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Online measurement of gas and liquid flow rate in wet gas through one V-Cone throttle device

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ABSTRACT

In the present study, an accurate cost-effective online system for metering both the gas flow rate and the liquid flow rate in wet gas with only one V-Cone throttle device is developed. The two-phase mass flow coefficient is employed to correct the measurement deviation of the V-Cone throttle device. The effects of the liquid densiometric Froude number, the gas densiometric Froude number and the ratio of gas density to liquid density on the two-phase mass flow coefficient are experimentally investigated. The equivalent diameter ratio of the V-Cone throttle device is 0.55. The experimental fluids are air and tap water. The operating pressure, the superficial gas velocity and superficial liquid velocity range from 0.1 MPa to 0.3 MPa, 4.87 m/s to 25.26 m/s and 0 to 0.38 m/s, respectively. The results show that the two-phase mass flow coefficient linearly increases with the liquid densiometric Froude number and is affected by the gas densiometric Froude number and the ratio of gas density to liquid density. On the basis of the two-phase mass flow coefficient, the correlation for measuring the gas flow rate of the wet gas is developed. To reflect the influences of the liquid on the measurement, the pressure loss ratio of the V-Cone throttle is proposed. By incorporating the gas measurement correlation of the wet gas, the wet gas correlations to simultaneously meter the gas and liquid flow rate are concluded. In the present cases, the relative error of the gas mass flow rate predicted by the correlations is within ±5.0% and the mean absolute percentage error is 2.52%; the full scale relative error of the liquid mass flow rate is within ±5.0% and the mean absolute percentage error is 7.03%. The method proposed in this study creates a simple inexpensive wet gas metering system that can operate well in a significant range of industrial applications.
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1. Introduction

As a distinctive gas-liquid two-phase flow, wet gas is defined as a gas–liquid mixture with the Gas Volume Fraction (GVF) of no less than 95% [1]. It widely exists in industrial processes, particularly in the natural gas industry [2]. The gas flow rate and liquid flow rate of the wet gas are important parameters reflecting the output of a single well and they are also of great significance for accurately measuring the amount of liquid in gas reservoirs, rationally prorating the production and efficiently designing the techniques for increasing production. The development of an accurate and cost-effective online device for measuring the gas and liquid flow rate of wet gas has thereby drawn increasing attention in researches [3].

At present, the commonly-used wet gas meter is the so-called "combined type wet gas meter", which consists of two or more single phase meters (or sensors) combined in series. The majority of these wet gas meters are made up of differential pressure meters (e.g., orifice plate, Venturi meter and V-Cone meter) and other measurement sensors, such as velocity flowmeter, volumetric flowmeter, mass flowmeter, γ ray sensor, microwave sensor, and infrared sensor [3]. Since the 1950 s, researchers have been engaged with the exploration of an online wet gas measurement technology, and many companies and research institutes have developed a variety of devices. The Dualstream II wet gas meter developed by Solartron ISA [4], TTWGF wet gas meter by Tianjin University [5], WGFM wet gas flow meter by Elster-Instromet Ultrasonics [6], MPFM-50 flowmeter by Agar [7], Roxar flow meter by Emerson [8], Haimo wet gas flow meter by Lanzhou Haimo Technologies Co. [9] and Alpha VS/R flow meter by Weatherford [10] are some examples. These existing measurement devices can predict the wet gas accurately, but they are practically limited by

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Nomenclature

English symbols

A	Area of throttle device, $A = \pi D^2/4$ (m^2)
a	Coefficient in Eq. (10) (–)
b	Coefficient in Eq. (10) (–)
C	Coefficient in Eq. (10) (–)
D	Inlet diameter of DP device (m)
d	Maximum diameter of V-Cone (m)
DP	Differential pressure (Pa)
DR	Gas-to-liquid density ratio (–)
FSRE	Full-scale relative error (%)
f	Some function (–)
Fr_g	Gas densiometric Froude number, $Fr_g = \frac{U_{sg}}{\sqrt{gD}}\sqrt{\frac{\rho_g}{\rho_l - \rho_g}}$ (–)
Fr_l	Liquid densiometric Froude number, $Fr_l = \frac{U_{sl}}{\sqrt{gD}}\sqrt{\frac{\rho_l}{\rho_l - \rho_g}}$ (–)
g	Gravitational constant (m/s^2)
K	Two-phase mass flow coefficient (–)
k	Slope in Eq. (10) (–)
l	Intercept in Eq. (10) (–)
MAPE	Mean absolute percentage error (%)
MRE	Mean relative error (%)
m	Mass flow rate (kg/s)
N	Total number of test data (–)
P	Pressure (Pa)
RE	Relative error (%)
T	Temperature (°C)
U_{sg}	Superficial gas velocity, $U_{sg} = \frac{4m_g}{\pi D^2 \rho_g}$(m/s)
U_{sl}	Superficial liquid velocity, $U_{sl} = \frac{4m_l}{\pi D^2 \rho_l}$ (m/s)

Greek symbols

β	Equivalent diameter ratio, $\beta = \sqrt{\frac{D^2 - d^2}{D^2}}$ (–)
δ	Pressure loss ratio (–)
θ	Back-cone angle (°)
ρ	Density (kg/m^3)
φ	Font-cone angle (°)

Subscripts

1, 2 apparent	Different coefficient apparent
g	Gas
l	Liquid
sg	Superficial gas
sl	Superficial liquid
wg	Wet gas

Abbreviation

AF	Annular Flow
GMF	Gas Mass Fraction
GVF	Gas Volume Fraction
LVF	Liquid Volume Fraction
PSF	Pseudo-Slug Flow
RWF	Roll-Wave Flow
STF	Smooth Stratified Flow
WSF	Wave Stratified Flow

their innate disadvantages including complex structure and large size. In addition, some of them contain radiation-emitting devices which render their operation rather difficult. Most importantly, owing to their high price, they are not applicable for such natural gas wells with low production as Sulige gas field which is the largest land gas field in China. To economically exploit this type of oil-gas reservoirs, the inter-well concatenation technology is employed [11]. The lack of an accurate cost-effective online measurement of liquid flow rate and gas flow rate has limited the development of this technology.

The V-Cone throttle device has been widely used in the measurement of single phase gas and liquid flow owing to its high accuracy, wide turndowns, short straight length, excellent repeatability and stable signals [12–15]. In recent years, much research work has been devoted to the measurement of multiphase flow with the V-Cone throttle device [13,16–20]. Deviation was found when the measurement correlation of the single phase flow was used to measure the multiphase flow. Steven et al. [13,19] and He et al. [17] reported that the gas flow rate in wet gas predicted with the gas measurement equation was higher than the actual gas flow rate. The corresponding corrected measurement correlations have been proposed to correct the deviation. But the gas flow rate is predictable only when the information about the liquid flow rate or the liquid phase fraction is initially known with the ray method, the microwave method and the isokinetic sampling method [3], for example. It is still difficult to online measure both the gas flow rate and liquid flow rate by using only one V-Cone throttle device. When the differential pressure (DP) devices (e.g., the orifice plate, the Venturi tube and the V-Cone) are used to measure the wet gas flow, their pressure loss reflects much of the wet gas flow information and it is affected by many flow parameters, including the gas and liquid flow rate, the phase fraction and the gas-to-liquid density ratio [21]. Pressure loss has been used by the Venturi meter to measure the gas flow rate of wet gas [1,21,22], but the liquid flow rate of wet gas is not be metered simultaneously. Steven [23] once pointed out that gas flow rate and liquid flow rate can be measured through appropriate mathematical analysis with the V-Cone meter. When the relationship between pressure loss and liquid flow rate or liquid phase fraction is known, the online measurement of gas flow rate and liquid flow rate can be realized by combining the established corrected measurement correlation [17].

When the V-Cone throttle device is used to measure the single phase flow, the flow rate can be obtained by measuring DP of the V-Cone. In the measurement of the gas-liquid two-phase flow, the V-Cone throttle device will "over-read" the actual gas flow rate. In our previous work [15,24], we proposed a dimensionless parameter called two-phase mass flow coefficient to correct this "over-reading". The results demonstrated that the introduction of the two-phase mass flow coefficient of the V-Cone throttle device made a simple and accurate wet gas measurement correlation feasible. The objective of this paper is to develop an online measurement of gas flow rate and liquid flow rate through only one V-Cone throttle device. A wet gas correlation based on the two-phase mass flow coefficient is developed. Then pressure loss ratio of the V-Cone throttle device is analyzed and a liquid measurement correlation in wet gas is concluded. Finally, the implementation of the measurement is described.

2. Experimental set-up and test section

2.1. V-Cone test section

The sketch of the V-Cone throttle device in this study is shown in Fig. 1(a). The inside diameter of its inlet, D, is 50 mm. The

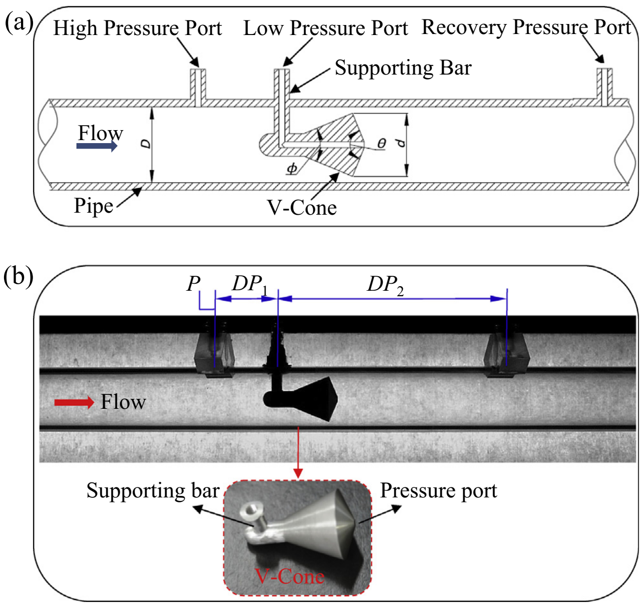

Fig. 1. (a) Sketch of V-Cone throttle device; (b) pictures of V-Cone test section ($\beta = 0.55$).

front-cone and back-cone are connected and held by a supporting bar. The front-cone angle, φ, and the back-cone angle, θ, are 45° and 135°, respectively. Two sets of differential pressures (i.e., DP_1 and DP_2) and one set of static pressure (P) at the inlet are measured (see Fig. 1(b)). The high pressure port is situated on the upstream side of the V-Cone where the influence of the approach impact pressure adjacent of the V-Cone is negligible. The low pressure is measured from the low pressure port which locates at the apex of the back-cone and passes through the V-Cone. The recovery pressure port is located at the 3D downstream of the back face of the V-Cone. To observe the gas–liquid two phase flow pattern, the polymethyl methacrylate (PMMA) pipe is used. The V-Cone throttle device with the equivalent diameter ratio, β, of 0.55 is tested. β is defined by Eq. (1).

$$\beta = \sqrt{\frac{D^2 - d^2}{D^2}} \tag{1}$$

where D is the inside diameter of the V-Cone device inlet, and d is the maximum diameter of the V-Cone.

2.2. Flow loop and experimental scheme

The experiments are performed in the Gas-Liquid Two-Phase Flow Loop of Xi'an Jiaotong University. The experimental fluids are air and tap water. More details of the experimental set-up are available in Ref. [15]. The V-Cone throttle device is positioned horizontally. The *i*-SPEED TR high-speed camera of Olympus with super-wide-angle lens is employed to record the gas-liquid flow.

The experimental conditions in the present work are given in Table 1, where U_{sg} and U_{sl} are superficial gas velocity and superficial liquid velocity, respectively (their definitions are available in Nomenclature). Four sets of pressure ranging from 0.1 MPa to 0.3 MPa are tested. Superficial gas velocity, U_{sg}, and superficial liquid velocity, U_{sl}, are shown in Table 1. Gas Volume Fraction (GVF) and Gas Mass Fraction (GMF) range from 97.94% to 100% and from 14.11% to 100%, respectively. The experimental conditions belong to the wet gas flow. As shown in Fig. 2, five types of typical flow patterns, i.e., Smooth Stratified Flow (STF), Wave Stratified Flow (WST), Roll-Wave Flow (RWF), Pseudo-Slug Flow (PSF) and Annular Flow (AF), are observed under the experimental conditions in Table 1. The flow condition distribution in the Mandhane flow pattern map [25] is shown in Fig. 3.

3. Gas measurement correlation in wet gas

3.1. Two-phase mass flow coefficient of V-Cone throttle device

The two-phase mass flow coefficient is defined by Eqs. (2) and (3) [15]:

$$K = \frac{m_{wg}}{m_{\text{apparent}}} \tag{2}$$

$$m_{\text{apparent}} = \frac{A\beta^2\sqrt{2\rho_g \Delta P_{wg}}}{\sqrt{1-\beta^4}} \tag{3}$$

where m_{wg} is the actual wet gas flow rate, which is the sum of gas mass flow rate (m_g) and liquid mass flow rate (m_l), $m_{wg} = m_g + m_l$; m_{apparent}, the apparent wet gas flow rate; ΔP_{wg}, the actual differential pressure in the wet gas produced by the V-Cone; ρ_g, gas density and A is the inlet cross-sectional area of the V-Cone device, $A = \pi D^2/4$.

The two-phase mass flow coefficient, K, denotes the influence liquid on the measurement of gas flow rate in wet gas when introducing a small amount of liquid into the dry gas. The dimensional analysis is conducted to determine the influencing parameters of K. With the similar method in Ref. [15], we consider the influences of Fr_l, DR and Fr_g on K and K is expressed as

$$K = f(Fr_l, \text{DR}, Fr_g) \tag{4}$$

where DR is the gas-to-liquid density ratio at flowing conditions, $\text{DR} = \rho_g/\rho_l$, ρ_l is gas density and Fr_g, Fr_l are gas densiometric Froude number and liquid densiometric Froude number, respectively.

When the function f is determined, wet gas measurement correlation is concluded by Eq. (5):

$$m_{wg} = \frac{KA\beta^2\sqrt{2\rho_g \Delta P_{wg}}}{\sqrt{1-\beta^4}} \tag{5}$$

The effects of Fr_l on K for different Fr_g and DR shown in Fig. 4 suggest that K linearly increases with Fr_l, which can be written as:

$$K = kFr_l + l \tag{6}$$

where k and l are the slope of the line and the intercept, respectively.

Table 1
Experimental conditions in present study.

D (mm)	β	Pressure (MPa)	U_{sg} (m/s)	U_{sl} (m/s)	GVF (%)	GMF (%)
50	0.55	0.10	6.69–25.26	0–0.31	98.40–100	14.11–100
		0.15	6.48–23.39	0–0.32	98.46–100	14.93–100
		0.20	5.53–21.65	0–0.38	98.20–100	16.25–100
		0.30	4.87–18.68	0–0.38	97.94–100	18.36–100

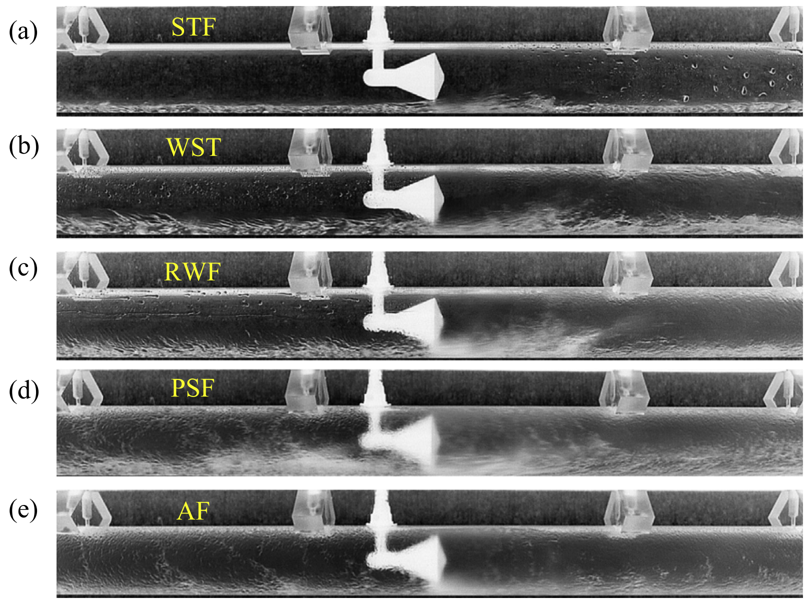

Fig. 2. Typical flow pattern through the V-Cone. The flow is from left to right. (STF: Stratified Flow, WSF: Wave-Stratified Flow, RWF: Roll-Wave Flow, PSF: Pseudo-Slug Flow, AF: Annular Flow) (a) $U_{sg} = 6.62$ m/s, $U_{sl} = 0.0076$ m/s; (b) $U_{sg} = 6.57$ m/s, $U_{sl} = 0.071$ m/s; (c) $U_{sg} = 12.77$ m/s, $U_{sl} = 0.057$ m/s; (d) $U_{sg} = 18.22$ m/s, $U_{sl} = 0.17$ m/s; (e) $U_{sg} = 22.64$ m/s, $U_{sl} = 0.031$ m/s.

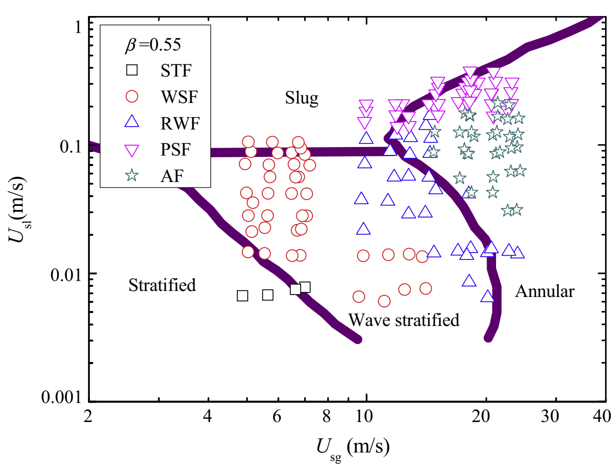

Fig. 3. Experimental conditions distribution in Mandhane flow pattern map (STF: Stratified Flow, WSF: Wave-Stratified Flow, RWF: Roll-Wave Flow, PSF: Pseudo-Slug Flow, AF: Annular Flow).

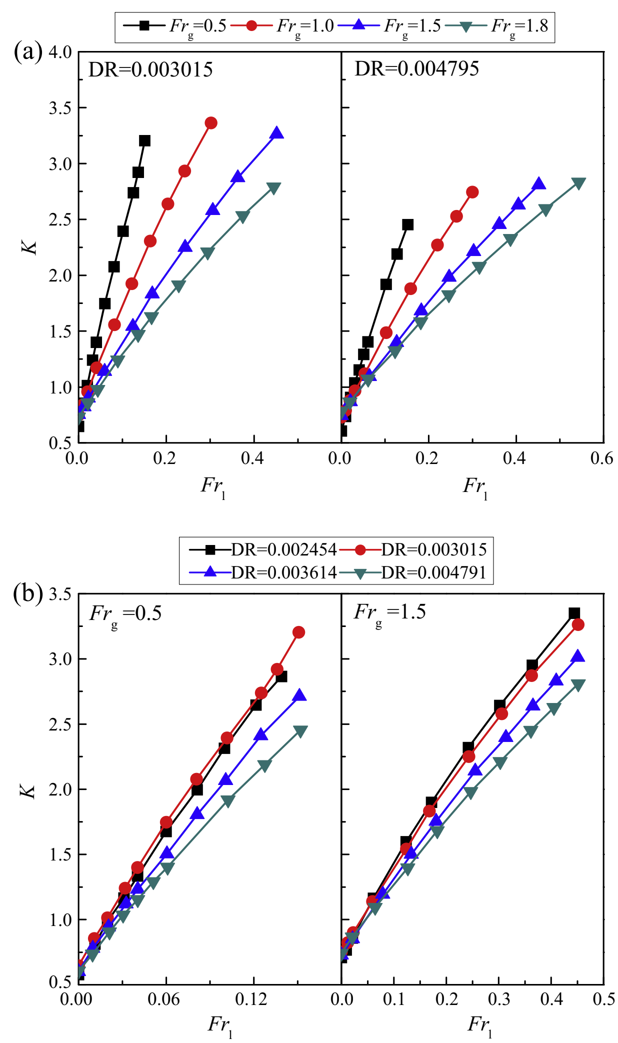

Fig. 4. Effects of Fr_l on K (a) for different Fr_g; (b) for different DR.

Fig. 4 shows that K decreases with the increase of Fr_g when other parameters hold constant, i.e., the slope, k, decreases with increasing Fr_g (see Fig. 4(a)). As shown in Fig. 4(b), K also decreases with the increase of DR, and k thus decreases with increasing DR. The intercept l equates the average of the dry gas flow coefficient, and $l = 0.7499$ in the present work. Thus the correlation of two-phase mass flow coefficient, K, is expressed in terms of Fr_l, Fr_g and DR as follows:

$$K = \exp\left(4.3052 - 18772.789(\rho_g/\rho_l)^2 - 1.9579\sqrt{Fr_g}\right)Fr_l + 0.7499 \tag{7}$$

3.2. Measurement correlation based on two-phase mass flow coefficient

According to Eqs. (2)–(7), the measurement correlation of gas mass flow rate of wet gas can be written as:

$$m_g = \frac{m_{\text{apparent}} K}{1 + \frac{Fr_l}{Fr_g}\sqrt{\frac{\rho_l}{\rho_g}}} \tag{8}$$

When the liquid flow rate of wet gas is known, the gas mass flow rate can be predicted with Eqs. (7) and (8). In the next section, we will discuss the measurement of the liquid flow rate and finally propose an online measurement of gas flow rate and liquid flow rate in wet gas through only one V-Cone throttle device.

4. Liquid measurement correlation in wet gas

4.1. Pressure loss ratio

Pressure loss ratio, δ, is defined as the ratio of the permanent pressure loss to DP of the convergent section of a throttle device [21]. For the V-Cone throttle device shown in Fig. 1(b), its δ is determined by Eq. (9).

$$\delta = \frac{\text{DP}_1 - \text{DP}_2}{\text{DP}_1} \tag{9}$$

In the present study, the relationship between pressure loss ratio and liquid fraction is investigated and concluded. The gas flow rate and liquid flow rate in wet gas can be measured simultaneously by combining the existing wet gas correlation, for example Eq. (8).

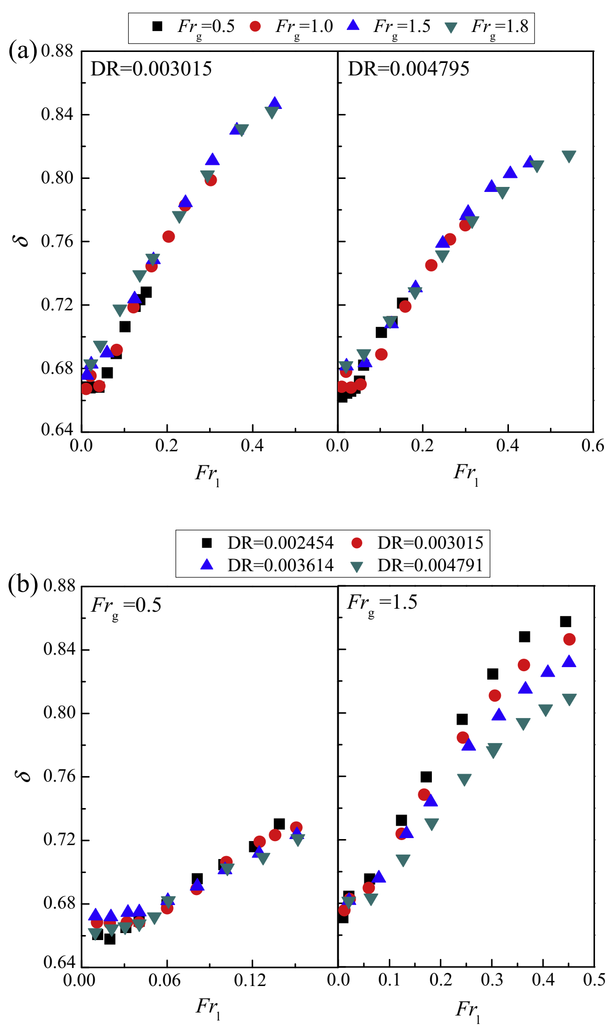

Fig. 5. Effects of Fr_l on δ ($\beta = 0.55$) (a) for different Fr_g; (b) for different DR.

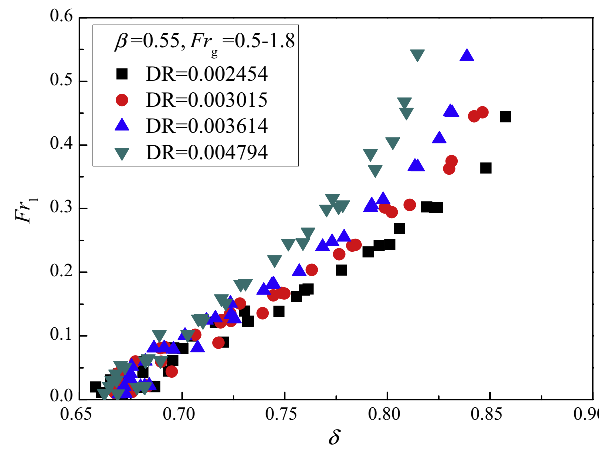

Fig. 6. Relationship between Fr_l and δ for different Fr_g and DR ($\beta = 0.55$).

The influences of Fr_l, Fr_g and DR on δ are analyzed as shown in Fig. 5. It is found that the sensitivity of δ to Fr_l depends on Fr_g and DR. In general, δ increases with the increase of Fr_l and decreases with DR increasing when Fr_l is higher than 0.1. The sensitivity of δ to Fr_l reduces as Fr_l increases. But in wet gas, δ exhibits great sensitivity to Fr_l. In addition, the change in its sensitivity to Fr_g is negligible under the present test conditions (see Fig. 4(a)).

With the effects of Fr_g on δ ignored, the relationship between Fr_l and δ for different DR is concluded as shown in Fig. 6. Fr_l can be represented by quadratic function of δ. The corresponding correlation is concluded as Eq. (10).

$$\begin{cases} Fr_l = a\delta^2 + b\delta + c \\ a = 2784\frac{\rho_g}{\rho_l} - 1.9922, \\ b = -3569.3\frac{\rho_g}{\rho_l} + 3.3708, \\ c = 1144.4\frac{\rho_g}{\rho_l} - 1.34 \end{cases} \tag{10}$$

where a, b and c are the coefficients that depend on DR.

The gas density, ρ_g, and liquid density, ρ_l, can be calculated by operation pressure and fluid temperature; the pressure loss ratio, δ, can be calculated from the front DP, DP_1, and the back DP, DP_2, as shown in Fig. 1. The liquid densiometric Froude number, Fr_l, is obtained and thus the liquid mass flow rate of wet gas, m_l, is measured.

The δ and DR are directly calculated by measured differential pressure, pressure and temperature. This calculation has the advantages of great accuracy and fast response, which can effectively reduce the influence of the propagation of error produced by gas flow rate measurement on liquid flow rate measurement; and overcome the disadvantages of traditional wet gas flowmeters which consist of two or more single phase flow meters in series and need two sets of corrected correlations.

4.2. Implementation of measurement

A typical V-Cone wet gas flowmeter developed on the basis of our work is shown Fig. 7. Four signals, i.e., operation pressure (P), front DP (DP_1), back DP (DP_2) and temperature (T), are measured by the sensors and the measurements are transferred to the data acquisition and processing system. Gas flow rate and liquid flow rate can thus be measured. The flow chart in Fig. 8 demonstrates the procedures of our measurement:

(1) Input operating pressure (P), temperature (T), front differential pressure (DP_1) and back differential pressure (DP_2).

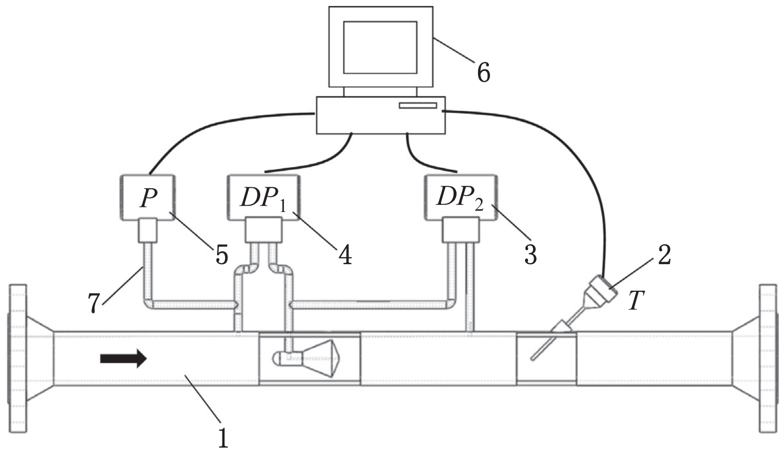

Fig. 7. Sketch of a typical V-Cone wet gas flowmeter: 1-V-Cone throttle device, 2-temperature sensor, 3-different pressure sensor 1, 4-different pressure sensor 2, 5-pressure sensor, 6-data acquisition and processing system, 7-pressure pipe.

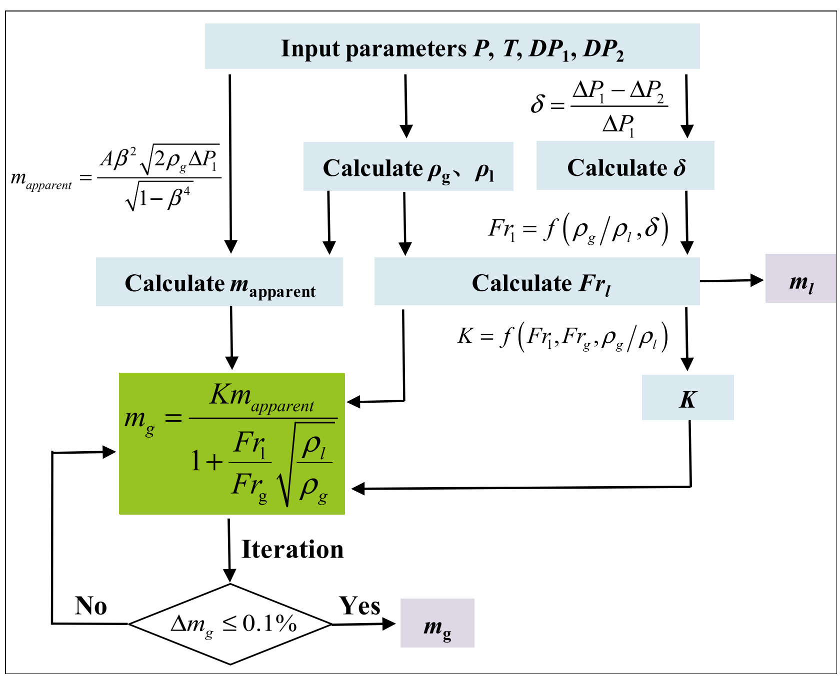

Fig. 8. Flow chart of gas and liquid measurement in wet gas using the present wet gas correlations.

(2) Pressure loss ratio (δ) is calculated by using front differential pressure (DP_1) and back differential pressure (DP_2) as defined by Eq. (9). Gas density (ρ_g) and liquid density (ρ_l) are calculated.
(3) Liquid densiometric Froude number (Fr_l) is obtained according to Eq. (10), and liquid flow rate is calculated.
(4) Apparent wet gas flow rate ($m_{apparent}$) is calculated by Eq. (3).
(5) Two-phase mass flow coefficient (K) is calculated by Eq. (7).
(6) Substitute $m_{apparent}$ and K into Eq. (8), and then gas mass flow rate (m_g) is obtained by iteration. The initial value of gas flow rate (m_{g0}) is calculated by Eq. (3). When the relative deviation between m_g and m_{g0} is less than 0.1%, the iteration ends. Otherwise, the new m_g is taken as the initial value of gas flow rate and the iteration continues.

4.3. Results and discussions

Relative error (RE), full-scale relative error (FSRE), mean relative error (MRE) and mean absolute percentage error (MAPE) are used to quantitatively evaluate our wet gas measurement correlations. RE is the indicator of the deviation of the predicted measurements from the experimental ones; MRE, the overestimate or underestimate of the experimental data by the correlations and MAPE, the prediction accuracy by the correlation compared with the experiments. They are defined by Eqs. (11)–(14).

$$\mathrm{RE}(i) = \frac{\text{Predicted } X(i) - \text{Experimental } X(i)}{\text{Experimental } X(i)} \times 100\% \tag{11}$$

$$\mathrm{FSRE}(i) = \frac{\text{Predicted } X(i) - \text{Experimental } X(i)}{\text{Maximum Experimental } X(i)} \times 100\% \tag{12}$$

$$\mathrm{MRE} = \frac{1}{N}\sum_{i=1}^{N}\mathrm{RE}(i) \times 100\% \tag{13}$$

$$\mathrm{MAPE} = \frac{1}{N}\sum_{i=1}^{N}[\mathrm{abs}(\mathrm{RE}(i))] \times 100\% \tag{14}$$

where $X(i)$ is the test parameter to be evaluated and N is the total amount of test data.

RE of the predicted gas flow rate is lower than ±5.0% under the present test conditions (see Fig. 9). As shown in Fig. 10, when Liquid Volume Fraction (LVF) is more than 0.5%, RE and FSRE of the predicted liquid flow rate are less than ±20.0% and ±5.0%, respectively. However, when LVF is less than 0.5%, RE increases with the decrease of LVF, and in most cases the predicted liquid flow rate is higher than the actual value. One of the primary reasons is the effects of LVF on pressure loss ratio. Fig. 5 shows that pressure loss ratio does not monotonously increase with liquid densiometric Froude number in the whole wet gas range. Under some conditions (e.g., $Fr_g = 0.5$), pressure loss ratio firstly decreases and then increases with liquid densiometric Froude number increasing. But this variation is not taken into account in the development of the liquid measurement correlation in wet gas. Hence, the predicted liquid densiometric Froude number is higher than the actual value, resulting in the higher predicted liquid flow rate than the actual value.

MRE and MAPE of the predicted gas flow rate and liquid flow rate are listed in Table 2. The positive value of MRE of gas flow rate suggests that gas flow rate is slightly overestimated and the negative value of MRE of liquid flow rate suggests that liquid flow rate is underestimated. MAPE of gas flow rate and liquid flow rate is 2.52% and 7.03%, respectively.

It is noteworthy that wet natural gas with GVF of less than 0.5% is usually produced from gas reservoirs with high gas–oil ratio, high temperature and high pressure. In these cases, owing to the very small fraction of liquid in wet gas, the measurement in the wellhead focuses on the gas flow rate. There are cases where gas flow rate and liquid flow rate have to be accurately measured, for example, in the fiscal or custody transfer measurement, so dedicated investigation is needed [2].

Also further study is required to discover the optimal range of our measurement device with different equivalent diameter ratio. When the flowmeter is appropriately selected, the measurement accuracy can be further improved. Our wet gas measurement correlations have the advantages as follows: first, the measurement device is cost-effective and compact owing to the fact that it consists of only one throttle in addition to the necessary pressure sensor, differential pressure sensor and temperature sensor; second, gas flow rate and liquid flow rate can be accurately measured simultaneously when LVF is more than 0.5%; third, our V-Cone throttle device has great self-cleaning ability and the pipe will not be easily clogged up by the dirty content in wet gas. Hence, it is applicable to the unprocessed wet gas, e.g., the wellhead wet natural gas. Nevertheless, its application range has to be further determined under the conditions of higher operating pressure and higher gas flow rate.

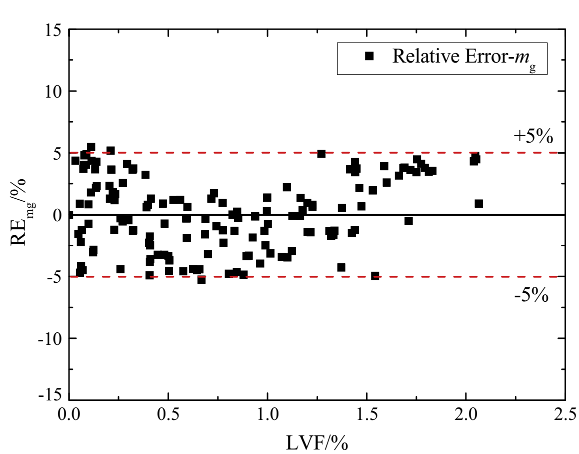

Fig. 9. Relative deviation of the predicted gas mass flow rate ($\beta = 0.55$).

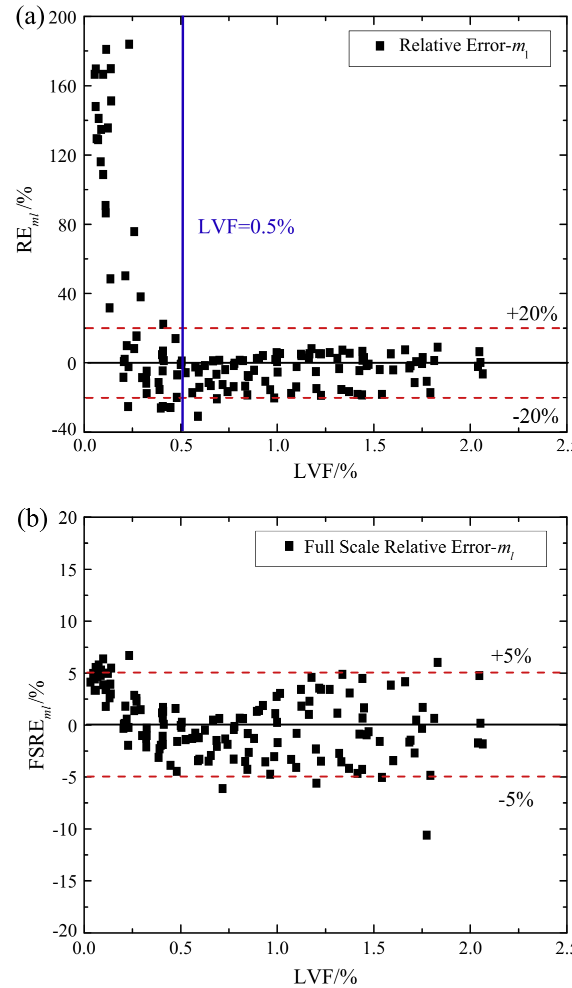

Fig. 10. Prediction deviation of liquid mass flow rate (a) relative deviation; (b) full-scale relative deviation.

Table 2
RE, MRE and MAPE of the wet gas flowmeter.

Parameter	Index	Error (%)
Gas mass flow rate, m_g	RE	−5.24 to 5.46
	MRE	0.093
	MAPE	2.52
Liquid mass flow rate, m_l (LVF ⩾0.5%)	RE	−26.94 to 31.17
	MRE	−1.77
	MAPE	7.03

5. Conclusions

An online measurement of gas flow rate and liquid flow rate in wet gas with one V-Cone throttle device is developed. The two-phase mass flow coefficient is employed to correct the deviation of the measurement device when it is used to measure wet gas. The coefficient linearly increases with the liquid densiometric Froude number and is affected by the gas densiometric Froude number and the ratio of gas density to liquid density. Their quantitative relationship is concluded. On the basis of the two-phase mass flow coefficient, a measurement correlation for predicting gas flow rate of wet gas flow is developed. To determine the influences of the liquid on the measurement, pressure loss ratio of the V-Cone throttle device is proposed. By incorporating the gas measurement correlation in wet gas, the wet gas correlations to meter gas mass flow rate and liquid mass flow rate are concluded. In the present cases, the relative error of gas mass flow rate predicted by the correlations is within ±5.0% and the mean absolute percentage error is 2.52%; the full scale relative error of liquid mass flow rate is within ±5.0% and the mean absolute percentage error is 7.03%. When the liquid volume fraction is less than 0.5%, to decrease the deviation of liquid flow rate, more work should be focused on wet gas with small fraction of liquid.

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