

A New Data Processing Algorithm for the Standard Meter

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Abstract: A new data processing algorithm was proposed against shortcomings in compensating algorithm for data of the standard meter. According to fluid continuity, volume data of flow for the standard meter were normalized so that difference values between calculating volume and standard volume were comparable. Using spline interpolating algorithm flow difference value of arbitrary flow point was obtained. Then this value was changed into corresponding value of present flow point. Approximate data to standard volume was obtained by modifying calculating volume. The algorithm changed three-dimensional interpolating operation into two-dimensional interpolating operation and improved accuracy of interpolating operation and precision of the whole calibrating facility. Results show that the algorithm is of fully operational, easy to implement and effective. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Standard meter, Data processing, Data normalization, Spline interpolation, Dimension.

1. Introduction

The flow meters must be calibrated by the standard calibrating facility before they leave the manufacturing factory, and their meter parameters were reached. There are two types of the calibrating facility including the primitive standard facility and the transfer standard facility. The former is of the highest precision in all of flow meter devices and it is implemented by the standard vessel. The latter is composed of the standard flow meter which has excellent repeatability and stability and is calibrated by the primitive standard facility. An example of the latter is the flow standard facility of standard meter method. Since the calibrating facility of standard vessel need big disposable investment and long construction period, the flow standard facility of standard meter method is utilized by many flow meter manufacturing enterprises [1-3].

The standard meter in the flow standard facility must be calibrated by the standard vessel calibrating facility before it is used in the calibrating facility of standard meter method. Then the standard meter can be used as transfer standard to calibrate the other checked meter [4, 5]. Since there is certain deviation between the standard meter and the standard vessel, calibrating error is inevitable and it degrades accuracy of the calibrating facility [6-7]. In order to narrow error introduced from deviation between the standard meter and the standard vessel, compensating algorithm is adopted to make data of the standard meter close data of the standard vessel. In the other hand, calibrated data of the standard meter is only from some finite flow points, so some interpolating algorithms should be used in practical application. Therefore, data processing of the standard meter is interpolating operation among three parameters including flow rate, deviation value and time interval. The interpolating operation actually belongs to three

dimension interpolation. Effective data is so less that error resulted from interpolation is larger [8-10].

A new data processing algorithm based on flow continuity is proposed in the paper. Data for the standard meter calibrated by the standard vessel calibrating facility is normalized and is of comparability. Thereby three dimension interpolating operation is changed into two dimension interpolating operation and interpolation precision is increased. This algorithm can effectively decrease uncertainty from data of the standard meter and improve calibrating accuracy of the whole calibrating facility.

2. Shortcomings of the Existing Data Compensating Algorithm for the Standard Meter

When the standard meter is calibrated by the standard vessel, only some finite flow points can be calibrated. Fig. 1 show that an example that three axes are respectively time, flow rate and flow difference value.

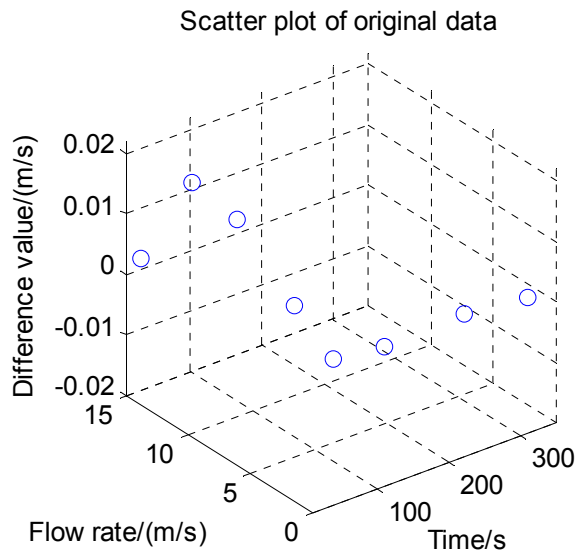


Fig. 1. Calibrated data of a certain standard meter.

Calibrated data are some discrete points in three dimension space. In practical application interpolating operation which belongs to three dimension interpolating operation must be implemented. In the condition of too little effective data, accuracy of interpolating result is not enough. The existing method is that calculating volume and standard volume are changed into flow through divided by time interval, and flow difference value is reached. Then interpolating operation is implemented to flow and flow difference value [11, 12]. By means of interpolating result, flow difference value of the current flow point is obtained. After the last value is

multiplied by time interval, volume difference value of the current flow point is calculated and calculating volume can be modified by volume difference value. Typical estimation algorithms include interpolating algorithm and curve-fitting algorithm [13]. The former is comprised by linear interpolation and three spline interpolation. The latter is usually implemented by least-square polynomial curve-fitting algorithm.

After interpolating operation is implemented, flow difference value E_v is multiplied by time interval t and volume difference value ΔV is obtained. According to error theory, total error is given by

$$\varepsilon(E_v \times t) = E_v \varepsilon(t) + t \varepsilon(E_v) \approx t \varepsilon(E_v), \quad (1)$$

where $\varepsilon(E_v \times t)$ is the total error, $\varepsilon(t)$ is the error of time interval, and $\varepsilon(E_v)$ is the error of flow difference value E_v .

Precision of time interval t is up to 10^{-6} and flow difference value E_v is very little so that the first part $E_v \varepsilon(t)$ can be ignored. Time interval t may be very large, such as time interval of the eighth flow point $t = 310.258$ s in Fig. 1. Even though precision of interpolating operation is up to 10^{-4} , combined error may be also very large. The calculating result is

$$\varepsilon(E_v \times t) \approx 310.258 \times 10^{-4} = 0.0310 \quad (2)$$

3. New Data Processing Algorithm for the Standard Meter

Precondition of the new data processing algorithm is that flow of calibrating media keeps constant in time interval at one calibrating point. According to flow continuity, this condition is satisfied when hydraulic pressure remains constant.

Calibrated data for the standard meter is from the primitive standard facility. Relative to the standard vessel, the flow-meter acted as the standard meter is checked meter in the situation. Therefore, the checked meter mentioned in the following data processing algorithm is just the standard meter calibrated by the primitive standard facility. Three sets of original data are obtained in calibrating procedure by the primitive standard facility including standard time interval t , calculating volume V_c which is measured by the checked meter in the standard time interval and standard volume V_s which is measured by the standard vessel in the same time interval.

The algorithm is introduced as follows.

3.1. Normalizing Data

In data of calculating volume obtained by measured from several flow points, difference values between standard volume and calculating volume are incomparable. Only when one of them keeps constant difference values of them have comparable. So we select calculating volume to make normalizing operation. The steps are as follows.

1) With selecting a certain fixed volume value V_c' , all calculating volumes of checked data for the standard meter are adjust to V_c' .

Principle of choosing the fixed volume V_c' is median method. All calculating volumes are rearranged in order from largest to smallest such as $V_{ci1} \leq V_{ci2} \leq \dots \leq V_{cin}$, where n is the number of calculating volumes.

When n is odd, median V_c' is given by

$$V_c' = V_{ci(\frac{n-1}{2}+1)}. \quad (3)$$

When n is even, median V_c' is given by

$$V_c' = \left(V_{ci\frac{n}{2}} + V_{ci(\frac{n}{2}+1)} \right) / 2. \quad (4)$$

2) To modify time intervals

According to principle that flow rate remains constant, we get

$$\frac{V_c'}{t'} = \frac{V_c}{t}. \quad (5)$$

Hence

$$t' = \frac{V_c'}{V_c} t. \quad (6)$$

3) To modify standard volumes

According the same principle, we get

$$\frac{V_s'}{t'} = \frac{V_s}{t}. \quad (7)$$

Thus,

$$V_s' = \frac{V_s}{t} t'. \quad (8)$$

3.2. Interpolating Algorithm

We design interpolating operation by using three-order spline interpolating algorithm. Since a fluid behaves as continuity, parameters received from fluid

should be smooth and continuous. Three-order spline function comprises segment three-order curves and its second derivative is continuous in consecutive points. Therefore, we select three-order spline interpolating algorithm to implement interpolating operation. In interpolating operation we select flow F_c as horizontal axis parameter, difference value ΔV between calculating volume V_c' and standard volume V_s' as vertical axis parameter.

3.3. Modifying Calculating Volume

In practical calibrating procedure, we can get standard time interval t'' and calculating volume V_c'' for the standard meter in every flow point. Then

we carry out flow in every flow point $F_c'' = \frac{V_c''}{t''}$. In

accordance with interpolating result in section 3.2, we get correspondent volume difference value $\Delta V'$ of flow F_c'' of every flow point and we modify calculating volume of the standard meter.

Step 1: To calculate standard time interval t' corresponding to the fixed volume V_c' in the current flow

$$t' = \frac{V_c'}{F_c''}. \quad (9)$$

Step 2: To calculate practical volume difference value in the flow point after normalized.

In the same flow, volume difference value is accumulated and it is proportional to time interval, that is,

$$\frac{\Delta V'}{t'} = \frac{\Delta V''}{t''}. \quad (10)$$

Therefore,

$$\Delta V'' = \frac{\Delta V'}{t'} t''. \quad (11)$$

Step 3: To modify calculating volume.

$$V_c = V_c'' - \Delta V'', \quad (12)$$

where V_c is the calculating volume for the standard meter after processed.

4. Algorithm Verification

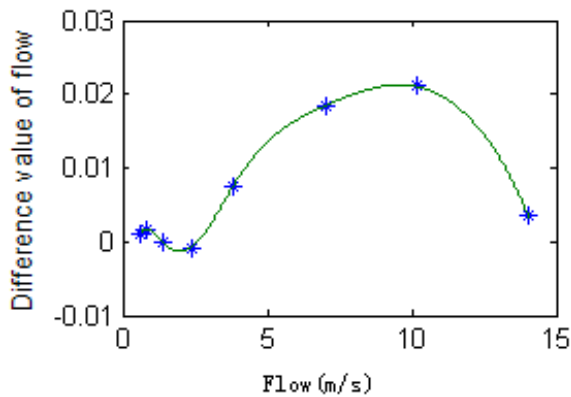
We carry out algorithm verification by the below data from a practical calibrating process. Data processing results are list in the Table 1.

Table 1. Practical calibrating data for the standard meter.

Flow point	Standard time t (s)	Calculating volume V_c (m ³)	Standard volume V_s (m ³)	Flow F_c (m ³ /s)	Fundamental error
1.	13.841	194.123	194.073	14.0252	0.026
2.	19.185	194.884	194.480	10.1581	0.208
3.	27.629	195.290	194.779	7.0683	0.262
4.	51.263	195.450	195.065	3.8127	0.197
5.	82.149	195.422	195.488	2.3789	-0.034
6.	136.673	194.953	194.976	1.4264	-0.012
7.	238.068	194.675	194.275	0.8177	0.206
8.	322.691	194.271	193.960	0.6020	0.160

From Table 1 calculating volumes and standard volumes measured from several flow points are not exactly the same and difference values between standard volumes and calculating volumes are not comparable. Therefore, we are not able to handle with directly difference value of the volume.

Fig. 2 is the result of three-order spline interpolating operation corresponding to data of Table 1.

**Fig. 2.** Result of three-order spline interpolating operation.

Linear interpolating operation is simple and easy to implement, but operation result is not smooth. Three-order spline function is made by segment three-order curves and its second derivative is continuous in consecutive points. Since a fluid behaves as continuity, parameters received from fluid should be smooth and continuous. Therefore, result of three-order spline interpolation is more in line with characteristic of fluid.

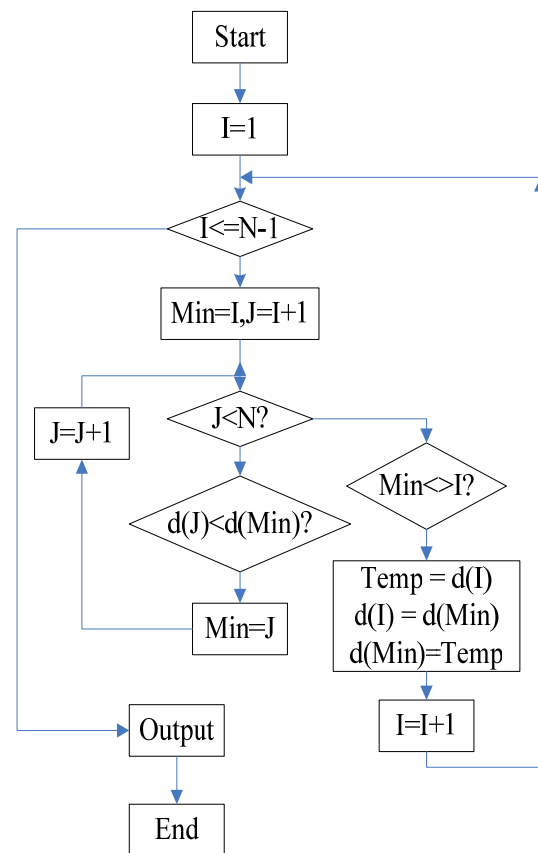
Data of the third column in Table 1 are sorted according to the smallest order. The sorting algorithm is bubble sort. Flow char of sort algorithm is shown in Fig. 3.

Results of sort are shown in Table 2.

The number of calculating volume n is even, so the median V_c' is given by equation (4) and its value is $V_c' = 194.919$.

Time interval data of the second column in Table 1 is modified according to equation (6).

Standard volume data of the fourth column in Table 1 is modified according to equation (8).

**Fig. 3.** Flow char of bubble sort algorithm**Table 2.** Results of sort for data of calculating volume.

No.	Result of sort
1.	195.450
2.	195.422
3.	195.290
4.	194.953
5.	194.884
6.	194.675
7.	194.271
8.	194.123

Difference values of volume are calculated by equation (11). Calculating volumes are modified according to equation (12).

According to the above algorithm, we process all data in Table 1 and arrive at data in Table 3.

We normalize calculating volumes in Fig. 1 according to the principle in section 3.1 into 194.919. Meanwhile, we modify accordingly standard volumes and standard time intervals and get volume difference values which are comparable. Then we carry out interpolating operation by using spline

interpolation algorithm and arrive at flow difference value corresponding to flow of the current flow point. Hence, we can modify directly calculating volume of the current flow point. By now we change three dimension interpolating operation into tow dimension interpolating operation so that we solve the problem that to multiply time interval can bring error in three dimension interpolating operation. It can be shown from Table 3 that flow of the every flow point and fundamental error are the same as the data in Table 1.

Table 3. Processed results by using the new algorithm.

Flow point	Standard time t (s)	Calculating volume V_c (m ³)	Standard volume V_s (m ³)	Flow F_c (m ³ /s)	Difference of volume E_v (m ³)	Fundamental error
1.	13.898	194.919	194.869	14.0252	0.050	0.026
2.	19.188	194.919	194.515	10.1581	0.404	0.208
3.	27.577	195.919	194.409	7.0683	0.510	0.262
4.	51.124	195.919	194.535	3.8127	0.384	0.197
5.	81.938	195.919	194.985	2.3789	-0.066	-0.034
6.	136.649	194.919	194.942	1.4264	-0.023	-0.012
7.	238.366	194.919	194.518	0.8177	0.401	0.206
8.	323.767	194.919	194.607	0.6020	0.312	0.160

Calibrated data in Table 4 is obtained from a certain checked meter using old algorithm. Data in Table 5 is obtained from the same checked meter using new algorithm. Data in Table 6 is obtained from the same checked meter using standard facility.

Table 4. Calibrated data of a checked meter by old algorithm using standard meter method.

Serial No.	Frequency	Flow(l/s)	Meter Constant
1.	722	14.021	201.393
2.	360	7.002	201.450
3.	178	3.510	201.362
4.	73	1.420	200.698
5.	42	0.815	200.632

Table 5. Calibrated data of the same checked meter by new algorithm using standard meter method.

Serial No.	Frequency	Flow(l/s)	Meter Constant
1.	720	14.001	201.290
2.	360	6.998	201.187
3.	180	3.551	201.268
4.	75	1.452	200.856
5.	43	0.819	200.798

Table 6. Calibrated data of the same checked meter using standard facility.

Serial No.	Frequency	Flow(l/s)	Meter Constant
1.	720	14.001	201.297
2.	358	6.985	201.193
3.	179	3.562	201.254
4.	75	1.455	200.883
5.	42	0.816	200.789

From the above three tables we can draw a conclusion that meter constant obtained by the new algorithm using standard meter method is close to the data from standard facility.

Three group data of meter constant are drawn in Fig. 4. We can see that the new algorithm improves precision of the calibrating system using standard meter method.

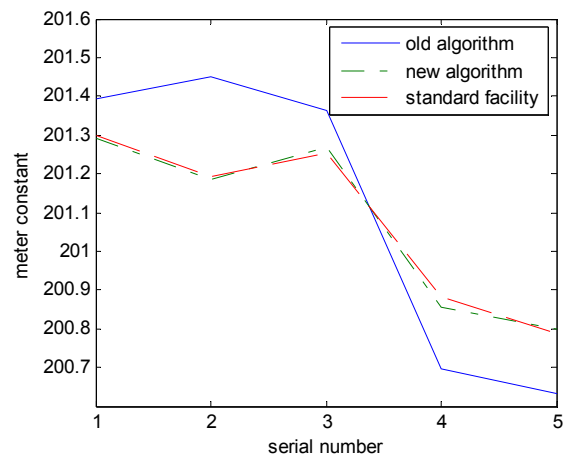


Fig. 4. Data comparison diagram.

5. Conclusions

According to continuity of fluid, when water pressure is invariable, flow rate of calibrating media remain unchanged in the time interval at the same flow point. Under this condition, we normalize data

for the standard meter to make difference values between calculating volumes and standard volumes comparable. Then we select spline interpolating algorithm and obtain flow deviation corresponding to any flow. Data which is interpolated is data when the standard meter is calibrated, so we need change flow deviation obtained in the above into flow deviation of the current flow point. Finally, we modify calculating volume and arrive at data which is close to the standard volume. The algorithm change three dimension interpolating operation into two dimension interpolating operation by using continuity of fluid and improve precision of interpolating result. By the new algorithm we can decrease effectively uncertainty from data of the standard meter and improve the accuracy of the overall calibrating facility.

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