A device for water content measuring of oil

A Gorbunov¹, N Evstegneev¹

¹ Department of Thermodynamics and Heat Engines, Gubkin Russian State University of Oil and Gas (National Research University), Moscow, Russia

Evsstegneev.n@gmail.com

Abstract. The authors of the paper describe the method of water content measuring using microwaves for oil transported by pipeline. There is a description of the experimental stand used for the determination of water content of oil by using microwaves and of the methodology of the planned experiments. There is also an algorithm for the mass concentration of water in gas-saturated water-oil emulsions determination according to the results of experimental research on the experimental stand.

1. Introduction

1.1. Relevance

Relevance of quality control of producing oil increases every passing year. Period of water-free operation for almost all of oil wells is short, and water-free production takes a small part from the lifetime of the entire production process.

Introduction of GOST R 8.615 – 2005 in the Russian Federation specified accuracy of water content measurements of oil and gas and required creating of brand new devices for flow rate and water content measurements both for specific well and the whole license block.

The solution of these objectives is associated with using new measuring devices like multiphase flowmeters, which are able to ensure control of production rate. This direction of oil and gas instrumentation has got a good development in many countries (Roxar, Micro Motion, Ultraflow, Agar, Schlumberger, Framo, Ozna, Mera, Argossi, etc.) [1,2].

At the Department of Thermodynamics and Heat Engines of Gubkin Russian State University of Oil and Gas (National Research University) research work which is dedicated to estimation of possibility of microwave using for water content determination is carried out. The work includes the following steps: theoretical justification of possibility of using microwaves for water content determination, creating of an experimental stand, conduction of experiments, development of method of water content calculation, application for a patent.

1.2. Theory of microwave heating

It is well-known that heat selectivity is one of the main features of microwaves [3]. Water molecules are dipoles, and when dipoles get into electromagnetic waves, they line up to the direction of magnetic inductivity vector of the waves. Frequency of microwaves is high, therefore that direction changes...
million time per second and molecules of water start rotating. This rotation causes friction between the molecules, and their kinetic energy transforms to heat energy. As a result, temperature of water molecules increases. This doesn’t happen with oil molecules because they are not polar.

Considering that fact, it should be predicated that only water phase of oil-water mixture transporting by a pipeline will be heated by microwaves. After the microwave processing heat exchange between water and oil occurs, and their temperatures become equal. Measuring of mass flow rate and temperatures before and after the processing makes possible to calculate water content of oil.

1.3. Ultrasonic preparation

In real conditions oil transporting by a pipeline contains water inclusions of different shapes and sizes, that causes to uneven disposition of water cross section of pipeline and requires significant amount of time for temperature equalizing after the microwave processing. Authors of the paper propose to solve this problem by preparation of flow with ultrasonic waves. That transforms oil-water mixture into highly-dispersed emulsion for better heat exchange between oil and water.

Water content may be determined with high accuracy by analysis of temperatures before and after the processing, and ultrasonic preparation allows to make sector of pipeline, where microwave processing occurs, shorter. Within permanent values of microwaves capacity subtraction between temperatures depends on water and oil properties and their ratio in initial mixture.

2. Experimental stand
For realization of proposed method of water content determination experimental stand was designed and constructed (pic. 1). Stand consists in sector of a pipeline (1), through which oil-water emulsion runs. On the begging of the pipeline flowmeter (2) and ultrasonic reactor (3) are placed. On some distance after ultrasonic reactor microwave generator (5) is located which is connected with a waveguide (6). In space inside the waveguide test area (4) of the pipeline is placed. Test area (sector) made of material pervious for microwaves, in our case it is quartz. Temperature sensors (7,9) are placed before and after test area. Data from temperature sensors and flowmeter is transmitted to unit of parameters control (8).
Processing of the results which are gotten from experiments is conducted with considering of influence of gas factors of water and oil.

Conduction of the experiments on the stand is planned on 2017 year.

3. Water content calculation

Under microwaves processing temperature of water will increase from $T_0$ to $T_{mw}$ and its internal energy will increase up to a value of $\Delta U_{mw}$:

$$\Delta U_{mw} = G_w \cdot c_{pw} \cdot (T_{mw} - T_0) \cdot K_w,$$

where $G_w$ - mass flow rate of water, kg/s; $c_{pw}$ - isobaric heat capacity of water, J/(kg K); $K_w$ - coefficient gas factor of water, $K_w = f$ (gas factor).

Considering that there are no heat leaks to the environment, it is need to find the length of pipeline, within which temperatures of water and oil in the end of control area become equal to $T_1$.

Thereby, water which is heated from temperature $T_0$ to $T_{mw}$ will transmit a part of obtained heat to oil $Q_1$ and then will cool down to $T_1$ in the end of the pipeline. Transmitted heat will be equal

$$Q_1 = G_w \cdot c_{pw} \cdot (T_{mw} - T_1) \cdot K_w.$$

Quantity of heat which will be transmitted to oil on the control area for its heating to temperature $T_1$ can be determined considering oil gas factor

$$Q_2 = G_o \cdot c_{po} \cdot (T_1 - T_0) \cdot K_o,$$

where $G_o$ - mass flow rate of oil, kg/s; $c_{po}$ - isobaric heat capacity of oil, J/(kg K); $K_o$ - coefficient gas factor of oil, $K_o = f$ (gas factor).

Considering that there are no heat leaks to the environment, from the law of energy conservation it should be noticed, that heat transmitted from water to oil is equal to heat obtained from water by oil

$$Q_1 = Q_2.$$

Considering (2) and (3) equation (4) can be written as

$$G_w \cdot c_{pw} \cdot (T_{mw} - T_1) \cdot K_w = G_o \cdot c_{po} \cdot (T_1 - T_0) \cdot K_o.$$

Because mass flow rate of emulsion is equal to addition of mass flow rates of water and oil

$$G = G_o + G_w.$$
It is possible to determine mass flow rate of water from equation (5)

\[ G_w = \frac{G \cdot c_{po} \cdot (T_1 - T_0) \cdot K_o}{c_{pw} \cdot (T_{mw} - T_1) \cdot K_a - c_{po} \cdot (T_1 - T_0) \cdot K_o}, \]  

(7)

and water content of emulsion

\[ m_w = \frac{G_w}{G} = \frac{c_{po} \cdot (T_1 - T_0) \cdot K_o}{c_{pw} \cdot (T_{mw} - T_1) \cdot K_a - c_{po} \cdot (T_1 - T_0) \cdot K_o}, \]  

(8)

It is necessary to specify described theoretical relation \( \Delta U_{mw} \) (1) for each specific construction and sizes of a device and determine relation of \( T_{mw} \) from different flow rate values. Coefficients \( K_a \) and \( K_o \) are features of specific oilfield, and they are determined empirically in every single case.

Obtained theoretical and experimental relations are entered to unit of parameters control. Program for water content calculation is specified after calibration of a device.

References

[1] Yermolkin O.V. Modern measuring devices and equipment for oil and gas production (interview). Gazovaya promyshlennost’, 2014, no. 1 (701), pp. 56–60 (In Russian).

[2] Rekomendatsiya MI 2825-2003. Sistemy izmereniy kolichestva i pokazateley kachestva nefti. Metrologicheskiye i texnicheskiye trebovaniya k proyektirovaniyu [Recommendation MI 2825-2003. measurement system oil quantity and quality. Metrological and technical requirements for the design]. Moscow, FGUP VNIIR Publ., 2003. 52 p.

[3] Rushchits A.A., Shcherbakova Ye.I. The use of microwave heating in the food industry and public catering. Vestnik Yuzhno-ural’skogo gosudarstvennogo universiteta, 2014, vol. 2, no. 1 (In Russian)