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Paper Authors

SHAIK HUSSAIN, K. BHARADWAJA, A.RAVEENDRA

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PERFORMANCE AND INTERNAL FLOW OF CROSS-FLOW FAN WITH INLET GUIDE VANE

[1]K. BHARADWAJA, [2]SHAIK HUSSAI
[1,2] Assoc.Professor, Department of Mechancial Engineering, Malla Reddy Engineering College (Autonomous), Maisammaguda(H), Gundlapochampally Village, Secunderabad, Telangana State -500100

The effect of angle and length of the inlet guide vane on the performance of the cross- flow fan was examined. By installing guide vane of one sheet in tongue division side in the suction region, the performance of the cross-flow fan becomes more high pressure and high efficient than the case without the guide vane. The prerotation of the inlet flow which is counter directional with the rotation of the rotor is generated by the guide vane. In the high flow region, the high pressure and high efficiency are obtained since the suction cascade work increases by the prerotation of the flow, and since the leading edge separation of the suction cascade is more avoided to high flow. Moreover, in the low flow region, it is possible to suppress the circulating flow in scroll side in the rotor suction inlet. Therefore, the high efficiency is obtained in the low power compared to the result without the guide vane.

Key Words: Cross-Flow Fan, Guide Vane, Prerotation, Turbomachinery, Fluid Machinery, Cascade, Computational Fluid Dynamics, Internal Flow

1.Introduction

The cross-flow fan has high pressure coefficient as the characteristic, because the forward curved vane is used, and because moreover, the fluid passes through the cas- cade twice. Then, it is widely used as a fan for the air conditioner integration, because the exit flow is two- dimensional. On the cross-flow fan, many theoretical and experimental researches have been carried out until now for the purpose of performance improvement, grasp of in- ternal flowing state and noise reduction(1) – (8). However, in the cross-flow fan, the internal flow including eccen- tric vortex formed in the rotor inside is complicated and has sufficiently and not yet clarified the optimum design method. Moreover, the pressure rise is small in present state, since the noise with the interference between in- side eccentric vortex and rotating blade increases as ro- tational speed increases. If the pressure and efficiency rise using the convenient method in the cross-flow fan is possible, the application more expands. If the pressure coeffi- cient increases, it is possible to decrease the circumferen- tial speed, and therefore the noise reduction becomes also Here, it intends to achieve performance enhancement of the cross-flow fan by installing guide vane for control- ling the flow of rotor inlet. In the previous report(9) one of author showed by installing guide vane of several sheets at suction cascade inlet of the cross-flow fan, and optimizing the angle, that the high pressure was obtained. However, many guide vanes installed in the entrance seem to lower the efficiency of the fan in order to generate the loss of the flow by itself. In this study, it is examined that the guide vane of one sheet is installed as a more convenient method in tongue division side in the suction region of the cross-flow fan. By this guide vane, it intends to achieve high pressure and performance enhancement of the fan by controlling the prerotation of rotor inlet flow. The effect of angle and length of inlet guide vane on the performance of the cross-flow fan is investigated.

2. Experimental Equipment and Experimental Method

Schematic drawing of cross-flow fan used in this study is shown in Fig. 1. The fan without the guide vane in Fig. 1 is a typical shape of cross-flow fan used generally. Based on air blower test method of JIS [Japanese Indus- trial Standard], the following were equipped behind the fan: □ 800 mm air tank and pipe line for the measurement of 150 mm tube diameter. Tap for the static pressure mea- surement, rectification wire gauze were installed in the air tank, and rectification lattice, orifice for flow measurement and auxiliary air blower were installed in the pipe line for the measurement. The rotor shape is D1 = 200 mm outer diameter, D2 = 149 mm inner diameter, B = 200 mm width, Z = 36 blade number of sheet, and the blade thickness is t = 1 mm in the circular arc shape. It is β1 = 20◦ blade inlet angle, β2 = 80◦ blade outlet angle. Casing has the suc- tion opening angle θs = 120◦ and discharge opening angle θd = 170◦. From the scroll beginning, the passage width of the scroll increases by the throat division rectilinear, and the extent in the passage after the throat division is 8◦. The normalized throat width is S 0/(R1θd) = 0.364.

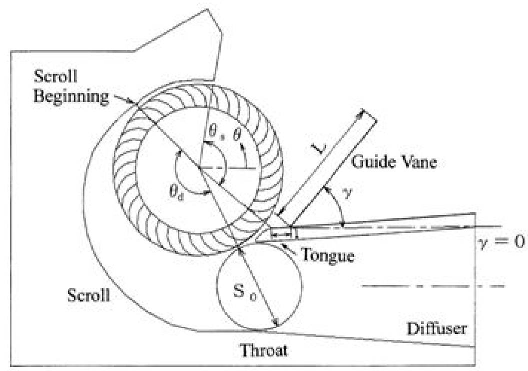

Fig. 1 Schematic diagram of test cross-flow fan

In this study, the internal flow was simulated by CFD
(Computational Fluid Dynamics) in order to confirm in- ternal flow results got in the test. Steady-state analysis in two dimensions was carried out using marketing code (FLUENT6.1) for the numerical analysis. Here, flow pre- diction by the steady-state analysis was tried considering blade number of sheet being abounding, and considering convergence and simplicity of the numerical analysis of the calculation, though the unsteady analysis had to be car- ried out in order to obtain the more actually near solution. In this calculation code, the equation of mass saving and momentum conservation was solved using the finite vol- ume method. In the wall surface part, the standard wall function was used, and the k-ε

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model was used for the tur- bulence model. The whole of the calculating area which took experimental equipment into consideration is shown in Fig. 2.

The calculation lattice is the 150 000 elements in all calculating area. The cascade part of the fan is about 30 000 elements, and the inside region of the fan is about 20 000 elements, and the remainder is used at inlet re- gion and exit region. In most of the calculation lattice, it was made using the non-structure quadrangular lattice

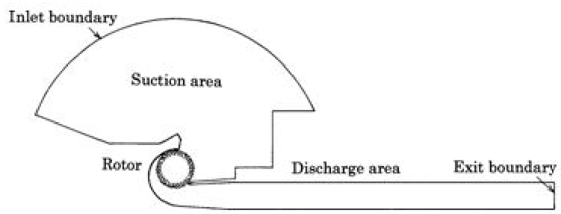

Fig. 2 Calculation area and boundary

which the strain increased, the non-structure triangular lattice was used. Suction region corresponded for 4 times of the rotor diameter was in- stalled in order to attempt the stability of the solution. The discharge region extended the discharge duct length to 10 times of the discharge duct width in order to satisfy the exit boundary condition. The boundary condition was set in suction region and discharge region, and the uniform flow velocity was given as an inflow condition, and as a outflow condition, the diffusion flux bundle gave it as a zero. And, inlet pressure of the suction region was given as an atmospheric pressure. The simple multi-criteria co- ordinate model was used for the rotor. In this model, it becomes a steady-state approximation. In the region ex- cept for the rotor, it is calculated in the absolute coordinate system, and in the rotor region, the governing equation is calculated in relative coordinate system considering rota- tional speed. In the process for the calculation, the data of absolute coordinate system and relative coordinate system is mutually exchanged as transformed information. The decision of the convergence was carried out at the residual under 1 10−5. It was all deduced that it was described in the conclusion of this paper from the experimental result, and the simulation result of the flow is used supplemental.

3.Experimental Result and Discussion

3. 1 Effect of the guide vane on the fan perfor- mance

Performance curves of the fan as angle γ of guide vane changes are shown in Figs. 3 and 4, when the length of guide vane is fixed L = 900 mm. The efficiency is higher than the case in which there is no a guide vane over near design flow rate (φ = 0.17) from low flow rate, when γ are 30◦, 40◦ and 50◦. It is equivalent or slightly high in comparing that without guide vane even in the high flow region. The power coefficient increases with the increase in γ. Especially, the power coefficient greatly increases.

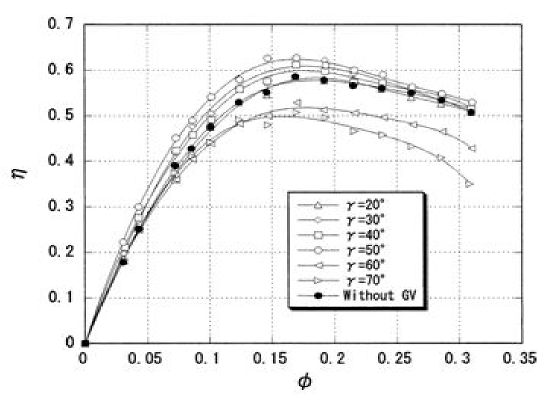

Fig. 3 E□ect of guide vane angle γ on η

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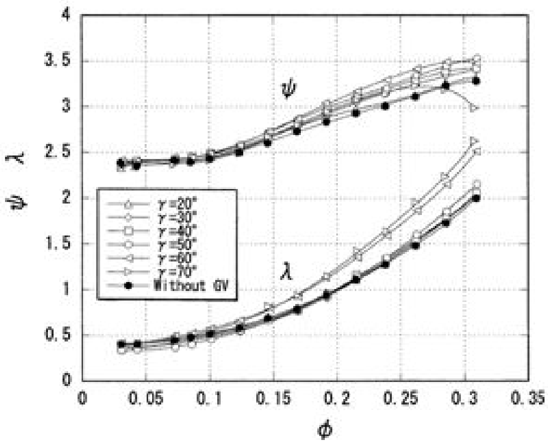

Fig. 4 E□ect of guide vane angle γ on ψ and λ

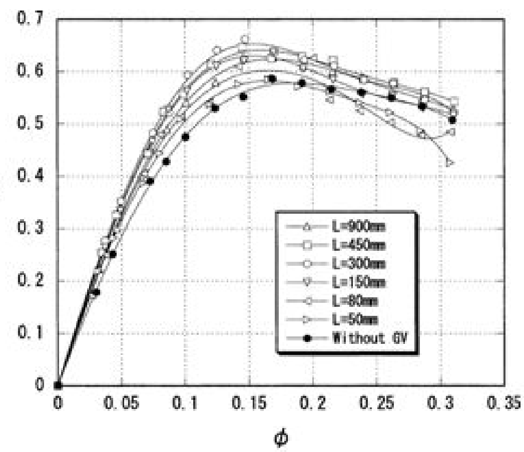

Fig. 5 E□ect of guide vane length L on η

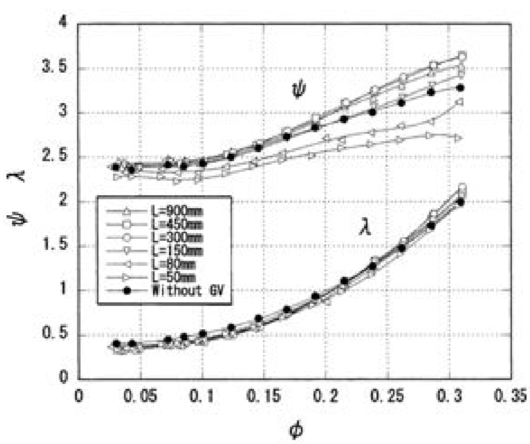

Fig. 6 E□ect of guide vane length L on ψ and λ

the low flow range and pressure rising in the high flow range has been connected with the high efficiency rise. On the guide vane length, it is proven that the effect is the highest in L = 300 mm (L/D1 = 1.5). The sufficient performance rise is not obtained, even if the guide vane length exceeds the length, even if it passes in the short- ness. With the length L of the guide vane is short, the ap- propriate prerotation is not obtained in the blade entrance. In the meantime, with the guide vane is long, friction loss along the guide vane increases, and the efficiency lowers. The pressure coefficient of guide vane length 300 mm in- creases further than without guide vane and L = 900 mm as well as the case of the efficiency over the full flow range. Especially, in the high flow range, the effect of guide vane has greatly appeared, and in φ = 0.32, the pressure coeffi- cients of 3.5 have been exceeded. It is shown that this pres- sure rise was generated, since the suction cascade work increases by guide vane. In the cross-flow fan, it is known that the suction cascade work is generally smaller than the discharge cascade work. However, it is possible to put on large work even in the suction cascade by the guide vane, and the high pressure is obtained without lowering the ef- ficiency.

In the rotor of the general turbomachinery, it hasrespectively and appropriately decided blade inlet shape and outlet geometry in the relationship between the flow. However, the suction cascade inlet becomes the discharge cascade outlet as it is in the rotor of the cross-flow fan. Therefore, it does not become a shape of which rotor inlet and outlet are respectively appropriate. Then, it becomes possible that rotor inlet and outlet flow are together done appropriate by using the inlet guide blade.

4. Conclusion

As a result of examining the effect of inlet guide vane on the performance of the cross-flow fan experimentally, following fact became clear.

(1) By installing guide vane of one sheet in tongue division side in the suction region, the performance of the cross-flow fan is more high pressure and high efficient than the case without the guide vane.

(2) The fan performance is the best for the guide vane in case of $\gamma = 50^{\circ}$ angle, and L = 300 mm (L/D1 = 1.5) length.

(3) The prerotation of the inlet flow which is counter directional with the rotation of the rotor is generated by the guide vane. In case of the high flow region, the high

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Subramanyam Pavuluri
https://orcid.org/0000-0002-2703-2358

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