Study on the relationship between the size change and the measured flow value of the Parshall flumes open channel weir tank flowmeter

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Abstract

At present, as an important measuring instrument for measuring sewage discharge, the principle of open channel flowmeter is the functional relationship between liquid level and flow. By measuring the liquid level of water flow in the tank, and then according to the flow value of the relationship between liquid level and flow in the corresponding Parshall flume, therefore, the accuracy of Parshall flume size is closely related to its measurement accuracy. In this paper, we introduce a kind of adjustable size of Parshall flume. Through experiments, we find out the relationship between the flow rate and the standard flow rate under different sizes, and then use the method of multiple regression to fit the correction equation.

1. Introduction

The working principle of open channel flowmeter is the functional relationship between liquid level and flow. By measuring the liquid level of water flow in the tank, the instantaneous flow value is calculated according to the relationship between liquid level and flow in the corresponding open channel. However, in the process of construction, affected by many factors such as construction cost and construction conditions, some open channel weir grooves will have some deviations from the standard size in practical application, and the size deviation may affect the accuracy of flow measurement of open channel weir groove flowmeter, and the most widely used Parshall flume is used. Therefore, it is hoped to study the relationship between the size deviation of Parshallflume and flow measurement error through experiments, the correction value of liquid level error under different non-standard dimensions is obtained, which can provide data correction for on-site detection of non-standard Parshall flume.

In this experiment, the No. 4 Parshall flume with 152mm throat is selected as the test object, and the width dimensions of the contraction section, throat and diffusion section of the Parshall flumeare expanded or reduced respectively. Then the indication error test is carried out with the standard electromagnetic flowmeter, and the law is observed, and the correlation between size and flow is analyzed according to its law. The independent variable is fitted by multiple linear regression equation: the flow of standard electromagnetic flowmeter (m^3/h) and dependent variable: Parshall flume flow (m^3/h) according to the linear relationship between the dimension (mm), the flow correctione quation due to the change of the dimension of the Parshall flume is obtained. The working principle of the experimental device is shown in Figure 1.

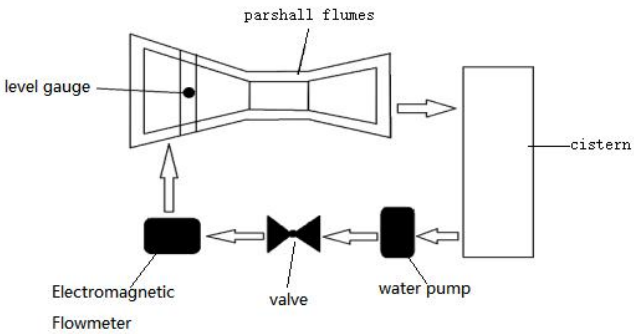


Figure 1: Schematic diagram of test device

2. Test device

The No.4 Parshall flume was selected for the test, and its standard dimensions are contraction section b1:400mm, throat b:152mm, and diffusion section b2:394mm. The test device is transformed from the water flow standard device of standard meter method. The test device consists of water pump, solenoid valve, 0.2-level electromagnetic flowmeter, Parshall flume, open channel flowmeter and measurement and control system. The structure of the test device is shown in Figure 1. Among them, the Parshall flume body is designed as an adjustable structure, which can adjust the dimensions of contraction section width B1, throat width b and diffusion section width B2 respectively (Figure 2 and Figure 3).

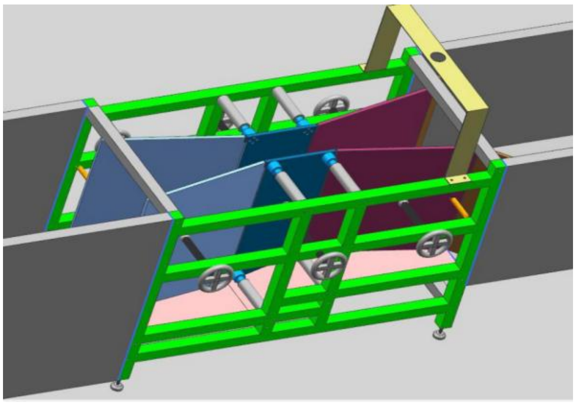


Figure 2: 3D model of Parshall flume

Figure 3: Parshall flume test site

3. test method

Adjust the sizes of all parts of the test tank, compare the instantaneous flow of the open channel flowmeter of the Parshall flume (hereinafter referred to as the tested table) with the instantaneous flow of the standard electromagnetic flowmeter (hereinafter referred to as the standard table), and calculate its relative error with Equation (1). Adjust the size as shown in Table 1. After each size change, take the liquid level H ≥ 0.10m as qmin to increase upward, and the relative error of a single measurement is calculated according to Equation (1).

$$E = \frac{Q_i - Q_{si}}{Q_{si}} \times 100\% \qquad (1)$$

Where: Q_i--Parshall flume display flow;

Q_{si}--Electromagnetic flowmeter displays flow.

4. test result

Increase the contraction section by 10mm and then decrease again. For each adjustment, record the liquid level, the instantaneous flow of the Parshall flume and the instantaneous flow of the electromagnetic flowmeter respectively, and calculate the relative error according to equation 1. According to the test results (as shown in Figure 4), the X axis is the liquid level height, and the Y axis is the error.

Table 1:dimension adjustment table of Parshall flume

number		Adjusted size (mm)									
test 1	contraction section width B1	400+50	400+40	400+30	400+20	400+10	400-10	400-20	400-30	400-40	400-50
	throat width b	152	152	152	152	152	152	152	152	152	152
	diffusion section width B2	394	394	394	394	394	394	394	394	394	394
test 2	contraction section width B1	400	400	400	400	400	400	400	400	400	400
	throat width b	152+10	152+8	152+6	152+4	152+2	152-2	152-4	152-6	152-8	152-10
	diffusion section width B2	394	394	394	394	394	394	394	394	394	394
test 3	contraction section width B1	400	400	400	400	400	400	400	400	400	400
	throat width b	152	152	152	152	152	152	152	152	152	152
	diffusion section width B2	394+50	394+40	394+30	394+20	394+10	394-10	394-20	394-30	394-40	394-50

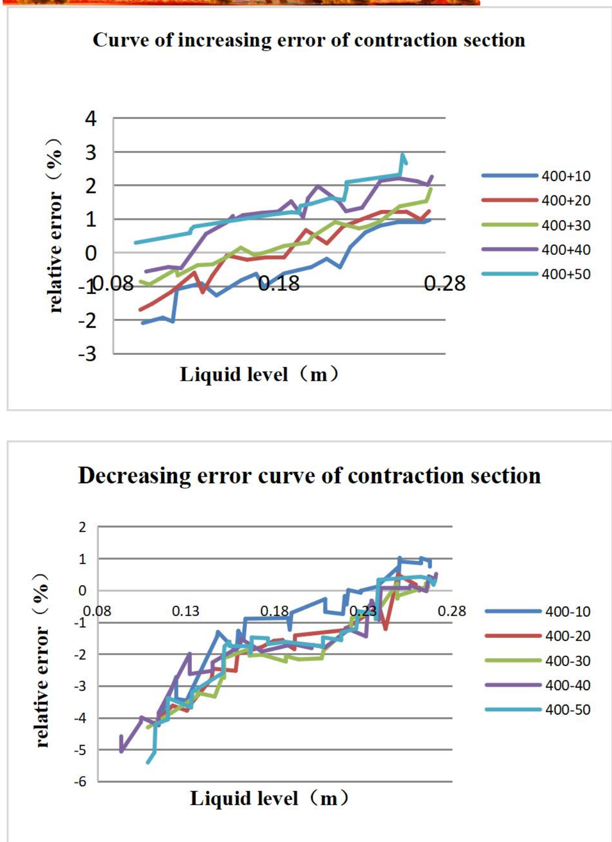


Figure 4: Error curve of shrinkage section size change

Increase the throat segment by 2mm and then decrease again. Record the results in the same way as above (as shown in Figure 5).

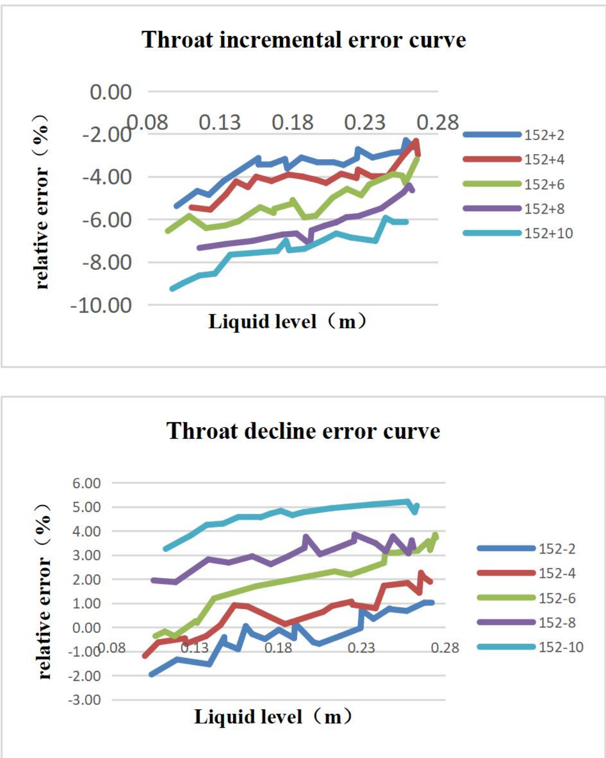


Figure 5: Throat size change error curve

Increase the diffusion section by 10mm and then decrease again, and record the results in the same way as above (as shown in Figure 6).

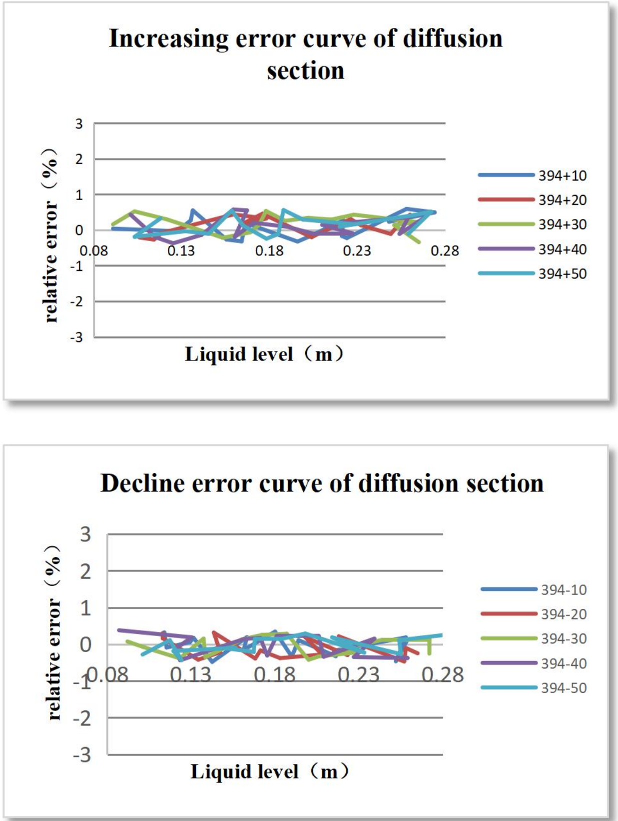


Figure 6: Error curve of diffusion section size change

As shown in the above figure (Figures 4, 5 and 6), it can be seen that the relationship between the shrinkage section of the Parshall flume and the throat size change and its error changes linearly. With the increase of the test flow, the error has a positive growth trend; However, the size change of the diffusion section of the Parshall flume has little effect on the flow error.

It can be seen from the experimental data that there is a linear relationship between the throat size change and the flow size and the resulting error. The standard value of the flow due to the size change can be obtained by fitting the linear relationship between the independent variables through the multiple linear regression equation. It is expressed by Equation (2) of linear regression equation.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \qquad (2)$$

Equation (3) is fitted according to the multiple linear regression model for the correction of the contraction section. To correct the throat section, it is necessary to reduce the flow to less than 80 (m^3/ h) As a low flow range, it will be higher than 80 (m^3/ h) As the high flow section, the flow in the high and low sections is respectively passed through the fitting equation (4) (5). By bringing the actual measured flow into the corresponding equation, the corresponding standard flow can be calculated.

Model		Non standardized coefficientNon B	Standard error	Standardization coefficient Beta	t	Significance
1	(constant)	14.868	0.462		32.175	0.000
	parshall flume size	-0.032	0.001	-0.025	-27.882	0.000
	parshall flume flow	0.980	0.001	0.999	1112.703	0.000

a.dependent variable:the estimated value of standard flow

$$Y=14.868+(-0.032X_1)+0.980X_2 \qquad (3)$$

Model		Non standardized coefficientNon B	Standard error	Standardization coefficient Beta	t	Significance
1	(constant)	-49.062	2.121		-23.128	0.000
	parshall flume size	0.994	0.007	1.023	147.382	0.000
	parshall flume flow	333.811	13.261	0.175	25.172	0.000

a.dependent variable:the estimated value of standard flow

$$Y=-49.062+333.811X_1+0.994X_2 \qquad (4)$$

Model		Non standardized coefficientNon B	Standard error	Standardization coefficient Beta	t	Significance
1	(constant)	-95.658	2.882		-33.189	0.000
	parshall flume size	642.531	18.763	0.097	34.244	0.000
	parshall flume flow	0.995	0.003	0.999	353.657	0.000

a.dependent variable:the estimated value of standard flow

$$Y=-96.616+642.531X_1+0.995X_2 \qquad (5)$$

Where:Y is the estimated value of standard flow; X_1 is parshall flume size; X_2 is parshall flume display flow; β is the regression coefficient.

Bring the values calculated in Equation (3) (4) (5) into the actual detection for verification. After the size is randomly adjusted, the error tests are carried out on the high flow interval and the low flow interval respectively, and the indicated values are corrected. The results are shown in Table 3,Figure 7; table 4, table 5 and Figure 8. It can be seen that the error is significantly reduced after using the correction equation, and it can be seen that the regression equation plays a correction role under different sizes.

Table 3: Regression test data of contraction section

size（m）	Standard flow（m³/h）	Display flow（m³/h）	Relative error before correction（%）	Display flow after correction（m³/h）	Corrected relative error（%）
0.39	47.81	45.95	-3.90	47.42	-0.83
	52.46	51.03	-2.73	52.40	-0.12
	56.31	54.31	-3.56	55.61	-1.25
	67.95	67.06	-1.31	68.11	0.23
	98.31	97.45	-0.87	97.89	-0.42
	126.47	125.90	-0.45	125.77	-0.55
	142.35	142.52	0.12	142.06	-0.20
	151.96	153.05	0.72	152.38	0.27
	164.18	165.84	1.01	164.91	0.44
0.35	45.62	43.30	-5.10	46.10	1.05
	58.74	56.58	-3.69	59.11	0.63
	70.87	69.37	-2.12	71.65	1.10
	82.07	80.62	-1.76	82.68	0.74
	90.10	88.58	-1.69	90.47	0.41
	115.92	114.20	-1.48	115.59	-0.29
	125.05	123.39	-1.33	124.59	-0.37
	132.50	130.90	-1.21	131.95	-0.41
	132.60	131.73	-0.66	132.76	0.12
	142.06	141.02	-0.73	141.86	-0.14
	142.50	141.20	-0.91	142.05	-0.32
	142.06	142.52	0.33	143.34	0.90

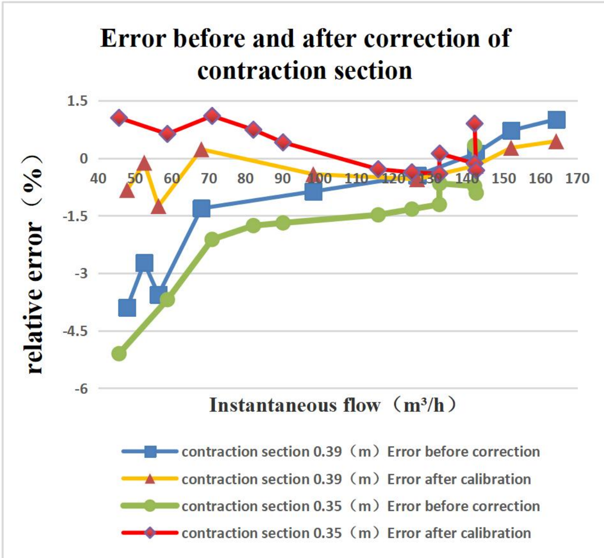


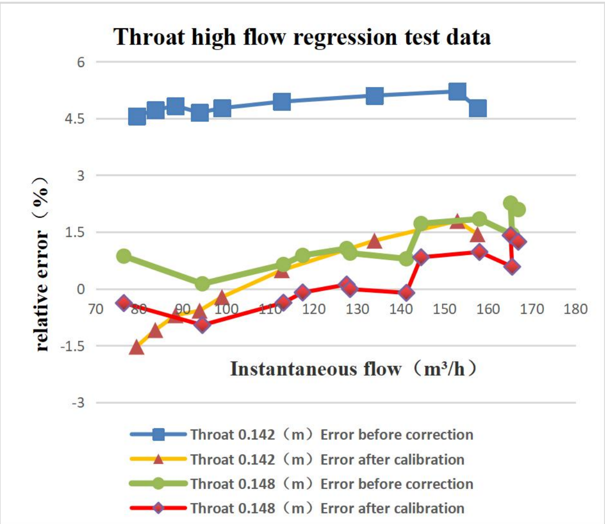
Figure 7: Error before and after correction of contraction section

Table 4: Throat high flow regression test data

size（m）	Standard flow（m³/h）	Display flow（m³/h）	Relative error before correction（%）	Display flow after correction（m³/h）	Corrected relative error（%）
0.14	79.39	83.01	4.56	78.18	-1.53
	83.68	87.63	4.72	82.77	-1.09
	88.31	92.57	4.83	87.69	-0.70
	93.83	98.19	4.65	93.28	-0.58
	98.96	103.68	4.77	98.75	-0.22
	112.67	118.23	4.94	113.22	0.49
	133.91	140.73	5.10	135.61	1.27
	152.91	160.87	5.21	155.65	1.79
	157.52	165.04	4.77	159.80	1.44
0.15	76.47	77.13	0.86	76.18	-0.38
	94.47	94.60	0.13	93.56	-0.96
	113.05	113.77	0.64	112.64	-0.37
	117.46	118.50	0.88	117.34	-0.10
	127.54	128.89	1.06	127.69	0.11
	128.33	129.53	0.94	128.32	-0.01
	141.22	142.34	0.79	141.06	-0.11
	144.59	147.08	1.72	145.78	0.83
	157.97	160.87	1.84	159.51	0.97
	165.47	167.84	1.43	166.43	0.58
	165.11	168.84	2.26	167.43	1.41
	166.87	170.35	2.09	168.94	1.24

Table 5: Throat low flow regression test data

size（m）	Standard flow（m³/h）	Display flow（m³/h）	Relative error before correction（%）	Display flow after correction（m³/h）	Corrected relative error（%）
0.14	38.36	39.11	1.94	37.88	-1.26
	46.27	47.14	1.87	45.86	-0.89
	58.40	60.04	2.81	58.69	0.50
	66.92	68.72	2.68	67.31	0.58
	76.91	79.17	2.94	77.71	1.03
0.16	44.61	42.18	-5.45	44.94	0.74
	53.21	50.26	-5.55	52.97	-0.46
	60.23	57.32	-4.84	59.99	-0.41
	64.86	62.12	-4.23	64.76	-0.16
	71.12	67.92	-4.50	70.53	-0.83
	75.00	71.99	-4.01	74.58	-0.57



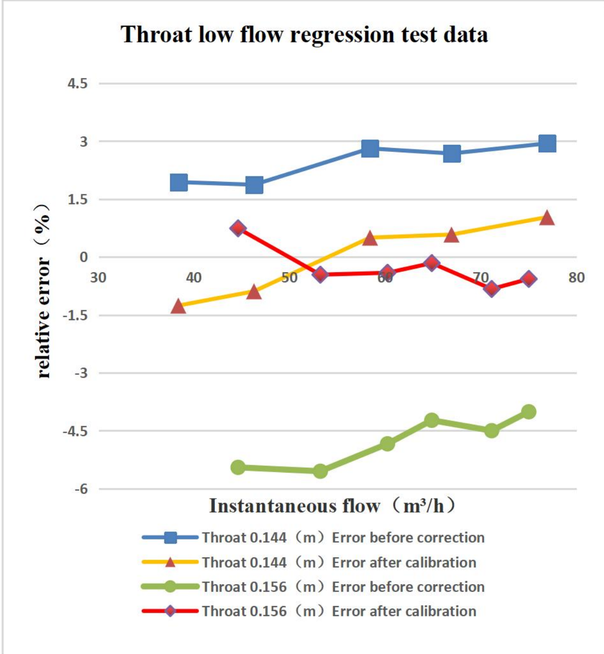


Figure 8: Error before and after correction of throat

5. Conclusion

In this study, the Parshall flume with a throat of 152mm is taken as the test object. After adjusting the width of the contraction section, throat and diffusion section of the Parshall flume, the indication error test is carried out, and its law is observed and its correlation is analyzed.

The test results show that the change of the size of the contraction section and throat of the Parshall flume will directly affect its flow. The greater the difference between the size of the contraction section and throat and the standard size, the relative error between the indicated value and the standard value of the flow of the Parshall flume will gradually increase, and its change has a certain linear relationship; The size change of diffusion section will not affect the flow. At the same time, a set of flow correction equation can be obtained by fitting the results with linear regression equations. After using the corresponding correction equation, the flow error caused by the size of the Parshall flume can be significantly reduced, and the corrected flow indication error can be controlled within ± 1.5%.

In addition, the test conclusions of this series can intuitively show customers the impact of non-standard self built tanks on the flow, show the economic losses caused by this, and promote users to rectify the self built tanks into standard finished tanks as soon as possible, so as to make the whole market more standardized and orderly. Moreover, if the modified equation can be applied to the actual detection work, the detection can be more accurate and credible. Based on this correction method, the existing detection standard can also be improved, so that it can have a wider application space.

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