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ABSTRACT

We always use SPL(A) to appraise disturbance of the noise to people. Based on the feature that A weighting network can reduce noise's sinsitivity when the noise frequency is under 500 Hz octave. This paper advances a point that useing the jet's feature of shifting peak frequency can change the peak frequency of the valve jet noise. So that we shift peak frequency from high frequency band to the frequency band which has larger attenuation in the A weighting network.

Adopting this method can make our way and make SPL(A) of the type L2-10/8-I air compressor decreasing by 1.3dB(A).

INTRODUCTION

The jet noise of the compressor's valve is the larger one in the compressor's total noise. To control it is very difficult in the day. I have advanced a method which reduces the Mach number M of the valve for reduction jet noise of the valve[1]. The mehtod is to reduce total sound energy of the valve jet. But some sound energy will be reduced consisting of some sound energy which have not trouble or have smaller touble to people. The work to reduce the null-trouble sound energy to people is nullity evidently.

The method of controling trouble noise in the total sound of the valve jet is approacted in the article. As A weighted sound level is a index to appraise the noise of different compressors, it is a control specific aim which is needed by us. A weighting network has a specific that has highly sensitivity in the high frequency, but it reactes slowly and has larger decrement in the low frequency. Therefore, shifting the frequency of the jet noise to the low frequency which has larger secrement in A weighting network can reduce the A weighting noise. Although the method hasn't reduced the total energy of the jet sound, its noise reduction efficiency is higher because it direct control the trouble in the total sound to people.

We have done some experiment on the suction valve of the first stage of the type L2-10/8-I air compressor by this method.

FUNDAMENTAL REDUCING JET NOISE BY SHIFT FREQUENCY

The jet noise is a strong noise with the wide-band frequency spectrum and its Strouhal number St of the peak frequency is 0.2[2]. But only some parts of the jet sound can interfere to us, because one can hear sound with frecuencies greater than 20 Hz and less than 20000 Hz. If we could push the frequency of the jet noise off the audible sound, it will be a best method for reducing noise, obviously it's quite difficulty. But we have gained some good enlightenments from the frequency response of the people's ear from 20 Hz to 20000Hz.

The Fig.1. shows the equal-loudness contoure (ISO) of people's hearing. The contours have shown us that people's hearing is the highly sinsitivity in the high frequency (1-4 KHz) and it reactes slowly in the low frequency. The lower frequency of a noise the smaller trouble to us under the same power of a noise source. We can make this property to control noise for us.

The A weighting networks can simulate the some frequency responses of the people's hearing. The A weighting network in middle of them has been desighed in accordance with the equal-loudness contour of 40 Phon. The frequency response of the A weighting network is even in 1-4 KHz. But the sinsitivity of the A weighting network will be reduced as(Fig.2) frequency reduces under an octave of 0.5 KHz or on an octave of 8 KHz and it has be decreased larger. So the A weighted sound level of the machine noise will be reduced as frequency of its noise source reduces. Therefore, when you appraise the noise of the different machine with the A weighted sound level, if only calculate the sound energy in the domain of 0.5 KHz-8 KHz octave, and you neglect others, you approximately get the sound energy of the A weighted sound level. The frequency 0.355 KHz is a lower cutoff frequency of the 0.5 KHz octave and 11.2 KHz is a upper cutoff frequency of the 8 KHz octave. It's a better approximation which has been proved by the test. So the frequency range from 0.355 KHz until 11.2 KHz is a main trouble range of the A weighted noise. And the main range to control the trouble noise must be this range. The least we can get from what is mentioned above is the conclusint that it will be the better method to control noise if we change the noise frequency and shift its all frequency or its part off this range. This is the fundamental reducing jet noise by shift frequency.

On the basis of the fundamental, Prof. Maa Dahyou has designed some micropore mufflers which s me jet noise frequency have shiftes from the high frequency end of 11.2 KHz off the main trouble frequency range of the A weighed noise[3]. The loss of the micropore valve is too great to be a chieved at the compressor. But we can change the peak frequency of the valve's jet noise and can shift it from the low frequency end of 0.355 KHz off the main trouble frequency range of the A weighed noise.

If the trouble noise energy is W_A among the total sound energy W of the valve's jet, the rest $(W-W_A)$ is introuble. From the point of view of the control noise, the numerical value $(W-W_A)$ must be the largest. In other words the larger the specific value $(W-W_A)/W$ the better the control noise. This article call the specific value $(W-W_A)/W$ a introuble efficiency of the A weighted noise. η_A is used in this article for the $(W-W_A)/W$

$$\eta_A = \frac{W-W_A}{W} = 1 - \frac{W_A}{W} \qquad (1)$$

where W_A — the ratio of trouble noise energy W_A of the A weighted noise to the total sound energy W of the valve's jet. The formula of the W_A/W has been given by Hoa Dahyou[3]

$$\frac{W_A}{W} = \int_{f_{Ad}}^{f_{Au}} Y \, df \qquad (2)$$

f_{Ad} — low cutoff frequency of the trouble noise of the A weighted noise, i.e. low cutoff frequency of the o.5 KHz octave, $f_{Ad} = 0.355$ KHz.

f_{Au} — upper cutoff frequency of the trouble noise of the A weighted noise, i.e. upper cutoff frequency of the 8 KHz octave, $f_{Au} = 11.2$ KHz.

Y — average value of the sound power of the specific relative frequency dW_f/dX within the scope of the total sound power

$$Y = \frac{1}{W} \frac{dW_f}{dX} \qquad (3)$$

W_f — the sound power under the relative frequency X which is the jet total sound power W.

X — relative frequency or a relative Strouhal number

$$X = \frac{S_t}{S_{to}} = \frac{f}{f_o} \qquad (4)$$

f — the frequency of the jet noise.

f_o — the peak frequency of the jet noise, it situates at its $S_{to} = 0.2$

$$St = \frac{fD}{V}\,\frac{C}{C_o} \tag{5}$$

$$f_o = \frac{S_{to} V}{D}\,\frac{C_o}{C} = \frac{V}{5D}\,\frac{C_o}{C} \tag{6}$$

D —— the diameter of the jet nozzle.
V —— the velocity of the jet flow.
C —— the sound velocity of the jet nozzle.
Co—— the sound velocity of the environment.

Substitute (4), (6) into (3)

$$Y = \frac{1}{W}\,\frac{dW_f}{df}\,\frac{V}{5D}\,\frac{C_o}{C} \tag{7}$$

Let the reference level of the Y is $W_o/X_o = 1/1 = 1$, so the level of the Y is that

$$10\lg \frac{Y}{W_o/X_o} = 10\lg Y = 10\lg\left(\frac{1}{W}\,\frac{dW_f}{df}\,\frac{V}{5D}\,\frac{C_o}{C}\right)$$

so

$$10\lg Y = 10\lg\left(\frac{1}{W}\,\frac{dW_f}{df}\,\frac{V}{D}\,\frac{C_o}{C}\right) - 7 \tag{8}$$

By means of the Von Gierke's power spectrum of the jet sound (Fig. 3)[2] we can get $10\lg(1/W \cdot dW_f/df \cdot C/D \cdot C_o/C)$, so that we may get Y by (8).

For the convenience of the calculation for the Y Prof. Maa Dahyou has given an explicit function relation by the Von Gierke's curve

$$Y = \frac{1}{\pi}\,\frac{1}{\left(X+\frac{1}{X}\right)^2} \tag{9}$$

On the basis of the function relation (9) this paper drew up a curve Y-X (logarithmic coordinate axis) (Fig. 4).

The rate of change of Y with X is that

$$\frac{dY}{dX} = \frac{8}{\pi}\,\frac{X(1-X^2)}{(1+X^2)^3}$$

From this, we abtain that

when $X=1$, i.e. $f=f_o$, the Y has maximum;

when $0<X<1$, the Y is anincrement type and its rate is $8X(1-X^2)/\pi(1+X^2)^3$;

When $1<X<\infty$, the Y is a reducing type and its rate is $8X(1-X^2)/\pi(1+X^2)^3$ too.

Substitute (9) into (2)

$$\frac{W_A}{W} = \frac{4}{\pi}\int_{X_{Ad}}^{X_{Au}} \frac{1}{(X+\frac{1}{X})^2}\,dX = \frac{2}{\pi}\left(tg^{-1}X - \frac{X}{1+X^2}\right)\Big|_{X_{Ad}}^{X_{Au}}$$

$$= \frac{2}{\pi}\left(tg^{-1}\frac{X_{Au}-X_{Ad}}{1+X_{Au}X_{Ad}} + \frac{X_{Ad}}{1+X_{Au}^2} - \frac{X_{Au}}{1+X_{Au}^2}\right) \qquad (10)$$

The numerical value of the W_A/W is equal to an area which is enclosed by line $X_{Ad}=0.355/f_o$, $X_{Au}=11.2/f_o$, $Y=0$, $Y=4/\pi(X+1/X)^2$, as shown abcd in Fig. 4. Under the same power of the jet noise the less area abcd, the less trouble noise of A weighted noise. The methods of the reduction area abcd have two: 1) Greatly heighten the peak frequency of the jet noise f_o in order that the moving distance of the area abcd is maximum towards the right; 2) Greatly lower the peak frequency of the jet noise f_o in order that the moving destance of the area abcd is maximum towards the left. The former is widely used in Prof. Maa Dahyou's micropore muffler, but the latter is used in this paper.

Substitute (10) into (1) and there are $X_{Ad}=0.355/f_o$, $X_{Au}=11.2/f_o$ so

$$\eta_A = 1 - \frac{2}{\pi}\left[tg^{-1}\left(\frac{10.845f_o}{f_o^2+3.976}\right) + \frac{0.355f_o}{f_o^2+0.126} - \frac{11.2f_o}{f_o^2+125.44}\right] \qquad (11)$$

On the basis of the (9) this paper drew up a curve (Fig. 5), from the curve we abtain that η_A of the jet noise is higher when the peak frequency of the jet noise is lower or higher and when $f_o \approx 0.8$ KHz the η_A is lowest. Therefore, when we design any valve, its peak frequency f_o must be farthest from 0.8 KHz.

EXPERIMENT

This paper has done some experiments with two kinds of the suction valve of the first stage on the type of L2-10/8-I air compressor. The two kinds of the valve have same power of the jet sound W and have different peak frequency of the jet sound f_o.

Because formula of the W is that

$$W = nkgpuD_o^2M^7 \qquad (12)$$

where n — the Lighthill constant.

k — specific heat ratio.

g — cravity accelaration.

p — jet pressure.

u — piston speed.

D_o — cylinder diameter.

M — Mach number of the valve.

$$M = V/C \qquad (13)$$

Substitute (13), into (6), get the formula of the f_0 with Mach number M

$$f_0 = \frac{MCo}{.5D} \tag{14}$$

$$C_0 = \sqrt{kRT} \tag{15}$$

From the (12), (14), (15) we know that change the diameter of the jet nozzle D under the same Mach number M of the valve the same environment temperature, we can do some experiments. The Fig. 6 shows the jet noise's octave sound spectrum of the first stage suction valve of the type L2-10/8-I air compressor, one of them is f_0=125 KHz octave, another is fo=500 KHz octave. The SPL(A) in the former case is 1.3 dB(A) less than the latter.

CONCLUSIONS

1) The method of the reducing jet noise with shift frequency can reduce its trouble noise. It consists of the method of rising frequency and method of lowering frequency.

2) In order to control any jet noise of the valve we can use two methods. They are reducing total power of the jet sound W and heighten the introuble efficiency of the A weighted noise.

3) Designing any compressor's valve, after given Mach number M of the valve we must make the peak frequency of the valve jet sound f_0 to be lowerest.

CONSULTING DOCUNENTS

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2. Von Gierke, H. E., "Recent Advances and Problems of Aviation Acoustics", Proc III ICA (Elsevier, 1962) 1055 - 1070.
3. Maa Dahyou, "Characteristics of the Flow Rate and Noise Radiation of Micropore Muffler", Chinese Journal of Acoustics, Vol. 3, No.1, P1,1984.

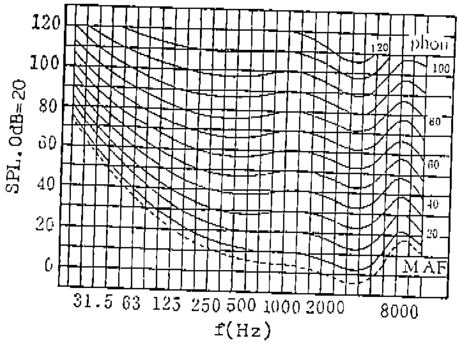

Fig. 1 The equal-loudness contours

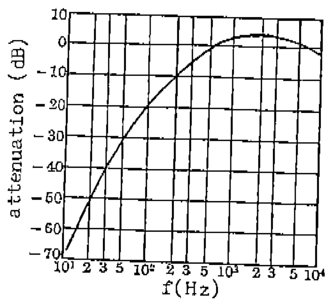

Fig. 2 The frequency attenuation of the A weighting network

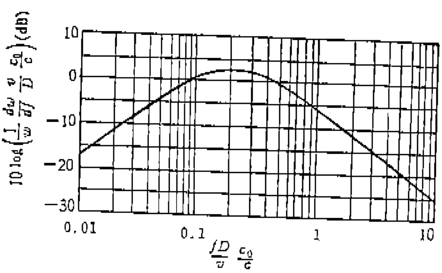

Fig. 3 The acoustic power spectrum of the jet noise

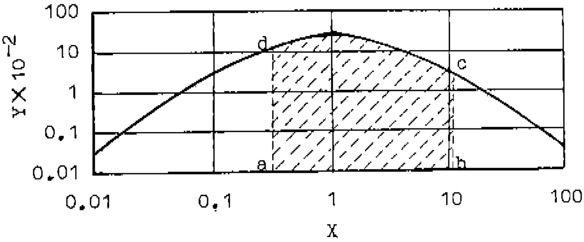

Fig. 4 Y - X curve

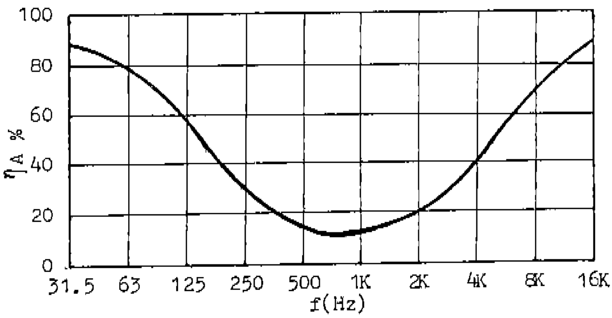

Fig. 5 A - f_0 curve of the jet noise

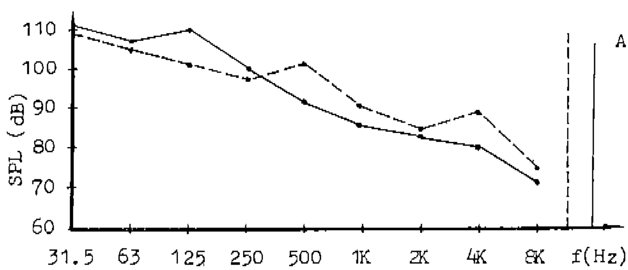

Fig. 6 The jet noise's octave sound spectrum of the first stage suction valve of the type L2-10/8-I air compressor,
——— the peak frequency f_0= 125 Hz octave;
- - - - - the peak frequency f_0= 500 Hz octave.