Study on the Jet Flow Ventilation Pressurization Technology

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Abstract: Up to now, more and more highway and railway tunnels generally use the jet flow type longitudinal system, Although the jet flow ventilation system has many merits, its ventilation efficiency to be low, is only generally about 15%. In order to enhance the ventilation efficiency, may use the heavy-caliber air blower, the high injection velocity, arrange the jet fans reasonably and so on. This article uses a method, which establishes shrinkage pipe at the jet flow outlet, so as to enhance the jet fans outlet injection velocity. Through theoretical analysis and calculation. Indicated this method can enable the jet flow turbo-charged to have the remarkable improvement, hence the jet flow ventilation efficiency also has a great scope of enhancement.

Keywords: jet ventilation, shrinkage pipe, pressurizing ,ventilation efficiency

With the rapid development of traffic engineering, the number of highway and railway tunnels dramaticly increase. The vertical-jet flow ventilation is very common in chinese tunnel ventilation, which has many metris, such as safe and reliable、control convenient and flexible、better ventilation effect, meanwhile in construction investment、operation costs and so on, all of which have a significant economic benefits. However the jet flow ventilation also has the shortcoming of the vertical ventilation, there are mainly not conducive to fight the fire, tunnel cumulative effect of the pollutants density. In addition, the installed fans power of the jet flow ventilation system usually reach to several hundreds kilowatt, but the effective power is only several dozens kilowatt. Therefore the jet flow ventilation has a lower ventilation efficiency. How to enhancing the ventilation efficiency is an important research issue of ventilation technology.

1. Theoretical analysis of jet flow pressurization

The formula for single jet fan actual pressurization is (see Reference 2)

$$\Delta p_{ja}=k_j\times\beta(1-\alpha)\frac{2-\beta(3-\alpha)}{(1-\beta)^2}\times\frac{1}{2}\rho v_j^2 \qquad (1)$$

A simplified formula for single jet fan actual pressurization is (see Reference 2)

$$\Delta p_{ja}=k_j\times2\times\beta(1-\alpha)\times\frac{1}{2}\rho v_j^2 \qquad (2)$$

Δp_{ja} —Actual pressurization of jet fan

k_j —Pressurization coefficient of jet fan

β — Expansion ratio, $\beta=\frac{A_j}{A_t}$, A_t 、 A_j are the cross-section area of the tunnel and the jet fan export

α —Velocity ratio, $\alpha=\frac{v_t}{v_j}$, v_t 、 v_j are the velocity of the tunnel ventilation and the jet fan export

ρ — Air density

The discipline of jet flow pressurization indicates that the jet flow pressurization Δp_{ja} directly relates to the pressurization coefficient k_j , the expansion ratio β , the velocity ratio α and the jet flow speed v_j . The pressurization coefficient k_j is a result of friction of wall jet flow、collision of parallel jet flow、momentum exchange of jet flow and adjoint flow、local refluence phenomena and so on, which causes the jet flow energy loss and the jet flow theoretical pressurization less. The pressurization coefficient normaly is identified by experiments. Test and research results show that, the more rational arrangement of jet fans, the higher pressurization coefficient.

The jet flow pressurization Δp_{ja} and expansion ratio β are in direct proportion. When A_t is certain, the higher value of A_j will be a greater pressurization. Currently, the biggest jet fan is up to 1300mm diameter.

The jet flow pressurization Δp_{ja} is related to velocity ratio α and square of the jet velocity. When the jet velocity increased and ventilation velocity unchanged, the value of $(1-\alpha)$ and jet velocity square increased, jet flow pressurization is also increased. At present, foreign jet fan's maximum speed is up to 40m/s, domestic also achieves to 35m/s.

2. Analysis of tunnel jet flow ventilation system ventilation efficiency

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If jet fan group is z, each group with n unit running, the tunnel total jet flow pressurization is bound to the total resistance of ventilation air, namely:

$$z \times n \times \Delta p_{ja} = \left(\xi_{in} + \lambda \frac{l}{d_e} + 1 \right) \times \frac{1}{2} \rho v_t^2 \qquad (3)$$

ξ_{in} — Local drag coefficient of the tunnel imports

λ —Tunnel friction coefficient

l — Length of tunnel

d_e —tunnel equivalent diameter

Each jet fan rated power is p, total installed power is z×n×p, that's Σp. The tunnel ventilation system ventilation efficiency is

$$\eta_t = \frac{\Delta P_t \times Q_t}{\Sigma P} \qquad (4)$$

η_t —Tunnel jet flow ventilation system ventilation efficiency

Δp_t —Tunnel ventilation total resistance

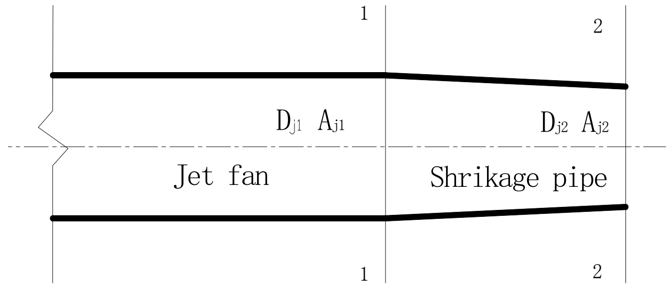
Q_t —Tunnel ventilation

The 4th formula shows that, the tunnel jet flow ventilation system ventilation efficiency has a relationship of the effective consumption power and the total installed capacity operation of jet fan power. when the total number of jet fan remains invariable, that is the total installed power unchanged, the tunnel ventilation airflow speed increases, ventilation airflow effective power also has a corresponding increase, therefore the tunnel ventilation system ventilation efficiency increases greatly too. When the tunnel ventilation velocity remains invariable, the higher jet flow pressurization, the less operating jet fan number and the total installed power. Therefore, the jet flow ventilation system ventilation efficiency has a substantial increase.

3. Analysis of pressurization after installing a shrinkage pipe

Most jet fans are stereotyped products, the text adopted a method, that installing a shrinkage pipe at jet fan export, in order to increase the jet speed and the jet flow pressurization, and achieve the aim of improving the ventilation efficiency. The figure of the shrinkage pipe at jet fan export is as shown.

After installing a shrinkage pipe, according to the jet theory, the jet flow pressurization coefficient approximate remains unchanged, so the jet flow pressurization formulas continue to apply. For the jet flow, air can be incompressible fluid handling, the continuous equation is



Fingure 1. Install shrinkage pipe at the jet fan outlet

$$v_{j1} A_1 = v_{j2} A_2 \qquad (5)$$

Among them, v_{j1}、A_{j1} and v_{j2}、A_{j2} are jet fan export and the shrinkage pipe export's speed and area. After installing a shrinkage pipe, the jet export diameter D_{j1} decreases to D_{j2}, the jet velocity v_{j1} raises to v_{j2}, improved $(\frac{D_{j1}}{D_{j2}})^2$ times. According to 2nd formula, the jet flow pressurization has a relationship of the velocity square. When tunnel ventilation speed remains changeless, the velocity ratio decreases, and the value of $(1-\alpha)$ increases, the velocity square has increased a larger proportion, so the jet flow pressurization also has improved greatly.

4. Analysis of ventilation effect after installing a shrinkage pipe

3rd and 4th formulas indicate, when each unit jet fan n and group z are invariable, after installing a shrinkage pipe, the jet velocity and pressurization have a big enhancement, the tunnel ventilation rate also has an enhancement. With the ventilation speed increasing, tunnel ventilation effective power also has a corresponding enhancement, when the total installed power is unchanged, the tunnel ventilation system ventilation efficiency also has a corresponding enhancement.

After installing a shrinkage pipe, when tunnel ventilation rate is unchanged, due to jet velocity and jet flow pressurization improving, it will reduce the number of jet fans. when each unit fan n is unchanged, the jet fan group can be reduced from z to m, and the overall rated power reduces to $m \times n \times p$. the total jet fans installed power reduces, ventilation effective power is in the same circumstances, it will improved the ventilation efficiency of the tunnel ventilation.

5. Calculation and analysis of a tunnel ventilation

For example, a certain section of a tunnel is 65m^2, equivalent diameter is 7.32m, length is 4.360km, the friction coefficient is 0.02, import drag coefficient is 0.5, jet velocity is 30m/s, diameter is 900mm, each unit with two jet fans, a total of 14 groups, each fan's rated power is 15 Kw, the total installed power is 420 Kw. According to 2nd formula, calculation of the jet flow pressurization is shown in the table below.

Tab. 1 Calculation of jet flow pressurization

v_{j2}	D_{j2}	A_{j2}	V_t	α	β	Δp_{ja}	ε
m/s	mm	m^2	m/s			N/m^2	%
30	900	0.6358	5.48	0.1827	0.0098	7.21	
35	833	0.5447	5.95	0.1700	0.0084	8.54	18.45
40	779	0.4764	6.34	0.1585	0.0073	9.83	36.34
45	735	0.4241	6.84	0.1520	0.0065	11.2	54.78

The results show that, when the jet flow velocity is 30m/s, the jet flow pressurization is 7.21N/m^2. After installing a shrinkage pipe, the jet velocity is controlled 35m/s,the jet flow pressurization is 8.54N/m^2, which increased 18.45%; the jet velocity is controlled 45m/s, the jet flow pressurization is 11.2N/m^2, increased 54.78%. It is clear that after installing a shrinkage pipe, the jet flow pressurization is more greatly enhanced.

When the tunnel ventilation rate and each group of jet fan number n are unchanged, according to 3rd and 4th formula, calculation of the group of jet fans m and the ventilation efficiency are shown in the table below.

The results indicate that, under the premise of meeting the tunnel ventilation, with no shrinkage pipe and jet speed is 30m/s, it needs 28 unit jet fans to ventalate. Tunnel ventilation rate is 5.48m/s, ventilation is 356.2m^3/s, the tunnel ventilation voltagedrop is 201.38N/m^2, tunnel consume effective power is 71.73 Kw, ventilation efficiency is 17.08%.

After installing a shrinkage pipe and the jet velocity is controlled 35m /s, it needs 24 unit jet fans, the ventilation efficiency increases to 19.92%; jet velocity is controlled 45m/s, it needs 18 unit jet fans, ventilation efficiency has reached to 26.56%. From the above calculation, we can see that when the jet speed increasing, it can reduce the fans number, therefore effectively enhance the tunnel ventilation system ventilation efficiency.

Tab. 2 Calculation of jet fans number and ventilation efficiency

v_{j2}	α	Δp_{ja}	m	η_t
m/s		N/m^2		%
30	0. 1827	7. 21	14	17. 08
35	0. 1566	8. 68	12	19. 92
40	0. 1370	10. 1	10	23. 91
45	0. 1289	11. 5	9	26. 56

6. Conclusion

6.1 Jet flow pressurization has enhanced greatly after installing a shrinkage pipe at jet fan outlet. For example, when the jet velocity enhancing from 30m/s to 35m/s, jet flow pressurization increased 18.45%; when the jet velocity increased to 40m/s, jet flow pressurization increased 36.34%.

6.2 The tunnel ventilation system ventilation efficiency also has improved greatly after installing a shrinkage pipe at jet fan outlet. For example when the jet velocity enhancing from 30m/s to 35m/s, jet fans number decreased from original 28 unit to 24 unit, ventilation efficiency improved from 17.08% to 19.92%; when the jet velocity increased to 45m/s, the number reduced to 18, ventilation efficiency will be increased to 26.56%.

6.3 If tunnel traffic volume increases, it needs to enhance the jet flow pressurization correspondingly. It is usual adding jet fans number to transform the original system. If adopting the method to make ventilation system transformation,which installing a shrinkage pipe at jet fan outlet,it will obtain a significant economic efficiency and a social benefits.

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