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Monitorning and control structure for pumping system of drilling fluid

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Abstract

Hydraulic drilling program has in view the correlation of circulated fluid flow and distribution of pressure drops in various elements of circulating system, in order to remove the cuttings at bottom of the hole. The present paper proposes a control system, based on automatic data acquisition, in order to accomplish all the hydraulic program objectives, which are modified as the drilling hole is deepening.

Key words: *control, optimization, efficiency.*

Introduction

Drilling fluid influences the rocks disintegration process, both, directly, by shattering the rock from the bottom of the hole, by jets getting out from the bit nozzles, and, indirectly, by bottom freeing of detritus. Detritus removal needs a minimum fluid flow, corresponding to that speed of ascendant current in the annular space, under whose value the bit packing risk appears. The flushing of bottom of the hole needs to set out a certain jets speed at bit nozzles, and this means to know, from previous experience, either jets flow and speed, or hydraulic power, which provides for each structure and system of beds, a complete flushing at maximum rate of advance.

If the necessities of bottom flushing are not known, or if they overtake the available capacities of pumps, then the designed hydraulic system takes into consideration the forwarding either of maximum hydraulic power to bottom, or a maximum hydraulic impact; this implies a correlation of the fluid flow circulation and the distribution of pressure drops in various elements of circulating system.

The forwarding of maximum hydraulic power to bottom, using all installed power, sets down the optimal flow from the maximum condition of the function expressing the hydraulic power, depending on flow:

$$P_h = pQ - \alpha\gamma Q^3, \qquad (1)$$

where p is pressure at pumps, α is pressure drops coefficient in the elements of system and γ - fluid specific weight;

Maximum hydraulic impact at bottom of the hole supposes the maximization of the product $\gamma Q v_j$,where v_j is fluid jet speed at bit nozzles and it is obtained only at the certain flow or pressure.

Generally speaking, tacking into account the external characteristic of piston pump too, it results nine possible working methods to accomplish these demands within the available pumps power, as the drill hole is deepening.

Used Models

When the minimum ascending speed is obtained, assuring the removal of the whole quantity of detritus drilled in a time unit, the flow is the reference variable of program and has minimum necessary value:

$$Q = Q_{min} . \tag{2}$$

Optimum flow, necessary to maximize the hydraulic power at bottom of the hole, results from the maximum condition of function (1) and it is:

$$Q_{opt} = \sqrt{\frac{p}{3\alpha\gamma}} , \tag{3}$$

and the area necessary for nozzles section is determined by the equation of pressure drops, for $Q = Q_{opt}$, resulting in:

$$A_d = \frac{1}{2\varphi\sqrt{\alpha g}} . \tag{4}$$

Fluid flow coefficient through the bit holes, φ, is listed in a table, according to holes shape and to the ratio between their section area and bits section area.

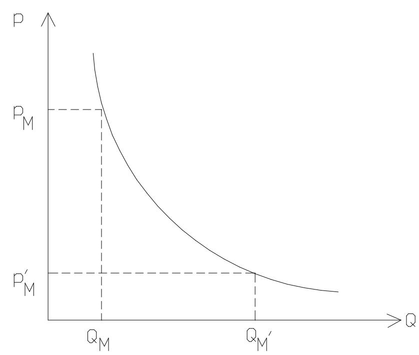

Fig. 1. Pump external characteristic

From the point of view of pump external characteristic (fig.1) the following situations may appear:

a) $Q_{min} > Q_M$. It is working with $Q = Q_{min}$ and the nozzles area is recalculated with the relation:

$$A_d = \frac{1}{\varphi\sqrt{g\left(\frac{p}{\gamma Q^3} - \alpha\right)}}. \tag{5}$$

The flow remains constant by the depth, nozzles area increases and jets speed decreases. If jets speed restrictions exist, the flow is recalculated;

b) $Q_{min} < Q_M$. We can start with flow Q_M and pressure p_M . At these parameters we may work respecting the criterion of maximum hydraulic power at bit ($p_s = p/3$) to the depth:

$$H_1 = l_{pg} + \frac{p_M}{3\alpha_1\gamma Q_M^2} - \frac{\alpha_2}{\alpha_1}, \tag{6}$$

where l_{pg} is the length of drill stems.

Further on the depth H_1 the flow is reduced to value Q_{min} , nozzles section decreases and jets speed increases. With the flow Q_{min} we may work to the depth:

$$H_1 = l_{pg} + \frac{p_M}{3\alpha_1\gamma Q_{min}^2} - \frac{\alpha_2}{\alpha_1}. \tag{7}$$

Maximum hydraulic impact criterion is obtain in two ways:

- at the certain flow:

$$Q_{opt} = \sqrt[3]{\frac{P_p}{4\alpha\gamma}}, \tag{8}$$

where P_p is the power transmitted to pumps. In this case ¾ of this power will be consumed at bottom of the hole;

- at a certain pressure with a corresponding optimum flow:

$$Q_{opt} = \sqrt{\frac{p}{2\alpha\gamma}}. \tag{9}$$

At bottom of the hole a half of the power transmitted by the pumps will be consumed.

Hydraulic System Programming

Optimization of hydraulic system in accordance with the above-mentioned criteria, while well drilling is moving forward, needs nine working methods:

1. $Q_{min} > Q_M$.

1*a*. It is adapted $Q = Q_M'$ and it is working with pressure p_M' , to the depth H_1, where the criterion $P_p = 4\alpha\gamma Q^3$ can be respected. The necessary area for nozzles, which will increase by depth, while the jet speed decreases, is calculated.

1*b*. The flow is reduced by depth to $Q = Q_{min}$. Nozzles area (it must increase) is calculated so that jet speed remains constantly.

2. It is working with $Q = Q_{min}$ and pressure p_M' to the depth H_2, where it is possible to respect the same criteria. Nozzles area must increase, while jet speed must decrease by depth.

3. $Q_{min} < Q_M$.

3*a*. Drilling starts with $Q = Q_M$ and $p = p_M$. It is working with the depth H_1 disponible from criterion $P_h = 3P_p / 4$. To maintain a constant flow nozzles area must increase by depth and jet speed must decrease.

3*b*. From H_1 it is working decreasing the flow by the relation (3), so that decreasing the nozzles area too, the jet speed remains constant to the depth H_2 .

3c. From H_2 to a new depth H_3 it is working with $Q = Q_{min}$ and $p = p_{min}$. Nozzles area will increase in accordance with the maintaining a constant flow and jet speed will decreases.

3*d*. Further it is working with the $Q = Q_M$ and $p = p_M$, but with the condition $P_h = P_p / 2$. It may go working to the depth H_4 .

3*e*. To the depth H_5 where it is possible to respect the criterion $P_h = P_p / 2$, the flow is reduced to Q_{min} .

3*f*. It is working with Q_{min} and p_M to the last possible depth.

Monitoring and Control Structure for Pumping System

From all above-mentioned aspects it follows that to carry out the hydraulic program we need data acquisition necessary to specify pumps pressure (depending on motor drive speed) and to calculate the necessary area of bit nozzles (depending on drilling depth). Controlled electric driven system needs the structure from figure 2, which supposes a static frequency converter, using the modern method of direct torque control – DTC, with the well-known advantages.

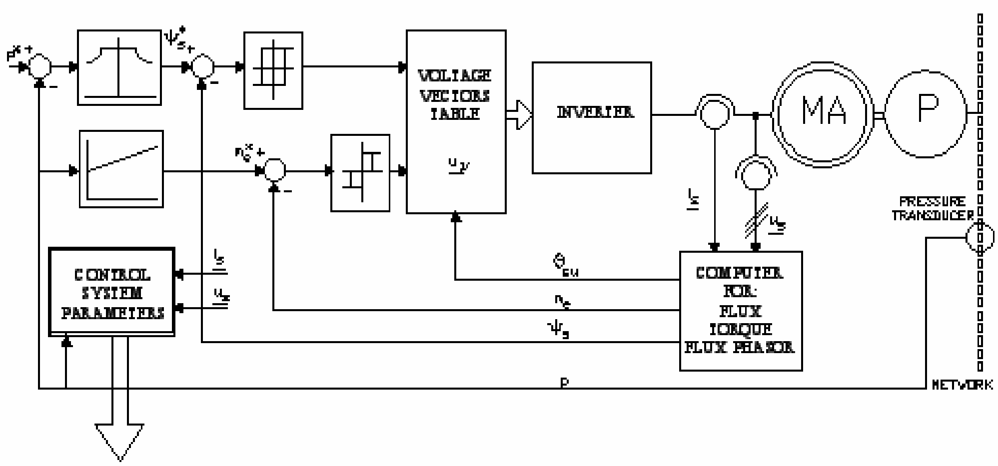

Fig. 2. Principle scheme of the automatic system

Monitorized technological parameters are: pumps pressure, flow (it depends on motor speed at piston pumps), motor speed, fluid density (varring with drilling program) and drilling depth.

On these parameters the computer will be an operating guide; it will monitorize, diagnose and prognose the state of hydraulic process and based on memorized program, it will give references for process control.

Analogical data acquisition needs a structure of the following main elements: signal adoption (conditioning) block, analogical multiplexer, input amplifier, sampling-storage block, analog to digital converter, buffer register and control block.

The specific of technological process recommends an acquisition system with multiplexing of converters outlets from each channel and using of one converter for each signal source. Structure of such a data acquisition system is shown in figure 3.

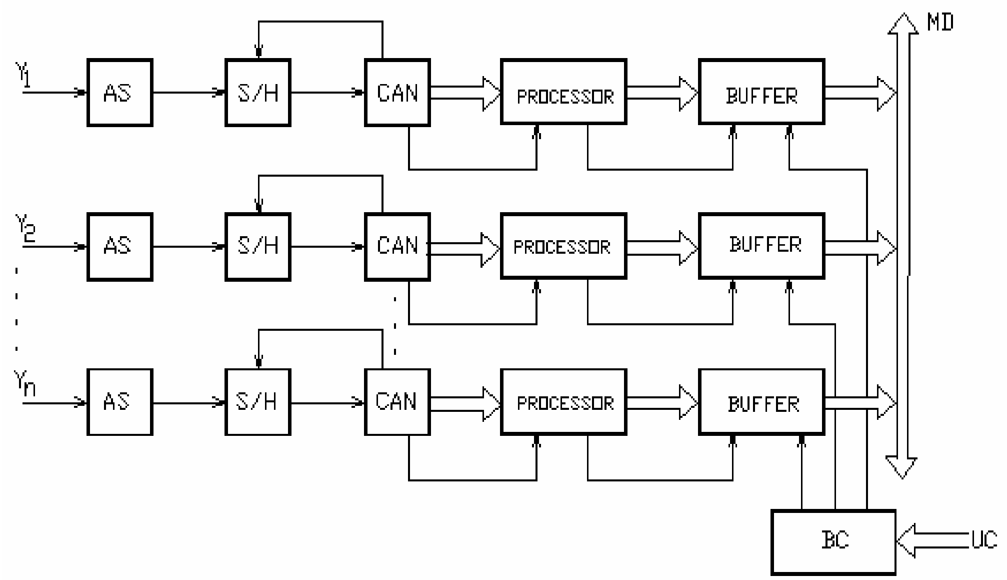

Fig. 3. Data acquisition system

On each measuring channel a circuit for signals adoption, coming from transducers is installed before the converter, as well as a circuit for sampling storage. Data obtained from conversion are local processed by a processor for each channel, before to be digital multiplexed and send to central calculus unit. Buffer registers store temporally the information to be transmitted.

The system is advantageous because, having a converter for a single channel, we can use relative slow converters and consequently, cheaper, because we do not need a high speed for data acquisition here. Second, the systems of parallel conversion are very advantageous in case of application, where the transducers are placed on a larger surface.

By local conversion and transmission of the results under a digital form, a good immunity to disturbances is assured

It is also important the possibility of a slight galvanic separation of the signal source and its converter from the rest of system.

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Structuri pentru supravegherea si comanda sistemului de pompare a fluidului de foraj

Rezumat

Programul hidraulic al forajului îşi propune să coreleze debitul de fluid circulat şi distribuţia căderilor de presiune în diferitele elemente ale sistemului de circulaţie în scopul evacuării detritusului de la talpa sondei. Lucrarea propune un sistem de conducere, bazat pe achiziţia automată a datelor, care să asigure realizarea tuturor obiectivelor programului hidraulic, obiective ce se modifică odată cu adâncimea găurii de sondă.