Experimental Study on Influence of Open/closed-end Conduit on Flame Intensity

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Abstract

The flame propagation velocity and the flame temperature was proposed to represent the flame intensity. The influence of open/closed-end conduit on flame intensity in different work conditions were studied, such as lubricate, sticking heat-insulated materials in ignite side, etc. The experimental conduit is rectangular in cross section, measuring 80mm×80mm in width. The research result shows that when the gas explosion, the influence of open/closed-end conduit on flame intensity in gas explosion initial stage is relatively little. After that, the flame acceleration degree, the acceleration range, the flame propagation velocity maximum, in open-end conduit is greater than that in closed-end conduit, but the flame temperature at the back part in open-end conduit is obviously less than that in closed-end conduit. The reason is that the reflected waves suppress the flame propagation, and produce the oscillation burning, increase the burning rate.

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Keywords: gas explosion; terminal side of conduit; flame intensity; flame temperature; reflected wave

1. Introduction

Gas explosion in coalmine is one of the most harmful catastrophes as well as a very complicated theoretical and experimental research subject. How to prevent the gas explosion in coalmine is of significance to safe production. In recent years, with the increase of mining depth and intensity and gas eruption, severe gas explosion accidents took place frequently. Such as December 8, 2010, there was one of the most harmful gas explosion accidents has occurred in Sanmenxia, Henan province, 26 people were killed; on March 28, 2011, there was one of the most harmful gas explosion accidents has occurred in
Baishan, Jilin province, 13 people were killed. These accidents bring tremendous influence to society. A well work environment usually is tunnel system with support. According to the statistic of gas explosion accidents, it can be seen that most of accidents occur at drive-working surface in coal mine, and the combustion wave and explosion wave produced by gas explosion develop, transmit and decay along tunnel. The environment of the explosion accident can be regarded as the conduit system with igniting side closed. The influence of open/closed-end conduit on gas explosion flame intensity is studied to benefit the theoretical study of mine gas explosion and its prevention and control.

2. Flame Intensity

The flame propagation velocity (the flame propagation velocity) is the flame velocity relative to the rest frame, depends on the flow disturbance before flame face[1]. Now the research on rules of gas explosion, generally use the flame propagation velocity to represent the flame intensity, and neglect the other parameters, burning rate, which is directly related to the ferocity of mixed gas explosion, this is insufficiency. The burning rate is concerned with reaction material, and it is the characteristic parameter of reaction material. The greater the burning rate, the greater the quantity of heat released by reaction, the flame temperature is high. Because the temperature measurement is more easy than the burning rate measurement, so it can use temperature index instead of burning rate to represent the flame intensity. The flame propagation velocity and temperature are used to represent the flame intensity, this article expect to deep comprehension about the gas explosion rule.

3. Experimental System

The frame diagram of the experimental system for gas explosion is shown in Fig.1. This system is composed of five parts: the gas explosion chamber, dynamic data acquisition and analysis system, flame velocity measuring system, gas explosion pressure measuring system and igniter. The main characteristic and function of them can be obtained in reference[2].

![Fig.1 Schematic diagram of experimental system for gas explosion](image)

This chamber is rectangular in cross section, measuring 80mm×80mm in width and totally 21m in length. The igniter side of chamber is closed when testing; the influence of open/closed-end conduit on gas explosion transmission rules is studied. As the magnitude of flame propagation velocity in Gas explosion varying, the influence degree of open/closed-end conduit on gas explosion transmission rule may be different. In order to grasp and compare roundly and systematically the influence of open/closed-end conduit on different magnitude of flame propagation, the experiment is divided into two kinds of situations: 1) Terminal side of lubricate conduit is open or closed. 2) Heat-insulated materials being
sticked in ignite side and the terminal side of conduit is open or closed. To fix temperature and flame sensors on typical measuring points, gas mixture with methane volumetric content of 9.5% were filled into experiment chamber. In gas explosion the flame velocity, the temperature in open/closed-end conduit under different experimental conditions is measured.

4. Experimental Results and Analysis

Both sides of the chamber are closed in experiment, pumping vacuum to certain vacuity, gas mixture with methane volumetric content of 9.5% were filled into experiment chamber, then ignite and measure the rule of each parameter, which is the experimental result of conduit with both sides closed. Equally, both sides of the chamber are closed in experiment, pumping vacuum to certain vacuity, gas mixture with methane volumetric content of 9.5% were filled into experiment chamber, then open the terminal side of the conduit, ignite and measure the rule of each parameter, which is the experimental result of chamber with terminal side open.

4.1. Experimental Results in Open/closed-end Lubricate Conduit

The results are the flame propagation velocity and flame temperature on each measuring point in gas explosion in open/closed-end lubricate conduit, which are shown in Table 1 and Table 2 respectively. Each number of experimental point in table 1 and table 2 is the arithmetic mean of numerous experimental data. Fig.2.(a) and Fig. 2.(b) show respectively the influence curve of open/closed-end lubricate conduit on flame propagation acceleration and flame temperature.

### Table 1 Influence of open/closed-end lubricate conduit on flame propagation velocity

<table>
<thead>
<tr>
<th>Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of measuring points(L/D)</td>
<td>10</td>
<td>28</td>
<td>52</td>
<td>70</td>
<td>102</td>
<td>134</td>
<td>165</td>
</tr>
<tr>
<td>The closed-end lubricate conduit/m/s</td>
<td>10.5</td>
<td>23.7</td>
<td>39.3</td>
<td>99.7</td>
<td>92.3</td>
<td>78.8</td>
<td>53.1</td>
</tr>
<tr>
<td>The open-end lubricate conduit/m/s</td>
<td>10.5</td>
<td>23.9</td>
<td>40.0</td>
<td>104.9</td>
<td>127.9</td>
<td>131.1</td>
<td>123.2</td>
</tr>
</tbody>
</table>

### Table 2 Influence of open/closed-end lubricate conduit on flame temperature

<table>
<thead>
<tr>
<th>Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of measuring points(L/D)</td>
<td>29</td>
<td>49</td>
<td>68</td>
<td>99</td>
<td>130</td>
<td>161</td>
<td>228</td>
</tr>
<tr>
<td>The closed-end lubricate conduit/℃</td>
<td>665.3</td>
<td>868.8</td>
<td>742.6</td>
<td>844.3</td>
<td>1047.8</td>
<td>1031.5</td>
<td>985.7</td>
</tr>
<tr>
<td>The open-end lubricate conduit/℃</td>
<td>687.7</td>
<td>856.6</td>
<td>699.9</td>
<td>750.8</td>
<td>828.1</td>
<td>850.5</td>
<td>657.2</td>
</tr>
</tbody>
</table>
From Table 1 and Fig.2.(a), it can be seen that open/closed-end lubricate conduit nearly has no influence on flame acceleration in initial stage, but after that in open-end lubricate conduit, the degree of flame acceleration, the range of flame acceleration increase. In closed-end lubricate conduit, the maximum of flame velocity take place at the 4th measuring point (L/D=70), its value is 99.7 m/s. In open-end lubricate conduit, the maximum of flame velocity take place at the 6th measuring point (L/D=134), its value is 131.1 m/s.

From Table 2 and Fig.2.(b), it can be seen that open/closed-end lubricate conduit nearly has no influence on flame temperature in initial stage, but after that the flame temperature difference at the same measuring point in open/closed-end lubricate conduit increase. The maximum of flame temperature difference take place at the 7th measuring point (L/D=228), its value is 328.5°C.

4.2. Experimental Results of Heat-insulated Materials being Sticked in Ignite Side of Open/closed-end Conduit

The heat-insulated materials are sticked in ignite side, whose depth is 0.8mm and length is 2m, it can effectively reduce the heat dissipated to chamber wall, reduce heat loss and raise flame propagation velocity of gas explosion, chamber terminal separated into two situations: open-end and closed-end. The experimental results are showed in Table 3 and Table 4. Fig.3.(a) is plotted by data of Table 3, Fig.3.(b) are plotted by data of Table 4.
From Table 3, Table 4 and Fig. 3, it can be seen that the influence of open/closed-end conduit on flame acceleration, flame temperature in gas explosion initial stage is little; But after that in open-end heat-insulated conduit, the degree of the flame acceleration, the range of acceleration increase;
and after that at the same measuring point, the temperature in closed-end heat-insulated conduit is much bigger than in open-end heat-insulated conduit.

4.3. Theoretical Analysis

Experiment explosion chamber is both sides closed or semi-closed system, the influences of the reflected waves at the back part on the flame propagation and flame temperature are discussed and analyzed from the following aspects:

1) The reflected waves is in opposite direction to flame propagation, the companion flow, which produced after reflected waves pass through, is in opposite direction to flame propagation, play a leading role to flame propagation, that is to say, the total result in flame propagation is suppressed by reflected waves at the back part[3]. While in open-end conduit, without influence of reflected waves at the back part, the propagation velocity of flame, range of acceleration increase, the rate of releasing heat in explosion raise, the expansion to do work power of high temperature combustion product increase.

2) As the reflected waves meets the flame face, the companion flow velocity that produced by reflected waves at the back part suppresses the flame burning speed, but also increases the flame turbulence, oscillation burning is taken place, and then flame burning much more fully, so the flame temperature at the back part in closed-end conduit is bigger.

The experiment shows that the measured flame temperature curve at the back part in closed-end conduit has multiple peaks, shown in Fig.4. This proves that the oscillation burning is exist and the above analysis of flame temperature is correct.

Fig.4 Actual measuring curves of flame temperature in closed-end lubricate conduit
5. Conclusions

The conclusions can be drawn through above research:

- The acceleration range, acceleration degree, maximum of flame propagation in open-end conduit is greater than those in closed-end conduit.
- The flame temperature at the back part in closed-end conduit is greater than that in open-end conduit.
- The reflected waves is in opposite direction to flame propagation, the companion flow, which produced after reflected shock wave pass through, is in opposite direction to flame propagation, it suppresses the flame propagation and oscillation burning is taken place.

References