Interesting Flame Propagation Pattern of Gas Flame Interacting With Dust Deposit

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Abstract The acceleration of gas flame propagating over dust deposited on the bottom of a flame acceleration tube is studied experimentally. When premixed gas is ignited in one end of the tube and flame accelerates forward, transient flame of three front structure is induced. After a short time, the three front flame becomes a complex gas-dust flame. The transient three front flame structure consists of a gas flame, a forward dust flame and a backward dust flame. The reason of the backward dust flame occurrence is that a delay or induction time is necessary for deposited dusts lifted and ignited. Because of the existence of the backward dust flame, the curve of flame velocity along the tube tangentially gives a birdlike configuration.
Keywords: gas flame, dust deposit, flame propagation, accelerating flame

INTRODUCTION

The phenomena of flame acceleration in the mixture of combustible gas and/or dusts with air are quite important for the prevention and mitigation of the fire and explosion in the mixtures. Especially for the practical underground mines, coal dust deposits always exist on the floor or wall of the well gallery. Once the gas is ignited somewhere and the flame propagates along the well, the deposited dusts will be entrained into air and participate in the process of the combustion. As a result, the flame is accelerated and a more severe explosion will occur. Many researchers focus their studies on the phenomena of flame accelerations of gas or dusts and air mixtures[1~6]. Most of previous investigations were performed on the model setup, the flame acceleration tube (FAT). Their works were mainly related to the acceleration process of gas flame or dust flame respectively.

In the present paper, the interaction of gas flame with dust deposit and the propagation of complex gas-dust flame induced by gas flame were experimentally studied in a newly developed experimental system. An interesting propagation pattern of gas-deposited dust flame is presented.

EXPERIMENTAL DETAIL

The self-developed experimental system include five sections as shown in Fig.1, a flame acceleration tube (FAT), a flame velocity measuring system, a spark ignition source, a gas mixing system and a data acquisition and digital transient recorder.

The FAT sets horizontally made of hyaloid perspex plate and is of 1480mm long, 89×89-mm quadratic cross section. The ignition system is a high-voltage electrostatic equipment. The flame propagation velocity is detected using photodiodes mounted on the tube wall. Gas concentration is less than stoichiometric concentration. About 4.0 gram coal dust is layered

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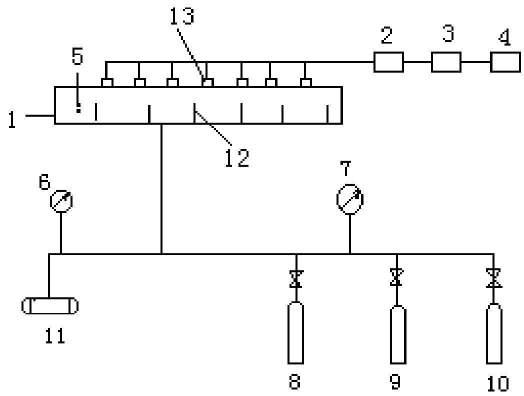
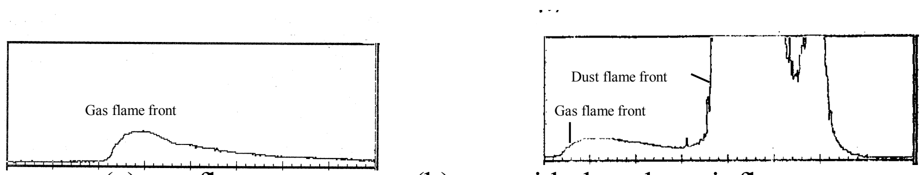
homogeneously on the bottom of the tube. After gas flame passes over dust deposit, the maximum concentration of dust cloud induced is about less than 135g/m^3 because the mass of the coal dusts entrained into the gas by the flow is less than 40% of total dusts deposited in the dust layer[8,9]. The coal dust parameters are same as presented in [8]. Because of the difference between luminous intensities of gas flame and dust flame, the fronts of gas and dust flame can easily detected by light signals output by photodiode as shown in figure 2.



1.FAT 2.Electricity transducer 3. Data acquisition and digital transient recorder 4.Printer 5.Spark ignition source 6.Manometer 7.Vacuum-meter 8.Gas mixture 9.Air 10.Methane 11.Vacuum-pump 12.Obstacle 13. Photodiode

Fig.1 Experimental Apparatus



(a) gas flame (b) gas with dust deposit flame

Fig.2 Flame light signals detected by photodiodes

RESULTS AND DISCUSSIONS

Based on the light signals of gas and dust flames output by photodiodes, the flame front trajectories of gas and dust flame can be drawn out in Fig.3. It is obviously that the flame trajectory consists of three parts. First part relates to the gas flame denoted by *OA*. The second part *AiC* is trajectory of dust flame where curve *Ai* and *iC* are corresponding to forward and backward dust flame respectively. The last part *AB* is trajectory of gas-dust complex flame. The point *i* is dust ignition location where is depart from gas ignition location *O* because the deposited dusts should have fluid and thermodynamic delay times which are long enough for dusts raised into air from deposits and heated to so high temperature as to be ignite.

As discussed above, with gas flame accelerating over a dust deposit, there are three stages. From gas ignition to dust ignition ($t_0<t<t_i$), gas flame accelerates gradually. After dust ignition ($t_i<t<t_2$), advancing gas flame is accompanied with a forward dust flame and a backward dust flame falls back to gas ignition end. While a short time($t>t_2$), the advancing gas flame and forward dust flame integrate each other and the gas-dust integrated flame succeed. The backward dust flame will disappear in certain time. The times of dust ignition, and the formation and disappearance of the forward and backward dust flame are effected by experimental conditions such as the concentrations, and physical and chemical properties of gas and dusts used in the experiments, ignition energy, tube size and the boundary conditions etc.

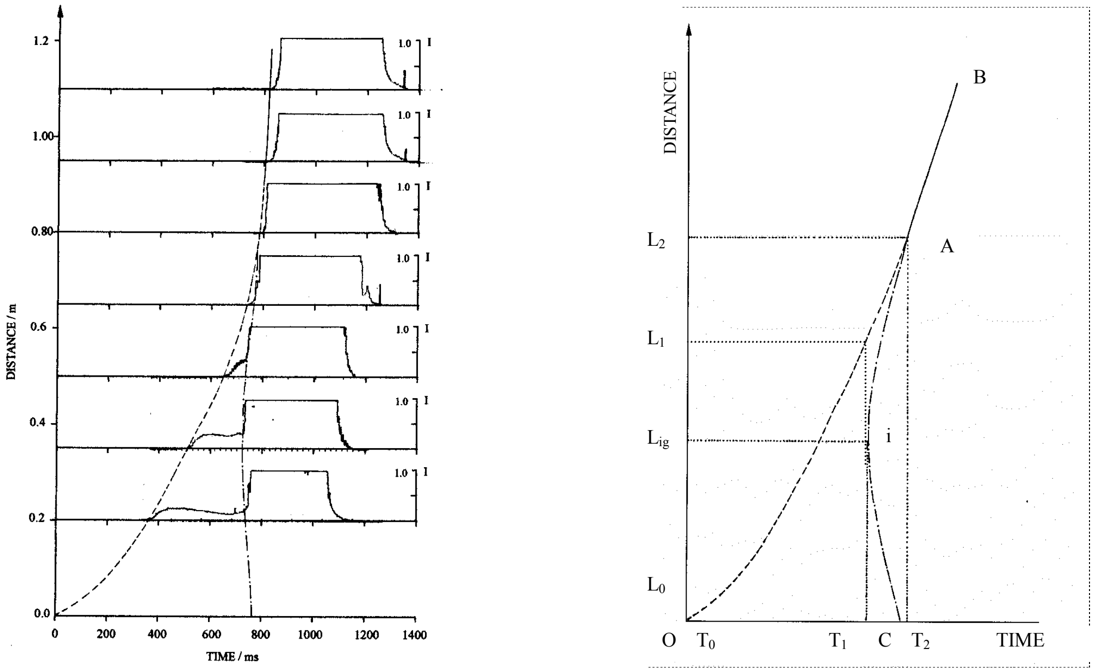
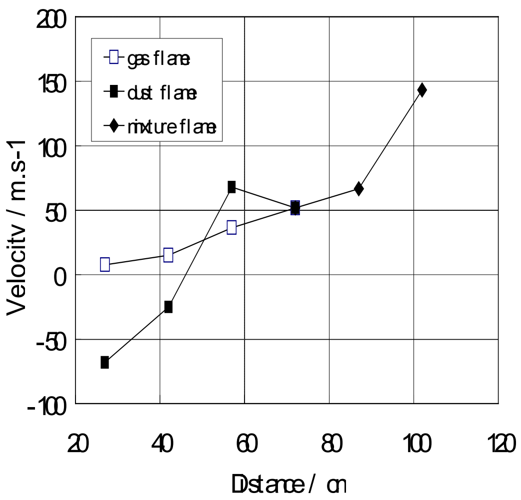


Fig.3 The trajectory of complicated gas-deposited dust flame

Figure 4 reveals the feature of flame of 7.9%methane-air mixture with coal dusts from the close end to the open end of the tube. Because of the appearance of the backward dust flame, the dust flame velocity presents negative which is corresponding to the point *i* to *C* in Fig. 3. Flame from open end to close end of the tube also shows same characteristics of negative dust flame velocity, which is shown in Fig.5. The velocity of the complex flame along the tube presents a bird like pattern obviously according to the Fig.4 and Fig.5.

The formation of the complex gas flame with dust deposits can be attributed to the entrainment and combustion of deposited dusts disturbed by gas flame-induced flow. As flame propagates along the tube, the expansion of the burnt gas products may cause gas flow in the tube so that a shear layer will produce on the surface of the dust deposit. Many investigators[5,7] have testified that a fast shear flow can cause an instability on the interface between gas and dust deposit so that the deposited dusts are entrained into gas flow. Others[7] convinced that the shear lifting force will generate in the shear layer due to the velocity gradient in the normal direction of the interface. This force will act on the dusts on the top of the deposit. If flow speed is fast enough, the shear lifting force can raise the surface dusts into gas flow. No matter whether dusts are entrained into gas flow due to the interface instability or the shear lifting force, the raising particles will be heated and then ignited by gas flame and burn continuously until wipeout. Because the induced time should be needed for the surface dusts being entrained into gas and ignited by the gas flame, the dust ignition location is depart from where gas was ignited and the dust flame will propagate back to there. So the transient three-front flame including a backward dust flame appears.



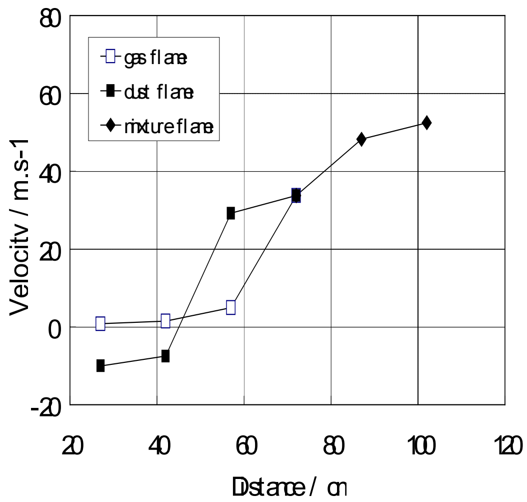


Fig.3 Flame velocity from close to open end   Fig.4 Flame velocity from open to close end

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