2. For both of the models, as the hot air of the machinery space moved to the electric/electronic space, the temperature of the electric/electronic components therein went up. What's more, the phenomenon of air stagnation was observed in the lower part of the machinery space, and the cooling of the core was found to be concentrated only where motor was located. In the case of Model 2, in which the sinus filter was not located in the area of air stagnation, its heat release performance was more efficient than Model 1.

Figure-5 shows the temperatures of the major electric/electronic components of Models 1 and 2. The heat release performance of Model 1 was very poor, with the temperature of the inverter and sinus filter higher than 70℃, and the temperature of the controller reaching 57℃. In the case of Model 2, the temperatures of the electric/electronic components were similar except for the sinus filter, whose temperature was 60℃ or lower due to the change of its location.

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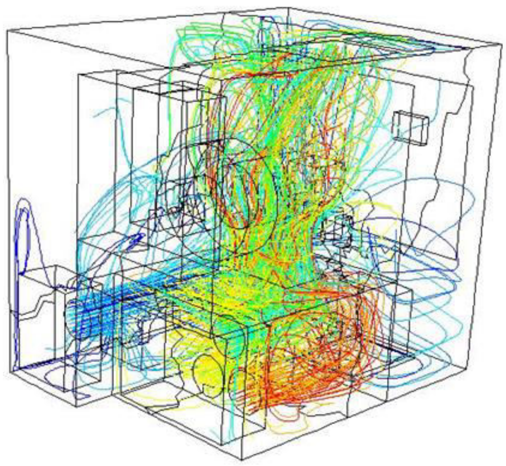
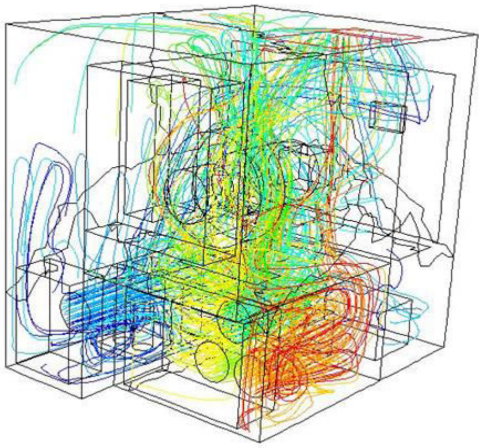


(a) Model 1



(b) Model 2

Figure-4. Streaklines of model 1 and model 2.

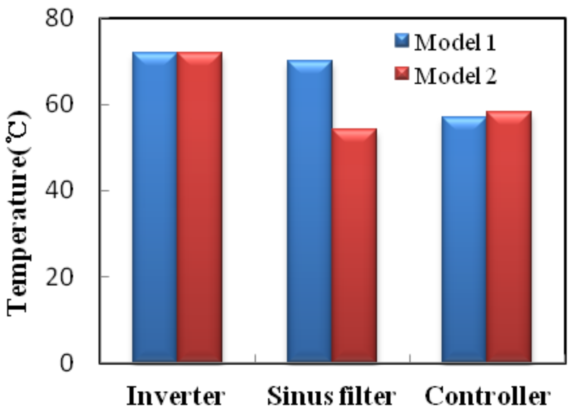
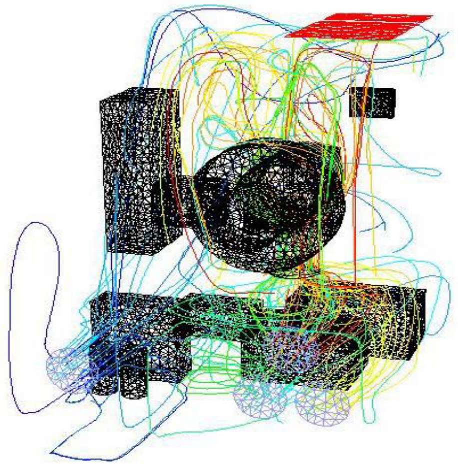


Figure-5. Temperature variations with models.

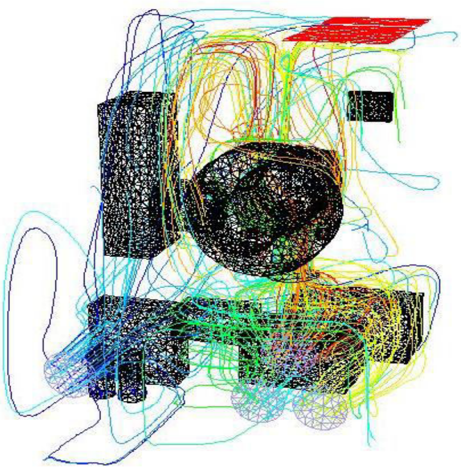
Internal temperature variations according to type of filters

Models 3-1 and 3-2 had the same structure as Model 2 except for the partition wall, and for these models, dual filters and a single filter were assumed. Figure-6 shows the flow distribution for Models 3-1 and 3-2. The internal flow of Model 3-2 is smoother compared to Model 3-1, and this is because a single filter has smaller pressure drops than dual filters. Therefore, if contamination is not an issue, a single filter offers more advantages when it comes to heat release performance.

Figure-7 shows the temperatures of the major electric/electronic components of Models 3-1 and 3-2. When a single filter was used, the temperatures of the electric/electronic components were more evenly reduced, by 2～4℃, compared to when dual filters were used. Therefore, in the case of Model 3-2, the target temperatures of the electric/electronic components were all satisfied.



(a) Model 3-1



(b) Model 3-2

Figure-6. Streaklines of model 3-1.

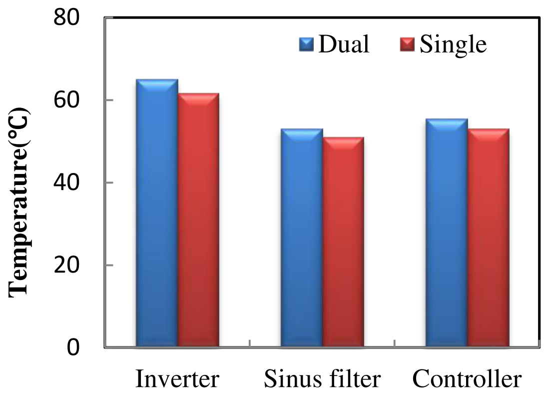


Figure-7. Temperature variations of model 3-1 and model 3-2.

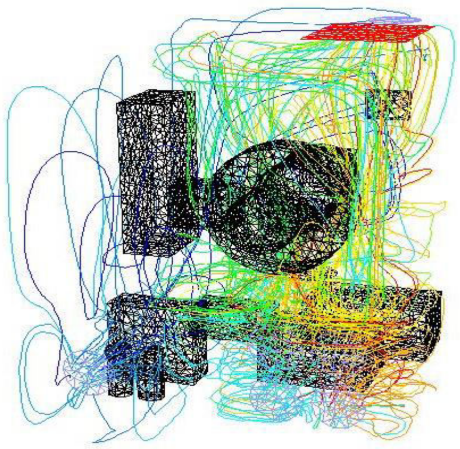


Figure-8. Streaklines of model 3-3.

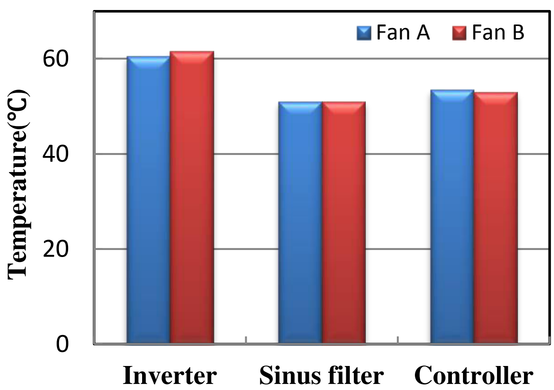


Figure-9. Compare temperature of the model 3-2 and model 3-3.

Internal temperature variations according to type of fans

Model 3-3 is a model equipped with Fan B which has a higher capacity than Fan A. Figure 8 shows its internal air flow patterns. As shown in the figure, its overall flow patterns were similar to those of Model 3-2, which means the heat release performance of the electric/electronic components were not improved noticeably.

The temperatures of the electric/electronic components of Models 3-2 and 3-3 are shown in Figure-9. The temperature differences of the electric/electronic components are just 1°C to 2°C between Model 3-3 and Model 3-2. This means that Fan A, which is smaller than Fan B but has excellent performance, is more suitable for the cooling of a turbo blower.

CONCLUSIONS

The conclusions of this study, in which a CFD analysis was conducted to optimize the heat release performance of a 200HP turbo blower, are as follows:

1) When the machinery space and the electric/electronic space of a turbo blower are partially connected, the hot air of the machinery space and is not discharged directly but moves to the electric/electronic space and raises the temperatures of the electric/electronic components therein. Therefore, the cooling effects are significantly greater when the two spaces are completely separated using a partition wall.

2) When a turbo blower is operated in an environment without a risk of contamination, a single filter is more effective for the cooling of the turbo blower.

3) The selection of a fan for the optimization of cooling flows is important when packaging a turbo blower. However, in this study, no performance difference was observed between Fan A and Fan B.

Going forward, it is necessary to conduct a cooling performance test using a pilot model of a 200 HP turbo blower.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2011-0024805) and by the Human Resources Development program (No. 20154030200940) of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Trade, Industry and Energy.

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