APPLICATION OF HYDRAULIC FLOW UNITS FOR ENHANCED RESERVOIR DESCRIPTION

I.R. Nabokin
Scientific advisors associate – professor O.S. Chernova, associate professor V.P. Merkulov
National Research Tomsk Polytechnic University, Tomsk, Russia

At present, the depletion of oil and gas reserves from fields with a relatively isotropic and homogeneous geological structure is increasing, as a result of which oil engineers need to develop complex, heterogeneous reservoirs. For the successful production of oil and gas detailed study of the enclosing strata is required. Despite the significant development of petroleum engineering, the evaluation of geological formations in order to predict the reservoir properties remains one of the most difficult aspects.

The most widely used method for determining porosity and permeability in Russian industry is the correlation of core data with the results of well logging. This approach has a certain share of the error when it is used in a heterogeneous geological section, since it is practically impossible to determine single correlation dependence for the whole interval. On the other hand, the technique of hydraulic flow units allows achieving an acceptable level of description and assessment of the reservoir by taking into account its heterogeneity.

The purpose of the paper is to justify the effectiveness of the application of the hydraulic flow units technique to determine the reservoir properties of rocks building up a reservoir, the accuracy of which are critical for simulation and modelling.

According to J.O. Amaefule [1], the "hydraulic flow unit" is defined as the representative elementary volume of the rock within which the geological and petrophysical properties affecting the fluid flow are mutually consistent and predictably different from other rocks. In other words, this is the zone of the reservoir, which is sufficiently sustained laterally and vertically and has the same fluid flow characteristics. The main parameters of the hydraulic flow unit are associated with facies, but their boundaries may not correspond to facies ones. The parameters that affect the fluid flow directly depend on the geometry of the pore throats. Thus it can be said that, facies can include a number of hydraulic flow units due to differences of pore geometry.

The basic equation used in the theory of hydraulic flow units is derived by the transformation of the Kozeny-Carman equation [2]:

$$0{,}0314\sqrt{\frac{k}{\phi_e}} = \left[\frac{\phi_e}{1-\phi_e}\right]\frac{1}{\sqrt{F_s}\tau S_{gv}}$$

where: k – permeability,
φe – effective porosity,
Fs τ – Kozeny coefficient,
Sgr – specific area.

The equation may be represented as:

$$Rqi = \phi_z \cdot Fzi$$

where: Rqi – reservoir quality index;
Fzi – flow zone indicator;
φz – normalized porosity.

The determination of the Fzi parameter is the basis of the reservoir classification used in the theory of hydraulic flow units.

The use of the technique for predicting the reservoir properties consists of determining the number of hydraulic units based on the base wells in which the core was sampled in the production interval. This step can be performed in three different ways:

1. cross-plot log (Rqi) = log (φz) + log (Fzi);

2. Analysis of the probability density distribution;

3. cluster analysis.

After determining the number of Hydraulic Flow Units, the correlation dependencies are distributed into wells in which the core has not been selected. Three methods are most commonly used:

1. Unmodified Lorentz plot.

2. Statistical correlations. In this method, using the regression method, a correlation is established between permeability and a set of logs. Thus, instead of establishing a correlation with one variable (porosity), the dependence of the aggregate data (permeability-logs) is determined.

3. Mathematical correlations. In the method, polynomial and power-law correlations of permeability and logs are determined.

After the distribution of the correlation dependences, a direct calculation of the permeability of the reservoir is made.

As a result of the science and technology development, more advanced tools are now being developed to apply the technique of hydraulic flow units, as a consequence of which there is a necessity of research in this direction. In addition, the method will allow determination of correlation dependences for water saturation and clay volume.

As a further work, it is planned to produce a complete cycle of log data interpretation, modelling and simulation using the described technique and consideration of possible risks using real field data.

References

1. Applications of core data in hydraulic (flow) unit zonation for improved reservoir description: Workshop on core analysis for reservoir management, - June 1994/. – Vienna, 1994. – 10 p.
2. Abbaszadeh M. et al. Permeability prediction by hydraulic flow units-theory and applications //SPE Formation Evaluation. – 1996. – Т. 11. – №. 04. – С. 263-271.

DEACTIVATION PATTERNS OF ZEOLITE-CONTAINING CATALYSTS OF CATALYTIC CRACKING

Nazarova G.Y., Shafran T.A., Kislinskaya A.A.
Scientific supervisor – professor E.N. Ivashkina
National Research Tomsk Polytechnic University, Tomsk, Russia

The various feedstock types are processed during a catalytic cracking: vacuum and atmospheric gasoils, residues of secondary refining processes, fuel oil, etc. With increasing the boiling point of fractions, the content of resinous compounds and metals rises. It has a significant effect on the catalysts deactivation which is lead to loss of the catalyst operational properties.

The reason of the activity chemical loss of the zeolite catalysts is the coke adsorption at acid sites. The catalyst deactivation by coke is a reversible process, the catalyst activity is generally recovered during regeneration. The catalysts deactivation, the accumulation and the amorphicity degree of coke (C/H ratio) undoubtedly depend not only on the feedstock characteristics, process conditions, but also the type and chemical composition of the catalyst (acidity, pore size and porous structure of the zeolite) [3].

Deactivation by heavy metals, including nickel and vanadium, lead to an irreversible activity loss and a change in the catalyst selectivity due to their deposition on the active surface, the pore space blocking and the catalyst structure destroying. It has a significant problem for refineries at increasing the consumption of the expensive catalyst.

Forecasting of the activity and the deactivation degree of the catalyst using mathematical models that are sensitive to the concentration of decontamination factors and take into account not only the feedstock nature, but also the structure-selective properties of the catalysts is an important step at the existing industrial catalytic cracking units optimization.

The aim of the work is to predict the activity of the regenerated catalysts depending on the nickel and vanadium concentrations in the feedstock taking into account its composition using the mathematical model. Reversible deactivation of the catalyst is taken into account by introducing into the model a function ψ= f(Ccoke) which is depend on the coke concentration formed on the catalyst in the reactor in accordance with the formalized scheme of hydrocarbons conversions [4]. Thus, the calculation of the relative activity of the coked catalyst concerning ZSM-5 (AZSM-5) and Y (AY) type reactions is described by an exponential dependence determined from experimental data, taking into account the acid and structural properties of the catalyst zeolites:

$$A_Y = A_0 \cdot e^{-0{,}077 \cdot C_к} \qquad A_{\text{ZSM}} = A_0 \cdot e^{-0{,}113 \cdot C_к}$$

here AY, AZSM – the relative activity of the coked catalyst concerning Y and ZSM-5 type reactions, respectively; A0 – the relative activity of the regenerated catalyst, depended on the concentration of the residual coke on the catalyst and the heavy metals in the feedstock, –0.077 и 0.113 – deactivation constants determined experimentally on the basis of the zeolites acidity data, Cк – coke content on catalyst, wt%.

The rate and degree of the coke formation increase with rising the zeolite acidity, the coke yield decreases with decreasing the pore size at equal acidity of the zeolite. However, deactivation is faster for the zeolite with the small pores (ZSM-5), because a relatively small amount of coke results in a significant catalyst activity loss [6]. Thus, the deactivation degree of ZSM-5 is higher in comparison with Y zeolite due to the stronger acidity of ZSM-5 zeolite [1] and a smaller pore size (0.2 nm less than for Y zeolite).

The catalyst deactivation degree depends on the regenerated catalyst activity (A0), which largely depends by heavy metals. The joint effect of heavy metals in the cracking feedstock is taken into account at prediction of the regenerated catalyst activity. Thus, deactivated effect of vanadium (dealumination) is reduced with increasing the nickel content, but dehydrogenation capacity of the catalyst and the content of coke on the catalyst increase.

To account for the nickel deactivation effect on the catalyst, the dependence of the dehydrogenation capacity of the catalyst (ϒ) on the metal content is revealed, characterizing the intensity of hydrogen formation during the dehydrogenation, aromatization, condensation and coke formation reactions of catalytic cracking:

$$\text{ϒ} = 0{,}142 \cdot e^{1{,}1554 \cdot \text{CNi}}$$

here CNi – the nickel content in the feedstock, ppm.