COMPUTER-AIDED DRILLING ANALYSIS

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ABSTRACT

There are many characteristics of a drilling operation that are under the control of the driller: weight on bit, rate of penetration, mud weight and mud flow rate, to name a few. It is difficult for even the most experienced driller to keep track of all these functions at once. This paper presents a computer program that may help to give a more accurate picture of downhole conditions.

The software will also provide an ongoing comparison of the present drilling conditions to a database of existing formations, to help determine the exact formation or strata being penetrated. This will be of benefit in locating casing seats, lost circulation zones and areas of abnormal pressure.

INTRODUCTION

This report proposes a statistical way to compare two sets of analogous information in such a way that many independent variables can be normalized versus a common denominator. The specific application detailed is the companion of ongoing drilling parameters against a database of geological data. The objective is to pinpoint the exact strata or formation being drilled at the time, or at least to provide additional information to aid in this determination.

The benefits of such a tool can be significant. Casing seats can be located more accurately to reduce the threat of abnormal pressure to the well integrity. Mud weights can be tailored to counter known formation pressures to reduce the problem of lost returns and to maximize the rate of penetration while drilling.

The instrumentation needed to implement such a statistical survey tool is simple and, in many cases, already in place. The data to be gathered and evaluated might include, but would not necessarily be limited to, the following ongoing drilling functions:

1. Rate of drilling rotation.
2. Weight on bit.
3. Pump flow rate.
4. Pump pressure.
5. Mud temperature.
6. Bit type.
7. Mud weight.
8. Mud viscosity.

These data will be measured and studied on a number of drill wells in a common field for typical values of each for any given formation type. The characteristic values need not be very accurate, but unique readings that can be rated, for example, as low, medium and high. These are judgmental figures that can be refined as investigations continue.

DATA COMPARISON

The end use of the systems will be the comparison of drilling data at an active drill well with figures recorded on file from nearby drill wells. Each parameter will be compared versus the file data on the basis of the low, medium and high ranges, plus sensitivity. The latter is, again, a judgmental function that is an indication of the formation's response to change, in, say, weight on bit.

The entire set of data is compared against a target line that signifies a perfect fit. Each parameter is rated on an individual basis by moving in the X and Y directions from the norm according to the function:

Range x Sensitivity (1)

Where range = 1, 2, 3
Sensitivity = 1,2,3

If the multiples of the known formation and the unknown one are the same, then the point will end back on the normal line. The more they vary, the further from the line the data point will be. When all these comparisons are made a least squares fit can be calculated of the resultant line, and the degree to which this line differs from the diagonal norm indicates the similarity between the formations. A rapid comparison by computers of the present data to all other formation sets on file will produce the best fit.

The range of each parameter is used to determine the allowable values, between 0 and 3. For example, consider a mud weight between 10 and 20: 10 - 13 would be a 1, 13-17 a 2 and 17 - 10 a 3.

In the attached diagram the target curve is at 45 degrees, meaning both the target and sample are identical. If the mud weight is point #2, and the target is 15 and the sample 20, then the final point will be offset from the diagonal as shown. This supposes a sensitivity of 1. Higher sensitivities will increase the distance from the target line, and cause the curve to be skewed in that direction.

The sensitivity of each parameter is determined by the importance of the characteristic in differentiating formation types. Mud weight, for example, would be one of the most critical factors, so its sensitivity would be high, while mud temperature low in sensitivity.

The least squares regression analysis is a common way to determine the equation of a line that most closely fits a set of (x,y) data points. The slope-intercept form of this function is calculated by:

m = n(Exy) (ExEy)/n((Ex*x) - (Ex)(Ey) (2)

where E = summation
n = number of points

and the y-intercept is

b = Ax - Ay (3)

where Ax = average of x values
Ay = average of y values

At this point the analysis is roughly equivalent to a weighted average of all the various parameters, normalized to unity. The process of taking a least squares fit of the numbers is a little more revealing than a weighted average, though. Instead of a single value for the magnitude of the difference between the sample and target, there is the equation of a line to signify this difference

y = mx + b (4)

where m = slope
b = y intercept

The line is compared versus the 45 degree diagonal, representing a perfect match of target to sample parameters. The equation for this line has a slope of 1 and an intercept of zero.

$$y = x \quad (5)$$

The comparison of the sample line to the diagonal offers several general evaluations. For example if the slope is close to unity but the intercept is not zero, the formation may be the same as the target curve, but at a different depth; shallower or deeper according to an intercept less than or above zero, respectively. The reason for making this assumption is that the lien with similar slope indicates a uniform divergence of all the parameters, which is consistent with the variation of the selected drilling parameters with depth.

The significance of a curve with a differing y intercept is more complex. One possibility is the evaluation of drilling progress; that is, a more swift drilling rate may be possible when all the given parameters are fit according to a skewed line. When a particular formation is being penetrated the line will naturally vary off the norm as some drilling parameters have more affect on the drilling progress than others. Modifying the parameters on the low side of the curve will indicate if a new formation is being encountered: if the line normalizes to the diagonal with a different set of functions, then it is a new formation. Otherwise it will shift to possibly 45 degrees, with a different intercept.

CONCLUSION

The quantity and variety of drilling parameters that indicate downhole conditions and formation characteristics make it difficult to evaluate all the pertinent data. It is hoped that a statistical study like that described here will assimilate all the information in such a way that the weighted values will give clean evidence of the downhole environment, sufficient to be of benefit in making critical drilling operational decisions.

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