APPLICATION OF MATHEMATICAL STATISTICS IN DRILLING

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Abstract- The article is devoted to questions to determine the values of hydraulic fracturing. There are several ways to determine the value of the hydrofracturing pressure. We have given specific recommendations of their choice. In connection with this there are mentioned results on the application of mathematical statistics in the article to determine the hydraulic fracturing pressure in drilling.

Keywords- Hydraulic fracturing, drilling, density of drilling fluid, rotor, the hydrodynamic pressure.

INTRODUCTION

It is known that in determining the design of wells, particularly the depth of the descent of the conductor string, and to regulate speed of production of technological procedure in the process of drilling wells it is necessary to know the magnitude of the hydraulic fracturing pressure (HFP).

There are several ways to determine the meaning of HFP, but there is no specific recommendations of their choice, depending on the geotechnical conditions of hole making. In this paper weattemptto solve this issue.

It is recommended to use statistical methods in areas where many wells have been drilled. Determination of the fracturing pressure gradient (Pp/H) by means of processing of field data are given in works (1), in which it is not considered the combined effect of hydrodynamic and hydrostatic pressures at values Pp/H.

In solving the problem by the statistical method, field data have been gathered, i.e., the density of the drilling fluid and value of hydrodynamic pressure in the annular space at the depth at which fracturing occurred. Based on the collected field data statistical relationship is installed between the factors Xi, H - hydrodynamic pressure occurring in the annular space at a depth H and the exponent y = ρ (ρ - density of the drilling mud) and is determined regression equation by the method of correlation and regression analysis.

There accepted two-levels of factors' change: the upper (+) and lower (-), which are measured from the baseline.

Calculations are made according to the plan given in Table 1.

Table 1.

Number of experiment	Factor		Index
	X_1	X_2	
1	-	-	y_1
2	+	-	y_2
3	-	+	y_3
4	+	+	y_4

Basically, for the evaluation of statistical communication it is used standardized correlation coefficient, which is calculated by the formula:

$$r_{xy} = \frac{1}{(N-1)\sigma_x\sigma_y}\sum_{i.j}^{N}(x_i-\bar{x})(y_i-\bar{y}) = \frac{1}{(N-1)\sigma_x\sigma_y}[(x_1-\bar{x})(y_1-\bar{y}) + (x_2-\bar{x})(y_2-\bar{y}) + (x_3-\bar{x})(y_3-\bar{y}) - (x_4-\bar{x})(y_4-\bar{y}) + (x_5-\bar{x})(y_5-\bar{y}) + \cdots + (x_N-\bar{x})(y_N-\bar{y})] \quad (1)$$

Where expectations (average values) are:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \; \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \quad (2)$$

Dispersion

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2; \qquad y_x^2 = \frac{1}{N-1}\sum_{j=1}^{N}(y_i-\bar{y})^2 \quad (3)$$

In (2) and (3), N - number of experiments in the planned experiment. The reliability of the value of the correlation coefficient is estimated by reliability criterion:

$$Q_r = \frac{|r_{xy}|}{\sigma_r}$$

where, σ_r - the standard deviation of the correlation coefficient that is equal:

$$\sigma_r = \frac{1-r_{xy}^2}{\sqrt{N}}$$

When the criteria for reliability Q> 2.6 with a probability of 0.95, it has can be assert the existence of a linear correlation between the analyzed parameters.

Further there has been constructed generalized standardized correlation matrix in the forms of that is shown in the Table 2:

Table 2

Factors	Correlation coefficient			$\bar{y}, \bar{x}$	σ_{xy}
	y_1	x_1	σ_{xy}		
y	I	r_{yx1}	σ_{xy}	$\bar{y}$	σ_y
x_1		I	$r_{x_1x_2}$	$\bar{x}_1$	σ_{x_1}
x_2			I	$\bar{x}_2$	σ_{x_2}

Results of correlation analysis allow us to make an empirical relationship, i.e, present the regression equation in the form of:

$y_1 = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + ...+a_nx_n$
where, a_1, a_2, a_3, ….a_n – coefficients determined from the system of equations;
$\sigma_1 r_{yx_1} = a_1 \sigma_{x_1} r_{x_1x_2} + a_2 r_{x_1x_2} \sigma_{x_2} + ... + a_n r_{x_1x_n} \sigma_{x_n}$
$\sigma_2 r_{yx_1} = a_1 \sigma_{x_1} r_{x_1x_2} + a_2 r_{x_1x_2} \sigma_{x_2} + ... + a_n r_{x_2x_n} \sigma_{x_n}$

$\sigma_n r_{yx_n} = a_1 r_{x_1} \sigma_{x_1} + a_2 r_{x_nx_2} \sigma_{x_2} + ... + a_n r_{x_nx_n} \sigma_{x_n}$
Coefficient

$$a_o = \bar{y} - \sum_{i=1}^{n} a_i \bar{x_i}$$

Solving the system of equations, we find the regression equation.
In the paper / 1 / on the basis of the field data there has been established statistical connection between the factor xi = P, H (H - depth of the well, P - hydrodynamic pressure in the annulus) and a measure of y = ρ1 (ρ1 - density of drilling mud) and is determined the regression equation by the method of correlation and regression analysis / 2 /. Below is an example of defining HFP values using the above mentioned method for Kurovdag area in Azerbaijan.

Table 3

Factors	Levels			Variability interval
	-	+	basic	
x_1	900	2500	1700	800
x_2	4.0	4.3	4.15	0.15

Table 3

x_1	x_2	y
900	4.0	1400
2500	4.0	1960
900	4.3	1450
2500	4.3	2000

Based on field data in the Kurovdag area for the base level we can take x_1 - seam depth (1700 m) and x_2 - hydrodynamic pressure in annulus (4.15 MPa). These values were obtained by determining the upper (+) and lower (-) factor level changes. Calculations performed according to the plan of Table 2, changes of factors and results are given in Table 3.

To construct a standardized correlation matrix we determine the correlation coefficients according to the following formula:

$$r_{xy_1} = \frac{1}{(N-1)\sigma_x\sigma_y} \sum_{i,j}^{N} (x_i - \bar{x})(y_1 - \bar{y})$$

Where,

$$\overline{x_1} = \frac{1}{N}\sum_{i=1}^{n} x_1 = 1700$$

$$\bar{y} = \frac{1}{N}\sum_{i=1}^{n} y = 1700$$

$$\sigma_x^2 = \frac{1}{(N-1)}\sum_{i=1}^{n} (x_i - \bar{x}) = 853333.33$$

$\sigma_ч$=923.76

Similarly calculated the correlation coefficients r_{yx_2} and $r_{x_1x_2}$, which are summarized in the table, called the normalized matrix. Using correlation analysis, solving the system of equations according to / 2 /, we find the equation regression for these materials by means stratigraphic succession of area Kurovdag:

- for Apsheronline
$y=0.0022871+0.00000336x_1+0.002175x_2$;
- for Akchagil suite
$y=0.0052324+0.00000215x_1+0.0017917x_2$; (4)
- for pay section
$y=0.0058806+0.00000254x_1+0.000874x_2$

According to (4), calculations have been made and the results are summarized in Table 4. The results are satisfactory and, using the above mentioned method, it is possible to determine fracturing pressure for each area on the stratigraphic succession.

Table 4:
The values of the fracture pressure gradient

	Fracturing pressure gradient for space, kgs/sm², m								
	Kursangi area			*Neftachala area*			*Bahar are*		
	P пл/H	*P гр/H*	*P p/H*	*P пл/H*	*P гр/H*	*P p/H*	*P пл/H*	*P гр/H*	*P p/H*
1000-1500	-	-	-	0.125	0.165	0.181	-	-	-
1500-2000	-	-	-	0.125	0.165	0.194	-	-	-
2000-2500	0.120	0.162	0.148	0.125	0.163	0.217	0.115	0.159	0.151
2500-3000	0.140	0.175	0.193	0.165	0.182	0.226	0.120	0.162	0.164
3000-3500	0.153	0.184	0.217	0.165	0.193	0.221	0.120	0.162	0.164
3500-4000	0.153	0.184	0.218	0.182	0.203	0.226	0.120	0.162	0.174
4000-4500	0.166	0.195	0.204	0.182	0.203	0.228	0.120	0.162	0.182

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