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Characteristics of the Mechanical Transmission in the Process of Power Transmission the Long Pipelines

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Abstract: In the drilling process, in order to calculate changes of stress in the process of power transmission along the long pipelines, this study researched movement velocity's fluctuation of actuating mechanism and forms of excluding fluctuation. Then two partial derivative simultaneous equations were obtained. On the basis of the equations, the boundary conditions were stipulated. And laplace's equations of actuating mechanism were derived. Considering external force's influence on movement velocity's fluctuation of actuating mechanism, frequency characteristic was figured out, nonlinear differential equations were reached with Runge-Kutta, and the frequency characteristics grap was drawed. In the conversion process, stable and unstable region of transmission were revealsed. Laid the foundation for the research on reliability of drilling device.

Key words: Long pipelines, power transmission, characteristic of vibration frequency, stable and unstable region

INTRODUCTION

For deep drilling device, the mechanical drive's performance in many cases related with the limit load when the stress exceeds the proportional limit. So, the motion can be amended based on increase the stress for long-line power transmission. Then the application of this device as a transmission technology goal can be realized and the velocity fluctuations in demand for the formation of values can be formed according to the control .Now the existing methods for solving the problem of in indirect manner namely, by the end of active and passive side of the displacement. The literature (Medvedev, 2008) applied the theory of elasticity to obtain the following equation:

$$\xi\frac{\partial^2 u}{\partial t^2}-\frac{\partial[xf_k\frac{\partial u}{\partial x}]}{\partial x}=Q_H(x,t)$$

Solved as:

$$u(x,t)=\sum_{k=1}^{\infty}H_k\theta(x)\sin(p_kt+\alpha_k)$$

where, ξ, x: Mechanical long pipeline quality and elastic properties, f_k: Cross-sectional area, Q_H: External load intensity, H_k, θ_k, p_k, α_k: Constants determined by the initial conditions, u, x: The displacement along the pipe axis and the drive end of the center, t: Time.

Taking into account the long power transmission, it is very difficult to determine the stability of the drive, especially considering nonlinear equations and then the problem will be even more difficult. The main reason is that the frequency characteristic of the transmission during the drive is determined by waveform of the displacement and vibration. Then some way for solving mechanical reciprocating frequency characteristics is proposed.

MATHEMATICAL MODEL FOR LONG LINES OF MECHANICAL TRANSMISSION CHARACTERISTICS

Description of piping stress per unit volume per unit length and velocity changes: Figure 1 shows the drill column drill collar lifting transmission. The drill column includes screw power source 1, drill 2, drill collars 3, drill pipe columns 4 and drill drilling motor 5. After processing, the drill can be raised using the cranes (hoist).

Similar to the above devices using long metal pipes, rods, tubes or rope, active side with speed v_1 upward movement. The actuator can be converted into a weight particle of m moving with velocity v_2. So the resistance and viscous friction $F_{f2}= h_nv_2$ (h_n is proportional to velocity loss coefficient).

Assuming elastic pipeline longitudinal vibration using the following equation (Sedov,2009):

$$\frac{\partial^2 u}{\partial t^2}=E\rho^{-1}\frac{\partial^2 u}{\partial x^2} \quad (1)$$

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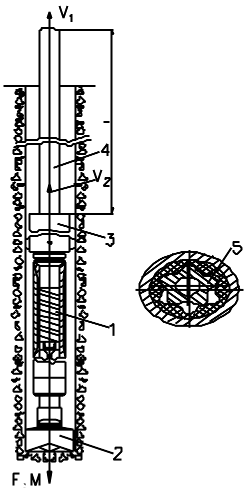

Fig. 1: Drill collar lifting transmission

where, E: Longitudinal elastic modulus, ρ: Density. Consider the viscous friction in the material without the energy conservation, then:

$$\rho\frac{\partial v}{\partial t}=-\frac{\partial \sigma}{\partial x} \tag{2}$$

where:

$$v=\frac{\partial u}{\partial t}$$

Compare Eq. 1 and 2 to obtain equations, then:

$$E\frac{\partial^2 u}{\partial x^2}=-\frac{\partial \sigma}{\partial t}$$

After integral x and differential t, the equation can beconverted as:

$$E\frac{\partial v}{\partial x}=-\frac{\partial \sigma}{\partial t} \tag{3}$$

Equation 2 and 3 described the stress change and velocity segment changes per unit volume and per unit length respectively in the pipeline. The way has not yet been adopted for studying reciprocating action of the mechanical vibration.

Establishment of reciprocating mechanical transmission characteristic equation: Suppose E and ñ is constant and the zero initial conditions is used the equation can be converted by the Laplace transform as(Ivanov, 2011):

$$\rho s v(s)=-\frac{d\sigma(s)}{dx}, E\frac{dv(s)}{dx}=-s\sigma(s) \tag{4}$$

where, v (s), σ (s): Laplace transform of v (t) and σ (t).

If doing x differential for first Eq. 4 and taking the second derivative of second Eq. 4 the equation can be converted as:

$$\frac{d^2\sigma(s)}{dx^2}-\theta_n^2(s)\sigma(s)=0$$

where, $\theta_n(s)=\pm s(\rho E^{-1})^{0.5}$: Distributed computing wave propagation coefficient.

Assuming x = 0, σ (s, x) = σ_1 (s, 0) dσ/dx = $-\theta_n^2(s)s^{-1}$ $Ev_1(s, 0)$, the equation can be solved using below form (Popov, 2007):

$$\begin{aligned}\sigma(s,x)&=\sigma_1(s,0)ch[\theta_n(s)x]-\\&-\theta_n(s)Es^{-1}v_1(s,0)sh[\theta_n(s)x]\end{aligned} \tag{5}$$

Similarly, relative to v (s, x) solving Eq. 4, having the form as flows:

$$\begin{aligned}v(s,x)&=v_1(s,0)ch[\theta_n(s)x]-\\&-\theta_n^{-1}(s)E^{-1}s\sigma_1(s,0)sh[\theta_n(s)x]\end{aligned} \tag{6}$$

Supplement the Eq. 5 and 6 constraints. Assuming the actuator completely consumed energy delivered on its mobile. Then:

$$\begin{aligned}&v(s,l)=v_2(s), v(s,0)=v_1(s),\\&\sigma(s,l)=\sigma_2(s), \sigma(s,0)=\sigma_1(s),\\&\sigma(s)=\left[F(s)+h_n v_2(s)+msv_2(s)\right]/f_2\end{aligned} \tag{7}$$

where, f_2: Cross-sectional area for m weight pipe, l-length of the pipe.

The reciprocating mechanical transmission characteristic equation can be obtained by simultaneous Eq. 5-7:

$$\begin{aligned}&v_2(s)[1+h_n\vartheta_n(s)s+m\vartheta_n(s)s^2]\\&=v_1(s)ch^{-1}[\theta_n(s)l]-F(s)\vartheta_n(s)s\end{aligned} \tag{8}$$

Where:

$$\begin{aligned}&\vartheta_n(s)=\vartheta_{no}Z_n(s);\\&\vartheta_{no}=lE^{-1}f_2^{-1};\\&Z_n(s)=th[\theta_n(s)l]/[\theta_n(s)l]\end{aligned}$$

Analysis: For application reciprocating mechanical transmission Eq. 8 which provides frequency characteristics without relation with computing and length the influence ofF on v_2 can be reached:

$$\begin{aligned}W_F(j\omega)&=v_2(j\omega)/F(j\omega)\\&=-\frac{\vartheta_n(j\omega)j\omega}{1+h_n\vartheta_n(j\omega)j\omega+m\vartheta_n(j\omega)(j\omega)^2}\end{aligned} \tag{9}$$

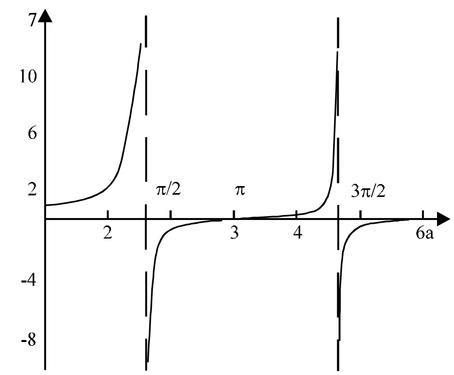

Fig. 2: Figure of Z(α)

When the F = 0 the influence of v_1 on v_2 can be reached:

$$\begin{aligned} Z_n(j\omega) &= th[\theta_n(j\omega)l]/[\theta_n(j\omega)l] \\ &= th[lj\omega(\rho E^{-1})^{0.5}]/[j\omega l(\rho E^{-1})^{0.5}] \\ &= tg\alpha/\alpha, \end{aligned}$$

Because of:

$$\begin{aligned} Z_n(j\omega) &= th[\theta_n(j\omega)l]/[\theta_n(j\omega)l] \\ &= th[lj\omega(\rho E^{-1})^{0.5}]/[j\omega l(\rho E^{-1})^{0.5}] \\ &= tg\alpha/\alpha, ch(j\alpha) = \cos\alpha(\alpha = l\omega(\rho E^{-1})^{0.5}) \end{aligned}$$

the:

$$\vartheta_n(j\omega) = \vartheta_n(\alpha) = \vartheta_{no} Z_n(\alpha)\cos\alpha$$

and:

$$\vartheta_n(j\omega) = \vartheta_n(\alpha) = \vartheta_{no} Z_n(\alpha)\cos\alpha$$

are not integrated functions and figure of $Z_n(\alpha)$ shows in Fig. 2. It can be seen from the figure that Z<0 (k = 0, 1, 2, …, n) when the$\alpha>0$ and $\pi/2+k\pi>\alpha>\pi+k\pi$.

If $\alpha>0$ the Eq. 8 suitable for short transmission line dynamic process is described in the known equation:

$$v_2(s)[1 + h_n\vartheta_{no}s + m\vartheta_{no}s^2] = v_1(s) - F(s)\vartheta_{no}s$$

With Eq. 9 determines the amplitude:

$$\begin{aligned} A_F(\omega) &= \frac{\vartheta_n(\alpha_n)\omega}{\{[1 - m\vartheta_n(\alpha_n)\omega^2]^2 + [h_n\vartheta_n(\alpha_n)\omega]^2\}^{0.5}} \\ &= \{[1 - m\vartheta_n(\alpha_n)\omega^2]^2/[\vartheta_n(\alpha_n)\omega]^2 + h_n^2\}^{-0.5} \end{aligned}$$

When:

$$[1 - m\vartheta_n(\alpha_n)\omega^2]/[\vartheta_n(\alpha_n)\omega] = 0$$

the amplitude of A_F is maximum value. After a series of algebraic transformation, this condition is summarized as known equations. The resonant frequency in accordance with the fixed end of a similar initiative to the natural frequency of the drive and can be solved according to the literature (Medvedev, 2008) proposed method.

EXAMPLE SIMULATIONS AND ANALYSIS

Figure 3 shows the amplitude A and phase φ of the frequency logarithmic characteristic curve, which means a affect of resistance force F on the mechanical vibration of the actuator drive (i.e., drill chain shown in Fig. 1) of the moving speed. And the transmission including drill (Φ114×10, $L_Ó$ = 1000 M) placed at the ends of the column drill chain management (Φ203×60, L_G = 20 M), D1-195 hydraulic rotary positive displacement auger motor and Φ215.9 drill. Transmission parameters:

$$E = 2\times10^5 \text{MPa}, h_n = 10 \text{ Ns m}^{-1}, m = 3.44 \text{ kg}\cdot\text{s}^2 \text{ cm}^{-1}$$

Then, the amplitude can be calculated by the equation A = 20 lgA_F and the phase can be calculated by the following equation:

$$\phi = arctg[Im\ W_F(j\omega)/R_e W_F(j\omega)]$$

It can be seen from the equation that the resonance occurs when the frequency ω = 7, 21, 35.6, ...

In view of the importance of the frequency characteristics the mechanical transmission actuator velocity versus time characteristics must be evaluated correctly. So in order to resolve this problem the Eq. 8 can be decomposed as:

$$\begin{aligned} v_1(s)\cos^{-1}\alpha &= v_2(s) + \vartheta_n(\alpha)f_2 s\sigma(s), \sigma(s)f_2 \\ &= F(s) + h_n v_2(s) + msv_2(s) \end{aligned} \quad (10)$$

Doing inverse Laplace transform for function:

$$F_1(s) = \vartheta_n(\alpha)f_2 s\sigma(s), F_2(s) = V_1(s)\cos^{-1}\alpha$$

Then:

$$\begin{aligned} L^{-1}|F_1(s)| &= (2\pi j)^{-1}\int_{c-\infty}^{c+\infty}\vartheta_n(\alpha)f_2 s\sigma(s)e^{st}ds \\ &= \vartheta_n(\alpha)f_2(2\pi j)^{-1}\int_{c-\infty}^{c+\infty}s\sigma(s)e^{st}ds \\ &= \vartheta_n(\alpha)f_2\frac{d\sigma(t)}{dt}, L^{-1}|F_2(s)| = v_1(t)\cos^{-1}\alpha \end{aligned}$$

So, the Eq. 10 can be converted as:

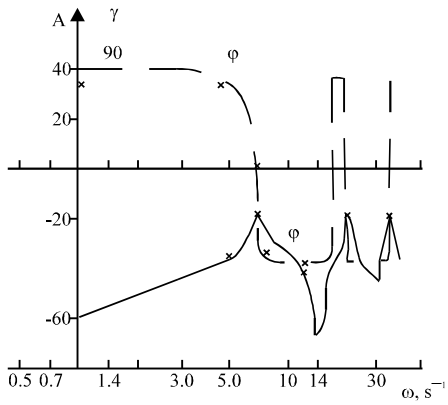

Fig. 3: Characteristic curve of frequency logarithmic

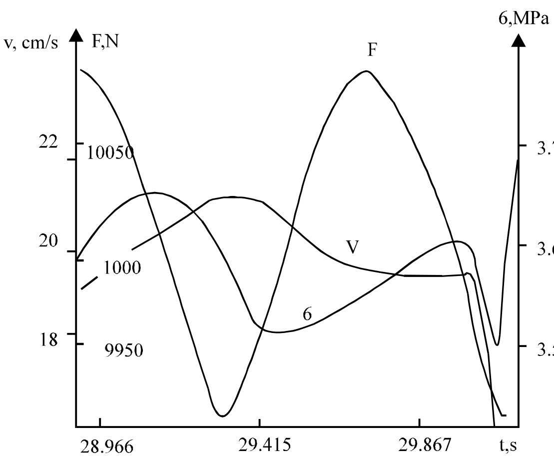

Fig. 4: Character curve of ó (t), v (t)

$$v_1(t)\cos^{-1}\alpha = v_2(t) + \vartheta_n(\alpha)f_2\frac{d\sigma(t)}{dt},$$
$$\sigma(t)f_{22} = F(t) + h_n v_2(t) + m\frac{dv_2(t)}{dt} \quad (11)$$

Then, the Eq. 11 is resolved using Runge-Kutta numerical method when the step is 2×10^{-4}, 4×10^{-4}s, velocity is v_1 = 0.2 m sec^{-1} and resistance is F = 9800 (1+0.01sinωt)[N].

Different vibration frequency under the action of the force F can be calculated as following: change the velocity to v1 = 0.2 m sec^{-1} and maintain the velocity when the ω = 0 then change the velocity every 10 seconds. And the vibration frequency is shown in Fig. 3 by a small cross. It can be seen that the stability the frequency characteristics of a certain time result is close the results calculated by the Eq. 9. And it also accurate can be checked using different methods.

During the simulation process it is found that if Z <0 the solution becomes unstable. In the above-mentioned transmission parameter, the instability occurs at

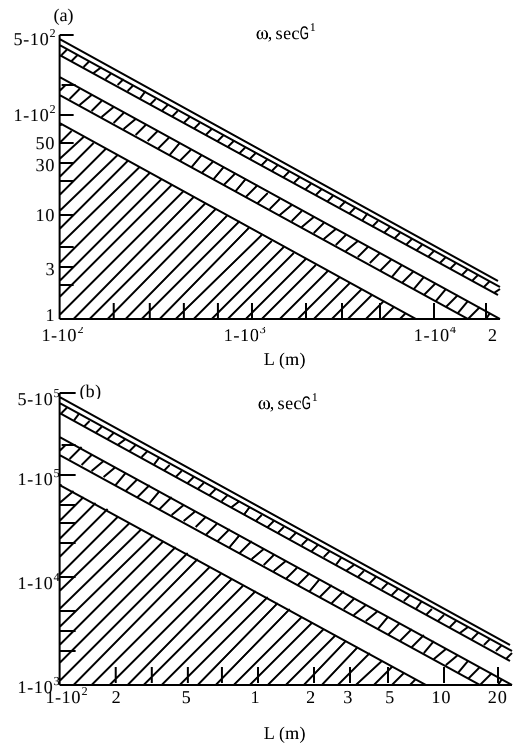

Fig. 5: Transmission region for the pipe

ω = 7.87~15.7, 23.6~31.5, 39.3~47.2…, i.e., the frequency is bigger than the resonance frequency. Now the curve of σ (t) and v (t) is shown in Fig. 4. Changing the value ω, speed sharply stopped while the stress hysteresis of several Δt = 0.1 sec and then increases rapidly.

The unbalance characteristic area (where Z <0) can be determined as the stability of the drive transmission path pipe work area (hatched) and non-stable region, shown in Fig. 5. And the Fig. 5a) is small and large length frequency stability region while the Fig. 5b) is the high-frequency vibration and the small length stabilization zone.

In the study system shown in figure 1, when the column rises the frequency of slurry in it can be decried as:

$$\Omega_p \approx z v_2 f_D / w$$

Where, w-Motor capacity (constant), z: rotor teeth:

$$f_D = \frac{\pi D_D^2}{4}$$

Cross area of the drill.

Because the rotor eccentrically mounted the different values Ωp of vibration friction should be introduced under the different rising velocity. Then:

$$\alpha = l\omega(\rho E^{-1})^{0.5} = k_{\omega} l(\rho E^{-1})^{0.5} v_2, \text{where } k_{\omega} = zf_D / w$$

In this case some conclusion can reached that there will be an equivalent tool sticking phenomena at some speed such as the screw hole drill motor D1-54. When the height is 1 km the minimum velocity is about 1.14 cm sec^{-1}.

CONCLUSION

For long mechanical power transmission line the stability of the system may be lost in the case of this study noted. More ever the hydraulic and torsion vibration also caused instability. This study gives some reference for the mechanical structure of the drilling device design and the movement of the drilling process parameter settings.

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REFERENCE

Ivanov, 2011. Mathematical Foundations of Automatic Control Theory. Energy Press, Moscow, Russia.

Medvedev, 2008. Vibration Theory. Oriental Press, UK.

Popov, 2007. Hydraulic and pneumatic mechanical adjustment. Engineering, 32: 23- 24.

Sedov, 2009. Continuum mechanics under the environmental characteristics. Mining, 28: 11-12.