Determination of water saturation of oil reservoirs with the using of fuzzy logic method

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Abstract

Determination of water saturation is necessary to estimate the probability of producing a volume of oil for a given reservoir size. To obtain information about the technical condition of wells and successfully conduct development in conditions of inaccurate data, it is necessary to study the reservoir and filtration properties of reservoirs using the possibilities of fuzzy logic theory. Therefore, the paper considers a method that does not require all porosity values**.**

Key words: rock, porosity, logging, water saturation, cross-plot, fuzzy logic; fuzzy c-mean clustering

The development of oil fields requires knowledge of the nature and dynamics of well injectivity, including the possibility of maximum reservoir coverage with injected water. Injection into wells of fresh water from open reservoirs and effluents from oil fields leads to siltation of the filtration surface with introduced suspended solids, resins, oil products and salts. At the same time, there is a decrease and often a complete loss of reservoir injectivity and, ultimately, a decrease in oil production.

Insufficient reservoir coverage is observed due to the geological structure of the reservoir, heterogeneity, reservoir properties of rocks, namely: porosity, permeability, residual oil and water saturation of the reservoir. [1,2] In this regard, in order to increase the injectivity of productive rocks, it is of great importance to consider the distribution of water in the pores of the productive formation, which significantly affects the phase permeability of rocks for oil, water and gas, that is, the exploitation of oil and gas deposits is due to filtration huge masses of liquids in a porous medium, the properties of which determine the patterns of oil and water filtration, well flow rates, and reservoir productivity.

Water saturation characterized by both the wettability of rocks by displacing fluids, the intensity of capillary processes in the formation, and the amount of oil in the pore space of the formation. The water saturation value can be used to determine the likelihood of hydrocarbon production as well as to estimate the volume of oil for a given reservoir size. [3]

Nowdays uses a maschine learning method, which is a a class of artificial intelligence methods, the characteristic feature of which is not the direct solution of the problem, but learning through the application of solutions to many similar problems. [11] Alrumah and Ertekin have predicted water saturation around vertical and horizontal wells with the using an artificial neural network. The main advantage of neural network model is possibility to create modeling process which does not require the data that are often difficult to obtain in practise. Most currently in useprocess automation applications,

Fuzzy logic allows you to apply the experience of operators and process control technologists.But, the disadvantage of this model is the process is not available for other estimations. The development of a fuzzy rule base is interactive process. For the most part, this is a collection of knowledge and experience. One of the benefits of fuzzy logic is the ability to build a rule base approved specialists before checking its work in real conditions. The qoal of this paper is to determine water saturation of the drilling process at various depths using a fuzzy system. Here, the water saturation prediction is based on the variables of depth. A method for determining the parameters of a fuzzy inference system is described the Takagi-Sugeno system. The properties that must satisfy both systems as universal approximators for their identity.An algorithm for the formation of membership functions of the right parts of the rules of the system is given Mamdani and the method of forming the system as a whole. Fuzzy rule formation uses fuzzy c-means clustering (FCM) and zero-order Sugeno fuzzy logic. The FCM method is used for determining the most optimal number of rules used in the setting of fuzzy rules.

Consider ways to measure water saturation. To characterize the water saturation of reservoir rocks, the water saturation coefficient S_w is used. The water saturation of a formation is defined as the ratio of the pore volume or the proportion of the pore space (Fig. 1) occupied by water to the total volume of the pore space. To determine Sw, many other petrophysical parameters must be known, which can be obtained from well logging or laboratory core measurements. The total volume of water per unit volume of rock is the product of εS_w, and the total volume of hydrocarbons is $\varepsilon(1 - S_w)$

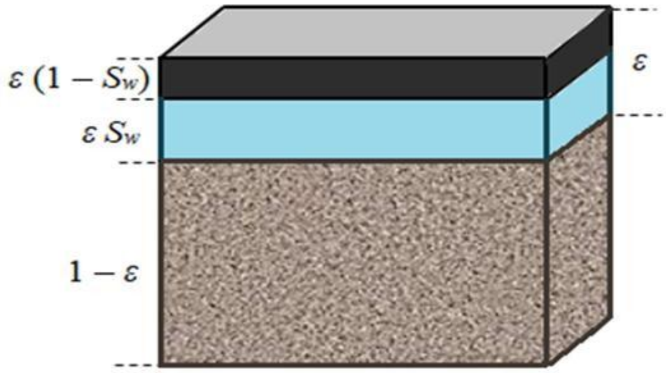

Figure1. Determination of water saturation of the rock.

Fuzzy Logic of Zero-Order Sugeno

Fuzzy logic inference systems clear predicate rules If ... Then . Every rule of thumb the (referred to the tors of the following). Sugeno fuzzy logic model is an approach to produce fuzzy rules from the applied input-output data. Zero-order Sugeno fuzzy logic is stated in the following formula. If $x1\ is\ A1,\ \ldots,\ and\ xn\ is\ An, then\ z = b$ where $(x1, \ldots, xn)$ is the input of fuzzy logic, Ai is the fuzzy set on the i-th input, b is a real constant.

In contrast to some other types of fuzzy inference, fuzzy systems Takagi - Slowly generates clear numerical values. The most importantly, the following is a referral to the same, The following is the same
In the consequent of the rules. The reference is being referred to the reference to the following
The basis of the dependence between the blocks of fuzzy rules, allowing the construction
The initialization of matrix $U = [uij]$, U 0 ii. In the k-th step calculate the center of vector C (k) = [cj] with U k $Ci = \sum uij\ mxj\ n\ j$=1 $\sum uij\ n\ m\ j$=1 (1) iii. Update U k, U (k+1) iv. $dij = \sqrt{\sum}\ (xi - ci)\ n\ i$=1 a. uij = 1 $\sum$ (j) 2 m−1 $c\ k$=1 v. If | $(k + 1) - (k)$| < ε then, stop. Here after, the data were divided into 75% for training data and 25% for testing data. Furthermore, the input variables used in this study are depth,effective porosity, effective porosity of density-neutron log, total porosity, and total porosity of density-neutron log. The output variable of the fuzzy system is water saturation. The next step was the clustering process using FCM, which was followed by the fuzzification and processing of the fuzzification results data using the zero-order Sugeno fuzzy system.
The obtaining of the optimal cluster is provided through a try and error method to get the lowest MAPE value for training and testing data. The results are presented in Table 1.

Table 1. The results of error method

Data	MAPE Training	Testing	Mean MAP
10	27.71424	29.1206	28.91746
11	24.94677	28.8411	28.89395
12	30.48908	27.639	27.56409
..	…	…	…

150	15.55787	15.2627	15.41031
151	14.16582	13.6453	13.90558
152	14.22539	14.1753	14.20036
…	…	…	…
481	10.98571	10.8308	10.90829
482	10.72528	10.5390	10.63216
483	10.93887	10.4922	10.71557
484	9.939734	9.34355	9.641644

After that, the obtained center was then used to create a zero-order Sugeno fuzzy rules with 3 fuzzy rules. The obtained center matrix can be seen in Table 2.

Table 2 The center of optimal cluster

Clust	Depth	PHIE	PHIE_DN	PHIT	PHIT_DN	SWE
1	1570.6344	0.1575109	0.1575110	0.1575115	0.1575116	0.2079081
2	1665.3021	0.1753974	0.1753982	0.1754032	0.1754039	0.1768089
3	1456.9996	0.2009874	0.2009879	0.2010350	0.2010355	0.1890310

Based on Table 1, 3 optimal clusters are obtained and therefore there are zero-orderSugeno fuzzy rules which can be stated as follows:

“IF x1 = DEP1 and x2 = PHIE1 and x3 = PHIE_DN1 and x4 = PHIT1 and x5 = PHIT_DN1, THEN y =b1”

“IF x1 = DEP2 and x2 = PHIE2 and x3 = PHIE_DN2 and x4 = PHIT2 and x5 = PHIT_DN2, THEN y =b2”

“IF x1 = DEP3 and x2 = PHIE3 and x3 = PHIE_DN3 and x4 = PHIT3 and x5 = PHIT_DN3, THEN y =b3”

Conclusion

In this research was done the prediction of water saturation. The method of fuzzy logic is proposed is the reality of the reference is the same of the following. Taking into account the hierarchy of blocks of fuzzy rules this method makes it possible to reduce the dependence of the result and input data.This method allows more unmistakable prediction results and create a transparent water saturation prediction process by describing it through fuzzy rules. In general, our results demonstrate that the proposed methods provide a reliable determination of the water saturation value Sw and the possibility of using them in the study of any carbonate or shale-sand reservoirs.

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