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Correction and Measurement of Transmittance of Smoke in 8 – 14 μm Waveband

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Abstract: To reduce the effects of smoke temperature on the transmittance measurement in 8 – 14 μm waveband, the transmittances of infrared smoke was analyzed with and without infrared radiation source. Results show that the transmittances of 5 g smoke agent is 40% – 50% and 15% – 20%. And the infrared smoke formed by burning leads to smoke cloud with a strong radiation. Then, a different correcting method was carried out. The transmittance is corrected by subtracting from the transmittance of infrared smoke without infrared radiation source, and transmittance of the smoke agent with infrared radiation source decrease to 25% – 35%.

Key words: infrared physics; smoke; radiation; transmittance

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1 Introduction

It is well known that smoke is an effective screening agent. And the infrared smoke screen is widely used, whose transmittance is an important parameter to evaluate the obscuring performance in common infrared waveband (1 – 3 μm, 3 – 5 μm, 8 – 14 μm). In modeling the effects of infrared (IR) screening smoke, one should account for the fact that the smoke itself is a strong source of IR radiation, and the degree of effect depends upon the aerosol optical thickness, emissive, and temperature. The problem has been recognized for some time by the users[1]. A smoke medium that contains isolated, heated, point-like sources called hot smoke is a more effective screening agent[2-3], so the temperature of the smoke cloud is usually higher than the ambient. However, hot smoke cloud is an impact on the transmittance measurement after smoke agent burnt. A wrong result would be aroused in 8 – 14 μm waveband. The reason lies in the background radiation of the infrared smoke owing to temperature difference. In order to reduce the impact, instead of radiometer and spectrometer, IR-imaging equipment is used to evaluate the obscure performance of smoke[4-8], and laser equipment[9], but the sampling data is stochastic from IR-imaging equipment and the width of waveband of laser equipment is narrow. Therefore the phenomenon of infrared smoke was analyzed in the paper in 8 – 14 μm waveband. Based on spectrometer, the relevant experiments were designed, and a correction method was presented for the smoke transmittance in 8 – 14 μm waveband.

2 Experimental

2.1 Experiment instruments

That the spectrometer is Open path Fourier transform infrared remote sensor (OPAG33, Bruker Optics), used to measure transmittance of smoke. The scanning time of spectrometer is 32 s, scans 10 times in succession. The infrared radiation source is a standard blackbody (HFY-200B blackbody) which is made in Shanghai Institute of Techno-Physics of Academy of Science of China. A standard smoke-chamber is used to discharge and flow with smoke.

2.2 Contrast testing

Test-1, 5 g smoke agent was lighted up in the smoke-chamber, and the temperature of the infrared radiation source was set to 773 K. Fig. 1 shows that the transmittance varies with the wave-number. Test-2, smoke agent was still 5 g, but the infrared radiation source was shut, and the results shown in Fig. 2. Test-3, 40 g smoke agent burned up in the smoke-chamber, and temperature of the infrared radiation source was set to 773 K. Its spectra are shown in Fig. 3.

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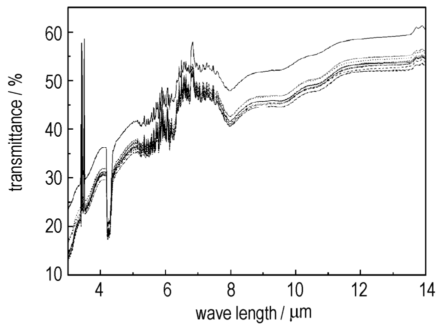

Fig. 1　The spectra of transmittance of 5 g smoke agent with the infared radiation source

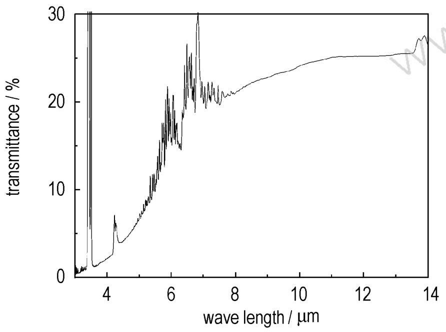

Fig. 2　The spectra of 5 g smoke agent without the infrared radiation source

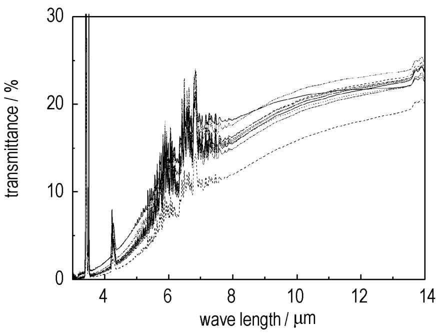

Fig. 3　The spectra of transmittance of 40 g smoke agent

3　Results and discussion

Fig. 1 shows the range of the transmittance is obvious, which is from 40% to 50% in 8 - 14 μm (1250 - 714 cm^{-1}) waveband. In the Fig. 2, transmittance in 8 - 14 μm should be zero because the infrared radiation source is shut, but the varying range is still shown from 15% to 20%. In testing-3, the quantity of smoke agent is increased 8 times more than that in test-1, the infrared from the radiation source should be scattered entirely by the thick smoke, but the result same as that of test-2.

The investigation indicates, the transmittance of smoke in 8 - 14 μm waveband is affected, and the background spectrum due to higher temperature of the smoke than the ambient. Thus its results could not be used to evaluate the obscure performance of the burning-type infrared smoke before the transmittance measured is processed. In fact, the varied quantity of transmittance in Fig. 2 and Fig. 3 are the radiant from smoke. In this phenomenon, the radiant quantity may be calculated by Plank' s law of radiation when the temperature of blackbody and wave length has been known, and its unit is W · μm^2. Plank's radiation formula follows as:

$$M_\lambda = c_1 \lambda^{-5} \frac{1}{e^{c_2/\lambda T} - 1} \qquad (1)$$

Where, c_1, first radiant constant, 3.7418 × 10^{-4} W · μm^2; c_2, second radiant constant, 1.4388 × 10^4 μm · K; λ, wave length, μm; T, temperature, K.

The temperature of the burning-type smoke cloud is 343 - 353 K and the ambient is 283 - 303 K. The temperature of blackbody is 773 K. The radiant quantity calculated based on Plank's radiation formula are shown in the Fig. 4.

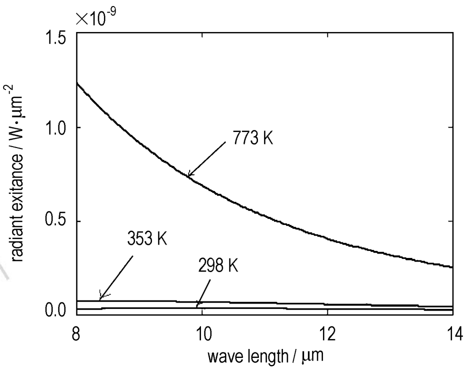

Fig. 4　The curves of radiant quantity of blackbody

The affect range in 8 - 14 μm is estimated by the equation (2).

$$\eta = \frac{M_{\lambda \cdot smoke}}{M_{\lambda \cdot b}} \times 100\% \qquad (2)$$

Where, η, the effect range of transmittance, %; $M_{\lambda \cdot smoke}$, the radiant quantity of smoke cloud, W · μm^2; $M_{\lambda \cdot b}$, the radiant quantity of the blackbody, W · μm^2.

Based on Plank's law of radiation and the temperature of smoke cloud of 353 K, the range of transmittance is from 8% to 16% in 8 - 14 μm. Therefore, a correcting method was carried out to evaluate transmittance of the infrared smoke as following.

First of all, data curves in Fig. 1 are translated into the discrete series, and put into a database as listed in Table 1. Secondly, the smoke background based on Fig. 2 is put into the databases in Table 2. Finally, the radiation ratio of Table 2 are subtracted from the versus transmittance of Table 1 one by one. Its results are listed in Table 3.

Table 1 The conversion data from the original curves of transmittance in Fig. 1

wave length /μm	transmittance					
	32 s	64 s	96 s	……	288 s	320 s
2.998997	0.234008	0.166108	0.168712	……	0.132606	0.12841
3.000733	0.234244	0.16634	0.168972	……	0.132868	0.128645
3.00247	0.234482	0.16659	0.169187	……	0.133117	0.128881
3.00421	0.234699	0.166812	0.169354	……	0.133319	0.129079
⋮	⋮	⋮	⋮		⋮	⋮
13.93889	0.60708	0.538828	0.556633	……	0.546668	0.530409
13.97646	0.605331	0.537563	0.555428	……	0.545517	0.529241

Table 2 The conversion from the smoke radiation curve in Fig. 2

wave length/um	the ratio of radiation from smoke
2.998997	0.001755
3.000733	0.001861
3.00247	0.001937
3.00421	0.001985
⋮	
13.93889	0.238181
13.97646	0.237506

Table 3 The correcting data of transmittance

wave length /μm	transmittance ratio					
	32 s	64 s	96 s	……	288 s	320 s
2.998997	0.232253	0.166108	-0.06354	……	-0.19615	0.196147
3.000733	0.232383	0.16634	-0.06341	……	-0.19628	0.196279
3.00247	0.232545	0.16659	-0.06336	……	-0.19648	0.196475
3.00421	0.232714	0.166812	-0.06336	……	-0.19668	0.196679
⋮	⋮	⋮	⋮		⋮	⋮
13.93889	0.368899	0.538828	0.187734	……	-0.35893	0.358934
13.97646	0.367825	0.537563	0.187603	……	-0.35791	0.357914

According to the Table 3, the spectrum curves of transmittance against waveband are plotted in Fig. 5 respectively.

It can be clearly seen from a comparison between Fig. 1 and Figure. 5 in 8 – 14 μm waveband. In Fig. 1 the range of transmittance is nearly 50%, but the range in Fig. 5 by difference correcting is from 25% to 35%.

4 Conclusion

The higher temperature than the ambient, leads to the signal noise from IR radiation of hot smoke and the transmittance are different in 8 – 14 μm waveband. To evaluate the infrared smoke performance, a correction method is applied to reduce the noise effect by subtracting the rate of infrared radiation of the smoke, and the range of transmittance decreases from 40% – 60% to 25% – 35% in 8 – 14 μm.

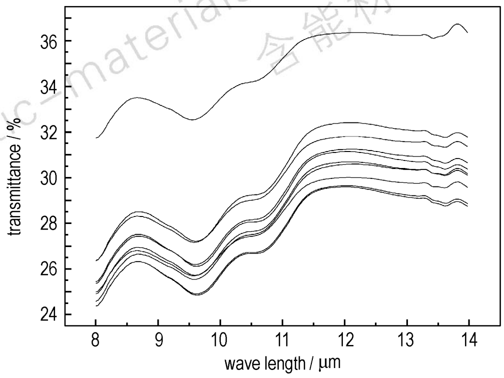

Fig. 5 The spectra of transmittance in 8 – 14 μm waveband after difference correcting

The method not only is used to analyze the transmittance based on Fourier-transform-infrared spectrometer, but it is practicable to compare the data from the infrared radiometer.

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8 - 14 μm 波段红外烟幕透过率的测试与修正

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摘要: 为了减少烟幕温度对 8 - 14 μm 波段烟幕透过率的影响,分析了有红外辐射源和没有红外辐射源的燃烧型红外烟幕的透过率。结果发现两种情况下 5 g 发烟剂被点燃后的透过率分别是 40% - 50% 和 15% - 20%,燃烧形成的红外烟幕导致烟幕云团具有很强的红外辐射。为此提出了减差修正法,烟幕的透过率通过减去没有红外辐射源时的透过率得到修正,5 g 发烟剂的透过率减小为 25% - 35%。

关键词: 红外物理; 烟幕; 辐射; 透过率

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Measurement of Detonation Velocity of Industrial Explosive Using Continuous Detonation Velocity Method

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Abstract: The average detonation velocity and continuous detonation velocity of powdery emulsion explosive and emulsion explosive were measured respectively by electrometric method and continuous velocity probe. Results show that, for powdery emulsion explosive with the charge density of 850 $kg \cdot m^{-3}$ and 820 $kg \cdot m^{-3}$, the average detonation velocities are 4526 $m \cdot s^{-1}$ and 4020 $m \cdot s^{-1}$; the corresponding continuous detonation velocity ranges are 4300 - 4600 $m \cdot s^{-1}$ and 4000 - 4300 $m \cdot s^{-1}$ during the stable detonation phase. For emulsion explosive with the charge density of 900 $kg \cdot m^{-3}$ and 840 $kg \cdot m^{-3}$, the average detonation velocities are 4384 $m \cdot s^{-1}$ and 2345 $m \cdot s^{-1}$; the corresponding continuous velocity ranges are 3370 - 4592 $m \cdot s^{-1}$ and 2871 - 3420 $m \cdot s^{-1}$. The detonation velocity measured by the continuous velocity probe method is in accord with the detonation velocity measured by the traditional electrometric method, and the continuous velocity probe method can even give the true course of detonation development for industrial explosive.

Key words: explosion mechanics; continuous detonation velocity; average detonation velocity; industrial explosive; detonation development