Research of flow velocity measurement system based on polarity correlation algorithm

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Abstract

This paper summarizes the basic principle of correlation method in the flow velocity measurement, and then advances an improved algorithm of polarity correlation method. Since then has carried on the algorithm analysis of polarity correlation method and circuit implementation. Based on the Monte Carlo method of the simulation experiments show that the polarity correlation algorithm can replace the common correlation algorithms on the peak point determination, and due to the particularity of its algorithm, it has good anti-interference function. The comparison of experimental measurement speed and speed setting by the Monte Carlo method shows that if the two sampling sensor spacing meet certain conditions, the measurement speed and its fitted curve could have a better Goodness of Fit, and the measurement speed can accurately response the speed setting by the Monte Carlo method. According to the experiment it can validate the feasibility of the algorithm, which could have an accurately measurement on flow velocity.

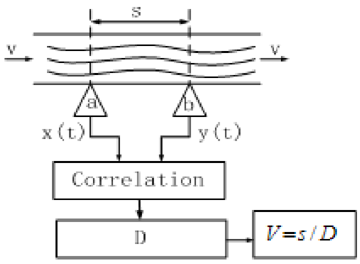
Keywords: flow velocity measurement; polarity correlation algorithm; the peak point; the correlation function

Introduction

Flow velocity measurement based on acoustic Doppler, pitot tube, and heat dissipation are commonly used for conventional fluid. While the mine water have a lot of sediment, and containing a large amount of gas sometimes, but also for a small number of special mines, it’s easy to form acidic water. These special conditions are very difficult for flow velocity measurement with a conventional tachometer. For these fluids difficult to measure velocity which at present the measurement based on correlation algorithm are the best choice.

Basic principle

As shown in figure 1, there are two sensors of the same type which we called a and b in a distance of s. When the fluid flows, the sensor converted flow noise to electrical signals. After the conversion the electrical signals and the flow noise presented a certain relationship. x(t) and y(t) are the output signals by the two sensors of a and b respectively, in the case of distance s is fairly small, the waveforms of x(t) and y(t) are basically identical, but have a time interval for D of time delay.[1] The time fluid flow from a sampling sensor to b sampling sensor can be react by the value of D, as shown in figure 2.



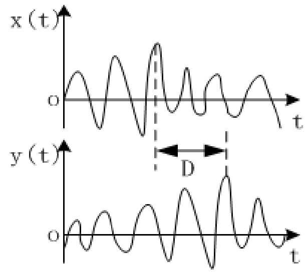


Fig 1 Principle of flow velocity measurement based on polarity correlation algorithm

Fig 2 Two signal's delay time

Polarity correlation algorithm

In the Flow Velocity Measurement system based on correlation algorithm, we only care about the delay of D about their correlation function, and neglect the information of amplitude about the correlation function. So on the basis of the cross-correlation algorithm, we can have the two signals digital quantified, and neglect the amplitude value of the two signals, which only take its positive and negative sign for digital calculation. Compared with the cross-correlation algorithm, the polarity correlation algorithm is a simplified algorithm which can accelerate the velocity of operation. The formula is expressed as follows[2]:

$$R_{xy}^{''}(\tau) = \frac{1}{T}\int_0^T \mathrm{sgn}[y(t)]\mathrm{sgn}[x(t-\tau)]dt \quad (1)$$

Because sgn(x) and sgn(y) only can take the value of +1 or -1, according to the truth table of correspondence between the two, we use logical " 0" indicates -1, and logical 1 indicates +1, the circuit of polarity correlation algorithm can be achieved in Figure 3[3].

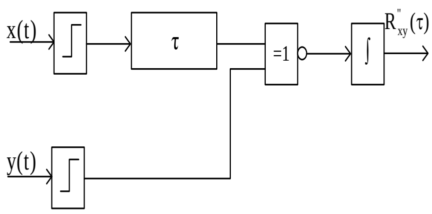


Fig 3 Implement circuit of polarity correlation algorithm

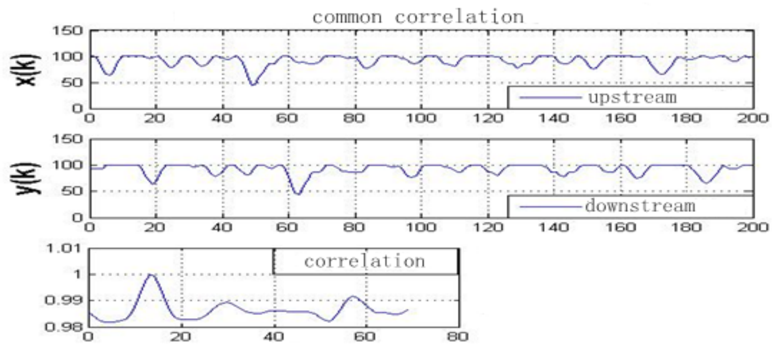
Simulation and analysis

This experiment is used the Monte Carlo method to build simulation platform. The measurement environment is set with gas/liquid two-phase flow because it is simple and common relatively, the work environment is a round pipe with radius of 30 mm and length of 260 mm, the sensor distance s and setting velocity v are variables, Vis the related velocity measured by the algorithms. Two sensors sample points each for 200, including 130 points for use and the remaining 70 for the delay. Flow velocity measurement is proceed in this environment parameters. The waveforms of the two algorithms are shown in Figure 4.

The peak point position experimental simulation are did at different distance s set by 35,75,115 and set the velocity v from 1 to 9. The experimental results is shown in Table 1. As can be seen from Table 1, the peak point determined by the polarity correlation algorithm and that determined by the common correlation algorithm are basically the same, even if they are different at some point, it is only the difference between a sampling time unit, which proved the feasibility of the polarity correlation algorithm instead of ordinary from experimental data. Theoretically if the input signal is a Gaussian distribution, then the relationship between the polarity correlation function and the common correlation function is[4]:

$$R_{xy}^{"}(\tau) = \frac{2}{\pi} * \arcsin \frac{R_{xy}(\tau)}{\sqrt{R_x(0)R_y(0)}}$$

(2)



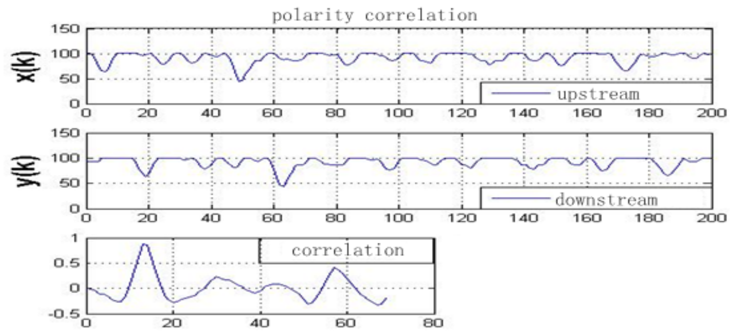


Fig 4 the simulation waveform

Simulation experiments are conducted in the noiseless environment, in which case can we see that the two algorithms to determine the location of the peak is consistent. But when it was conducted in the practical engineering applications, measuring equipment will be in the harsh environments, which outside interference noise is varied, and output of the sensor might be affected. While peak position determination based on common algorithms is largely depend on the amplitude of sampled signal, which will affect its peak point determination, and will impact the accuracy of the measurement. Due to the special nature of the polarity correlation algorithm, it depend less on the amplitude of the actual sampling signal, which is better in anti-interference. Compared to common algorithm, it is more suitable for flow measurement in a noisy environment with a higher accuracy. The above experiments have demonstrated the feasibility of the polarity algorithm replace common algorithm, therefore the following experiment's target is flow velocity measurement based

on the polarity algorithm.

Table 1 Comparison of the peak point based on two algorithms

v	s=35		s=75		s=115	
	peak point(C)	peak point(P)	peak point(C)	peak point(P)	peak point(C)	peak point(P)
1	36	36	70	70	91	91
2	19	18	38	38	59	59
3	13	13	26	26	39	39
4	10	10	20	20	30	30
5	8	8	16	16	24	24
6	7	7	13	13	20	20
7	6	6	12	12	17	18
8	5	5	10	10	15	16
9	4	4	9	9	14	14
similarity	88.89%		100%		77.78%	

s / v	10	30	50	70	90	110	130
1	0.9091	0.9677	0.9804	1.0000	1.3149	1.7460	5.9091
2	1.6667	1.8750	1.9231	1.9444	1.9565	1.9643	1.9697
3	2.5000	2.7273	2.9412	2.9167	2.9032	2.8947	2.9545
4	3.3333	3.3333	3.5714	3.6842	3.7500	3.9286	3.9394
5	3.3333	4.2857	4.5455	4.6667	4.7368	4.7826	4.8148
6	5.0000	5.0000	5.5556	5.8333	5.6250	5.7895	5.9091
7	5.0000	6.0000	6.2500	6.3636	6.4286	6.4706	6.5000
8	5.0000	6.0000	7.1429	7.3562	7.5000	7.3333	7.6471
9	5.0000	7.5000	8.3333	8.3423	8.3818	8.4615	8.6667
linearity	17.58%	2.29%	2.04%	0.17%	0.69%	1.95%	8.32%

Table 2 Experimental data of the velocity based on polarity correlation algorithm

Analyze the error between experimental measurement velocity V and the velocity v set by Monte Carlo method. S is the distance between the two sensors that the value is from 10 to 130, every 20 interval take a value. In the case of v is from 1 to 9, to measure the velocity V. The result is shown in Table 2. As can be seen from Table 2, the spacing s is in the range from 30 to 110, the measured velocity V is closer to the set speed v, which shows a good linearity. In the two values at 10 and 130, the linearity is poor. When s is 10, and v is small, it can still show a good measurement on V, when v is greater than 4, the measurement error increases between V and v. When s is 130, the main reason for its poor linearity is caused by the $v = 1$, and the other measurement velocity is good. The main reasons are due to the error caused by correlation between the y(t) and x(t), when $s = 10$ and the $v > 4$, because of the spacing is small, and v is big, therefore the delay between sampled signal waveform y (t) get by downstream sensor and waveform x (t) get by upstream sensor signal is small or not exist, which resulted in a larger error. When $s = 130$, $v = 1$, because of its greater distance, and the v is relatively slow, so that the correlation degree between the upstream and downstream sensor signals decrease, and that flow velocity measurement based on polarity correlation algorithm can't work. Therefore in practical engineering applications, strict requirements must be made of the two sensor mounting pitch, through a large number of practical applications and the data based on this simulation we can get the sensor spacing formula as following: $s = (1\sim4) R$ (where R is the radius of the measurement pipe). If we do flow velocity measurement on this environment, we can get a accurate result based on the polarity correlation algorithm.

Summary

By use the polarity correlation algorithm to measure the flow velocity, it can ensure the accuracy of the system, and improve computing speed. Due to the characteristics of the polarity correlation algorithm, the linear deviation of its function would not affect the measurement for delay and velocity. But for other applications such linear deviation will result in large errors, which must make the appropriate changes, such as using the polarity correction algorithms, introduced some certain pseudo-random signals, in order to eliminate the linear deviation of the polarity correlation function.

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