SANYO DENKI TECHNICAL REPORT No.7 May-1999
Feature

Development of Cross-Flow Fan

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1. Introduction

An electric motor is a rotating machine that converts electric energy into rotating power and generates heat as a conversion loss while converting said energies. The heat thus has a so big influence on motor life that it is important how pull the heat out of the motor.

The heat generated from a motor normally dissipates by conduction, convection, and radiation. In the case of a small motor, it is normally made to dissipate naturally by contriving ways with the structural materials or shape of the motor. To medium to large size motors forced convection cooling using mechanical means such as cooling fans is normally applied because there is a limit to the efficiency and economy of the natural cooling method such as used on small motors. A separate cooling fan has to be used on a variable speed motor and the volume of cooling air generated by a fan mounted on the motor shaft is often insufficient as the rotating speed slows down.

The cooling fan is a critical point having a great influence on the performance and economy of the motor.

Based on our successful development of the cross-flow fan as a cooling fan for motor use, we will try to describe the outline of our efforts here.

2. Background of Development

The development of our AC servo motor "S" series (induction servo) "S4" and "S6" aimed to achieve the following 3 points with an emphasis on developing a "durable and human friendly motor" as our concept of development:

1. low noise
2. downsizing
3. long life

In order to realize these objectives, we decided that we had to develop an original cooling fan, as we were not satisfied with any the ready-made fan motors.

3. Characteristics of Cross-Flow Fan

Cooling fans can be roughly divided into axial-flow, centrifugal, and cross-flow fans. The conceptual diagram of the static pressure and air volume characteristics of each type of fan are as indicated in Fig. 1 below:

Reviewing the desirable Static pressure/Air volume characteristics of cooling fans we concluded that cross-flow fans have the most suitable characteristics in order to secure a sufficient air volume under the condition of a high pressure loss through the complex air passage of a motor. Centrifugal fans lack sufficient air volume while axial flow fans generate too low air pressure.

We had to verify most of the required characteristics and elements of the cross-flow fan by experiments since there were not sufficient documents, materials, or actual experiences available about the fan. However, after we managed to confirm the fundamental performance of the type of fan, we could successfully improve such

characteristic features as the air volume and noise by utilizing the ″analogy of principles among fans.″ The external view of the newly developed cross-flow fan is shown in Fig. 2 below.

Fig. 3 indicates the structural view of a cross-flow fan. The air flow is generated between a cone shaped cup and a casing with a peripheral wall slanted outward toward the outlet. Cup angle q_1 and casing angle q_2 are defined according to the specified characteristics of the air volume and noise. If cup angle $q_1 < 30°$, the characteristics come closer to that of an axial flow fan and, if $q_1 \geqq 45°$, then they come closer to that of a centrifugal fan. The optimum values of the air volume and noise characteristics were selected through experiments.

Casing angle q_2 was defined as indicated out of consideration of the areas of the inlet and outlet and as the result of various experiments. Measures to prevent the ingress of water inside such as the labyrinth and other structures are provided.

The characteristics of the cross-flow fan are described below:

3.1 Air volume and Noise

(1)With regard to the features of the cross-flow fan itself, the mounting angle a of the vane to the cup affected the air volume and noise characteristics in particular. The optimum mounting angle a was selected after experiments as shown in Fig. 4.

(2)The pressure loss of the device through the flow path has such a great influence on both air volume and noise that the aimed value could not be achieved by the implementation of the cross-flow fan alone. The geometry of the air passage of the motor had to also be taken into consideration. We have taken various measures for optimization including securing the largest areas for the air passage through the motor, revising the geometry of the motor air passage to avoid turbulence, and installing static vanes that double as motor cooling fins in order to secure streamline flow. These are the solutions that we have at this time.

(3)All these efforts helped increase the air volume by about 50% and reduced noise by about 7dB as compared with the current (axial flow) fan. Fig. 5 indicates the resultant air volume and noise characteristics in comparison with the current (axial flow) fan. The characteristics obtained by the combination of the motor and the cooling fan is represented by the intersection point with the motor pressure loss curve.

The indications of the noise from the spindle servo motor for a machine tool of 7.5 to 30kW output as compared with other competitive products are made in Fig. 6. Our ″S4″ motor using a cross-flow fan is substantially lower in generated noise as compared with other competitive products.

3.2 Long Service Life

(1)The vanes of the cross-flow fan are made of steel like the current fan. The life of the bearings was extended to twice the current life by reducing the weight of the rotating parts and selecting suitable bearing material for the inner rotor.

(2)The yield strength for the gravitational acceleration has been raised to twice that of the current fan or higher by increasing the stiffness of the component materials.

(3)The protection class IP45 has been achieved by implementing a labyrinth structure in the boundary between the rotating and the fixed parts and opening a water drain as shown in structural diagram Fig. 3.

3.3 Electrical Characteristics

Using an holding mold has minimized the development costs of the motor for the cross-flow fan. Although the design flexibility was limited by this selection, we have optimized the distribution of the electric and magnetic loads by making a 3 phase wire winding type motor. This significantly improved the efficiency and raised the overload resistance level. Fig. 1 shows the electrical characteristics of the device.

We are confident that the fan can operate with less trouble than ever even under poor power supply conditions as we have successfully reduced the input power by half and expanded the range of continuous operating voltage from 180-200V to 170-253V.

Table 1 Electrical characteristics

Item	Unit	Current model	Cross-flow fan
Outer fan diameter	mm	φ200	φ170
Voltage	V	200 ± 10%	200 to 230 $^{+10\%}_{-15\%}$
Phase number		1	3
Frequency	Hz	50/60 ± 3	50/60 ± 3
Rated input power *	W	100/90	47/56
Rated rotating speed *	min^{-1}	2750/3200	2660/2900
Rated current *	A	0.75/0.65	0.17/0.17
Protection type		IP30	IP45

* indicates values when working on 200V.

4. Conclusion

As introduced above, we are confident that the newly developed cross-flow fan can satisfy our customers' demands for improvements exceeding our initial target. We developed this cooling fan starting with the motor in pursuit of our goal of developing a cooling fan and motor which are structured to match each other.

We have applied for three patents related to the cross-flow fan, passed the TUV certification tests, and started volume production. We expect that the use of cross-flow fans for cooling medium to large electric motors will keep on increasing and that we will be able to meet the demands of our users.

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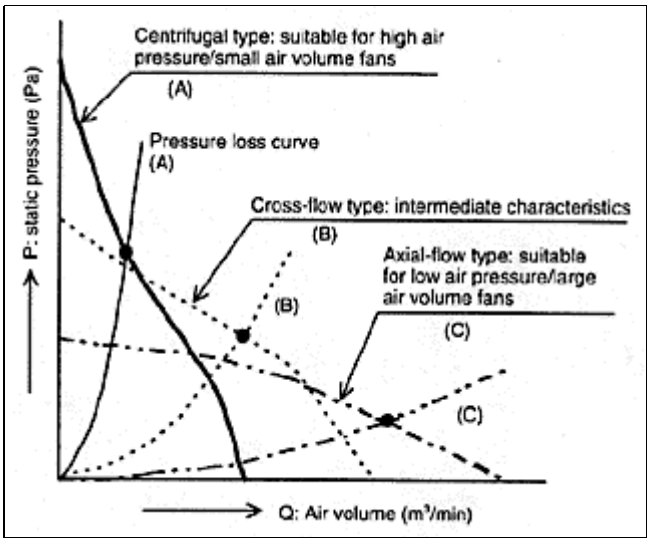

fig. 1 Type and Static pressure/Air volume characteristics of cooling fan

fig. 2 Cross-flow fan external view

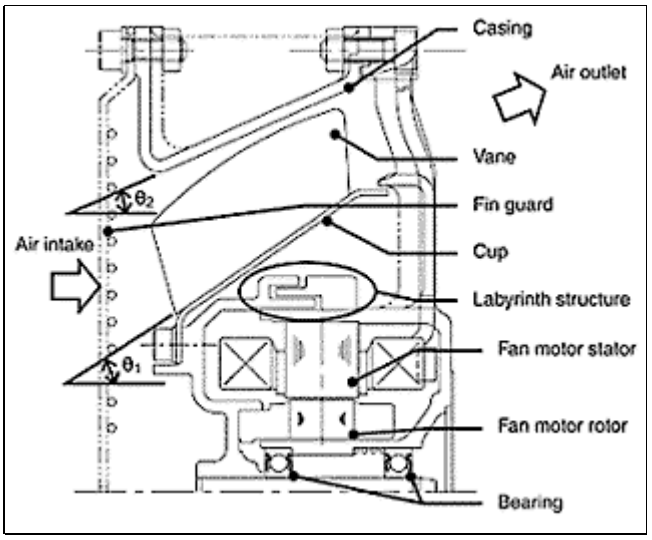

fig. 3 Cross-flow fan structure

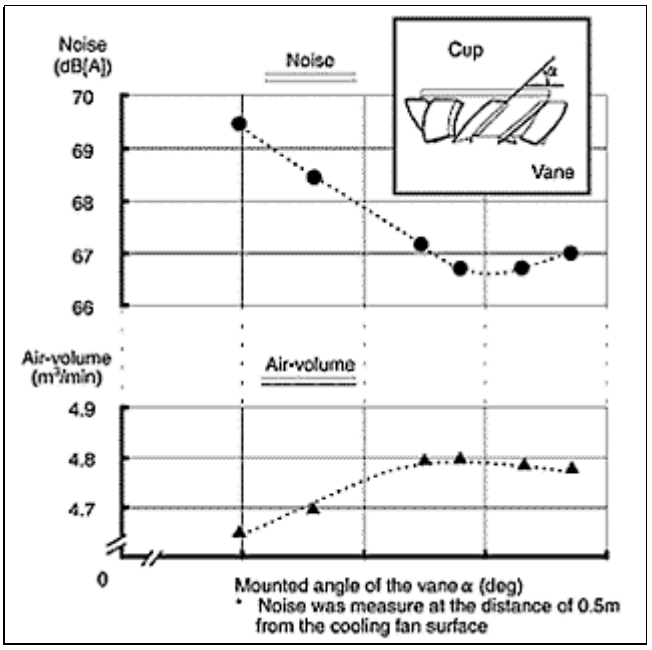

fig. 4 Mounting angle of the vane and noise/air volume

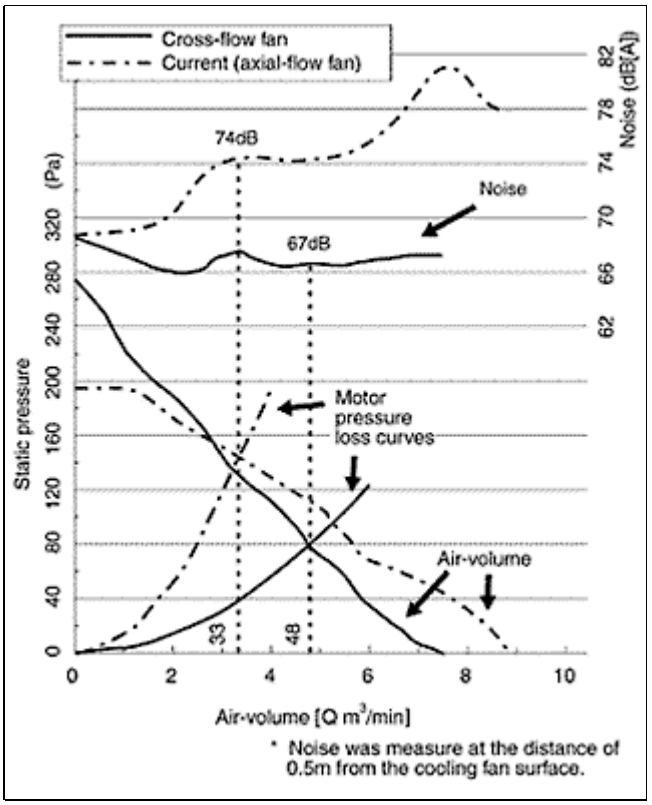

fig. 5 Air volume and noise characteristics of the current(axial-flow) fan and the cross-flow fan

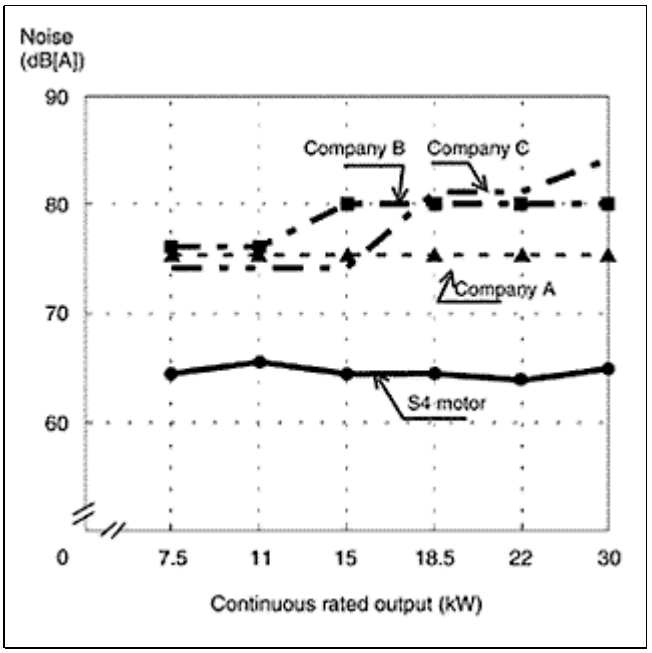

fig. 6 Comparison of noise levels