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Considerations on the Raising and Descent Operations of the Drillstring into the Hole

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Abstract

This paper focuses on the possibilities of mechanical and mathematical modeling of the drillstring during the raising descent movements into the hole.We concentrate on the dangerous situations which can appear and on the ways of cancelling them by referring to the technical literature in this field.

Key words: *drillstring vibrations, hole, drill accidents.*

In order to replace the worn out bit, it is necessary to extract the whole drillstring, to replace the bit with a new one and to introduce the drillstring into the hole.
This succession of operations, even if it is necessary, has two great deficiencies:

- it takes a long time;
- during it, the drillhole does not increase its depth;

The desire to diminish the time of progress of the raising and descent operations of the drillstrings may lead to dangerous situations followed up by serious drilling accidents.

In order to choose some work strategies which may lead to the decrease of the time of the action, in order to avoid the drilling accidents, it is necessary the study of the dynamic of the drillstrings during the axial-vertical displacement. For this purpose, we may use the mechanic pattern-making which appears in the Fig. 1.

By imposing the equilibrium of the inertness forces, forces which are applied externaly and which are in connection (the d'Alembert principle), on the infinitesimal element, of a certain volume Adx, it results the mathematical model of the movement, under the form

$$-\rho A\ddot{S}dx + N'dx + Fdx = 0, \qquad (1)$$

where: ρ is the specific mass;A represents the surface area of the transversal section;S represents the movement of the section x at the time t;N is the axial effort; F is the projection on the longitudinal axis x of the resultant of the distributed forces, forces which are applied externally.

We specify that, in order to model the drillstring, we consider A= const., equal to the surface area of the ring-shaped transversal section of the drill-pipe. Because the tool joints have bigger transversal areas, it results a growth of the specific mass, ρ, with 12% in comparison with the steel mass [1]. Following the drilling fluid mass (adherent, in vibrating movement with the drillstring), the size of the equivalent specific mass will increase with 8% [1].

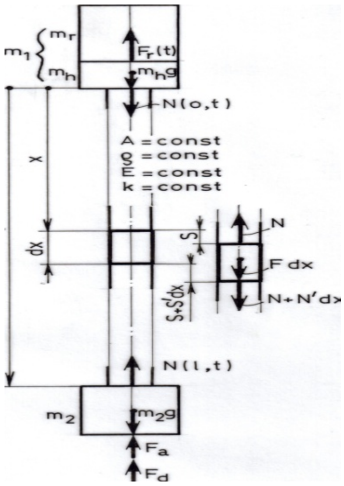

Fig. 1 Mechanical modelling of the drillstring

The axial effort will be illustrated by

$$N = \sigma A\,, \tag{2}$$

where σ is the specific axial effort.

In 1982 it was considered, for the first time [1], that it was useful that the material of the drillstring be shaped by a viscous-elastic pattern of Kelvin type, having the constitutive law

$$\sigma = E\varepsilon + k\dot{\varepsilon}\,, \tag{3}$$

where: E is the module of the longitudinal elasticity; k is the coefficient of the internal damping; ε is the lenghtening (the specific enlargement). Refering to the E module, [1], we may notice a slight increase of its size, with 4%. The size of the damping value in the drillstring material, k, may be determined easily by studying the logarithmic decrement of its vibrations. Its size is impressive, even if all the studies, in this domain, neglects it. The distribution of the forces, externaly applied, whose resultant on the vertical line is marked with an F, are dued to the gravitational field and to the friction with the drill fluid during its plastical running inside and outside the drillstring.

By introducing the relations (2) and (3) in (1), it results the mathematical pattern of the section movement x, $0 < x < l$ of the drillstring at the time t, $t \geq 0$,

$$\rho\ddot{S} - k\dot{S}'' - ES'' - F/A = 0\,. \tag{4}$$

The dangerous situations are in the cases where the axial effort N and/or the movement S surpass the admissible values.

For the superior extremity of the drillstring, the equilibrium of all forces, at $x = 0$, leads to

$$m_1\ddot{S} - kA\dot{S}' - EAS' - m_h g + F_r(t) = 0\,, \tag{5}$$

where: $m_1 = m_r + m_h$; m_h is the hook mass; m_r is the reduced mass of the moving elements from the drill installation, for the raising or the descent movement; g is the gravitational acceleration; F_r is the force of the hook of the motor couple (in order to raise or to descend).

If this extremity is stopped, we add the condition

$$S(0,t) = 0\,. \tag{6}$$

The dangerous situations for the superior extremity are:

a) $N \leq 0$,

- if the drillstring is attached with slips, the drillstring takes out the slips and it falls down into the hole;

- if the drillstring is hanging into the elevator, the superior extremity is mooving freely, up, and it is supposed, at its return, to strike violently the elevator, by breaking it and the drillstring goes down into the hole;

b)$N > N_{admisibil}$, axial plastic deformations appear into the drillstring followed up by their breaking and freely descent into the hole.

For the inferior extremity of the drillstring, the equilibrium of all forces, at $x = l$, leads to

$$m_2\ddot{S} + kA\dot{S}' + EAS' - m_2 g + sF_f + F_a + F_d = 0, \tag{7}$$

where, moreover,

m_2 is the drill collars mass; F_f is the friction force of the drill collars with the fluid or with the walls of the hole; s has the values (+1) for the descent and (-1) for the raising; F_a is the hidrostatic force; F_d is the hidrodynamic force of the drill fluid.

The dangerous situations for the inferior extremity are:

a) the oscillation amplitude is bigger than the distance between the hole and the basis of the drill, resulting an axial violent striking of the hole, followed by the distruction of bit geometry;

b) the total pressure, $(F_a + F_d)/A$ may be bigger than the limit pressure of the walls of the hole, resulting their fissuration and the change between fluids during the axial oscillations; erruptive manifestations may be initiated, with very serious consequences.

The determination of the efforts and of the axial deformations of the drillstring, regarded as an permanent elastic-dissipative, supposes the solution of the differential equation with partial differentials of third order, with the conditions of the extremities (5, 6,7).

For the first step, the dynamic deformations, u(x,t), will be studied over the deformation state under its own weight, S(x,0), by using the change of the variable,

$$S(x,t) = S(x,0) + u(x,t). \tag{8}$$

With the new variable, the equation (4) changes into,

$$-\rho A\ddot{u} + EAu'' + kA\dot{u}'' = 0. \tag{9}$$

By putting $a^2 = E/\rho$ and accepting

$$u(x,t) = X(x)T(t)\,, \tag{10}$$

the previous equation (9) changes into

$$X\ddot{T} - a^2 X'' T - \frac{k}{\rho} X'' \dot{T} = 0\,. \tag{11}$$

By separating the variables and by imposing the condition that, for the existence of the vibration movement, each member of the equation must be equal to a negative constant,-p^2, we have

$$X'' + \frac{p^2}{a^2} X = 0 \tag{12}$$

$$\ddot{T} + \frac{k}{E} p^2 \dot{T} + p^2 T = 0 \tag{13}$$

The proper functions X(x) are obtained by the settlement of the eq. (12) under the mentioned limited conditions. In order to give satisfaction to the condition of surpassing the commonplaces, we may obtain a series of proper infinite values $p_1, p_2, \ldots,$ named the spectrum of the problem.

Corresponding to a value p_i it will be obtained the proper function, $X_i(x)$ and the general form of the solution (10), representing the normal way of vibration, will be

$$u(x,t) = X_i(x) T_i(t)\,. \tag{14}$$

By overlapping the proper ways of vibration the general solution of the equation will be obtained

$$u(x,t) = \textstyle\sum_i X_i\,(x)\,T_i(t). \tag{15}$$

The forced wave motions will be obtained through a development which followes up our own formulas $X_i(x)$ This comes back to consider the principles coordinates $T_i(t)$ as generalized coordinates of the movement $q_i(t)$, size which will be determined by the study of the power equilibrium of the mechanical elastic-dissipative pattern. In this way, the expression of the kinetic energies E_c, potential energies E_p and (since 1982) dissipative energies E_d will have a particular form, being square functions of the generalized coordinates or generalized speeds. Using these replacements, the solution which describes the dynamic movements will have the form

$$u(x,t) = \sum_i X_i(x) q_i(t) \ . \tag{16}$$

The generalized coordinates $q_i(t)$ will be determined using Lagrange's equations of second form, improved:

$$\frac{d}{dt}\left(\frac{\partial E_c}{\partial \dot{q}_i}\right) - \frac{\partial E_c}{\partial q_i} + \frac{\partial E_p}{\partial q_i} + \frac{\partial E_d}{\partial \dot{q}_i} = Q_i \ , \tag{17}$$

where, for the first time, $E_d = \frac{kA}{2}\int_0^l \dot{u}'^2 \, dx$

Q_i the generalized force of non-conservative type, corresponding to the generalized coordinate q_i.

By solving (17) and by introducing the generalized coordinates q_t(t), determined in this way, we obtain in (16) the general solution of the longitudinal displacement of the drillstring during the operations of raising and descent operations.

In this stage, we can try different raising and descent strategies in order to reduce the total time of the action, but, with the prevention of the dangerous described situations , which may lead to drilling accidents into the hole.

Even if these raising and descent operations can lead to serious accidents with various implications on the environment and costs, they are not sufficiently studied in the technic literature.

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Considerații asupra operațiilor de ridicare şi coborâre a garniturii de foraj în sondă

Rezumat

În lucrare sunt reliefate posibilitățile de modelare mecanică si matematică ale garniturii de foraj în timpul mişcărilor de ridicare şi coborâre în sondă. Sunt evidențiate situațiile periculoase ce pot să apară şi căile de evitare a acestora cu referiri la literatura tehnică din domeniu.