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A New Approach to Predict Bit Life Based on Tooth or Bearing Failures

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Abstract

This paper presents a new methodology to predict the wear for three-cone bits under varying operating conditions. In this approach, six variables (weight on bit, rotary speed, pump rate, formation hardness, bit type, and torque) were studied over a range of values. A simulator was used to generate drlling data to eliminate arrors coherent to field measurements. The data generated was used to establish the relationship between complex patterns.

A three-layer artificial neural network was designed and trained with measured data. This method incorporates computational intelligence to define the relationship between the variables. Further, it can be used to estimate the rate of penetration and formation characteristics.

The new model was successful in predicting the condition of the bit. In this study, the value of 0.997 was obtained by the model as the correlation coefficient between the predicted and measured bearing wear and tooth wear values. The validity of the model was demonstrated with data from an existing field.

Introduction

There are numerous technological advances made in the design and manufacture of drilling bits. The demand to drill faster and physically for a longer period is the driving force behind these developments. Consequently , the trip times and the time spent to drill a well are reduced. This in turn yields a cost effective drilling operation.

The need to understand the bit behavior has been long recognized[1-3]. Several investigators conducted research to estimate the bit condition based on operational parameters and measured data from offset wells[4-9]. The models developed are based on assumptions that limit their applicability.

Neural Networks. Recently, neural networks successfully applied in different areas of petroleum engineering[10]. The capability to identify complex relationships is well suited to solve problems inherent to oil and natural gas operations. When sufficient data exists, the use of neural networks are demonstrated in several areas such as multi-phase pipe flow[11,12], reservoir characterization[13,14], production[15,16], and drilling[17,18]. Especially the drilling operation provides a unique challenge due to the number of variables involved. These parameters range from unknown formation characteristics and down hole conditions to surface operating conditions. A neural network to predict the rate of penetration values at a well based on recorded data was presented earlier[18].

In this study, a new neural network was designed and used to predict successfully the bit wear and life.

Approach

A new methodology is introduced to predict the bit tooth and bit bearing wear while drilling. In this study, a neural network model was selected to investigate a complex drilling problem.

The study consists of simulated and field measured data sets. Approximately 8000 set of measurements were recorded using the rig floor simulator available in the departmental facilities. The use of simulated data provided additional information such as bit tooth and bearing wear that were not recorded in the field during the drilling operation. The bit condition in the field is determined only after it is pulled. The data recorded using the rig floor simulator consisted of bit tooth and bearing wear values as a function of time. The range of data used in this study are given in Table 1 where the formation drillability varied between 30 and 75 with smaller values representing harder formations. Similarly, the formation abrasiveness values represent an increasing abrasiveness from one to eight. The wellbore configurations and other operational parameters were kept constant during rig floor simulator runs.

Several neural networks were developed to predict the bit tooth and bearing wear values. All networks used a typical three-layer feed-forward back propagation similar to Figure 1. The neural network models used in this study were consisted of 80 hidden neurons, nine or ten input parameters, and one or two output parameters. First and second neural networks were designed to predict bit tooth wear and bit bearing wear, respectively, using all recorded parameters. A third neural network was designed to predict both bit tooth and bearing wear at the same time with all other parameters.

A second set of data consisting of the drilling records from several wells in the United States were used to develop a new neural network. Approximately 500 sets of parameters were included in this data set and the range are given in Table 2

The neural network developed with field data was similar to previously developed networks in terms of design and had three layers, namely, input, hidden, and output. The input parameters consisted of bit type, bit diameter, weight on bit, rotary speed, rate of penetration, footage, formation type, and the mud circulation rate. The hidden layer consisted of 24 neurons and output the parameter was the bit life in hours.

Discussion of Results

In this study, the data sets were divided into two groups and one set was used to develop the network and the second set was used to test the neural network developed in the first part. The test set was consisted of randomly selected ten percent of the total data set. The neural network was trained with the rest of the data until a satisfactory result was achieved. The results from this study are given in Figures 2 through 6. The comparison plots were prepared using the test data. Several neural networks were designed but the results from the final networks are discussed.

Figure 2 plots the neural network predicted bit tooth wear values against the measured tooth wear values for the test set. The neural network developed in this study consisted of ten input parameters namely, bit type, weight on bit, rotary speed, mud pump rate, formation drillability and abrasiveness, rotary torque, time, bit bearing wear, and the rate of penetration. The data set covered a wide range between zero and one for the bit tooth wear. There were 80 hidden neurons in the hidden layer and the resulted correlation coefficient (r) was 0.997.

Figure 3 shows the results obtained for the neural network developed to predict the bit bearing wear. This neural network used similar input parameters as the bit tooth wear prediction and the resulting correlation coefficient (r) was 0.997.

The results from the neural network used in the prediction of both bit tooth and bearing wear are shown in Figures 4 and 5. In this approach, both bit parameters were eliminated to simulate more closely the field operations where data from the bit tooth and bearing wear were not available prior to the bit pullout. Thus, only nine input parameters (namely, bit type, weight on bit, formation drillability and abrasiveness, rotary torque, pump rate, time, and rate of penetration) were used in the development of the model. In this network 80 hidden neurons were used in the middle layer and two neurons in the output layer. The correlation coefficients (r values) obtained for bit tooth and bearing wear were 0.996 and 0.994, respectively.

Figure 6 shows the results obtained with the field data for the prediction of bit life. The bit conditions in this data set were recorded after the bit was pulled whereas the simulated data contained all degrees of bit tooth and bearing wear values ranging from zero to one as a fraction. Although two test set values deviated from the straight line, the remainder of the measured time values were in close agreement with the predicted time values. The correlation coefficient for this test set was 0.902.

Conclusions

1. A new neural network was developed and used successfully to predict the bit tooth and bearing wear.
2. The data covers all ranges of bit tooth and bearing wear and thus widely applicable for all bit conditions.
3. The neural network developed with field data was successful in predicting the bit life using fewer data points compared to neural networks developed with the simulated data.
4. The correlation coefficients for the measured and predicted values obtained in this study ranged between 0.902 and 0.997.
5. The neural networks developed in this study are valid for three cone bits when the data are within the ranges listed in Tables 1 and 2.

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TABLE 1 - RANGE OF MEASURED PARAMETERS

Parameter	Range
Formation drillability	30 - 75
Formation abrasiveness	1 - 8
Bearing wear	0 - 1
Tooth wear	0 - 1
Pump rate, str/min	50 - 105
Rotating time, sec	0 - 42,220
Rotary torque, ft/blf	176.3 - 6,748
Weight on bit, lbf	0 - 93,900
Rotary speed, rpm	40.4 - 139.2
Rate of penetration, ft/sec	0 - 51.3

TABLE 2 - FIELD MEASURED PARAMETERS

Parameter	Range
Bit type	1 - 60
Bit size, in.	5⅞ - 20
Formation type	1 - 9
Bearing wear	0 - 9
Tooth wear	0 - 9
Pump rate, gpm.	0 - 2,448
Rotating time, hrs.	0 - 206
Interval drilled, ft.	0 - 4,044
Weight on bit, 1,000 lbf	0 - 75
Rotary speed, rpm	0 - 350
Rate of penetration, ft/hr.	0 - 116.3

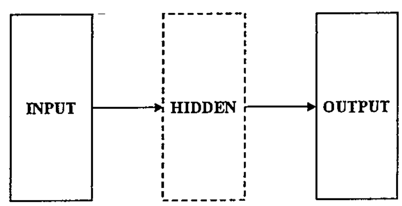

Fig. 1 - A typical three layer feed forward neural network.

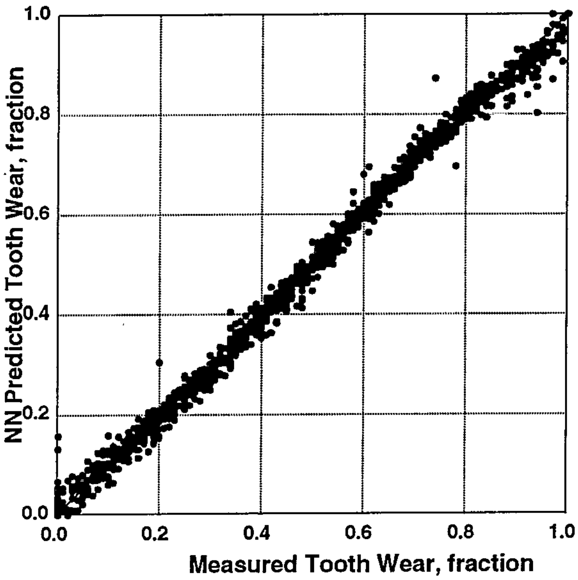

Fig. 2 - Comparison of neural network predicted values with the measured values for bit tooth wear.

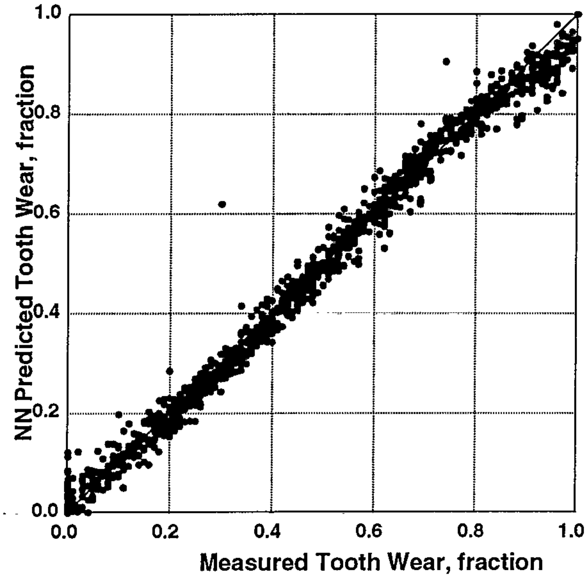

Fig. 4 - Comparison of neural network predicted values with the measured values for bit tooth wear when the bit bearing wear values are excluded.

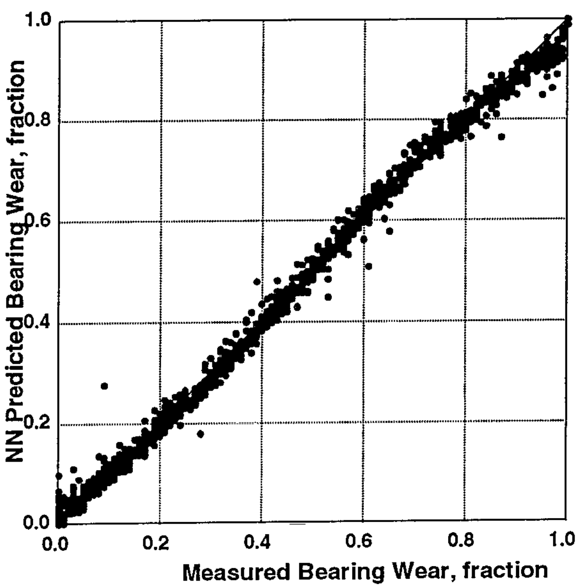

Fig. 3 - Comparison of neural network predicted values with the measured values for bit bearing wear.

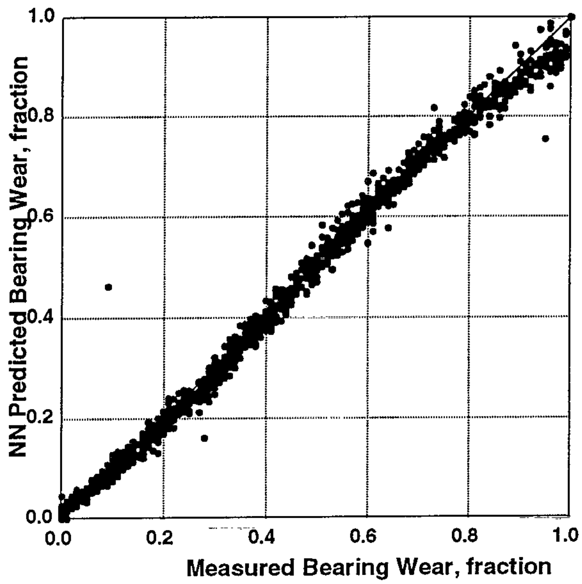

Fig. 5 - Comparison of neural network predicted values with the measured values for bit bearing wear when the bit tooth wear values are excluded.

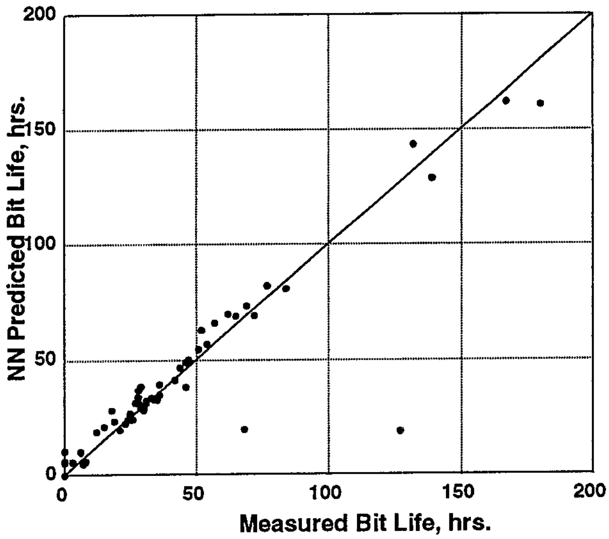

Fig. 6 - Comparison of neural network predicted bit life with field measured bit life.