infrasonic radiation properties of an axial blower

Huang Qibai and Xu Zhiyun
School of Mechanical Science & Engineering, Huazhong University of Science and Technology, Wuhan, 430074, P.R. of China

The relationship between the directivity of infrasound emitted by an axial blower, rotational speeds of the impeller, blade type, thickness of blade trail edge, and infrasonic noise radiated by the blower is studied through experiments. Therefore, the infrasonic radiation law is revealed. Furthermore, a theoretical basis for infrasonic control of the axial blower is provided.

1. Introduction

Non-steady air current is the major source of aerodynamic infrasound owing to the interaction of the intake turbulence of the impeller, the eddy for releasing of the blade trail edge, the turbulence boundary layer of the blade, and so on. As a pneumatic device, the axial blower has a high level infrasonic energy radiation. In reference [3], it has been indicated that the aerodynamic noise energy radiated by an axial impeller is mainly concentrated in a lower frequency range, especially in the infrasonic frequency bands, and the infrasonic energy adds up to 95 percent of the total acoustic energy radiated by the blower. So, revealing the infrasonic radiation law by studying the features of the pneumatic blower is not only useful for controlling its infrasonic radiation, but also hopefully for the optimization of design with lower infrasonic radiation. In this paper, various axial impellers will be taken as the experimental objects to study the relationship between the parameters of the blower construction and infrasonic radiation.

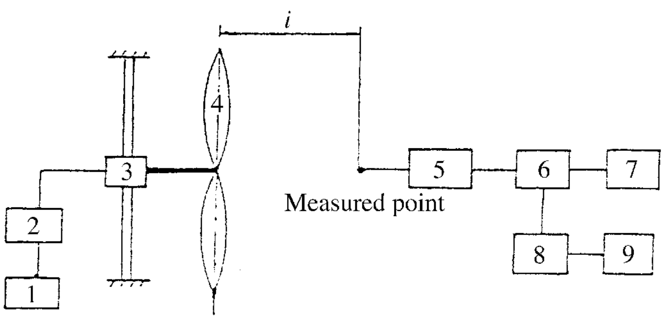

Figure 1. Infrasound measuring and signal analysis system
1. AC power 2. Regulator 3. Motor 4. Impeller
5. Sound level meter B&K2231 land microphone B&K4155
6. Tape recorder Sony 7. Oscilloscope
8. Dynamic signal analyzer SD375 9. Printer

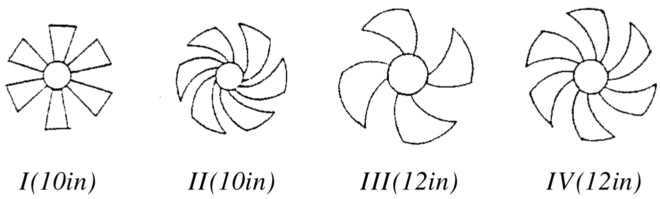

Figure 2. Impellers used in the experiment
I,II,IV – plastic impeller, III – iron impeller

2. Device and apparatus

The device and apparatus used in this experiment are sketched in Figure 1. The motor is held on a rigid frame with three fulcrum bars, and the impeller is mounted on the motor spindle. The microphone and sound level meter are fixed on the tripod and located on the same horizontal line with the motor axis. Furthermore, the microphone can be moved on the horizontal plane around the axis. To prevent the regenerative noise by the interaction of the air current and the microphone, a nose cone is fixed in front of the microphone. We can conveniently record and analyze the infrasound radiated by various impellers. The types of the impellers used in this experiment are listed in Figure 2.

3. Infrasonic directivity of an axial impeller

In order to analyze the infrasonic directivity of the axial impeller, we select the impeller type IV as the experimental object. With the system illustrated in Figure 1, we can measure and test the radiation features of infrasound radiated by the impeller in various directions. In the experiment, the microphone is 1m away from centre of the impeller, and the infrasound signal is recorded on the tape recorder, then, third-octave frequency band analysis is completed on dynamic data analyzer SD375. The frequency spectra in the directions 0û, 22.5û and 45û are shown in Figure 3. Figure 4 illustrates the infrasound (0 to 20Hz) pressure level in several directions.

It can be deduced from the analysis of Figure. 3 and Figure. 4 that:

a In the direction θ= 0û, the infrasound pressure level radiated by the axial impeller is highest. According as the increment of the angle θ, the infrasonic energy decreases gradually. It can be known that the axial impeller infrasound has obvious directivity along its axis.

b Wherever the measuring point is, the infrasonic sound pressure level decreases accordingly to the increment of frequencies. In other words, the lower the frequency is, the higher the energy of the aerodynamic infrasound may be.

c In the lower frequency band range from 2 to 3.15 Hz, the infrasound frequency spectra in the directions 0û and 22.5û are similar. The peaks of both appear at 2.5 Hz.

d In the frequency range 5 ~ 20 Hz, the trends of the infrasonic spectrum in the direction 22.5û are similar to that at 45û.

e Axial impeller infrasonic energy is mainly concentrated in the direction 0û

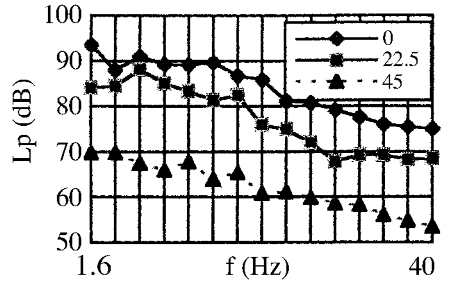

Figure 3. The infrasonic directivity spectra of an axial impeller

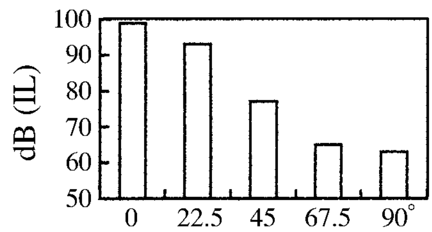

Figure 4. The directivity of an axial impeller

4. The relationship between axial impeller and infrasound radiation

By adjusting the input voltage of the motor with regulator, we can alter rotational speeds of the impellers. As for axial impeller type IV with various rotational speeds, the low frequency spectra are shown in Table 1. Figure 5 illustrates the infrasonic frequency spectra with three speeds, and the measuring point is located 1 m away from the impeller.

As it is seen from Table 1, the aerodynamic sound energy radiated by axial impellers is significantly concentrated in the range of infrasonic frequency band. Moreover, the faster the impeller rotates, the higher the infrasonic sound pressure level may be. It is also shown in Figure 5 that the infrasonic frequency spectra of the impellers working with various speeds are very complex. In the frequency bands ranged from 8 to 40 Hz, along with the increment of frequencies, the infrasound and the low frequency noise decreased gradually. In the frequency bands ranged 1.6 ~ 8 Hz, the infrasonic frequency spectra vary greatly. As example, when n = 1320 r.p.m. the infrasonic peaks appear in three frequency bands with middle frequencies 1.6 Hz, 2.5 Hz and 5 Hz; whereas n = 1000 r.p.m, the peaks concentrate in three frequency bands with middle frequencies 2 Hz, 4 Hz and 8 Hz.

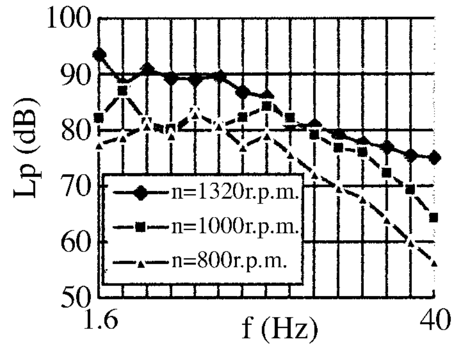

Figure 5. Infrasonic frequency spectra of impeller type IV with various speeds

It is obvious that the infrasonic peaks vary with the rotational speeds of the impellers, which is mainly of the blade surface. Accordingly, by adjusting the rotational speeds to alter the air flowing status, we can control the characteristics of infrasound radiation and the sound energy.

Table 1. The relationship between speeds and infrasound radiation

Rotational speeds r.p.m.	dB (Lin) 2-2000Hz	dB (Lin) 20-20000Hz	dB (IL) 0-20Hz
n=800	90~94.5	68.5	89.4
n=1000	93.9~96.1	74.0	93.1
n=1320	98~101.1	85.3	99.2

5. Relationship between blade trail edge thickness and infrasound

Blade trail edge thickness has significant effect on release of vortex noise. In this section, we will take the axial iron impeller type III as the experimental object to study the relationship between them. The measuring results of the low frequency noise and infrasound are illustrated in Table 2. Figure 6 shows infrasonic frequency spectra (for third-octave bands) of two kinds of iron impellers with different blade trail edge thickness.

Table 2. Relationship between blade trail edge thickness and infrasound

Edge thickness	dB(IL)	dB(A)	dB(Lin) 20-20000Hz
0.8mm	87.6	53.8	61.0
4.0mm	87.8	55.3	62.7

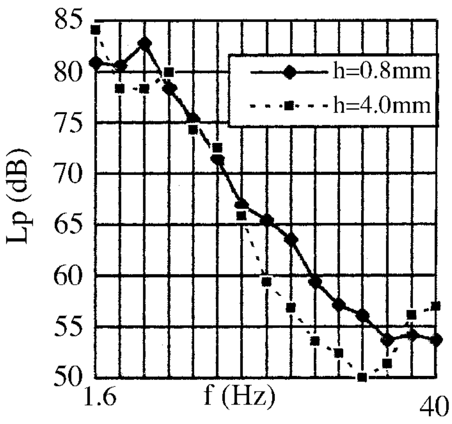

Figure 6. The infrasonic spectra of an axial impeller type

As has been shown in Table 2, when the blade trail edge thickness varies from 0.8mm to 4.0 mm, the linear sound pressure level of the blower increases by 1.7 dB in the frequency range 20~ 20,000 Hz, and the A-weighted sound level has a increment of 1.5 dB. Whereas, only 0.2 dB increment with infrasonic sound pressure level arises. It is thus clear that, the blade trail edge thickness has no obvious influence on infrasonic radiation. Although change of the blade trail edge thickness has no decided influence on general infrasound level, which can be seen from the third-octave frequency band spectrum illustrated in Figure 6, it alters the frequency construction of the infrasound radiated by the impeller. The infrasound in frequency range from 6.3 to 20 Hz will reduce when the blade trail edge thickness increases. As we see it, this is because of the size alteration of edge eddy for releasing when the blade trail edge thickness changes, which causes the frequency of radiated sound to move into audio frequency bands. Moreover, when the trail edge thickness is up to 4 mm, the infrasonic energy in 3 bands with middle frequency 1.6 Hz, 3.15 Hz and 5 Hz is to some extent higher than that at 0.8 mm. Thus, although the alteration of the blade trail edge thickness has no decided influence on the general infrasound level, we can adjust the blade trail edge thickness for changing the infrasonic construction to reduce the influence on human body.

Table 3. The relationship between the blade type and sound radiation

Blade type	dB(Lin) 2-20000Hz	dB(Lin) 10-20000Hz	dB(Lin) 20-20000Hz	dB(A)	dB(IL)
I radial blade	89.9~96.1	84.0~86.0	72.0~76.0	52.0	91.9
II bent blade	92.8~94.1	83.2~85.2	74.5	50.1	92.8

6. Relationship between blade type and infrasound

The aerodynamic characters of the axial impellers vary with blade type. This section is involving in studying and analyzing the relationship between the blade type and the infrasound radiation. The impellers used in this experiment are impeller type I with radial blade and impeller type II with bent forward grazed blade. The experimental results are illustrated in Table 3. Figure 7 shows the infrasonic frequency spectrum of two kinds of impellers.

It can be seen from Table 3 and Figure. 7:

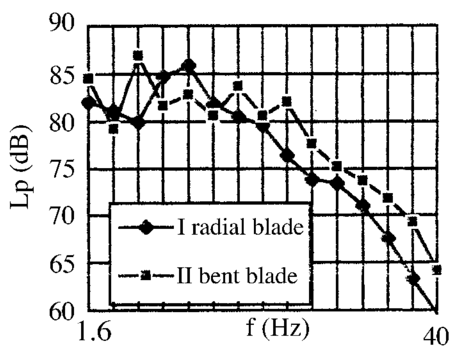

Figure 7. The relationship between blade type and infrasonic radiation

1. As for the general infrasound level, an impeller with bent blade is higher than one with radial blade.
2. As for noise or the A-weighted sound pressure, the bent forward grazed blade is good for noise reduction. At the same speed, the A-weighted sound level of the noise radiated by the bent forward grazed blade has a decrement by 2 dB to that of radial blade.
3. The altering scope of the linear general sound pressure level of radial blade is greater than that of the bent blade.
4. The peak noise spectra of impeller with bent blade arises in the frequency band with middle frequency 2.5 Hz, whereas, the peak radiated by radial blade appears in the band with middle frequency 4 Hz. In the frequency range 5 ~ 40 Hz, the sound pressure level of impellers with bent blades is always higher than that with radial blades.

7. Conclusion

1. In the aerodynamic sound radiation of axial blower, the sound energy in infrasound frequency band is dominant, which adds up to nearly over 95 percent of the total sound radiation.

2. Infrasound radiated by the impeller with axial blade has obvious directivity along its axis. In other words, the radiation is beamed forward.
3. The infrasonic energy radiated by axial impeller increases according to the increment of rotational speeds of impeller. At low rotational speeds, infrasonic energy in higher frequencies increases greatly with the increment of the rotational speeds; whereas at high rotational speeds, accordingly as the increment of speeds, infrasonic energy in lower frequencies has an obvious increment.
4. The blade trail edge thickness of the impeller does not have significant influence on the general infrasound pressure level, whereas the alteration of the trail edge thickness may affect on the frequency construction.
5. The axial impeller with radial blades is helpful for infrasound reduction.

ACKNOWLEDGEMENT

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parliament

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20th November 2001, In the debate on Heathrow (Terminal 5)

The Secretary of State, Mr Stephen Byers said,

'I am today publishing the inspector's report into Heathrow terminal 5, as well as my decision letter. Copies of both have been placed in the Library of the House. My decision and the reasons for it have been set out in the decision letter itself.

After considering the inspector's report and taking into account all the relevant considerations, I have today given my approval to the development of terminal 5 at Heathrow airport. Such a development is in the national interest. It will enable Heathrow to remain a world-class airport, and it will bring benefits to the British economy. At the same time as giving my approval to the development, I have imposed conditions in order to protect the interests of those living in the vicinity of Heathrow airport.

First, a limit on the number of flights each year has been set at 480,000. The limit has been imposed on a precautionary basis, and because of the inspector's concerns about noise. It was recommended by the inspector himself. Last year, Heathrow handled some 460,000 flights and just under 65 million passengers. Even with a limit of 480,000 flights, the inspector adopted a figure of 90 million passengers each year as the capacity of Heathrow if terminal 5 is built – an extra 25 million passengers at Heathrow each year.

Secondly, the noise effects of terminal 5 will also be limited by a condition restricting the area enclosed by the 57-decibel noise contour to 145 sq km as from 2016. Again, this follows the inspector's recommendation.

The inspector recommends stricter controls on night flights. I recognise that there is considerable concern about night noise, but I am not legally entitled to change the night noise regime without consultation. I shall consult on extending the night quota period when I next make proposals for the night noise regime for the BAA London airports. I have decided that the consultation will take place by 2003 at the latest.

The House should also be aware that we have already announced a change to the system of so-called westerly preference at