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The Influence of the Tool Joints Geometry on the Dynamics of the Drill String

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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. It outlines how to take into account the geometry of joints in construction of drilling string equivalent mechanical model.

Key words: *drillstring, tool joint, dynamic analysis*

The drill string is typically made up of the different sections (drill pipe or often heavyweight drill pipe, BHA and others). Each section is made up of several components, joined together using special threaded connections known as tool joints.

The drill pipe furnishes the necessary length for the drill string and serves as a conduit for the drilling fluid. Drill pipe sections (or joints) are hollow, seamless tubes manufactured from high grade steel. The tool joints or connectors for the drill string are a separate component and are attached to the pipe after its manufacture.

Pulling the drill string out of or running the drill string into the hole is referred to as tripping. The desire to diminish the time of the tripping 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 tripping, in order to avoid the drilling accidents, in [1] was made the study of the dynamic of the drillstrings during the axial-vertical displacement in the hole. To this end, it was made mechanical and mathematical modeling of the drillstring during the raising descent movements into the hole.

In this paper, we analyze the influence of geometry of the tool joints on the dynamics of the drill string.

The tool joint, with mass m_{ei}, spring constant c_{ei} and length l_{ei}, will be replaced with an equivalent pipe having equal cross-section area of drill pipe, A. The mass specific ρ_x and the modulus of elasticity E_x of the equivalent tool joint are easily obtained:

$$\rho_x = \frac{m_{ei}}{A * l_{ei}}; \tag{1}$$

$$E_x = \frac{l_{ei}}{A} * c_{ei}. \tag{2}$$

The equivalence between the tool joint and its equivalent model is shown in figure 1.

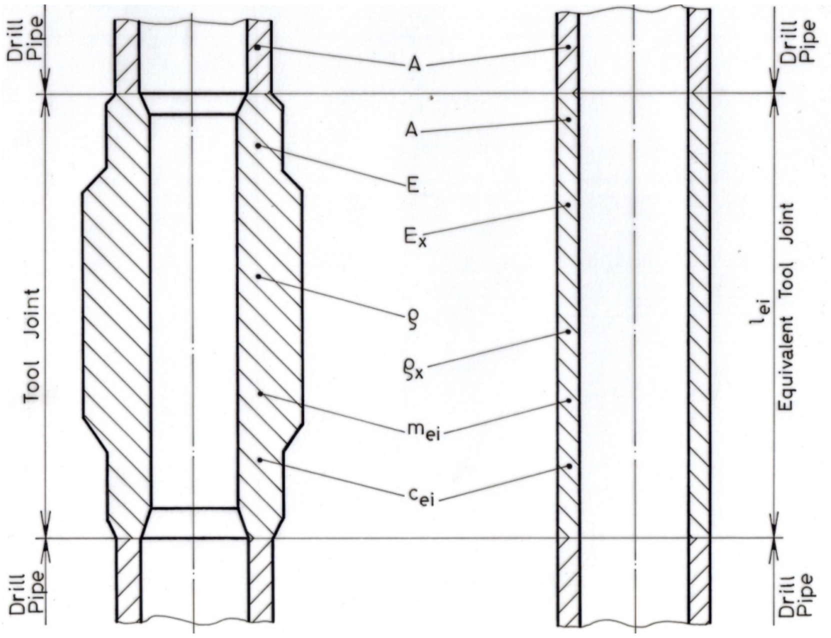

Fig. 1. The tool joint and its equivalent model.

For equivalent tool joint, the mathematical model of motion is formally identical to that used for studying the dynamics of drill pipe. The difference lies in different values of the mass specific and the modulus of elasticity (what are the ρ_x and E_x).

Replacing the tool joint with equivalent tool joint, for the drill string is obtained a model composed of sections, shown in figure 2, a. If the drill pipes have the nominal size variations, then this case is presented in figure 2.b.

Studying the dynamics of this model consists of sequentially solving the mathematical model presented in [1]. The conditions for compatibility between two successive tubes are equal corresponding values of displacements and efforts in the upstream and downstream connection section.

Displacements and efforts, in section x, can be described by functions:

$$U(x)=X_0\cos\left(\frac{p}{a}x\right)+\frac{a}{pEA}N_o\sin\left(\frac{p}{a}x\right); \tag{3}$$

$$N(x)=N_0\cos\left(\frac{p}{a}x\right)-\frac{p}{a}EAX_0\sin\left(\frac{p}{a}x\right); \tag{4}$$

where the notations are explained by the author in the paper [1].

By a dynamic analysis for the drill string, with 5-inch nominal diameter, consisting of 300 pieces of drill pipe and tool joint proper, we obtain a fundamental pulsation, p=5.1032 rad/s. If the variations introduced by the geometry, due to the mass and elasticity of tool joint, are neglected, then the fundamental pulsation is, p=5.4999 rad/s.

The calculation example shown above, it follows that the study of drillstring dynamics, by neglecting the mass and spring constant variations introduced by tool joints, introduce errors of 7.2%, between the fundamental pulsations. By placing the approximation of equivalent tube for Tool Joint, dynamic calculation is accessible but still laborious.

To facilitate calculation, we can build a mechanical model of the equivalent drill string (with features evenly distributed, ρ_{te} and E_{te}, see figure 2, c), which has the same fundamental pulsation, p=5.1032 rad/s.

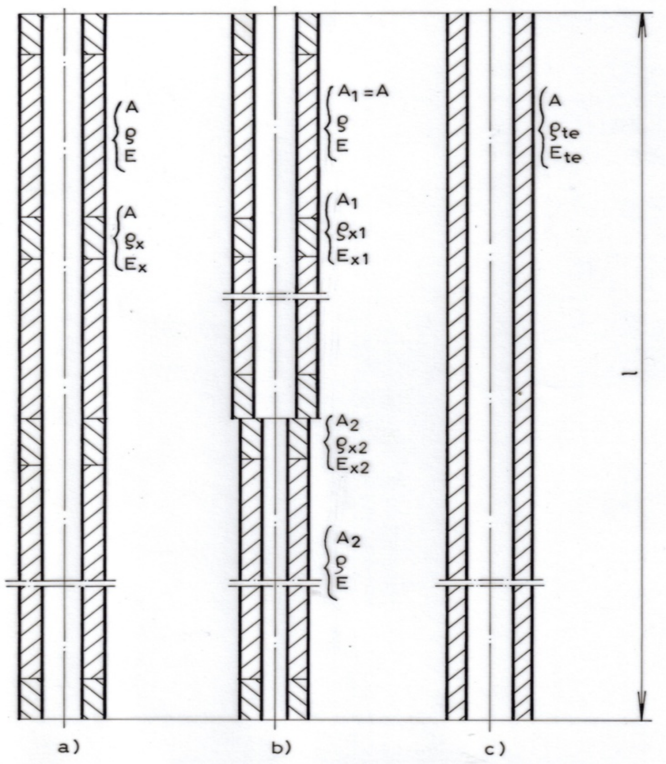

Fig. 2. The models of drilling string.

Mathematical expression of the fundamental pulsation is:

$$P=\pi\frac{a_{te}}{l_{te}}, \quad (5)$$

where a_{te} is the speed of propagation of elastic deformation and l_{te} is the length of drillstring.

If p=5.1032 rad/s, it results a_{te}=4799.12 m/s. If we impose the condition of equal masses of two elastic systems, then it results:

$$p_{te}=9133.2 \text{ kg/m}^3;$$

$$E_{te}=2.1035*10^{11}\text{Pa}.$$

These values of the equivalent drill string represent increases of 16.34% and corresponding 0.16%, compared to the same size of the body drill pipe. That is why we should not neglect the existence of the tool joints geometry in length of drillstring, if we want a fair resolution of the dynamics of the tripping!

References

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Influența geometriei racordurilor speciale asupra dinamicii garniturii de foraj

Rezumat

In lucrare sunt reliefate posibilitatile de modelare mecanica si matematica ale garniturii de foraj in timpul miscarilor de ridicare si coborare in sonda. Sunt evidentiate modalitatile de a lua in considerare geometria racordurilor speciale in construirea modelului mecanic echivalent garniturii de foraj.