XXI IMEKO World Congress "Measurement in Research and Industry"
August 30 – September 4, 2015, Prague, Czech Republic

A METHOD OF LIGHT FUEL MASS FLOW MEASUREMENT BY ULTRASONIC FLOWMETER

Zhang Xiaozhong[1] *Meng Fangin*[2] *Song Shengkui*[3] *Wang Jiehui*[4]

[1] Air Force Logistics college, Xuzhou City Jiangsu province,China,zxzcn@china.com
[2] Air Force Logistics college, Xuzhou City Jiangsu province, China, *mfq6828@163.com*
[3] Air Force Logistics college, Xuzhou City Jiangsu province, China， qipeijun76@163.com
[4] Air Force Logistics college, Xuzhou City Jiangsu province, China，wjh3210@sohu.com

Abstract–The mass flow measurement is generally necessary in light fuel oil delivery, but measurement value of the ultrasonic flow meter is volume flow rate, it cannot meet the requirement of mass flow measurement. In this paper, relationship between the light fuel ultrasonic velocity, fuel density and temperature is analyzed through a large number of experimental data, the neural network model of different light fuel density and temperature and its ultrasonic propagation velocity is found. By use of this network model, a method of mass flow measurement by a ultrasonic flow meter has been given. Compared with the density compensation method，this method do not need to enter the fuel standard density, and can further improve the light liquid fuel mass measurement accuracy，density error is less than 0.23%, error of mass flow is less than 0.35%.

Keywords: flow measurement, ultrasonic flow meter, mass flow measurement

1. INTRODUCTION

Although Ultrasonic flow meter has the characteristics of small pressure loss, wide range of flow rate, and has been used more and more in light oil flow measurement, Ultrasonic flow meter still belongs to the volume flow meter in the measuring principle, it cannot meet the quality measurement requirements. Some flow meter can give mass flow with temperature compensation calculation or by adding density sensor, so its mass flow measurement accuracy relay on the accuracy of inputted the standard density and density sensor .

It has been proved that between the liquid density and Acoustic wave propagation speed has a certain functional relation at a certain temperature, so we can get volume flow and density information by a ultrasonic delay signal, and turn ultrasonic flow meters to mass flow meters. But the functional relation is varying with different oil products and production batches of light fuel. the neural network model of different light fuel density and temperature and its ultrasonic propagation velocity is found. By use of this network model, a method of mass flow measurement by a ultrasonic flow meter has been given. Compared with the density compensation method，this method do not need to enter the fuel standard density, and can further improve the light liquid fuel mass measurement accuracy，density error is less than 0.23%, error of mass flow is less than 0.35%. This paper proves that detecting the liquid density by ultrasonic delay is a feasible method in an ultrasonic flow meter.

2. ULTRASONIC MASS FLOW MEASUREMENT METHODS

An inserting ultrasonic mass flow measurement principle shown in Figure 1. The axis distance between ultrasonic transducer is L, the angle between the sound propagation direction and the vertical direction of the axis is θ.

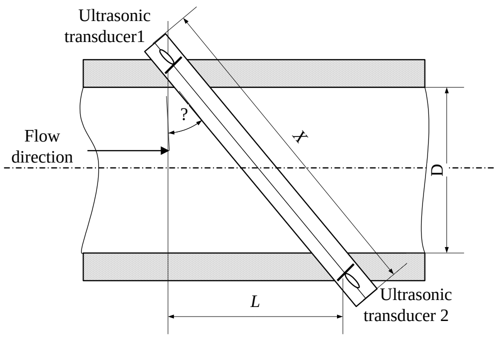


fig.1 inserting ultrasonic mass flow measurement principle

So the follow formula can be gotten.

$$t_{12} = \frac{L}{c sin\theta + u} \quad (1)$$

$$t_{21} = \frac{L}{c sin\theta - u} \quad (2)$$

t_{12},t_{21} respectively are the upstream and downstream propagation time(s). c is ultrasonic velocity in liquid media(m/s).

By the ultrasonic flowmeter principle, the average flow velocity can be gotten by following formula.

$$u = \frac{L}{2}\left(\frac{1}{t_{12}}\frac{1}{t_{21}}\right) \quad (3)$$

If the measurement system delay (including circuit and calculaation delay)is neglected, c can be calculated by following formula.

$$c = \frac{L}{2\sin\theta}\left(\frac{1}{t_{12}} + \frac{1}{t_{21}}\right) \quad (4)$$

A mass flow can be gotten by formula (5) .

$$q_m = \rho q_v = f(c,t)\,Au \quad (5)$$

In formula (5), q_m is mass flow (kg/s）, q_v is volume flow（l/s）, ρ is oil density（kg/l）, it can be described as a function of temperature t and ultrasonic propagation velocity c in still medium. A is pipe section area (cm^2), u is average flow velocity on cross section(cm/S).

3. THE DENSITY FUNCTION RELATED WITH TEMPRATURE AND ULTRASONIC VELOCITY

According to the theoretical analysis, the liquid density can be gotten by ultrasonic velocity by following formula.

$$c^2 = K/\rho \quad (6)$$

K is volume expansion coefficient, it varies with the temperature and sorts of petroleum products. As the density is relevant to the composition too, by formula 4, it is clear that a certain relation among density , temperature and the ultrasonic velocity.

Literature 2 shows that the velocity of pure hydrocarbon mixture comply with linear law of mixing frequency, that is, the ultrasonic velocity of mixture is the weighted sum of the sound velocity of each component in the mixture and can be expressed as.

$$v = \sum v_i \frac{x_i}{\rho_i} \quad (7)$$

In this formula, x_i — Volume coefficient of each component;

ρ_i—density of each component;

v_i—sound velocity in ith componen.

For formula (6) and (7), we can get that the varying law of ultrasonic velocity of light fuel depends on its component, and it is certainly that the density depends on its componen too, so the function relation of ultrasonic velocity and density of light fuel will vary according to different fuel sort and its production batch.

Some experiments were done for different sorts of light fuel, 10 sample were chosen in our experiments, they come from 3 diferrent oil refinery, and it consists of jet fuel, diesel oil and gasline. Fig .2 shown result curve of velocity and temperature.

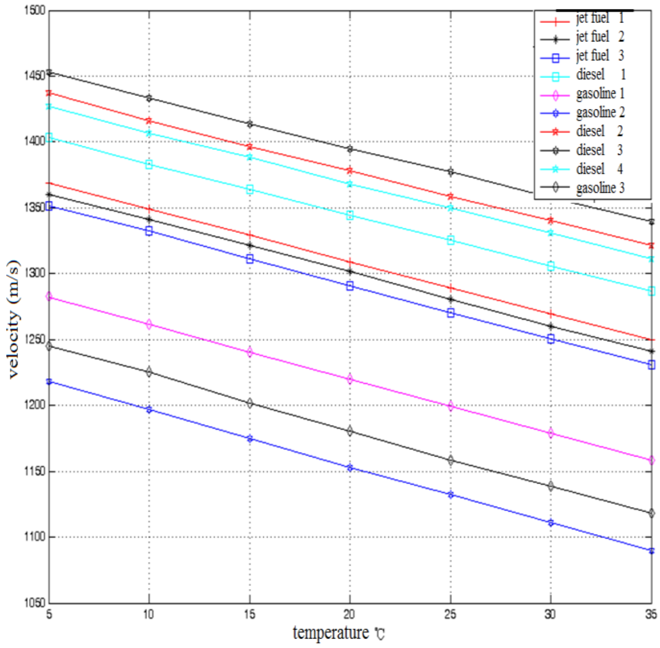
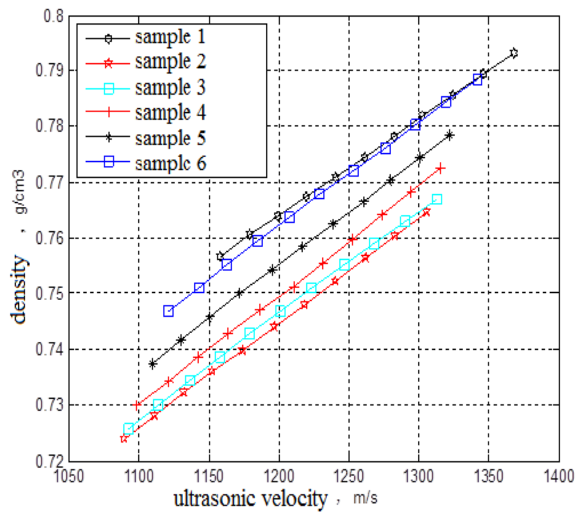
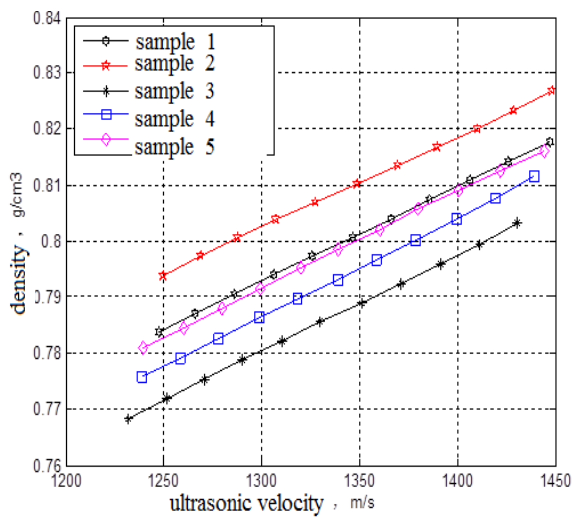


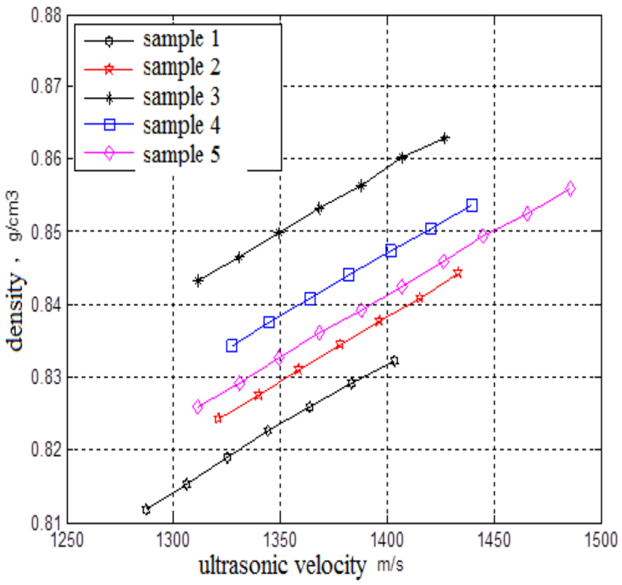
Fig.2 velocity and temperature curve of different oil products



(a) Gasoline



(b)jet fuel



(c) diesel

Fig.3 density and velocity curve of different oil products

Although a certain relation existed , but it is difficult to described by traditional math formula. So an artificial neural network is used to represent this internal relation.

According to experiment data shown in fig2 and fig3, the density of light fuel can be decided by its temperature and ultrasonic velocity. But it is difficult to get an express that describe the relation of density, velocity and temperature by maths methods.

Fortunately, It has been proved that a multilayer perception (MLP) has an ability of infinitely approximating any nonlinear function. So a back-propagation (BP) artificial neural network has been designed to express the relation between density of light fuel and its temperature and ultrasonic velocity.

In our experiment research, three BP networks has been constructed, and they respectively are jet fuel ,diesel oil and gasline density model.

As a example , jet fuel density model is discussed as follow. The experiment data of jet fuel is shown in table 1 that come from differnt refinery and production batchs . A BP artificial neural network has been constructed and its structure giagram is shown in Fig. 4 . This BP network has two inputs and one output, the inputs are temperature and velocity , and output is density. In the BP network model , the activation function of implicit layer is hyperbolic tangent non-linear function, one of output layer is linear function. The 20 data samples were randomly chosen as train samples, and the other were used as check samples.

By use of experiment data, the artificial neural network model can be trained and tesed. The table 1 is Some experimental data.

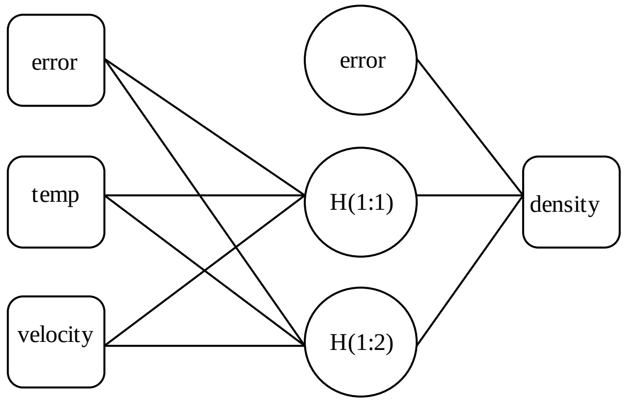


Fig.4 BP neural network structure diagram of jet fuel density

Table 1 experiment data of jet fuel

No.	**temp (℃)**	**Velocity (m/s)**	**dencity (g/cm^3)**	**Prodict dencity (cm^3)**	**Error (%)**
1	35	1231.134	0.7678	0.7696	-0.11
2	30	1250.822	0.7718	0.7716	0.08
3	25	1270.585	0.7753	0.7741	0.17
4	20	1290.773	0.7788	0.7772	0.18
5	15	1311.03	0.7821	0.7809	0.13
6	10	1332.257	0.7855	0.7862	-0.10
7	5	1351.59	0.789	0.7891	0.00
8	35	1243.448	0.7818	0.7837	-0.21
9	30	1262.268	0.7855	0.7857	-0.01
10	25	1282.285	0.7891	0.7895	-0.05
11	20	1302.019	0.7927	0.7931	-0.04
12	15	1321.802	0.7959	0.7966	-0.08
13	10	1342.074	0.7994	0.8009	-0.17
14	5	1362.216	0.8028	0.8047	**-0.23**
15	35	1249.746	0.7934	0.7930	0.06
16	30	1269.499	0.797	0.7965	0.05
17	25	1288.903	0.8004	0.7995	0.10
18	20	1308.86	0.8039	0.8031	0.07
19	15	1329.419	0.8074	0.8074	-0.04
20	10	1349.101	0.8107	0.8102	0.00
21	5	1368.692	0.814	0.8126	0.08

4、CONCLUSIONS

By this methods, if jet fuel, diesel and gasoline of light fuel are measured respectively, the maximum density measurement error is less than 0.23%(shown in table1). considering volume measurement error of a high precision ultrasonic flow meter is less than 0.20% , the mass flow measurement error ultrasonic flow meter will be less than 0.35% according to the formula (1). So a ultrasonic flow meter can be used in mass flow measurement. At the same time, the experimental results also has reference value on study of hydrocarbon product density and acoustic relationship.

Ultrasonic flow meter will have abroad application if it can give a mass flow. This paper proves that detecting the liquid density by use of ultrasonic delay is a feasible method in an ultrasonic flow meter. It lay the foundation of ultrasonic mass flow meter. But this method will depend on a great deal of experimental data, so for a real practical mass flow meter, the more experimental data is need to train the model, and a self-learning program is useful too.

REFERENCES

[1] Wang xionggang, Zhao Xiaokai, Oil density measuring instrument design based on ultrasonic characteristics(in Chinese),Acoustic technology, 2007.05 :90-92

[2] Li Hui, lin Weiguo, Zheng Zhiai, et al，Study on crude oil density measurement method of online pipeline(in Chinese)，measuring technique：33-36

[3] Hormic K, Stinchcombe M,White H. Multilayers feedforward networks are universal approximators [J].Neural Networks,1989,2(5):358-366