Research on The Algorithm of Oil Well Liquid Level Depth Measurement Based on The Echo Method

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Abstract. Measuring the depth of oil well fluid level is an important basis for realizing the reasonableness of oil well mining method, and measuring it accurately can provide an important guarantee for the reasonableness of oil well mining method. In this paper, several methods of measuring the depth of oil well liquid level are briefly introduced, and a method of calculating the depth of oil well liquid level based on the location of tubing coupling by The Echo Method is proposed, and the method is proved to be accurate.

1. Introduction
Oil is a non-renewable resource. In oilfield production, the liquid level of oil well directly affects the production efficiency of oil wells[1]. Focusing on the depth of the oil well level in the process of exploitation so as to know the well production capacity and the sinking depth of the pump. Only by the information of the oil well to formulate the oil well mining method, can unnecessary losses be reduced in the process of exploitation and make the most effective use of resources, which is of great significance to the rational development of oil fields.

2. Brief Introduction of Oil Well Liquid Level Depth Measurement Method
As an important indicator in the process of oil exploitation, the liquid level of oil well is measured by many methods.

2.1. The Echo Method
Sound velocity measurement is according to the characteristics that the state of incident wave and reflected wave superimposed varies periodically with the distance from the reflected interface to the sound source. The Echo Method is to measure the depth of oil well liquid level by utilizing the theory that infrasonic waves propagate in the annular space between tubing and casing and generate reflection signals when encountering the liquid level[2].

2.2. The Buoy Method
The object has a certain buoyancy in the liquid, and The Buoy Method is to measure the oil well liquid level by using this theory. When the buoyancy force is greater than the weight of the buoy, the buoy will float on the liquid surface, which is shown as the resistance of the instrument. It is generally required that the buoyancy force of the buoy immersed in water is 1.3~1.5 times of the weight of the buoy itself and the weight of the buoy is not less than 5kg[3]. If the weight of the buoy is too light, it is easy to be stuck by the oil pollution in the pipe string, oppositely, the required volume of the buoy becomes larger, and the casing space is limited, which is easy to increase the error.
2.3. The Manometer Measurement Method

The theory of The Manometer Measurement is basically the same as that of the pressure measurement method. The measurement result of The Manometer Measurement Method is more accurate than that of The Buoy Method. Compared with The Buoy Method, The Manometer Measurement Method is more complex and troublesome and requires higher professional skills of operators. The Manometer Measurement Method can be used in all oil wells, but the premise of this method is to know the location of the measurement point and accurately judge the approximate position of the oil well fluid level, so it is difficult and complicated to operate and select the location of the measurement point, which requires a professional person to carry out the measurement[4].

In this paper, The Echo Method is used to measure the depth of oil well liquid level. Acoustic pulser and data acquisition board are installed at the wellhead of oil well. The data acquisition board sends sound waves back to the upper computer in the form of hexadecimal data and stores them in the database, and the computer program is used to draw the sound wave and calculate the liquid level.

Compared with The Buoy Method and The Manometer Measurement Method, The Echo Method is simpler and safer. However, after the acoustic wave form is collected by The Echo Method, it is necessary to use the waveform to calculate the depth of the liquid level. Currently, there are two main methods for calculating the depth: sound velocity method and coupling method.

It is necessary to know the sound velocity of oil well before using the sound velocity method to calculate the fluid level of oil well. Although the calculation is simple, the measurement error of the sound velocity greatly reduces its accuracy. In terms of the coupling method, the current use of tubing coupling to measure the liquid level is to use the number of tubing coupling and its average spacing[5]. And the coupling method described in this paper, with comparison, finds out the corresponding coupling position in the coupling wave and calculates according to the calculation expression, in which the correction of coordinate position deviation in the calculation process greatly improves its accuracy.

3. The Theory and Realization of Coupling Method for Calculating The Fluid Level of Oil Well

3.1. Theory

Tubing coupling is a drilling tool in oil field, which is mainly used for the connection of tubing. The length of the tubing in the oil well is certain, basing on the acoustic data measured by The Echo Method, the fluid level of the oil well can be calculated by using the time interval between the wave peaks generated by the sound at the tubing coupling.

Selecting a section of waveform whose amplitude of echo wave shape changes distinctly and the periodicity is better called coupling wave, and calculating the position of tubing coupling by coupling wave. As can be seen from the example Fig.1, the first 1000 data points of acoustic data can be selected as the coupling wave, the subscript position corresponding to the coupling can be calculated, and the location of echo wave valley can be determined. Finally, the depth of oil well liquid level can be calculated by combining the tubing length and the coupling position of the coupling wave. The example of coupling wave is shown in Fig.2.
3.2. Algorithm
Steps of the algorithm are obtained as below:
Step1: take a record from the database, convert the hexadecimal data into a double array and select the first 1000 data points to form an array and regard it as coupling wave, and mark the first index X_{first}=500;
Step2: the minimum value of the first calculation process is found within the interval of [X_{500}, X_{550}] and marked as Y_{first}, its array index is marked as X_{first}, and the offset is 3.
Step3: in the second calculation process, the minimum value interval is [X_{left}, X_{right}], and X_{left}=X_{first}+3, which corrects the starting point of the second calculation to the middle point of the Y-axis, X_{right}=X_{left}+42, and the minimum value is marked as Y_{second} whose array index is marked as X_{second}.
Step4: the third interval is [X_{left}, X_{right}], where X_{left}=X_{first}+(X_{second}-X_{first})*10-16 and X_{right}=X_{left}+32, and the minimum value is marked as Y_{tenth} whose array is marked as X_{tenth}, that is the tenth coupling position of the tubing;
Step5: from the 2000th data point of the acoustic data array to the last data point, this part of the data is used to determine the position of the liquid echo valley. The minimum value obtained in the interval [2000, X_{last}] is marked as Y_{liquidlevel}, and its index is marked as X_{liquidlevel}.
Step6: mark the length of the tubing as 9.6 meters per section, and calculate its liquid level according to expression 1.

\[ d = \frac{(X_{liquidlevel} - 50)*9.6*10}{(X_{tenth} - X_{first})} \]

Expression 1

4. Experimental Results
The 10 groups of data of the experiment are shown in table 1, and the curves drawn by the liquid level calculated with the sound velocity method, the traditional coupling method and the coupling method in this paper are shown in Fig.3. It can be clearly seen from the curve of the liquid level error shown in Fig.4 that the error curve of the coupling method is obviously flat and the error is obviously small.

| Actual liquid level | The sound velocity method | The traditional coupling method | Coupling method in this paper |
|---------------------|---------------------------|-------------------------------|-----------------------------|
| 1286.3              | 1226.51                   | 1275.34                       | 1282.33                     |
| 1153.4              | 1123.92                   | 1133.6                        | 1150.44                     |
| 1187.8              | 1147.65                   | 1162.32                       | 1180.83                     |
| 1245.6              | 1205.84                   | 1228.46                       | 1237.56                     |
| 1098.5              | 1043.72                   | 1065.73                       | 1089.51                     |
| 1231.6              | 1201.9                    | 1211.9                        | 1225.68                     |
| 1301.9              | 1257.23                   | 1287.53                       | 1297.89                     |
5. Conclusion
The algorithm of sound velocity method is simple and clear, but this method should know the sound velocity of each oil well clearly, and it’s not accurate as the coupling method. Unlike traditional coupling method, steps of the coupling method described in this paper are more complex, yet the correction of coordinates deviation in the process of calculation improve the accuracy greatly. It doesn't need sound velocity of every well or data acquisition sampling frequency and can be more accurate to calculate the liquid level depth of oil wells.

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