Experimental Study on the Thermal Management of Turbo Blowers

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Abstract-- Turbo blowers are used in a variety of industrial applications including power plants. Recently, the problem of thermal management in the packaging of turbo blowers has garnered attention. Thermal problems occur because turbo blower capacity is increasing at the same that its volume is decreasing. Thus, in this paper, an experimental study was conducted to investigate the heat release performance of a 200 HP turbo blower. The experimental results successfully verified how the heat release performance of the 200 HP turbo blower could be optimized through an appropriate combination of air flow passage, fan, and filter.

Index Term-- Turbo blowers, Cooling passage, Thermal management, Filter

1. INTRODUCTION

Industrial fluid machinery that compresses air or gas can generally be categorized according to their compression ratio. Fans have a compression ratio lower than 1.1, blowers have a compression ratio between 1.1~2.0, and compressors have a compression ratio over 2.0. Among these, blowers are fluid machinery widely used in semiconductor/LCD processing, aeration tanks of sewage and wastewater treatment facilities, and power plant desulfurization systems. In particular, turbo blowers are used in various industrial devices that require relatively high pressure, such as gas supply systems, air mixture systems, agricultural machinery, and air flotation devices. Moreover, turbo blowers have a wide operational range, high efficiency, and simultaneously can be used semi-permanently. Industrial turbo blowers are mostly high capacity and are used in power plants, ventilation systems, and waste treatment. [1]

Recently, the advancement of high speed rotating machinery technology, including high speed motors, variable frequency operation and non-contact bearing, have allowed for the enhancement of turbo blower efficiency and miniaturization.[2] Today, further technology development is being actively pursued in various related fields, including the development of a 300 HP large scale oil-free turbo blower.[3]

Turbo blower technology development is mainly focused on efficiency improvement, noise reduction, and miniaturization. Kim and Lee[4] applied an air foil bearing to a 75kW turbo blower and experimentally studied its vibrational properties. The results revealed that the air foil bearing provides appropriate damping for stable operation within the total dynamic range. Park et al.[5] investigated efficiency changes according to the impeller blade hub and tip thicknesses, which showed that changes in the blade thickness caused changes in the slip coefficient.

Ise et al.[6] used an externally applied pressure bearing to simplify a small scale turbo blower structure and implemented it experimentally up to approximately 350Hz. The maximum discharge air flow rate was 19.2 × 10-5 m³/s and the pressure was 1.77kPa. Tschiptschin and Azevedo[7] researched the causes of turbo blower blade failure. Their study showed that at least one of the blades in the intermediate pressure stage undergoes failure through the corrosion-fatigue mechanism. Seo et al.[8] utilized CFD to perform an aerodynamic analysis of the turbo blower. Through this, it was determined that secondary flow in the lower and upper portion casing of the impeller disk degrades the performance of the turbo blower. Park et al.[9] studied blower pressure characteristics based on multi blower duct formation. The study revealed that longer duct lengths resulted in enhanced efficiency and the pressure loss was minimized when the duct curvature radius was maximum.

To date, turbo blower related research has mainly concentrated on improving the turbo blower performance. However, the problem of thermal management that accompanies the power increases and miniaturization of turbo blowers has garnered little attention. Therefore, in this study, to experimentally optimize the thermal performance of the turbo blower the partition wall, fan, and filter were varied during the packaging of a 200HP turbo blower. Fig. 1 shows the major component of the 200HP turbo blower.

![Fig. 1. Major component of a typical turbo blower](image)

\[
\text{Machine room} \\
\quad \text{Partition wall} \\
\quad \text{Electrical room} \\
\quad \begin{array}{l}
\quad \text{Turbo blower} \\
\quad \text{Water pump} \\
\quad \text{Core} \\
\quad \text{Radiator etc.} \\
\quad \begin{array}{l}
\quad \text{Sinus filter} \\
\quad \text{harmonic filter} \\
\quad \text{MCCB} \\
\quad \text{Inverter etc.}
\end{array}
\end{array}
\]
2. **Experimental Method and Apparatus**

Fig. 2 shows the schematic for each model considered in this study. First, model 1 is the reference model, incorporating the conventional dual filter and suction fan. Also, a partition was used to completely separate the machine space and electrical space, and an additional fan was used to facilitate the airflow at the center of the machine space. Model 2 replaced the dual filter of model 1 with a single filter. Model 3 changed the filter and exhaust fan of model 1. Meanwhile, model 4 changed the filter and suction fan types from model 1. Table 1 shows the specifications of each model package. A total of 4 models were considered with varying filter, fan type, number of fans, and exhaust fan. Here, fan A used a suction fan, mid fan, and exhaust fan, and fan B used only a suction fan. Table 2 shows the specifications of fans A and B.

A turbo blower prototype was manufactured and the temperature of each major part was measured in order to verify thermal performance. After powering on the turbo blower, a T-type thermocouple was used to measure the temperature once it became stable. Table 3 shows the maximum allowable temperature of each part. Flow rate was assumed to be 150 LPM.

3. **Result and Discussion**

3.1 Temperature Variation According to Filter Type

Models 1 and 2 were considered to investigate how the part temperature varied according to the filter type. A dual filter was installed on model 1 and a single filter was installed on model 2. As shown in Fig. 3 (a), the temperatures of the inverter and sinus filter when the dual filter was applied were around 66°C and 49°C, which is below the maximum allowable temperature, while the controller temperature was 52°C, exceeding the maximum allowable temperature. Thus, dual filters did not satisfy the thermal performance. Fig. 3 (b) shows the part temperature variation according to time when a single filter was installed. While the inverter temperature...
Table I

Model specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>Filter</th>
<th>Fan</th>
<th>No. of fans</th>
<th>Exhaust fan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dual filter</td>
<td>A</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Single filter</td>
<td>A</td>
<td>5</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Single filter</td>
<td>A</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>Single filter</td>
<td>B</td>
<td>3</td>
<td>No</td>
</tr>
</tbody>
</table>

Table II

Fan specifications

<table>
<thead>
<tr>
<th>Fan type</th>
<th>Maximum air flow rate (m³/min)</th>
<th>Maximum pressure (mmH₂O)</th>
<th>Speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>24</td>
<td>19</td>
<td>2,750</td>
</tr>
<tr>
<td>B</td>
<td>46</td>
<td>22</td>
<td>1,500</td>
</tr>
</tbody>
</table>

Table III

Measured temperature of each component

<table>
<thead>
<tr>
<th>Component</th>
<th>Maximum allowable temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverter</td>
<td>68°C</td>
</tr>
<tr>
<td>Sinus filter</td>
<td>55°C</td>
</tr>
<tr>
<td>Controller</td>
<td>45°C</td>
</tr>
</tbody>
</table>

decreased around 5°C compared to that of the dual filter, the sinus filter and controller temperatures showed little change, decreasing 0.4°C and 1.2°C.

3.2 Temperature Variation According to the Increase in the Number of Fans

Model 3 added one fan type A for suction and one fan type A for exhaust. Fig. 4 shows the model 3 part temperature variation according to time. After the temperature reaches a normal state, the inverter temperature was 69°C, sinus filter temperature was 49°C, and controller temperature was 37°C. All 3 parts showed temperatures below the maximum allowable temperature with a margin so it was determined that appropriate thermal performance was obtained. Table 4 shows the temperature and margin temperature of each part.

3.3 Temperature Variation According to the Fan Type

Similar to model 4, fan B with a large capacity was implemented and the number of fans were reduced to maintain the total consumption of power. Also, the fan installation location was optimized and the major part temperatures were observed afterwards. After the temperature reached a normal state, the inverter temperature was 60°C, sinus filter temperature was 49°C, and controller temperature was 37°C. All 3 parts showed temperatures below the maximum allowable temperature with a margin so it was determined that appropriate thermal performance was obtained. Table 4 shows the temperature and margin temperature of each part.
1) The maximum allowable temperature of the controller is lower than that of the sinus filter and inverter, so determining the thermal performance of the controller is more important.

2) In the case of model 1, the temperature of each part exceeded the allowable temperature due to inadequate cooling air flow, caused by the excessive pressure drop produced by the use of a dual filter. However, even when replaced with a single filter, sufficient thermal performance was not obtained.

3) In the case of model 3, the maximum allowable temperature was satisfied but with no temperature margin. On the other hand, model 4 secured margin temperatures. Thus, changing the fan type was determined to be more efficient than increasing the number of fans.

For the ongoing development of a 300HP class turbo blower, an active thermal management system is necessary.

5. ACKNOWLEDGEMENTS
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