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STUDY ON THE REDUCTION OF ROTATING NOISE EMITTED FROM CENTRIFUGAL FAN

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1. Introduction

The noise generated aerodynamically by a fan is broadly divided into rotating noise, which is dominant at the blade passing frequency and its harmonics, and turbulent noise, which appears across a broad band. The rotating noise is discrete and it makes a large contribution to the overall noise level, so reducing rotating noise is important for making fans quieter. In this research we tried to reduce rotating noise by improving the shape of the casing tongue. To verify the effects of these efforts, we measured the fluctuations in flow velocity near the tongue and the pressure fluctuations at the surface of the tongue and examined the correlation between these and the rotating noise.

2. Experimental equipment and method

As shown in Figure 1, the fan tested was a No. 3 single-suction type turbo fan with an impeller outlet diameter of 450 mm, an impeller outlet width of 111 mm, and 12 vanes. The main dimensions of the tongues that were tested are listed in Table 1.

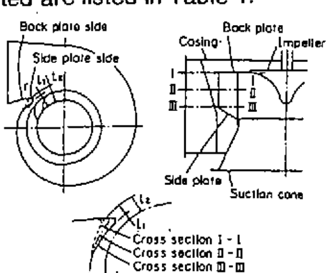

Fig. 1 Explanatry drawing of tongue

Table 1 Tongue dimensions [mm]

Type	t_m	t_1	t_2	t_m / D_2 [%]
A7	7	7	7	1.6
A32	32	32	32	7.1
MA18	18	7	29	4.0
MA32	32	19	45	7.1
MA62	62	50	75	13.9

$t_m = (t_1 + t_2)/2$

While in a conventional tongue (symbol A) there is a uniform clearance across the width of the vane, in a modified tongue (symbol MA) the clearance varies across the width of the vane, with the clearance t_2 on the main plate side of the impeller being wider and the clearance t_1 on the side plate side being narrower. The number gives the mean tongue clearance t_m (= $(t_1+t_2)/2$). The original tongue is A7. Performance was measured in conformity with JIS B 8330. The impeller rotation speed was kept to 1500 rpm. The noise level was measured with a microphone placed at point D in Figure 2. The fluctuations of the flow velocity were measured by inserting a hot wire probe from the side of the casing as shown in Figure 3 and traversing the vicinity of the tip of the tongue in the width direction. The pressure fluctuations were measured with a semiconductor pressure transducer attached to pressure holes at the tip of the tongue. These fluctuations of the flow were measured by taking the trigger pulse from the impeller shaft and obtaining a signal synchronized to the position of the impeller. Denoting by e the position in the width direction of the casing, e=0 represents the casing wall on the impeller main plate side, and e=1 on the suction intake side.

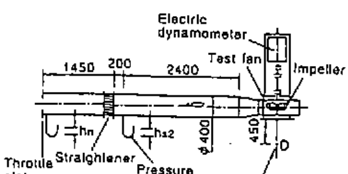

Fig. 2 Test apparatus [mm]

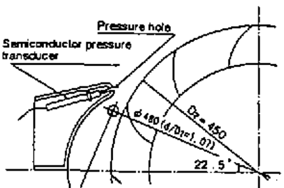

Fig. 3 Measuring setup [mm]

3. Results and considerations

Figure 4 shows the noise spectrum at the maximum efficiency flow rate η_{max}. The rotating noise appears at the 1/3 octave band center frequency 315 Hz, which includes the blade passing frequency 300 Hz, and the second-, third-, and fourth-order components appear as dominant components at 630, 1000, and 1250 Hz, respectively. The modified tongues showed a great reduction in rotating noise, with a maximum reduction of 8 dB as compared with original A7.

The relationship between the mean tongue clearance ratio t_m/D_2 and the sound pressure level of the rotating noise at η_{max} is shown in Figure 5. For both conventional models and modified models the noise reduction effect is greater as t_m increases, but once the t_m/D_2 exceeds 10%, the effect of widening the clearance gradually decreases. Comparing a conventional one and a modified one at the same t_m, the modified one has a greater reduction effect, but when the clearance is made wider, the difference between the two is small. This is thought to be because widening the clearance reduces the flow velocity near the tongue and attenuates the effect of the modified shape.Figure 6 shows the coherence function γ between the velocity fluctuations in the width direction of the tongue and the rotating noise (300 Hz). A7, A32, and MA32 all show a similar trend, but compared with A7 the γ is lower for A32 and lower still for MA32. And in the range e=0.5-1.0 there is almost no correlation. From this it can be concluded that the part that is directly subjected to the flow where e=0-0.5 is the region of rotating noise.

As shown in Figure 7, the relationship between t_m and the mean value of the γ at e=0-0.5 has the same trend as Figure 4. This indicates that the shape of the modified tongue (its three-dimensional shape) mitigates the interference and reduces its contribution as a source of noise.

Figure 8 shows the phase difference with the pressure fluctuations at cross-section II. With a conventional model there is no phase difference from the impeller main plate to the middle of the vane width, but with the modified models, depending on the effectiveness of the shape, the phase is different on the impeller main plate side where the clearance is wide, and conversely the phase advances on the side plate side where the clearance is narrow, and the phase shift likewise corresponds to the change in the shape. It is thought that this phase shift eliminates the simultaneity of the flow interference, evens out the pressure fluctuations, and helps reduce the rotating noise. The amplitude of the pressure fluctuation is shown in Figure 9. Overall, it is high for A7, lower for A32, and lowest for MA32. In particular, on the impeller main plate side, A7, whose clearance is narrow, shows a high value, and A32 and MA32 show lower values as the clearance becomes wider, and the clearance and the size of the amplitude correspond. This is thought to be because widening the clearance attenuates the periodic pressure fluctuations of the wake from the vane and interferes with the tip of the tongue. Figure 10 shows the coherence between the pressure fluctuations on the tongue surface and the rotating noise. This shows the same trend as the γ between the flow fluctuations and the rotating noise

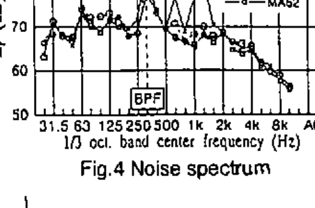

Fig.4 Noise spectrum

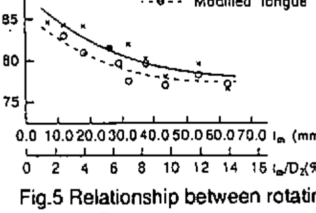

Fig.5 Relationship between rotating noise and t_m

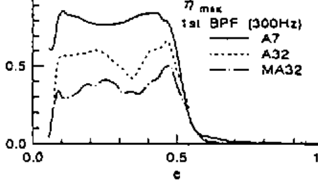

Fig.6 Coherence between velocity fluctuations and rotating noise

shown in Figure 6. With A7 the γ is high, about 0.8. With A32 and MA32, although their t_m has the same value, the γ for MA32 is about 0.2 smaller than for A32.. This confirms that in terms of pressure fluctuations on the tongue surface too, the modified tongue is effective in reducing rotating noise.

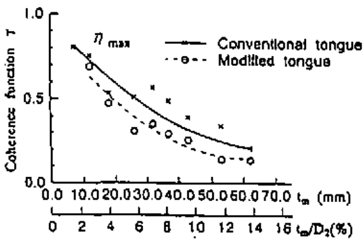

Fig.7 Relationship between coherence and t_m

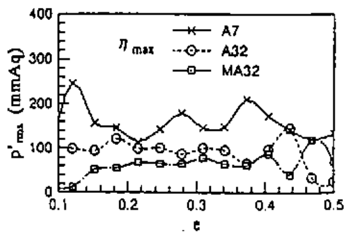

Fig.9 Amplitude of pressure fluctuations

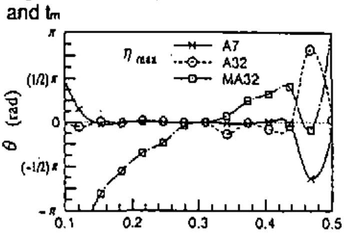

Fig.8 Phase difference of pressure fluctuations

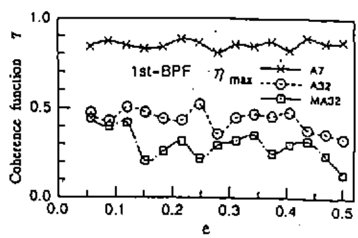

Fig.10 Coherence between pressure fluctuations and rotating noise

4. Conclusions

(1) A modified tongue has the effect of reducing the rotating noise sound pressure level by up to 8 dB as compared with the original A7 tongue.
(2) The coherence g between flow velocity fluctuations near the tongue and the rotating noise indicates that the part that is directly subjected to the flow at e=0-0.5 is a region of noise source. Also, for the A7 the correlation is large, with g being nearly 1. With a modified tongue, on the other hand, the γ is to 0.4 or less, reducing its degree of contribution as a noise source.
(3) The three-dimensional shape of a modified tongue, in which the clearance varies along the width of the tongue, eliminates the simultaneity of the interference between the flow and the tongue, thereby mitigating the pressure fluctuations.
(4) The correlation between the pressure fluctuations on the tongue surface and the rotating noise tends to be similar to the correlation between the flow fluctuations and the rotating noise.

Reference

[1] S.Suzuki, et al, Proc. of Inter-Noise95, p101 (1995)