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Extremum Median Filter Method Used in Data Analysis of Spray Heat Exchange Temperature Test

Zhi Fengdong[1, a], Xuwen Cheng[1, a *], Yudong Han[3,c], Jituo Tang[4,d], Gong Dan[5,f]

[1,2,3,4,5]School of Mechanical Electronic & Information Engineering, China University of Mining and Technology (Beijing), Beijing, 100083, China

[a]dzf@cumtb.edu.cn, [b]z1033670740@126.com, [c]75101742@qq.com,

[d]947771458@qq.com, [f]83423182@qq.com

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Abstract: Researching the gas's temperature change trend was important for the system design of spray tower in which the liquid and the gas was mixed and the heat was exchanged. In temperature measurement, it must be concerned that the test data contain impulse noise due to the internal complex environment of spray tower. In order to get the real and accurate data and to acquire temperature change characteristics, the thermocouple sensors were used to do multipoint temperature measurement in different experimental conditions. The method of extremum median filter was used to remove impulse noise of signal. The simulation was made with MATLAB. The analysis result shows that the method can remove impulse noise of temperature signal and get accurate temperature data.

Introduction

Coal mine return air heat recycle technology is a kind of technology to extract and re-use of the heat in the return air of coal mine [1]. The mine return air spray heat exchanger is a device of revolving the heat of wind to the droplet by spraying. The efficient operation of the device is important for energy conservation. In order to improve the heat transfer efficiency in heat transfer process, some research had been done, such as [2] Chuntao Du studied the effects of the droplet diameter of the heat transfer efficiency, however, there were no research on accurate measurement and collection of temperature in the heat transfer process. Random impulse noises in the temperature signal have a negligible impact on the accuracy of the data. In order to accurately measure the temperature of the air in the heat exchanger spray, the author used extremum median filter method for removing impulse noise filter to obtain accurate temperature data, which provided a basis for further study heat transfer efficiency [3]. Conventional median filter deals with all signal acquisition in the same way, that is, the data value of the temperature signal values are replaced by the value of its neighbors, and the extreme points of the signal points are treated as the noise and filtered, which results in the noise spreading in the neighborhood, and reduces the filtering effect. This method has limitation in dealing with impulse noise. The extremum median filter takes different functions in removing impulse noise and dealing with useful signal. When the impulse noise is removed, non-noisy data will not be affected, which is beneficial to accurately measure the temperature of the heat exchanger when the spray [4].

Spray heat exchange temperature signal acquisition

Spray heat exchanger temperature signal acquisition bases on the spray heat transfer test system platform. Mine return air enters the spray tower through inlet, upstream, and heat exchanges with water spraying by the spray nozzle atomization rafts. In spray heat test system, spray tower is circular, spray rows are four. Because the spray tower is circular, in accordance with the distribution of mine ventilation velocity approximation theory, the maximum wind speed is the center, the minimum is the edge [5], the section of spray tower can be divided into n equal area concentric rings, the air wind speed at each point of the ring is about the same value. The velocity field of air wind in the spray tower has some effects on the heat exchange efficiency. The temperature characteristic points are chosen by the multi-point thermocouple temperature measurement to show the temperature of the entire section. The air wind speed of center is the largest, where the temperature change is the maximum, as a measuring point. In a cross section, according to the wind speed decreasing from the center to the edge, the cross section is divided into two equal portions by the circle; the temperature on the circle is the average temperature of the cross section. In order to eliminate accidental errors, the average temperature value of the four points is taken as the temperature of the circle to eliminate the errors [7]. The center point and the four points are selected as measuring points, the thermocouple are arranged on rafts spray in accordance with the above method, and then, the temperature test is done when spraying. Since the complicated process of heat exchange, the temperature of water drops is different from the air. Therefore, some measures must be taken to deal with the test errors.

Extremum median filter method

Median filter is a common impulse noise filtering method. This method changes the value of the signal point when it removes impulse noise. To improve the shortage of median filter method, the extremum median filter is proposed. The value of the noise's temperature is replaced with the average value of its neighbors, and the value of the real temperature signal remains unchanged. In one group of data, if the data is equal to an extremum of its neighbors, the point may be noise, and it may be an edge portion of the data. In order to distinguish whether it is the noise point, it needs further judgment. If the difference between the point and the mean of its neighbors is greater than a constant c (the constant c is determined by the test carried out in the specific conditions, the temperature difference between the water and air in the test value is about 10 degrees Celsius, while the same measuring point temperature changes little and thus take the constant c as 6), the point is noise, or it is the signal [8]. Set x_m represents the temperature values of the m-th data sampling point, Q_n represents computation of the data in the neighborhood, the point is the center in the neighborhood(the amount of data within a neighborhood is n=2J+1, wherein n is an odd integer, J is a positive integer), g_{m} represents candidate noise, z_m represents noise points.

(1) The value of the data within the neighborhood are compared to obtain its neighbors minimum, if the data signal is equal to the minimum, it is candidate noise.

$$a = \min(Q_n[x_m])$$
$$g_m = \begin{cases} 1, (x_m = a) \\ 0, (x_m \neq a) \end{cases}. \quad (1)$$

(2) For all candidates noise points meet $g_{\mathrm{m}} = 1$, the rest data of the neighborhood forms a set of t_{m}. Calculate the mean of t_{m}

$$b = \frac{\sum t_m}{L}. \tag{2}$$

(3) For all candidates noise points meet g_m =1, comparing with b, if the difference is greater than the constant *c*, and the point is considered to be the real noise point, otherwise the signal point.

$$z_m = \begin{cases} 1, (|x_m - b| > c) and (g_m = 1) \\ 0, else \end{cases}. \tag{3}$$

(4) After extremum median filter, the value of each point is

$$y_m = \begin{cases} b, if (z_m = 1) \\ x_m, else \end{cases}. \tag{4}$$

According to the principle of extremum median filter, write MATLAB program, the program flow chart is shown in figure 1.

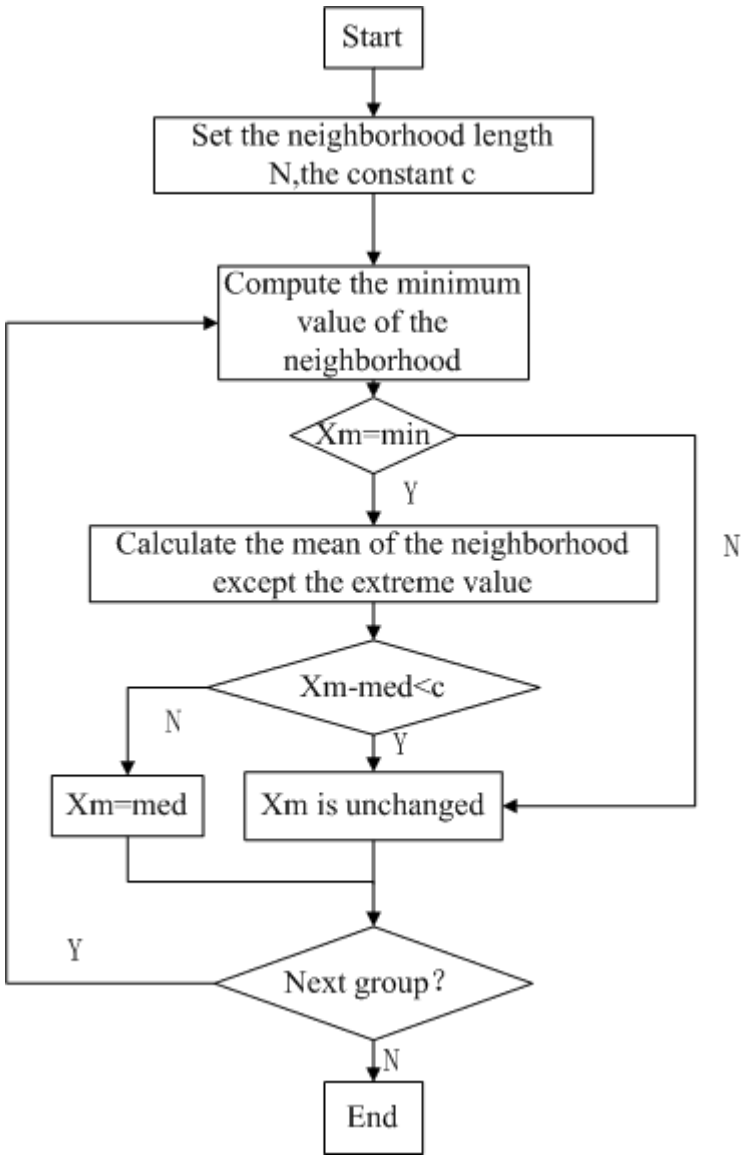
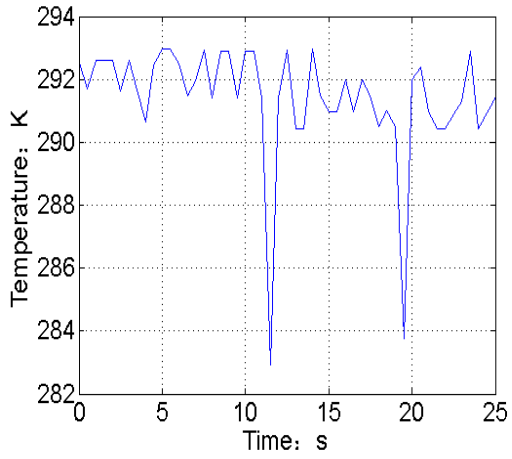


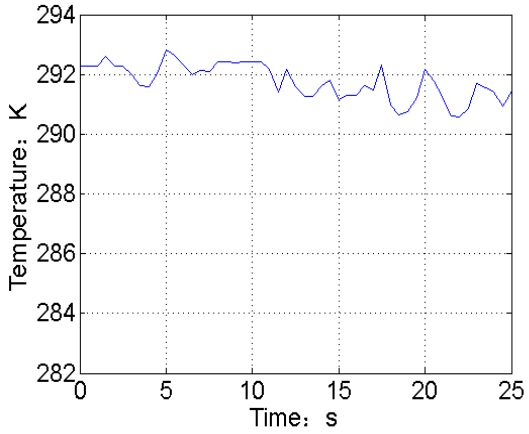
Figure1. Extremum median filter process flow chart

The experimental results and analysis

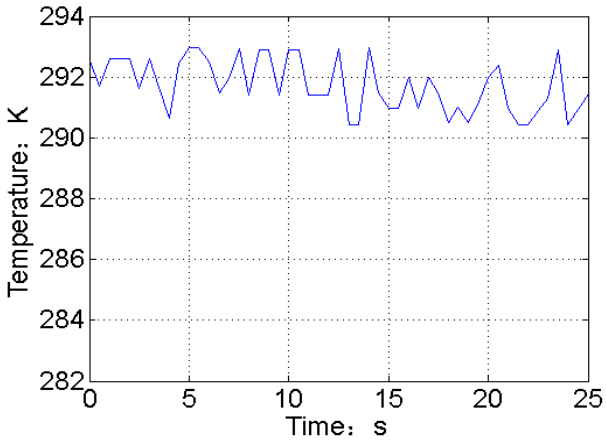
Heat spray test was performed by test platform to get the pre-filtering temperature data measured at the center point of the bottom row of spray tower. The original temperature data curve is shown in Figure 2(a). It can be seen that there are two temperatures significantly lower than the others. When the droplets fall on sensitive portion of the temperature sensor, the measured value of the temperature sensor changes suddenly, and it indicates the presence of impulse noises. Using MATLAB software and conventional median filter to deal with the pre-filtering data, the filter temperature curve is shown Figure 2(b). After the conventional median filter, the temperature data have been removed in the curve. Comparing with Figure 2(a), it can be obtained that the fluctuation of temperature data in Figure 2(b) is small, and it tends to be gentler after filtering because the impulse noise is removed. However, the value of the real temperature signal is also changed, and the details of the whole data are changed too, which results in data inaccurate. According to the principle of extremum median filter, the MATLAB program was developed to filter the pre-filtering data, and the curve after filtering was shown in Figure 2(c). Comparing with Figure 2(a), it can be seen that the impulse noise is completely removed, the temperature value of the noise point is replaced by the average within the neighborhood, and the value of the real temperature signal point remains unchanged. Comparing with Figure2(b), Figure 2(a), extremum median filter method removes impulse noise better and retains the original signal, restores the true temperature curve data.



(a) Before filtering



(b) After conventional median filter



(c) After filtering

Figure2. Graph of temperature changes

Conclusions

(1) The complex environment in spray tower makes it difficult to acquire temperature data of heat exchange process since the droplets fell on the temperature sensing portion, resulting in impulse noise and inaccurate temperature data, seriously, temperature data will have errors.

(2) The uniformly distributed multi-point thermocouple sensors were used for temperature measurement, and the extremum median filter was used to deal with the temperature data.

(3) Simulation and analysis with MATLAB show that the extremum median filter can remove the impulse noise signal and complete retention the signal point.

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