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Increasing Detection Accuracy of Loading Capacity of Drilling Rigs

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Abstract— **Increasing detection accuracy of loading capacity of the drilling rigs is investigated and the methods are presented. The methods of calculating the average value of the period have been proposed according to numerous records of signals zeros. The structural scheme and mathematical models of the system have been developed and the errors in the calculation of the period have been investigated.**

Index Terms— **special oscillations, oscilloscope, frequency, zero detector, time interval, calculation methods, period.**

I. INTRODUCTION

Physical and mechanical properties of obsolete and exploited equipment and their existing defects and technical-exploitation characteristics for current period are one of the important issues to be detected for measuring technique. In this regard, detection of loading capacity, one of resource parameters of drilling rigs having been obsolete or installed in another site, is the urgent problem of the oil-gas extracting industry.

Non-destructive - vibrating method is widely used to determine the loading capacity of drilling rigs. The essence of this method is that, free oscillation movements are ensured by providing an impulsive force to one of their fastening cables in the unloaded and loaded modes. In this case, the loading capacity of the drilling rig is determined by the following equation by measuring its free special oscillations frequency - period [1, p. 35-38].

$$N_f = N_P \frac{f_0^2}{f_0^2 - f_y^2} = N_P \frac{T_y^2}{T_y^2 - T_0^2}$$

here, N_f, N_P is accordingly the actual load capacity of the drilling rig and the mass of suspected load on it; f_0, T_0, f_y, T_y is frequency and periods of special oscillations in the unloaded and loaded modes.

Oscillogram of the signals obtained from seismic receivers in the microcontroller system currently created are recorded on the the personal computer memory as well as displayed on its screen. In this system, the frequency of special oscillations is determined by the oscillogram, as in the measurements carried out by light or digital oscillography. In this case, the measurement results accuracy depends on the tact frequency of the microcontrollers, the number of analogue-digital transformations performed at a unit time, and the operator's record of special oscillations frequency range in the oscillogram. The impact of the first and second factors on the measurement accuracy can be reduced thanks to modern technical means. In the third case, the operator visually records the range corresponding to three periods of special oscillations in oscillogram by determining it. In most cases, the operator's subjective records lead to great errors. This situation will be more apparent in the measurements carried out in the unloaded and loaded modes, when the frequency of special oscillations of the drilling rig is nearer [1, p. 35-38, 2, p. 26-29].

The period of signals can be automatically calculated via microcontroller systems with analogue-digital converters. In these systems, removing barriers from the useful signal are solved via software. Various mathematical transitions, digital filtering or complex algorithms and correlation analysis performing signal frequency transformations are used for filtering via software [3, p. 42-46].

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II. STATEMENT OF THE PROBLEM.

Investigation of increasing detection accuracy of special oscillation frequencies-periods, development of the structural scheme and mathematical models of the measuring system.

III. SOLUTION METHODS.

As it is known, increasing the number of measurements can reduce the impact of systematic and random errors on the measurement result. For this purpose, the article proposes recording the occurence moments of sequentially-forming signal levels in a range appropriate to the special oscillations of drilling rigs. In this case, the number of possible informative time intervals calculated according to two recorded periods of time and the maximum value N_0 is determined by the following equation [4, p. 33]:

$$N_0 = C_n^2 = \frac{(n)!}{2!\cdot(n-2)!} = \frac{1}{2}n(n-1) \quad (3.1)$$

Here, n is the number of the recorded time moments.

The main issue in recording the time moments is to accept a reference point of any level of the signal. If this level is accepted between zero and amplitude, then the number of informative time intervals will be as follows:

- when the number of the recorded time moments is double:

$$N_0 = 2C_{n/2}^2 = 2\cdot\frac{(n/2)!}{2!\cdot(n/2-2)!} = \frac{n}{2}\left(\frac{n}{2}-1\right) \quad (3.2)$$

-when the number of the recorded time moments is single:

$$N_0 = C_k^2 + C_{k+1}^2 = \frac{1}{2}k(k-1) + \frac{1}{2}k(k+1) = k^2 \,. \quad (3.3)$$

Here: $k = \mathrm{mod}(n/2)$

If this level is accepted as the amplitude or zero of the signal, then the number of informative time intervals is determined by the equation (3.1).

As it is known, the drilling rigs, durability conditions of which are ensured, have certain quality indicators. On the other hand, free oscillation process - dynamic process, subjected to compulsory oscillation by impulsive force, is off. The main quality indicator of the drilling rig dynamic process is discharge degree of of the transition process (ψ) [5, p. 326 - 327]:

$$\psi = \frac{A_1 - A_2}{A_1}$$

Here, A_1, A_2 respectively are the levels of sequentially occuring peaks-amplitudes of the signal.

In great values of ψ, special dances frequency is impossible to be determined accurately according to the obtained level. Thus, in convergent oscillations, it is impossible to determine the objective laws between time moments recorded according to any level of the signal (between signal zero and amplitude).

In small values of ψ, the value of N_0 is determined by equations (3.2) or (3.3). At this time, the maximum value of ψ is given beforehand according to measuring accuracy. In addition, the calculations carried out according to the records in the presence of electromagnetic barriers will be accompanied by a great error.

There are also some problems with recording time moments due to signal amplitude (in records performed via peak detectors). Thus, any exciting impact occurring at time interval near variation range of drilling rig oscillation direction causes the amplitude to be beaten (Earth quakes, wind direction changes, etc.). In addition, small displacements at any time of drilling rig oscillations can also lead to the formation of new peaks. Electromagnetic barriers is possible to be added to the mentioned issues. And this makes it difficult oscillation cycle to be determined accurately by peak detectors.

It is more appropriate to accept the zero level signal as the reference point. Zero detector is usually used to measure the phase shift of signals. However, taking into account the problems of recording informative time moments in the amplitude and given levels, zeros of the signal are simple to be recorded [6, p. 233-237]. In addition, the effects of mechanical excitement on durable condition of the drilling rig are insignificant.

Therefore, the system uses a zero detector and its output is connected to the interrupting input of the microcontroller (Figure 1, *a*). In the system SQ1, SQ2 - seismic receptors (CM-3KB) placed perpendicularly to each other on the upper balcony of the rig, ATS1, ATS2 - low frequency filters, G1, G2 - amplifiers, SD1, SD2 - zero detectors, MK - microcontroller. As SQ1 and SQ2, seismic receivers (A16XX, A05XX) with piezoelectric converters, performing separate recording of oscillations being perpendicular to each other, can also be used.

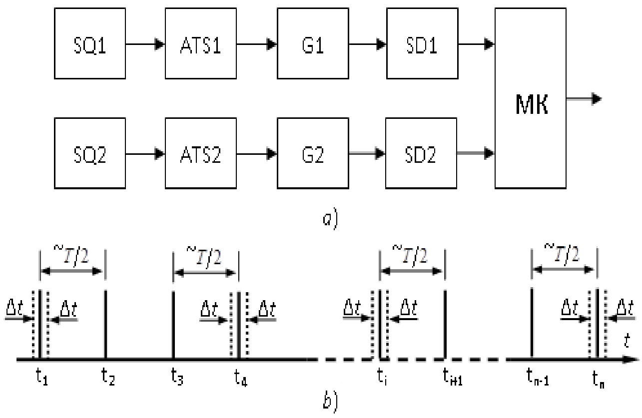

Figure 1. The structural scheme of the system (a), time diagram (b)

At first glance it is seen that, it would be enough to use an amplifier and a zero detector in the system. However, in addition to this, the switch is necessary to be included the system. This causes the small barrier generated by the switch to sit on a very weak seismic signal and strengthened by the amplifier. As a result, SD will not record the signal zero properly. Another disadvantage of adding the switch to the system is overlap of phase-shifting signal zeros recorded by SD1 and SD2 in the background of the obstacles.

Figure 1, *b* shows the diagram of ideal (whole line) and real (broken-line) time moments of the signal zero.

The calculated average value of the period of drilling rigs special oscillations in any system is recommended to be determined according to the following calculation methods:

1. Determine the period according to successive time intervals;
2. Determine the period of time interval while being calculated by possible combinations of time moments;
3. Determine the period according to the total number of time intervals calculated by possible combinations of time moments.

The following equations are given for the calculation of the period by mentioned methods.

According to the first method, any calculated period of the special oscillation is T_{1ij} :

$$T_{1ij} = 2(t_i - t_j), \quad i = 2 \div n, \quad j = i - 1.$$

Then, the calculated average value of signal period is as follows:

$$T_{1or} = \frac{\sum_{i=2}^{n} T_{1ij}}{N_1} = \frac{\sum_{i=2}^{n} T_{1ij}}{n-1}, \qquad (3.4)$$

Here, $N_1 = n - 1$ is the number of calculated periods.

According to the second method, any calculated period of special oscillation is as follows:

$$T_{2ij} = \frac{2(t_j - t_i)}{j - i}, \quad i = 1 \div (n-1), \quad j = (i+1) \div n$$

Then:

$$T_{2or} = \frac{\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} T_{2ij}}{N_2} = \frac{2 \cdot \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} T_{2ij}}{n(n-1)}, \qquad (3.5)$$

Here, $N_2 - (1)$ is determined according to the third method.

$$t_{3ij} = t_j - t_i, \quad i = 1 \div (n-1); \quad j = (i+1) \div n$$

$$N_3 = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (j-i) = (1+2+...+n-1) + (1+2+...+(n-2)) + ... + (1+2+3) + (1+2) + 1$$

$$N_3 = \frac{n(n-1)(n+1)}{6}$$

$$T_{3ij} = \frac{\sum_{i=1}^{n-1} \sum_{j=i+1}^{n} t_{3ij}}{N_3} = \frac{6 \cdot \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} t_{3ij}}{(n-1)n(n+1)} \quad (3.6)$$

It should be noted that, the important issue in the application of all three methods is to determine the signal zeros accurately. Thus, few additional compulsory oscillations occur during the passage of the drilling rig by the influence of the random external forces. In addition, external electromagnetic barriers, that are not filtered via ATS in measuring circle, need to be eliminated. Some problems also need to be solved in scheme-technical filtration of low and infrared frequency signals from the barriers. This is particularly becomes difficult when the ratio is small between useful signal frequency and cutting frequency [7, p. 42-45]. Therefore, the system proposes a method of filtering according to zero signals. The essence of this method can be seen from the oscillograms shown in Figure 2 (expanded images of the oscillogram several times is given in *a*, and dozens of times in *b*).

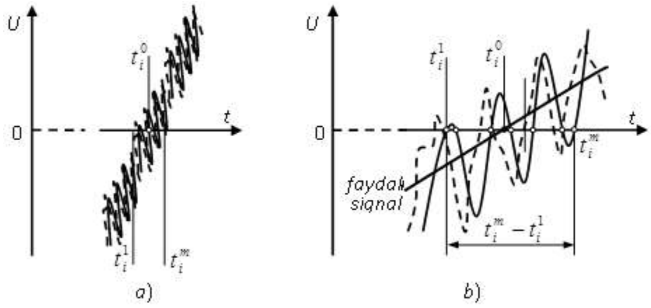

Figure 2. Oscillogram around zero of useful signal

As it is seen from figure 2, *b*, occurence moment t_i^0 of actual zero i of the useful signal can be determined by the following equations according to time moments $t_i^1, t_i^2, ..., t_i^m$:

$$t_i^0 = \frac{t_i^m - t_i^1}{2} \quad (3.7)$$

or

$$t_i^0 = \frac{t_i^1 + t_i^2 + ... + t_i^m}{2} \quad (3.8)$$

Detection of $t_i^1, t_i^2, ..., t_i^m$ time moments is carried out by the following sequence - algorithm:

- initially, differences between the two neighboring time moments are calculated:

$$\Delta t_i = t_i - t_{i-1}$$

- Their mathematical expectations are calculated on the base of time intervals Δt_i :

$$\Delta t_i^* = \frac{\sum_{i=2}^{n} \Delta t_i}{n^* - 1}$$

Here n^* is the number of signal zeros in the background of obstacles.

- time intervals Δt_i^0 ensuring the following condition is determined:

$$\Delta t_i^0 < \Delta t_i^*$$

- zero recording moments are determined according to time intervals Δt_i^0 ;
- one of the recording moment Δt_i^0 overlapping is determined and grouped;
- time moments $t_i^1, t_i^2, ..., t_i^m$ are determined for each of the groups obtained, time moments of calculated zeros are determined by using equations (3.7) or (3.8) the calculated zeros;
- The arrays are created on the base of time moments of calculated zeros of the useful signal;
- The main signal period is determined by (3.4), (3.5) or (3.6) any of the proposed calculation methods using time moments of the new array.

One of the important problems in determining loading capacity of the drilling rig in any system is to define signal period more precisely by the calculation method. For this purpose it is advisable to conduct a theoretical study of the calculation error of the period in a simple and general way by the proposed methods. Since the simmetricity of the suggested methods for the calculated time intervals is taken into account, the investigation of the errors must be carried out mainly according to incorrect recordings occurring within the boundaries and middle of the measurements. It is assumed that, according to the records carried out, zero determination was not accurate at all.

The analysis shows that, the maximum number of time intervals, calculated from available combinations of time moments by the second and third methods, is possible during incorrect recordings at the start and end of the measurement and is determined by the following equation:

$$N_{\Delta\max} = n - 1$$

In this case, the error occurs due to a calculation result in the period calculation by the first method, and then:

$$\delta_I(n) = \frac{(n-1)\frac{T_0}{2} + \frac{T_0}{2}\gamma - (n-1)\frac{T_0}{2}}{(n-1)\frac{T_0}{2}} = \frac{1}{n-1} \cdot \gamma \, . \quad (3.9)$$

Here, T_0 is the factual value of the period; γ is the maximum error of the period determination.

Calculation error by the second method:

$$\delta_{II}(n) = \frac{2\gamma\left(1 + 1/2 + 1/3 + 1/4 + ... + .1/(n-1)\right)}{n(n-1)} = \frac{2a(n)\gamma}{n(n-1)} \quad (3.10)$$

Here, $a(n) = 1 + 1/2 + 1/3 + 1/4 + ... + .1/(n-1)$.

Calculation error of the period by the third method:

$$\delta_{III}(n) = \frac{6\gamma}{n(n+1)} \tag{3.11}$$

If incorrect recording of zero occurs once in the middle of the measurement, then the following equation is appropriate:

$$\delta_I^1(n) = \frac{2\gamma}{n-1}; \quad \delta_{II}^1(n) = \frac{4\gamma}{n^2(n-1)};$$

$$\delta_{III}^1(n) = \frac{6\gamma}{(n-1)n(n+1)} \,. \tag{3.12}$$

For simplicity, let's define the following dependencies from (3.9) - (3.12) equations, depending on the number of measurements:

$$f_1(n) = \frac{\delta_I(n)}{\delta_{II}(n)} = \frac{n}{2a(n)};$$

$$f_2(n) = \frac{\delta_{II}(n)}{\delta_{III}(n)} = \frac{(n+1)a(n)}{3(n-1)};$$

$$f_3(n) = \frac{\delta_{II}^1(n)}{\delta_{III}^1(n)} = \frac{4(n+1)}{6n}$$

Figure 3 presents $f_1(n), f_2(n), f_3(n)$ dependencies graphs in only one incorrect recording of the dependence of period detection by three methods on the number of measurements.

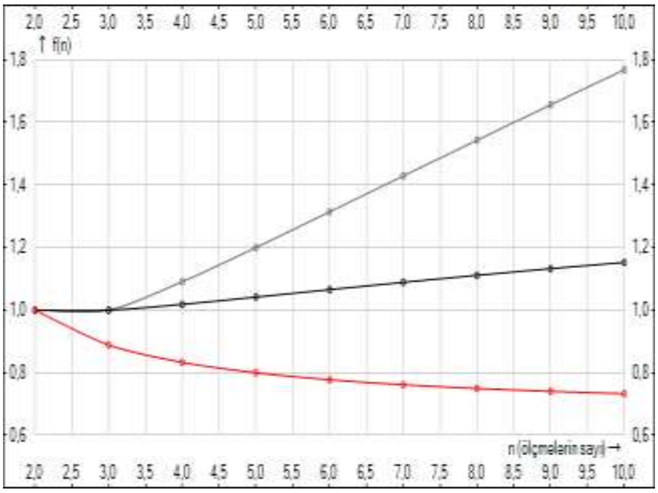

Figure 3. Relative dependence of period calculation errors depending on the measurement method

As it is seen from the graphs, error detection of the period is minimal due to the third method when incorrect recordings of signal zeroes are close to the start and end of the measurement, and when they are close to middle range it occurs due to the second method. For this, the measurement period is divided into three ranges and the probability theory is used to determine the probability of incorrect recordings in the given range. Then, the calculation method is applied in accordance with the range having a great probability.

IV. Conclusion

1. Methods for determining the calculated value of special oscillation period of drilling rigs have been proposed and their mathematical models have been developed.
2. The structural scheme of the measuring system has been developed.
3. Algorithm for the determination of the actual zeros of useful signal in the background of obstacles has been developed.
4. Errors of calculation methods have been investigated.

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