The research of press drop of compressed air foam flow through the bend

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Abstract. Compressed air foam system (CAFS) had obvious advantages in engineering. The flow model of compressed air foam in the pipeline was different from water flow model because the foam was the gas-liquid two phase flow with non-Newtonian fluid properties and compressibility, and, the water supply theory was not suitable for foam press pipeline transport. At present, there was little research on non-Newtonian fluid flow, especially the foam flow. This study researched the effect of foam flux, end valve and foam type on the press in the straight pipe and bend. The press drop in straight pipes and bends filled with compressed air foam was analyzed, and the result could provide experimental support for theoretical calculation of compressed air foam in bend.

1. Introduction

Compressed air foam system (CAFS) had obvious advantages in engineering. Compressed air foam had advantages of exquisite structure, uniform size and high stability compared with the traditional foam extinguishing system [1]. Compressed air foam could stay and accumulate on the surface of protected objects for a long time, so it could obviously increase the performance of fire extinguishing system [2].

In the fixed compressed air foam system, the foam concentrate was mixed with water in certain proportion to form the foam solution, which was mixed with gas of a fixed pressure. The mixture was adequately mixed and foamed, then delivered to the foam casting parts [3]. Therefore, the compressed air foam in pipeline was fully foamed except for the initial stage of the gas-liquid mixing, which was quite different from the low expansion foam extinguishing system. Moreover, the technology had obvious advantages in engineering. However, the flow model of compressed air foam in the pipeline was different from water, as the foam was gas-liquid two phase flow with non-Newtonian fluid properties and compressibility. The water supply theory was not suitable for the foam press pipeline transport [4,5].

At present both in China and abroad, there was little research on non-Newtonian fluid flow in pipes, especially in the bends. In addition, most research focused on the numerical calculation and theoretical analysis rather than experimental study [6]. This study researched that the effect of foam flow rate, terminal valve state and foam type on the pressure in the straight pipes and bends. The pressure drop of compressed air foam in straight pipes and bends was analyzed, and the result could provide experimental support for theoretical calculation of compressed air foam in pipes.

2. Experimental

2.1. Materials
Aqueous film forming foams extinguishing agent (3%AFFF and 1% Class A foam) were generated.

2.2. Experimental setup and procedure
The fixed compressed air foam system was manufactured independently in Tianjin Fire Research Institute and used in this study, as shown in figure 1. The system was mainly composed of a centrifugal pump, a screw air compressor, a foam proportioner, a foam generator and related measurement equipments. The turbine flowmeter, electromagnetic flowmeter and vortex flowmeter was used to measure the foam solution flow, the foam concentrate flow and the air flow respectively. The standard pressure gauge and pressure sensor were used to measure the pressure.

Figure 1. Fixed compressed air foam system.

The gas flow rate, the water flow rate and the foam concentrate mixing ratio of the CAFS were adjustable in order to meet the test requirements under different conditions, such as different supply intensity, mixing ratio, bubble condition, etc. Direct injection proportioner (Foampro 2002) was used for foam proportional mixing. The ratio of the mixture could be adjusted from 0.1% to 6%. The air flow was adjusted by the pressure regulator valve.

The data acquisition unit (DAQ9133) which could measure signals of thermocouple, thermal resistance, thermistor, direct voltage and direct current was used in this study. Four temperature measurement module NI 9213, two current measurement modules 9208 + 20 ma and two N voltage measurement module I 9205 + 10 v were configured in the data acquisition unit. The unit could achieve 64 channel temperature signal, 32 channel current and 64 channel voltage measurements and acquisition. The data acquisition unit was shown in Figure 2.

Figure 2. Data acquisition unit.

The bend pipe of compressed air foam pressure drop test was fixed up as shown in Figure 3. The pressure data of measurement point was real-time acquired by pressure sensors and NI data acquisition system.

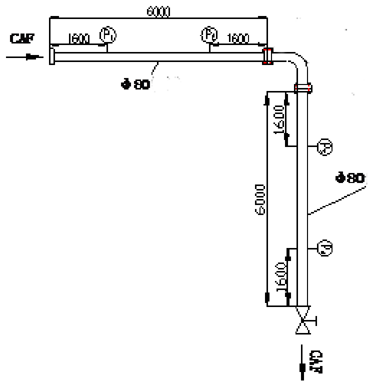

Figure 3. Schematic of the pipe arrangement.

Pressure data were chosen after the foam condition as well as the system parameters was stable. The pressure drop was calculated as shown in equation (1) - (3).

Pressure drop of unit bend:

$$\Delta P_2 = P_2 - P_3 - \frac{1.6\left(P_1 - P_2\right)}{2.8} - \frac{1.6\left(P_3 - P_4\right)}{2.8} \tag{1}$$

Pressure drop of unit straight pipe:

$$\Delta P_1 = \frac{P_1 - P_2}{2.8} \tag{2}$$

$$\Delta P_3 = \frac{P_3 - P_4}{2.8} \tag{3}$$

3. Result and discussion

3.1. Effect of foam flow rate on pressure drop

The pipeline pressure was influenced directly by the foam flux. In this study, 1% Class A foam was chose to study the effect of foam flow rate on pressure drop of the straight pipe and bend at the vapor-liquid ratio of 10/1, and the result was shown in Figure 4.

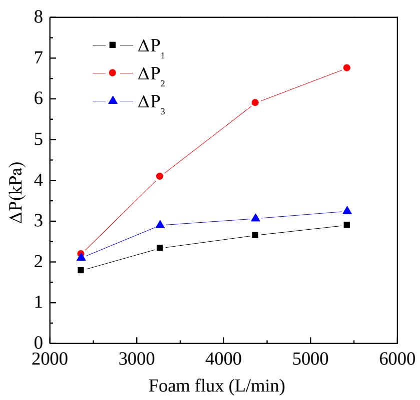

Figure 4. Effect of foam flow rate on pressure drop.

As shown in Figure 4, the pressure drop of the straight pipes and the bends were increased with the increase of foam flux, and the pressure drop of the bends was nearly three times of the straight pipes.

3.2. *End valve operation*

When the end valve was opened to 30°, 1% Class A foam was chose to study the effect of foam flow rate on pressure drop of the straight pipe and bend at the gas-liquid ratio of 10/1, and the result was shown in Figure 5. The comparison result of pressure drop in bend when the end valve was opened fully and to 30° was shown in Figure 6.

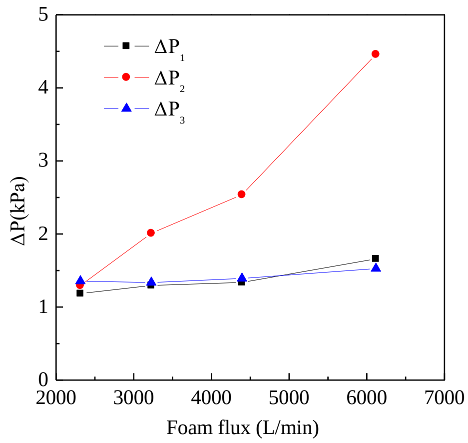

Figure 5. The pressure drop of straight pipes and bend.

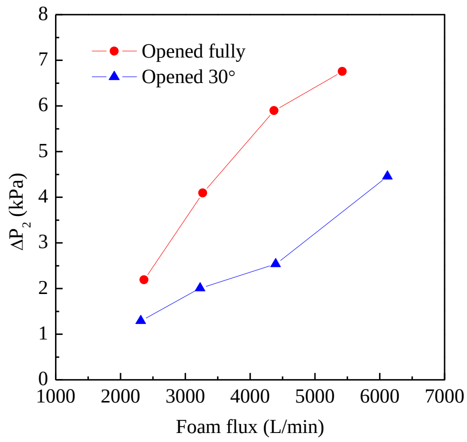

Figure 6. The pressure drop in bend.

As shown in Figure 5, the pressure drops of the straight pipes and the bends were increased with the increase of foam flow when the end valve was opened to 30°, and the pressure drop of the bend was higher than straight pipes. As shown in Figure 6, the pressure drop of the bend was lower when the end valve was opened to 30°than opened fully.

3.3. *Different type of foam extinguishing agent*

Different types of foam have different physical properties, such as viscosity, density, etc. The viscosity is one of the main influence factors of pressure drop. 1% class A foam and 3% AFFF was chosen in order to study the pressure drop of different type of compressed air foam in straight pipes an bends. The gas-liquid ratio was 10/1, and the results were shown in Figure 7.

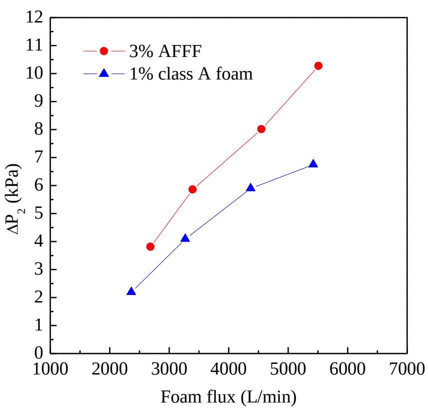

Figure 7. The pressure drop of different type foam in bends.

As shown in Figure 7, the pressure drop of 1% class A foam was smaller than 3% AFFF in bend.

4. Conclusion
This study researched that the effect of foam flow rate, end valve and foam type on the press in the straight pipe and bend. The pressure drops of straight pipes and bend were increased with the in-crease of foam flow, and the pressure drop of the bend was bigger than straight pipes. The pressure drop of the bend was smaller when the end valve was opened 30°than opened fully. The pressure drop of 1% class A foam was smaller than 3% AFFF in bend. The press drop in straight pipe and bend of compressed air foam was analyzed, and the result could provide experimental support for theoretical calculation of compressed air foam in pipe.

Acknowledgements
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