A Diagnosis and Localization Method of Slime Pipe Blockage which Pressure Wave based on Wavelet Transform

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***Abstract*—Aiming at the problem of blocked pipe in coal slurry pipeline transportation process, in the two phase of the project of 50MW unit in Shanxi Huangling coal gangue power generation company, the method of pressure wave slime pipeline blockage location is proposed based on *wavelet transform, which is the analysis of the pipeline* positioning principle based on the pressure wave method, the pressure wave is collected by the pressure sensor installed on the pipeline. Next, the abrupt change of the pressure signal is detected by the wavelet transform, which is integrated into the pressure wave method; Thus the pressure wave velocity and time difference are determined to realize the accurate location of the blockage point. The experimental platform of coal slurry pipeline transportation is built according to the proportion of 100:1, the simulation and experimental results show that the algorithm can be used for the location of the blockage fault in the viscous conveying pipeline system.**

Keywords-component slurry pipeline; Wavelet transform; Pressure wave method; Blockage fault location

I. INTRODUCTION

Slime is a by-product of coal washing industry; it is a kind of solid liquid two-phase flow which is separated from coal washing process, which accounts for 5-8%. The coal slurry pipeline transportation system is an important part in the process of boiler coal combustion, but the unstable quality of the coal slurry can lead to the blockage in the process of transportation. The blockage of the fault, the normal delivery of coal slurry, the safety and normal operation of the system will be a large extent, there are serious security risks. Therefore, it is very important to detect and diagnose the blockage fault of coal slurry pipeline.

There are many experts abroad to study the problem of viscous material conveying pipeline blockage, China University of Mining and Technology, many experts studied the coal slurry in the pipeline transportation, in 2009,Wu Miao, Pan Yue et al.[1] Put forward a method to calculate friction coefficient of high viscous materials in pipeline transportation through comparing the pressure at the different point on the same pipeline; in 2010, Feng Li, Liu Jiongtian et al[2] analyzed on Influencing Factors of Sedimentation Characteristics of Coal Slime Water; in 2016, Gao Jie, Hao Xuedi et al.[3] studied that the influencing factors of coal slime pressure loss in pipe flow at high pressure were investigated at a designed test facility. The experimental results show that pressure loss is directly proportional to flow rate, but inversely proportional to pipe diameter. It is also found that the pressure loss has a complex exponential relationship.

Secondly, experts at home and abroad have studied the problem of drainage pipeline or oil transportation, In 2012, Lee Jong-Hwi, Chu Ick-Chan et al.[4] discovered new technologies for preventing drainage pipe blockage in tunnel. there were so many methods to preventing drainage blockage, but the Quantum stick method and magnetic method are considered in this study. M. R. Khanarmuei, HRahimzadeh et al. in Indian [5] researched the effect of vortex formation on sediment transport at dual pipe intakes, experiments were performed on dual pipe intakes at three common intake withdrawal direction (vertical, horizontal and angle of 45°). Rushd, S. Sanders, S. A. in Canada [6] studied the parameter of the hydrodynamic roughness produced by a wall-coating layer of oil during the pipeline transportation of heavy oil-water mixtures. Ulanov, A.M. Bezborodov, S.A. in Russia[7] discovered the calculation method of pipeline vibration with damping supports made of the MR material. Lecreps, I. Orozovic, O. et al in

Australia[8] studied that physical mechanisms involved in slug transport and pipe blockage during horizontal pneumatic conveying. Other, in coal gangue power generation, many experts researched on blockage prediction of coal slurry transportation pipeline[9-11]. Also experts studied parameter characteristics and testing of piping material[12][13].

II. ANALYSIS OF PRESSRUE WAVE IN VISCUS MATERIAL CONVEYING PIPELI

When the viscous material conveying pipeline is blocked, the corresponding pressure change diagram is analyzed and shown in Fig .1. Pressure sensors are equipped in the two points of the O and A points of the slime conveying pipeline, the pressure distribution curve of the normal operation of the pipeline is shown in Fig. 1, then the pressure difference between the two ends of the OA is $vp1$. If the pipe is blocked, the pressure will increase before the block agep point and the pressure will drop after the blockage point, the pressure gradient of this process can be shown in curve 2.When the pipe blockage is relatively serious, the pressure gradient curve pipe as shown in curve 3. Here when the pipeline is blocked, the upstream pressure increases and the downstream pressure decreases, so that the pressure difference between upstream and downstream can be changed to $vp2$. Assuming the Po upstream sensor is installed at the O point, the downstream sensor is installed at the A point, so the pressure of the O point can be expressed as PO, the pressure of the A point is PA. the pressure at the point of O is expressed as po1 ,the pressure of the A point is PA1 when the fault occurs. the change relation of the points before and after the blockage can be expressed as follows formula (1):

$$\begin{cases} vP_1 = p_O - p_A \\ vP_2 = p_{O1} - p_{A1} \end{cases} \tag{1}$$

The variation of the pressure before and after the blockage can be obtained by the following formula (2):

$$vp_1 - vp_2 = E \tag{2}$$

If the E>T shows that the pipeline is blocked, the T is the threshold value of the detection, the general pipeline to the normal operation of the maximum pressure error.

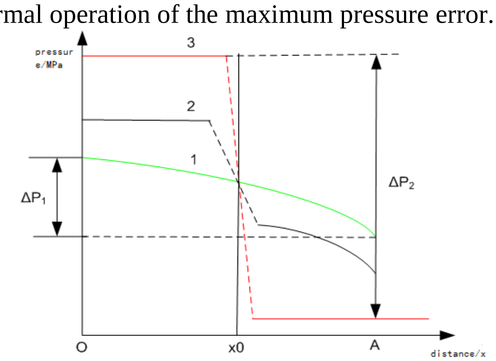


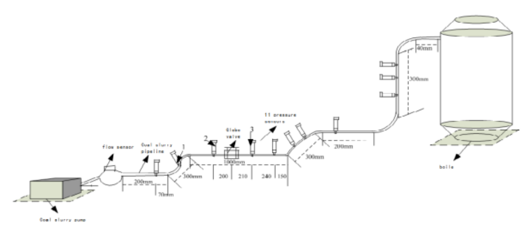
Figure 1. Schematic diagram of pressure variation in pipeline blockage

In summary, according to the variation of the pressure difference between the two ends of the pipeline before and after the pipeline blockage, the change of the difference E can be determined to detect whether the pipeline is blocked or not. According to the pressure change of the coal slurry pipeline, the pressure difference between the sensors is calculated with the measured pressure signals of each sensor, and then the blockage fault detection is realized.

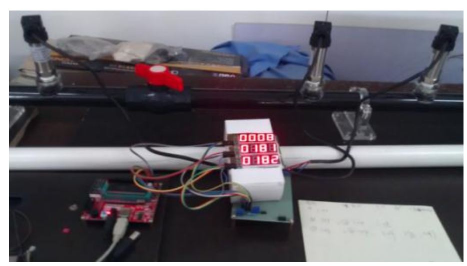
III. PRESSURE WAVE DECOMPOSING BASED ON WAVELET TRANSFORMING AND ITS PARAMETER DETERMINATION

A.Determination of Time Difference of Pressure Wave Based on Wavelet Analysis

The boiler for the two phase of the project of 50MW unit in Shaanxi Huangling coal gangue power Generation Company. According to the proportion of 100:1, we built an experimental platform for coal slurry pipeline transport as shown in Fig .2.



(a) experimental platform structure of coal slurry pipeline transportation



(b) part of the experimental platform for spherical valves between sensors 2 and 3

Figure 2. Experimental platform of coal slurry pipeline transportation

In the picture, in the case of the coal slurry pump open, The degree of slime blockage is simulated by the degree of the switch of the ball valve in the middle ofthe sensor 2 and the sensor 3 .When the coal slurry pipeline is blocked, the pressure value near the blockage point also changes.similar to the first singular point of the continuous signal, the pressure drop caused by the signal mutation caused, with the blockage is close to the vertical, the waveform of pressure drop signal can be collected by the pressure sensor installed on the pipeline, The wavelet transform can be used to obtain the abrupt change of pressure signal, Therefore the time difference of the pressure wave can be determined by detecting the pressure signal, that collected by the upstream sensor, and the abrupt change of the pressure signal collected by the downstream sensor, the pressure signal collected by the upstream and downstream sensors is shown in Fig .2, and the wavelet transform is used to denoise the signal [14], the abrupt point of the signal can be detected as shown in Fig .3 and Fig .4. Wavelet transform to determine the time difference of the pressure wave signal can be divided into the following steps:

a) The pressure signals collected rely on the upstream and downstream sensors are decomposed by wavelet:

b) According to the different scale, the decomposed signal is reconstructed.

c) The reconstructed signals are compared and the maximum modulus points which the two groups are detected;

d)According to the maximum value of the model, the abrupt change point of the signal is determined, the two groups of signals is calculated and the time difference of pressure wave signal propagation can be obtained.

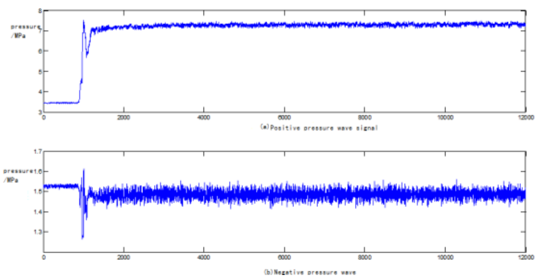
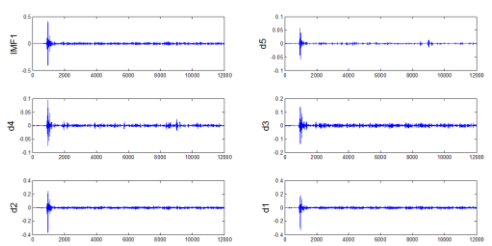
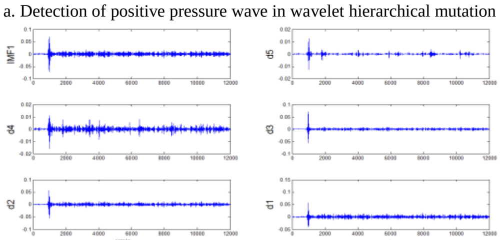


Figure 3. Positive pressure wave signal and negative pressure wave signal before and after the blockage



a. Detection of positive pressure wave in wavelet hierarchical mutation



b. Detection of the negative pressure wave in wavelet hierarchical mutation

Figure 4. a, b

B. Determination of Pressure Wave Velocity

Pressure wave velocity formula (3) as shown in:

$$v = \sqrt{\frac{K/\rho}{1+\frac{K}{E}\frac{D}{e}C_1}} \qquad (3)$$

Here,

K—Volume elasticity coefficient of fluid, Pa;

ρ—Density of fluid, kg/m3;

E—Elastic modulus of pipe, Pa;

D—Pipe diameter, m;

e—Tube wall thickness, m;

C_1—The correction factor related to the pipe constraint;

E, D, e, C_1 can be measured directly or obtained from empirical data. Both K and ρ are functions of temperature for fixed pipes[15].

Bulk elastic coefficient of coal slurry K: it indicates the change of the volume caused by the external pressure,its value is generally the reciprocal of the compression coefficient. Compressibility is the rate of change of the volume of the fluid when the fluid temperature is constanted.The formula is shown in formula (4).

$$\ln(F\times10^{10}) = 0.51992+0.0023662T+846596/\rho_0^2+2366.67T/\rho_0^2 \qquad (4)$$

Here,

F—Compressibility factor, 1/Pa

ρ_0— Standard density, kg/m3.

T—Fluid temperature, $°C$;

Bulk modulus $K=\frac{1}{F}$.

The standard density refers to the material density under the standard conditions. For example, at a temperature of 273K (zero), the pressure at a standard atmospheric pressure of the gas standard density. The temperature in the standard density 20 ℃, the pressure in a standard under the pressure of liquid. For example, the density of water at different temperatures can be obtained by inquiring the general rules for the determination of density and relative density of chemical products, People's Republic of China national standard GB/T4472-2011.See Table I. The water in the 0-30 ℃ degrees, the maximum density value is 999.972 kg/m3, the minimum value is 992.591 kg/m3 and the maximum change is kg/m3, which it can be seen from the Table I, and it can be ignored in formula (4) calculation, its bulk elastic coefficient K=0.3787×1010.

Coal slurry pipeline is DN200 carbon steel pipe material, Therefore, the pipe diameter D=219mm, the pipe wall thickness of E =10mm, the pipe elastic modulus E=206×109Pa。

TABLE I. DENSITY AT DIFFERENT TEMPERATURE

t	0	1	2	...	8	9

0	999.84	999.89	999.96	999.84	999.78
10	999.69	999.60	999.37	998.59	998.40
20	998.20	997.99	997.53	996.23	995.94
30	995.64	995.34	995.02	992.96	992.59
40	992.12	991.83	991.43	988.92	988.49

Pipeline constraint coefficient C1 can be classified according to the different support conditions. If both ends of the pipe are fixed, there is no axial movement, that $C_1 = 1 - \mu^2$, μ is the Poisson coefficient among them. The carbon steel material is used in the slime conveying pipeline,For carbon steel, $\mu = 0.26$. therefore $C_1 = 0.9324$

Substitution of F to formula (3), it can be obtained velocity formula (5) when the coal slurry in the water content of 30% wave .

$$v = \sqrt{\frac{K/\rho}{1 + \frac{K}{E} \cdot \frac{D}{e} \cdot C_1}} = \sqrt{\frac{0.3787\times10^{10}/1450}{1 + \frac{0.3787\times10^{10}\times0.219}{206\times10^9\times0.01}\times0.9324}} = 1.3781\times10^3 m/s \tag{5}$$

IV. STUDY ON THE METHOD OF PRESSURE WAVE BLOCKAGE LOCATION BASED ON WAVELET TRANSFORM

A. The Process of Pressure Wave Blockage Location Method Based on Wavelet Transform

Its can be finded that the wavelet transform can detect the abrupt change point of the signal from the above analysis, Therefore, when the coal slurry pipeline is blocked, the pressure wave can be detected at the upstream and downstream pressure transmitter, the time difference Δt is obtained between the pressure wave and the two pressure transmitters. And through the formula (6) to locate the position, the formula (6) is as follows.

$$L_i = \frac{L \pm v\Delta t}{2} \tag{6}$$

In the formula, L represents the total length the conveying pipe; L_i indicates the blockage of the pipeline;'±' means the detection of positive pressure wave, the wavelet transform of the hierarchical point takes the '+', In the detection of the negative pressure wave, the wavelet layered mutation point takes the '-'; On the basis of the above analysis, The flow chart of the pressure wave blockage localization method based on wavelet transform is gived in this paper , as shown in Fig .5.

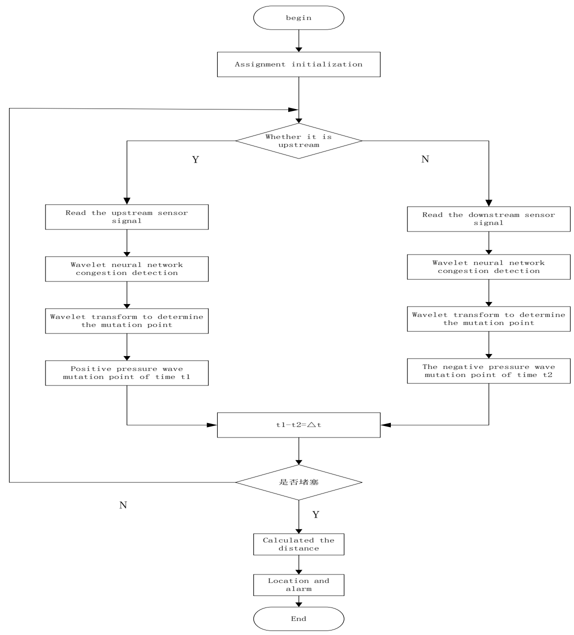


Figure 5. Blockage location flow of coal slurry transportation pipeline

B. Experimental Verification of Pressure Wave Blockage Location Based on Wavelet Transform

In the experiment, the length of the coal slurry pipeline L is 267m , the sensor installed upstream of the pipeline is called the upstream sensor, and the sensor installed downstream of the pipeline is called the downstream sensor, a ball valve is installed at a distance of 163.8 m from the upstream sensor to simulate the blockage of the pipeline, the wavelet transform can be used to obtain the position of the pressure signal when the pipeline is blocked from the point of view, that comes from the detection of the positive and negative pressure wave in Fig .3 and Fig .4, it is known that the abrupt change of barotropic wave occurs at 976th time points, and the negative pressure wave occurs at 968th time points, the difference of time between positive and negative pressure wave is 8, the sampling frequency of the system is 200Hz/s, so the time difference can be obtained as shown in formula (7)

$$\Delta t = t_1 - t_2 = \frac{976}{200} - \frac{968}{200} = 0.04s \tag{7}$$

Substitutio of the formula (6), the position of the blocking point of the positive pressure detection point can be obtained as a formula (8). The position of the blocking point of the negative pressure detection point is a formula (9)

$$L_1 = \frac{L + V\times\Delta t}{2} = \frac{267 + 1378.1\times0.04}{2} = 161.06\text{m} \tag{8}$$

$$L_2 = \frac{L - V\times\Delta t}{2} = \frac{167 - 1378.1\times0.04}{2} = 105.9\text{m} \tag{9}$$

The positioning error is as follows:

$$e_{x1} = \frac{163.8 - 161.06}{163.8} = 1.67\% \tag{10}$$

$$e_{x2} = \frac{108.1 - 105.9}{108.1} = 2.03\% \tag{11}$$

It is found that the location of the blockage of the pipeline can be determined by experiment, test, calculation and analysis.

V. CONCLUSION

Aimed at the difficult problem of the blocking location for viscous material pipeline transportation, a method of pipeline transportation jam location is discussed in this paper. Main research work is as follows:

a. Through the analysis of the pressure wave in the viscous pipeline, the mathematical model of the pressure change corresponding to the pipe blockage is established;

b. the method of pressure wave slime pipeline blockage location is proposed based on wavelet transform. Two factors that affect the positioning results are analyzed: the propagation velocity of pressure wave in the pipeline and the time of the pressure wave; then the velocity and time difference of pressure wave are determined, and the location of the blockage point is determined accurately.

c. On the basis of boiler of coal slurry pipeline of 50MW unit in Shanxi Huangling coal gangue power Generation Company’s delivery system, the experimental platform is built according to the proportion of 100:1, simulation and experimental verification are finished. Results show that the blockage location error is less than 2.03%.

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