Technologies for Helping Make New Dreams Come True

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1. Introduction

The market has been demanding a variety of cooling fan features, including those that provide high airflow, high static pressure, low noise, and low power consumption. Market changes have further intensified these demands, and we have always developed new products aiming to meet them. To continue to meet the market demand, which is expected to continue to grow in the future, we will need to incorporate new technologies into our products.

Furthermore, there has also been demand for preventive maintenance of equipment by remotely controlling and monitoring the status of cooling fans, and for a system that enables efficient cooling and ventilation of equipment using a combination of various sensors. To meet these needs, we have developed San Ace Controller as the industry's first IoT-ready fan controller that can connect to a network environment and remotely operate and monitor fans using an external device. We developed this San Ace Controller considering ventilation and pressure/humidity control applications for new markets such as residential and housing equipment, industrial equipment, and agricultural equipment. Nevertheless, we have received some requests to add new features to the controller.

In this article, we will describe new techniques for achieving higher cooling fan performance and new fan controller technologies required in the future.

2. Enhance Cooling Fan Performance

2.1 Foreword

Before describing the performance improvements of each fan component, we would like to introduce the airflow vs. static pressure characteristics and flow vs. pressure characteristics of our cooling fans that can be determined from their structure and properties.

Figure 1 shows an example of the airflow vs. static pressure characteristics of our cooling fans. This graph shows the airflow vs. static pressure characteristics of the highest-airflow models of our old and new fans of the same size. The order of product release was Fan A, B, C, D, then E. It can be seen that newer products have better airflow vs. static pressure characteristics.

Figure 2 shows these models in a non-dimensional manner. The impeller and frame characteristics (such as being a high airflow type or high static pressure type) can be determined by this process.

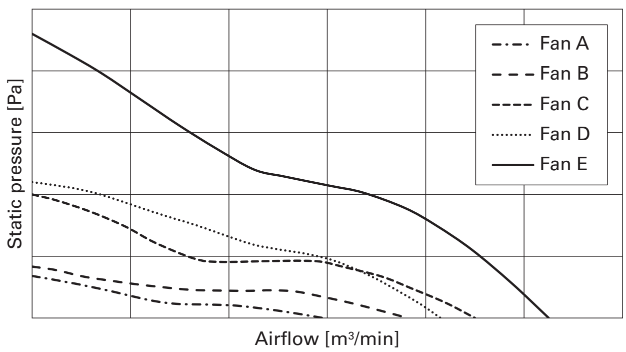

Fig. 1 Airflow vs. static pressure characteristics

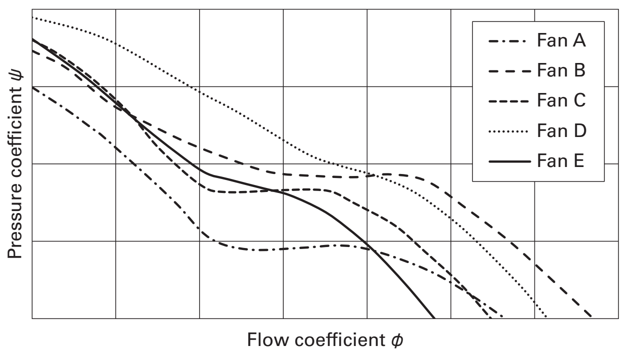

Fig. 2 Flow vs. pressure characteristic

Flow vs. pressure characteristics show the aerodynamic characteristics of fan impellers and frames. Put simply, the aerodynamic characteristics improve as the value increases (i.e., as the curve moves toward the upper right corner of the graph).

By comparing these two graphs, it can be seen that the latest model has the highest airflow vs. static pressure characteristics by far, but this is not the case with respect to the aerodynamic characteristics of its impeller and frame. This means that it is the motor and circuit combination of the latest model that achieves the highest airflow vs. static pressure characteristics.

Therefore, to improve cooling fan performance, it is important to appropriately improve the following:

(1) Aerodynamic performance
(2) Motor performance
(3) Drive circuit performance

It should also be noted that the fans in Figures 1 and 2 are all the same size. It can be said, then, that the graph in Figure 2 is a comparison of aerodynamic characteristics at the same rotational speed. Accordingly, technologies that achieve high airflow vs. high static pressure characteristics are highly dependent on improvements in the rotational speed of the motor.

We will now describe the techniques for enhancing performance by improving fan components.

2.2 Improve aerodynamic performance

The design of impellers and frames conventionally required repeated trial and error. This approach was very time-consuming and tedious.

In recent years, improvements in computer speed and simulation technologies have made it possible to automate the design process. “Simulation-based design optimization” is an approach in which a computer designs the optimal shape through trial and error based on required performance conditions. This type of approach is becoming more and more realistic, and we have also been using it in our company.

Figure 3 provides an example of simulation-based design optimization.

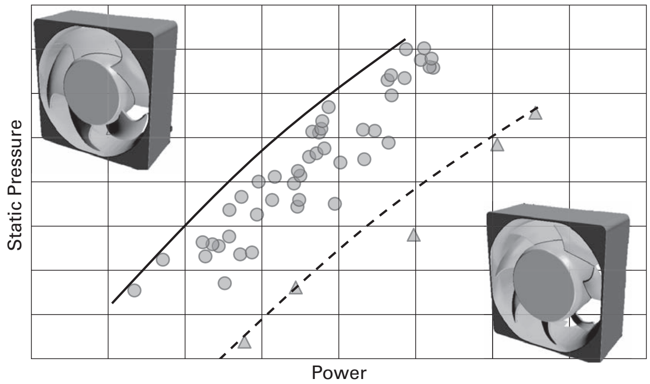

Fig. 3 Example of simulation-based design optimization

In this example, electric power is on the horizontal axis and static pressure on the vertical axis. Impeller and frame efficiency improves as the curve moves toward the upper left corner of the graph. The triangular plots (△) were obtained through conventional trial and error approach, while the circular plots (○) were obtained using recent simulation technology. This shows that the new approach enables the design of lower-power cooling fans with the same static pressure values.

With simulation-based design optimization, we can use parameters that inherit the expertise incorporated into our previous products, and then add new parameters to realize completely new types of impeller and frame designs. With this approach, we aim to achieve the industry’s highest cooling fan performance.

2.3 Enhance motor performance

As mentioned in Section 2.1, newer models do not necessarily have better aerodynamic performance. Impeller and frame combinations that achieve high aerodynamic performance require a motor with high torque. To achieve this, the diameter of the motor will usually need to be increased. A larger motor diameter can result in a smaller ventilation area, which in turn can create the differences in aerodynamic performance shown in Figure 2.

However, if the diameter of the motor can be reduced while maintaining its torque and reliability, this would enable the combination with an impeller and a frame that realizes high aerodynamic characteristics.

In the following sections, we will describe the miniaturization and efficiency enhancement of motors.

Higher motor efficiency means less loss. Motors are susceptible to the following types of loss:

(1) Copper loss
(2) Iron loss
(3) Mechanical loss

A large proportion of the loss is occupied by (1) and (2).

In the next section, we will introduce some techniques for reducing each type of loss.

2.3.1 Reduction of copper loss

The following techniques are used to reduce copper loss:

(1) Use of magnets with strong magnetic force

The use of magnets with strong magnetic force is necessary to generate a sufficient amount of torque using low currents. In this regard, the use of rare-earth magnets, such as neodymium, alnico, and samarium cobalt, instead of current mainstream ferrite magnets, can facilitate the reduction of copper loss.

(2) Improvement in the winding fill factor

Improvement in the winding fill factor is necessary to reduce the Joule loss caused by the current and winding resistance of the motor. This can be accomplished by increasing the conductor's cross-sectional area and improving the winding technique.

Specifically, flat wire can be used to increase the conductor's cross-sectional area while techniques such as aligned winding can be used to realize a higher fill factor; both help reduce copper loss.

2.3.2 Reduction of iron loss

Iron loss can be reduced by improving the magnetic material and the shape and structure of the stator (iron core).

We will now mainly describe some technical measures for stators.

(1) Use of electromagnetic steel sheets with low iron loss and high magnetic flux density

In recent years, silicon steel sheets have been used for stators, but the following materials have been attracting attention:

- Fe-based amorphous
- Nanocrystalline soft magnetic materials
- Fe magnetic powder cores

These materials are all characterized by their low iron loss and low eddy current loss, making them worthy for future consideration as stator materials.

(2) Thickness optimization for electromagnetic steel sheets

Currently, electromagnetic steel sheets with a thickness of 0.35 mm are widely used. However, due to the increased drive frequency of today's high-speed motors, eddy current loss has also been increasing. A solution to this problem is to laminate thinner steel sheets in a manner that reduces eddy current loss.

(3) Magnetic circuit design for motors

To develop a motor that meets the required specifications by incorporating the above-mentioned copper and iron loss reduction measures, it is necessary to optimally use the space inside the motor.

Electromagnetic field analysis is currently indispensable for designing motors. By using analysis techniques to optimize the structure and magnetic circuit, we have been designing highly efficient and reliable motors.

2.4 Improve circuit performance

Improvements in cooling fan performance have been accompanied by increased power consumption, requiring the use of devices that drive high currents. In general, these types of devices are large in size and generate a lot of heat. Also, designs that prioritize the optimization of aerodynamics limit the space (diameter) available for the PCB and decrease the area available for mounting electronic components.

For these reasons, the following two measures are needed when designing circuits:

(1) Compact component mounting
(2) Heat dissipation measures for electronic components and the PCB

In the following sections, we will describe some solutions to these challenges.

2.4.1 Compact component mounting

As mentioned previously, designs that optimize aerodynamics limit the space available for the PCB and decrease the area available for mounting electronic components. The following two approaches can be taken to solve these challenges:

(1) Reduce the number of components
(2) Use BGA (ball grid array) and LGA (land grid array) package components

Modules such as intelligent power modules (IPMs) can be used to reduce the number of components. Since IPMs integrate power devices and the drive circuit into a single module, they can reduce the number of components, contributing to space-saving mounting and smaller PCB designs.

Figure 4 shows an example of a conventional circuit and Figure 5 shows a circuit using an IPM.

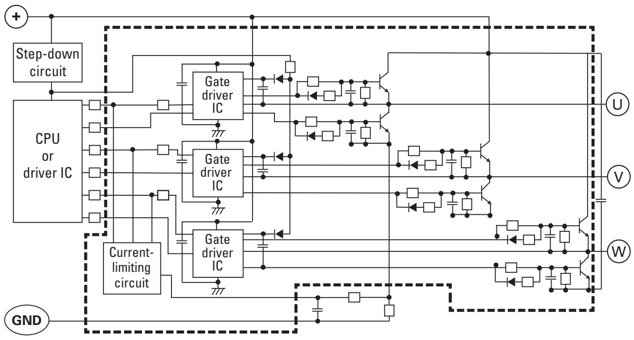

Fig. 4 Conventional circuit example

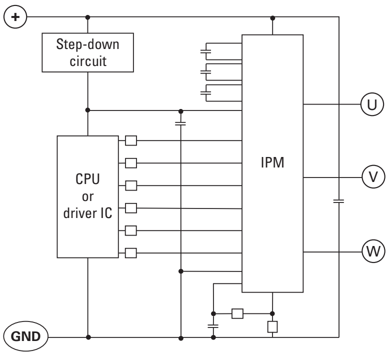

Fig 5 Example of circuit with IPM

In this example, the components inside the dotted line in Figure 4 are integrated into an IPM. This contributes to reducing the number of components and the mounting area.

The use of BGA and LGA packages ensures that the leads of electronic components do not protrude outside of their package. This helps reduce the mounting area.

These techniques have already been applied to some of our cooling fans and are expected to be used more in the future.

2.4.2 Heat dissipation measures for electronic components and the PCB

The motor and circuitry of cooling fans are generally not sealed. As a result, we have taken measures to promote heat dissipation due to convection and radiation caused by the flow of air from the rotating impeller.

As power consumption and mounting density increase in circuits, we expect that cooling through conventional approaches alone will become difficult. The circuit designs of cooling fans in the future will, in addition to conventional approaches, need to make use of conduction-based heat dissipation.

In recent years, conduction-based heat dissipation has been used in compact sealed devices, such as smartphones, digital cameras, and engine control units (ECUs), and we believe that this method should be considered when designing cooling fan circuits.

The following five methods are used to improve heat dissipation in sealed devices:

(1) Reduction of thermal resistance between components and the PCB
(2) Improvement of the PCB's thermal conductivity
(3) Reduction of contact thermal resistance
(4) Use of a heat spreader
(5) Improvement of the housing's thermal conductivity performance

Figure 6 provides a reference example.

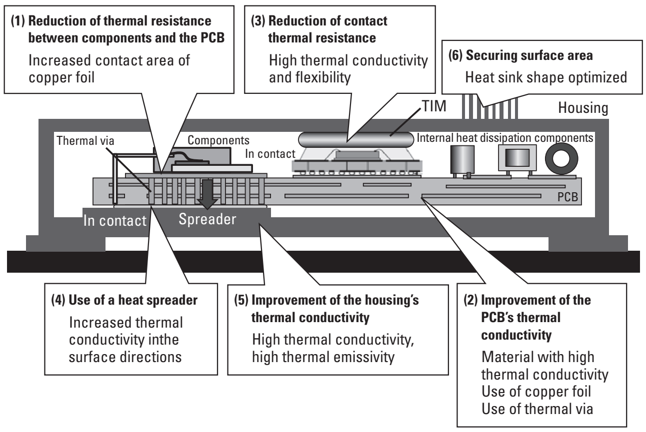

Fig. 6 Improving heat dissipation in sealed devices

We believe that these methods can be used with cooling fans to dissipate the heat generated by electronic components, and will help further improve their reliability.

3. New Technologies for Fan Controllers

3.1 Foreword

There has been market demand for preventive maintenance of equipment by remotely controlling and monitoring the status of cooling fans, and also for a system that enables efficient cooling and ventilation of equipment using a combination of various sensors. To meet these needs, we have developed San Ace Controller.

After releasing the controller, we started receiving the following requests from the market:

(1) Enhancement of sensor-based monitoring and control
(2) Open network support

We will now discuss these feature requests.

3.2 Enhancement of sensor-based monitoring and control

The current San Ace Controller supports the following dedicated sensors:

- Temperature sensor
- Humidity sensor
- Barometer
- Accelerometer

In addition to these, the market is requesting support for the following sensors:

- Dust sensor
- Odor sensor
- Presence sensor

To meet customer requirements, we plan to develop these dedicated sensors to enhance the functionality of San Ace Controller.

3.3 Open network support

The wired communication that the current San Ace Controller supports is Ethernet. However, there is increasing market demand for communication with slaves (sensors and external devices) that use open networks, such as EtherCAT and OPC UA (open platform communications unified architecture).

Figure 7 shows a configuration example for the current model, and Figure 8 shows a configuration example for a model with open network support.

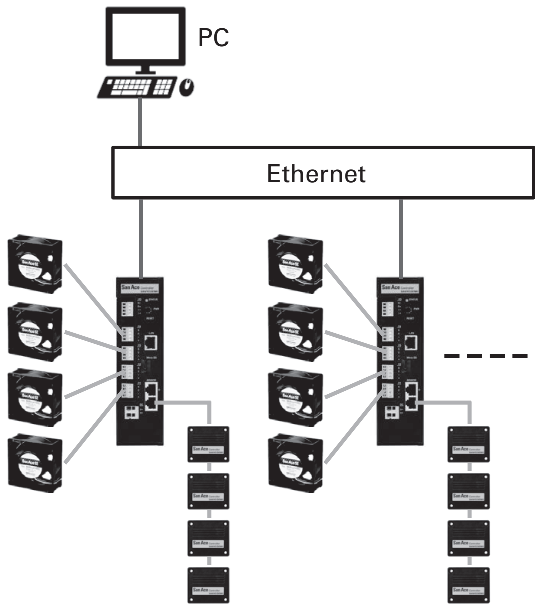

Fig. 7 Configuration example for the current model

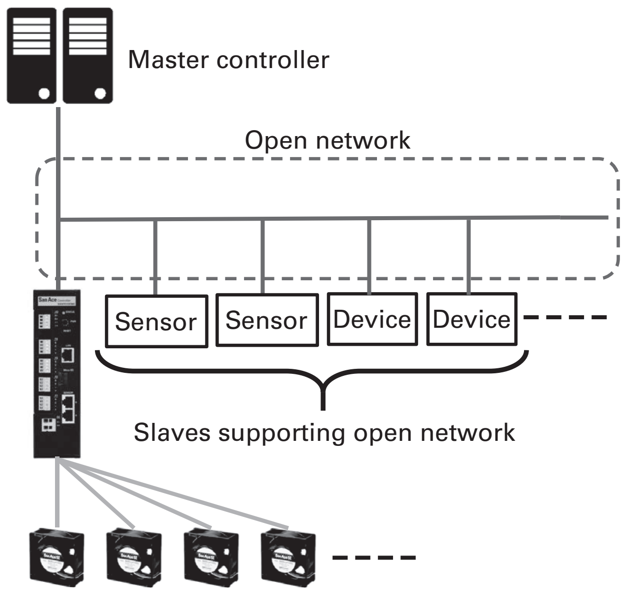

Fig. 8 Configuration example for an open network supported model

We currently do not offer a fan controller that supports open networks, so we need to develop one. Such a controller can control commercially available slaves. We are willing to develop one in the future because such a product can expand the scope of application for customers.

4. Conclusion

In this article, we described techniques for achieving higher airflow and static pressure for cooling fans, and also the new fan controller features and specifications.

The market is demanding not only higher airflow and static pressure, but also decreased noise, power consumption, and cost. We are working to meet these demands by employing new technologies and approaches.

Our current fan controller is the first in the industry to provide IoT features, and more requests will be expected in the future. We plan to meet these requests through feature enhancement and new fan controller development.

The Design Department in our Cooling Systems Division will continue to constantly develop new products. We are committed to always developing the industry's best products. Furthermore, we plan to continue developing and providing products that help our customers realize their dreams by identifying market changes and demands and by offering the best products and timely customizations.

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