Cooling System Technology That Changes The Conventional Trend

Technology for Large Air Volume and High Static Pressure : Counter Rotating Fan

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1. Introduction

In electronic equipment such as servers and communication devices, which are the kernel of IT (information technology) society, the miniaturization and improvement of the performance of the built-in parts represented by CPU and HDD are advancing at a marvelous speed. The heating value of these parts has also been increasing remarkably with the improvement of performance, which is expected to continue in the future. At the same time, miniaturization is one of the preconditions in this equipment and the mounting densities of parts arranged in the device chassis keep rising. Consequently, also for an aerodynamic characteristic of a fan motor for internal cooling of a device, there have been an increasing number of cases where measures for an extremely high heating value and measures for an extremely high system impedance are required. To put it concretely, fan motors need to become larger in air volume and higher in static pressure.

In the past, the solution offered to customers was either a high air volume product with an axial flow fan or a high static pressure product with a centrifugal fan, or both together. However, in the case where the demand level of high air volume and high static pressure is extremely high as mentioned above and coexisting of both is also required, simply improving the existing high air volume or high static pressure products by reviewing the blade design or improving the rotating speed is not sufficient.

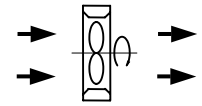
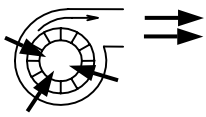
We have turned our attention to the counter rotating fan and have been developing it to bring a new solution to the customer. This text is going to describe what the customer's demands have been for future cooling fans and how the counter rotating fan will satisfy these demands.

We have recently released the 40mm sq. x 56mm thickness fan, "San Ace 40" counter rotating fan, and are already receiving a good number of inquiries. Please refer to the new product introduction article in this Technical Report for more information.

2. Past Demands and Measures

In the past, fan makers, when faced with the demand for high air volume and high static pressure from customers, improved the performance of the axial flow fan when high air volume was needed or improved the centrifugal fan when high static pressure was needed. The axial flow fan is suitable for cooling a device with comparatively low impedance since it can easily obtain high air volume though static pressure obtained is not so high. As for the centrifugal fan, it is not easy to improve air volume but easy to obtain high static pressure, and it is suitable for a device with high impedance. Each structure and their features are shown in Table 1 [1].

Table 1 Type, Structure, and Feature of the Fan

Type	Structure	Feature
Axial Flow Fan		(1) Low static pressure (2) High air volume (3) Suitable for a device with low or average mounting density and low ventilation resistance (4) Specific speed 1000 to 3000
Centrifugal Fan		(1) High static pressure (2) Low air volume (3) Suitable for a device with high mounting density and high ventilation resistance (4) Specific speed 150 to 1000

The past demands for an aerodynamic characteristic were roughly within the recommended operation area of these fan motors. The characteristic curve of SANYO's typical axis flow fan and centrifugal fan, and the past requirement areas are showed in Fig.1. The characteristic curve $\phi - \psi$ is used in this text to compare aerodynamic characteristics. ϕ:flow coefficient and ψ:pressure coefficient is non-dimensionally showing the air volume performance and the pressure performance respectively to compare aerodynamic performance regardless of the fan's outside diameter or the rotating speed [2].

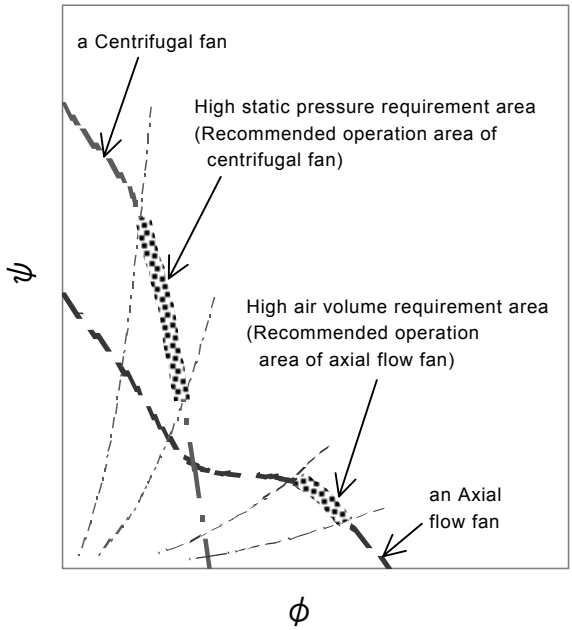


Fig.1 The Past Requirement Areas and the Difference of Aerodynamic Performance Between two types of Fan

3. New Demands - High Air Volume and High Static Pressure

Recently the demands for high air volume and high static pressure at much higher levels compared to the past is increasing and the demanded area is almost in the middle of optimized use area of the centrifugal fan and that of the axis flow fan. In addition, both the air volume level and the static pressure level are extremely high. Fig.2 exemplifies to what extent are the demanded area of recent and future 1U server and the characteristic curve of the current fan.

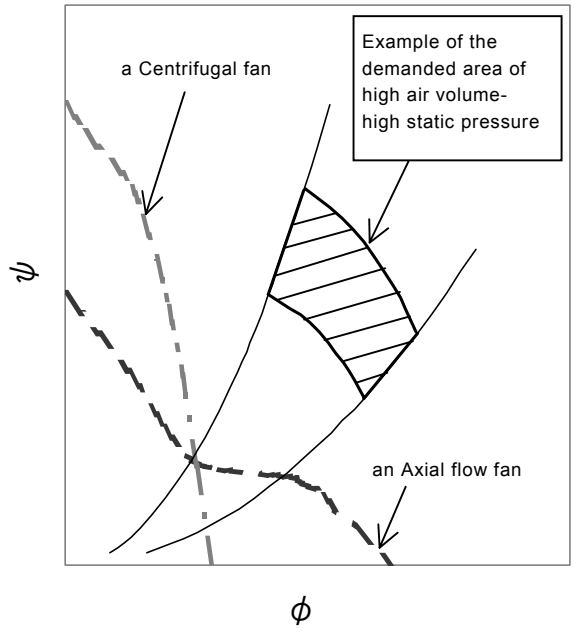


Fig.2 New Demanded Area

In this case, the past approach, such as changing the blade design or improving the rotating speed of the current product, is not enough even if improving axial flow fan which is suitable for high air volume though static pressure is comparatively low, since static pressure stall region would remain and the performance should be further improved (Fig.3). Besides, the system impedance which corresponds to the demanded area just crosses with the static pressure stall region and even if the performance improvement of the axis flow fan could be achieved up to this demanded level, it is not desirable to operate it in an unstable operation area.

It is also extremely difficult to reach the demanded area even with the conventional improvement of centrifugal fan that is suitable for high static pressure with low air volume.

On the other hand, there is a choice to improve static pressure by locating axial flow fans with the same direction of rotation in double stage in series if simply improving the performance of axial flow fan itself could not reach the demanded use area, and various examinations have been performed. However, when we locate axial flow fans in double stage in series, it is difficult to improve static pressure enough though some improvements in characteristic are seen. The static pressure stall region still remains either (Fig.4).

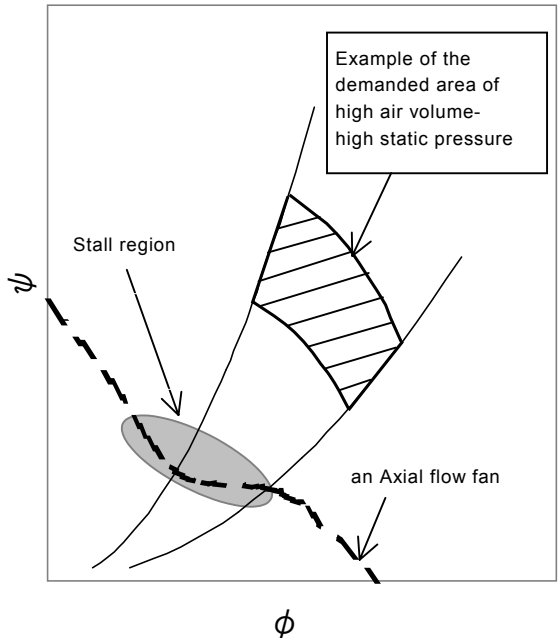


Fig.3 Example of an Axial Flow Fan

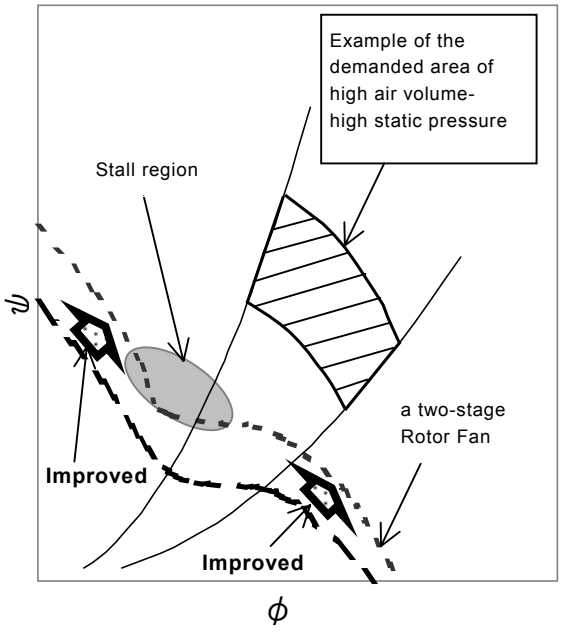


Fig.4 Example of Axial Flow Fan (a two-stage rotor fan)

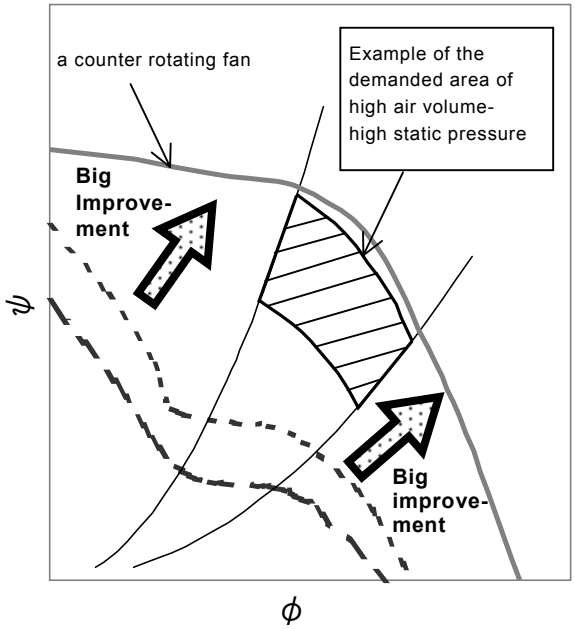


Fig. 5 Example of a Counter Rotating Fan

4. New Measure - Counter Rotating Fan

The counter rotating fan is a fan with the method of mutually rotating two moving blades in an opposite direction. This is a traditional technology, which has been adopted for use in aircrafts or helicopters, but examples of use as a cooling fan motor for electronic equipment are few. The main reason, I think, is that the weak point of the counter rotating fan's loud noise could not be overcome until now. It has also been thought that it would not produce as much pressure as the axial flow fan in double stage in series with enough distance[(1)].

We have realized an aerodynamic characteristic that satisfies the customer enough after the examination from various angles regarding the designs of front driving blade, back driving blade and shroud (Fig.5). Moreover, regarding the noise performance, for instance, specific sound of "San Ace 40" counter rotating fan is suppressed to the rise of about 3dB for 40mm sq. x 28mm thickness fan (hereafter, 40mm sq. 28mm thickness fan) as a single unit. It can be said that the noise performance of the counter rotating fan is almost near the ideal when considering that the noise level when two units are driving theoretically rises by 3dB when 40mm sq. 28mm thickness fan is simply considered to be one sound source. It is also about 6dB low for specific sound when 40mm sq. 28mm thickness fan is placed in double stage in series is considered to be one unit.

Lastly, I would like to describe briefly how the counter rotating fan clears the static pressure stall, an unique feature of the axial flow fan, with the $\phi - \psi$ characteristic, and additionally how the entire characteristic is greatly improved[(1),(3)-(5)].

With a general axial flow fan, peeling of the flow occurs easily in the low flowing area (high static pressure area), which causes whirlpool and three-dimensional backflow in the driving blade. As a result, rotating stalls occur and the static pressure stall appears on the $\phi - \psi$ characteristic curve. In addition, the pressure coefficient in range of partial flow rates does not rise either. At this time, much more swirl elements that try to spread in the direction of the radius are included than main current (axial flow) direction elements in air flow at the blade car exit. It is thought that the energy of the flow that tries to spread in this direction of the radius becomes a loss, and it disturbs the improvement of an aerodynamic characteristic (Fig.3 and Fig.6-1).

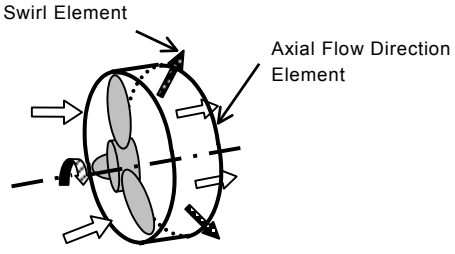


Fig.6-1 Image of the Flow in Range of Partial Flow Rates (an Axial Flow Fan)

Swirl elements remain in range of partial flow rates (high static pressure area) as well when axial flow fans with the same rotating direction are located in double stage in series. It is thought that the pressure coefficient does not increase to twice of that of a single purpose fan though $\phi - \psi$ characteristics improve a little and the stall remains too because collision loss is produced at this time in between the flow from the front driving blade and the driving blade of rear fan (Fig.4 and Fig.6-2).

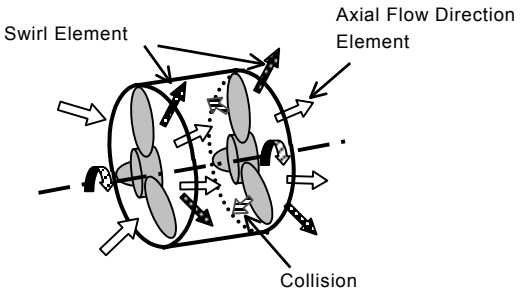


Fig. 6-2 Image of the Flow in Range of Partial Flow Rates (a two-stage Rotor Fan)

The counter rotating axial flow fan is the kind of fan on which the driving blade with the shape that can receive the flow from the front driving blade smoothly is located in the back flow of the front driving blade to rotate it in an opposite direction of the front driving blade mutually. Consequently, the swirl element of the flow can be converted into pressure (pressure recovery). Also the collision loss, which is seen on the double stage in series fan, can be decreased. Moreover, the entire $\phi - \psi$ characteristic is greatly improved, and the stall of static pressure, the unique characteristic of the axial flow fan, is cleared (Fig. 5 and Fig. 6-3).

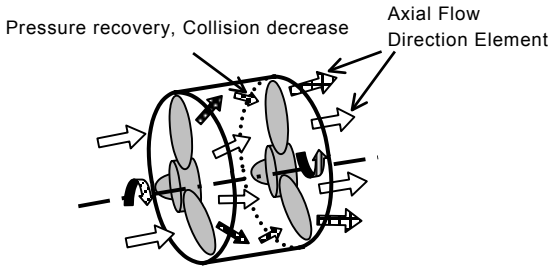


Fig.6-3 Image of the Flow in Range of Partial Flow Rates (a Counter Rotating Fan)

5. Conclusion

This text described how the new requests for future fan motors are high air volume and high static pressure, and also that the past measures of simply improving the performance of axial flow fan or centrifugal fan cannot satisfy it. Next, an outline of the counter rotating fan was presented. The counter rotating fan is a new solution for customers who need unprecedented volume of high air and high static pressure.

We have referred to the result of past research and the development documents for counter rotating fans in this article. I would like to express our gratitude here. We are not yet able to fully explain what is happening on compact counter rotating axial flow fan and one of the reasons is that we could not find an example of compact axial flow fan (so-called box fan) identical to those we are dealing with as a research object as far as we had investigated. We intend to continue the search for effective factors to the phenomenon investigation and the performance improvement, and to offer the market more epoch-making product in the future. Finally, I have made an effort to quote the content of the description of our senior engineers correctly when this text was brought together, but I humbly beg their pardon for any parts that possibly lack accuracy.

References

(1) Edited by JSME, Mechanical Engineering Handbook (1991)
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