reduce the risk of pipe sticking, which will reduce the unplanned drilling time for the well KHRIR-1-40 by 63% (451 hours) and save more than one million dollars in unplanned downhole time.

It can be concluded that it is more profitable for drilling companies to purchase the FMEA method, since, despite the fact that it can be used more expensively at all of the company's fields, instead of the ARIMA model, it is more economical, but it must be purchased for each field for which it will be implemented. Both methods reduce the risk of sticking problems, which can save the company $ 1,658,633.68 over two years of use [4].

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## PREDICTING THE YIELD OF TARGET PRODUCTS AND COKE FROM THE CATALYTIC CRACKING PROCESS UNDER CONDITIONS OF VARYING FEEDSTOCK COMPOSITION


**Arkenova S.B.[1], Nazarova G.Y.[1], Oreshina A.A.[1], Kaliyev T.A.[1,2]**

Scientific advisor professor E.N. Ivashkina E.N.[1]

***[1]National Research Tomsk Polytechnic University, Tomsk, Russia***

***[2]Pavlodar oil chemistry refinery LLP Pavlodar, Kazakhstan***


Catalytic cracking is considered one of the main processes in the refining industry for the production of high quality components for motor fuels and rich in propane-propylene and butane-butylene fractions wet gas. Currently, catalytic cracking involves various raw materials (vacuum and atmospheric gas oils, heavy residues of secondary refining processes, etc.), depending on the type of which, the technologies and process catalysts differ significantly. The processing of heavy feedstock with a high content of aromatic hydrocarbons, resins and heavy metals leads to an increase in the amount of coke formed on the catalyst surface, thereby affecting the heat balance of the "lift-reactor-regenerator" system and, as a consequence, to the formation of a low yield of gasoline fractions and gas. Thus, to simulate the process adequate, mathematical models should take into account the constantly changing group composition of the processed raw materials [1]. At the same time, the creation of an adequate model of catalytic cracking is complicated by the difficulty of identifying groups of hydrocarbons and the lack of analyzes to determine the group composition of feedstock in refinery laboratories. Thus, the development of a methodology for the relationship of such parameters as regular physical properties (fractional composition, density, viscosity) with the component composition of feedstock is relevant.

The purpose of this work is to develop an algorithm for calculating the group composition of vacuum gas oil based on its physical properties and to study the effect of the group composition of feedstock on the yield of target products and coke in catalytic cracking technology using a mathematical model of the process.

As a result of the performed numerical and experimental studies, a method was developed for calculating the group composition of vacuum gas oil based on the relations between the physical parameters of oil product [2]. The calculation error does not exceed 3%. The empirical formulas for determining the molecular weight and refractive index used in the calculation take into account the degree of paraffin content of fraction [3]:

$$MW = (7K - 21{,}5) + (0{,}76 - 0{,}04K)T_{av.m.} + (0{,}0003K - 0{,}00245)T_{av.m.}^2$$

$$n_D^{20} = 2{,}1500 - 10^{(\lg MW - 1{,}9939436 - 0{,}0019764 * T_{av.m.})},$$

where $MW$ – molecular weight of fraction, g/mol., $n_D^{20}$ – refractive index of fraction at 20 °C, $T_{av.m.}$ - average molar boiling point, °C; $K$ - characteristic factor:

$$K = \frac{1{,}216\sqrt[3]{T_{av.m.}}}{\rho},$$

where $T_{av.m.}$ - average molar boiling point, °K; $\rho$ – density of fraction at 15 °C, g/cm$^3$.

The developed technique is based on a system of three equations:

$$\begin{cases} x_p + x_N + x_{A+R} = 1 \\ 1{,}048 \cdot x_p + 1{,}03 \cdot x_N + 1{,}07 \cdot x_{A+R} = Ri \\ 0{,}74 \cdot x_p + 0{,}89 \cdot x_N + 0{,}95 \cdot x_{A+R} = VGC \end{cases}$$

The first equation is the molar balance of the group composition of vacuum gas oil, the second and third equations are additive law for refractivity intercept (Ri) and viscosity gravity constant (VGC). Determination of the group composition of heavy fractions on the basis of viscosity gravity constant and refractivity intercept was proposed by the authors in [4]. The

values of the average refractivity intercept of paraffins, naphthenes and aromatic hydrocarbons were 1,048, 1,03, 1,07, and their values of the average viscosity gravity constant were 0,74, 0,89, 0,95, respectively.

The system of equations is solved by Cramer's method with respect to $X_P$, $X_N$ and $X_{A+R}$ and the following expressions were obtained to calculate the molar concentration of hydrocarbon groups:

$$\begin{cases} x_p = -3{,}70056 + 8{,}474576 \cdot Ri - 5{,}6497 \cdot VGC \\ x_N = 28{,}7853 - 29{,}6610 \cdot Ri + 3{,}1073 \cdot VGC \\ x_{A+R} = -24{,}0847 + 21{,}1864 \cdot Ri + 2{,}54237 \cdot VGC \end{cases}$$

The final step in calculating the group composition is the conversion of the molar fractional concentration of hydrocarbon groups into a mass percentage, knowing their average molecular weight.

The group composition calculating module is programmed into the kinetic model of catalytic cracking, which will make it possible to predict the yield and quality of cracking products, including the mass of coke formed on the catalyst surface when the composition of the processed feedstock changes. The software implementation is made in Python (Fig. 1).

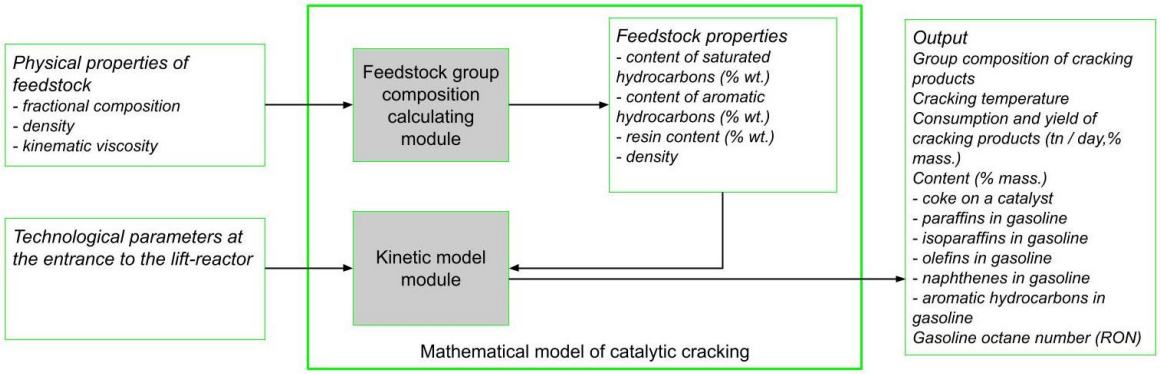


***Fig. 1 Scheme for calculating the yield of cracking products and coke with a change in the composition of feedstock***

Using the developed kinetic model based on a group approach, four samples of catalytic cracking feedstock were studied (Table 1).

***Table 1***

***Calculated values of saturated, aromatic hydrocarbons and resins concentrations in vacuum gas oil***

| Group composition | Feed 1 | Feed 2 | Feed 3 | Feed 4 |
|---|---|---|---|---|
| Saturated hydrocarbons,% wt | 75,4 | 64,0 | 55,5 | 50,1 |
| Aromatic hydrocarbons,% wt | 22,5 | 33,3 | 41,3 | 46,0 |
| Resins,% wt | 2,1 | 2,7 | 3,2 | 3,9 |

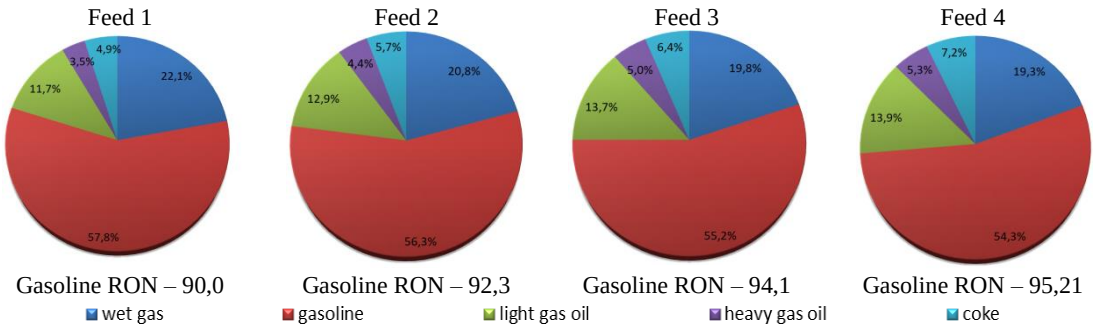


***Fig. 2 The yield of products and coke depending on the composition of the feedstock of catalytic cracking***

In accordance with Figure 2, with an increase in the concentration of paraffinic and naphthenic hydrocarbons in the feed from 50.1 to 75.4% wt. the output of gasoline increases from 54.3 to 57.8% wt. and gaseous products from 19.3 to 22.1% wt. A high content of aromatic hydrocarbons (46% wt.) and resins (3.9% wt.) in feed 4 contributes to a high rate of the coke formation reaction up to 7.2% wt., which leads to a decrease in the activity of the catalyst and the degree of conversion of feedstock and an increase in the production of heavy products: light (13.9% wt.) and heavy (5.3% wt.) gas oil. At the same time, the high content of aromatic hydrocarbons contributes to the high octane number of cracked gasoline.

The development and application of the methodology for group composition calculating in combination with kinetic model of catalytic cracking ensures the sensitivity of the model to the composition of the feedstock when predicting the effective

operating modes of the reactor-regenerator unit without the need for long experiments, which makes it possible to flexibly respond to changes in the composition of feedstock and market demand for oil products.

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## IMPROVING THE EFFICIENCY OF HYDRAULIC FRACTURING THROUGH FRACTURE GEOMETRY MODELLING


**Baffuor P.**

Scientific advisor professor Zyatikov P.N.

***National Research Tomsk Polytechnic University, Tomsk, Russia***


Hydraulic fracturing is considered to be one of the most used methods of enhancing oil recovery in Russia and beyond. It involves the creation of tensile cracks known as hydraulic fractures at specific intervals in the wellbore to increase hydrocarbon access in the reservoir.

These fractures are characterized by their height (*h*), length (*x*) and width (*w*). The ratio between the area of a fracture and that of an open hole wellbore is calculated using the formula below:

$$\frac{4x_f h}{2\pi r_w h} \approx \frac{x_f}{r_w} \qquad (1)$$

Where $x_f$ – fracture half-length, $r_w$ – wellbore radius and $h$ – fracture height.

Fractures are longer than the radius of the wellbore in which they are created, as well as the fracture area in contact with the reservoir rock compared to the area of the wellbore.

**Mechanical Properties**

In-situ stresses and the stress profile of a formation are necessary parameters needed in confining a fracture treatment in the productive interval during its design. The in-situ stresses control fracture orientation that is vertical and horizontal, its azimuth, height growth, width, treatment pressure and fracture conductivity.

Fractures grow perpendicular to the direction of the minimum in-situ stress; thus, stress direction can affect well-placement and spacing decisions [1]. The figure below illustrates the effects of stresses on fracture propagation.

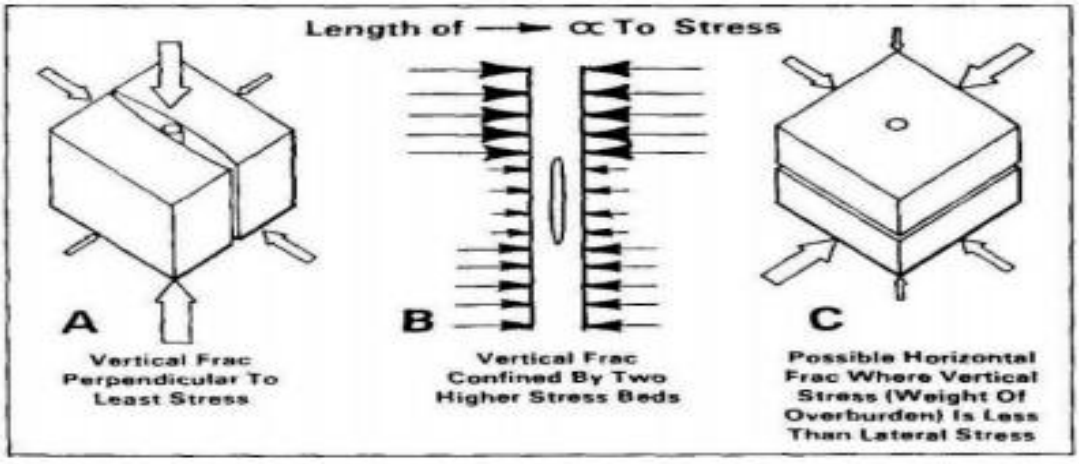


***Fig. 1 Effect of stress field on fracture propagation (John L. Gidley, 1990)***

**Fracture Models**

The different kinds of hydraulic fracture models, necessary for calculation of the fracture geometry include:

- **2D Models:** Perkins-Kern Nordgren (PKN), Khristianovich- Geertsma-DeKlerk (KGD)
- **Pseudo-3D Models:** MFRAC, StimPlan, e-StimPlan and FracCade
- **Lumped Parameter Models:** FracPro, FracPro-PT
- **3D Models:** GOHFER, N-StimPlan, Terra-Frac