

Investigation of the input signal frequency effect on the formed pulse of the hydraulic-powered pulse machine

M V Novoseltseva, I A Masson

National Research Tomsk Polytechnic University, 30, Lenina ave., Tomsk, 634050, Russia

E-mail: novmv@tpu.ru

Abstract. Nowadays, a special emphasis is placed on an output signal curve during the analysis of well drilling machines since these machines should have as high energy efficiency as it is possible. This work proposes factors that have an impact of input signal frequency on the formed pulse that are used to find the most efficient frequency for its further applying in the machine. Results of the conducted experiment are obtained by using a mathematical model that is created in Simulink Matlab.

1. Introduction

Nowadays, special emphasis is placed on an output signal curve during the analysis of well drilling machines. Efficiency of existing drilling impact machines is estimated by comparison of impact energy. The value of impact energy is variable and usually dependent on the borehole diameter and the type of a machine. Impact energy is not the only factor that contributes to the overall efficiency of drilling by impact machines; amplitude and the oscillation period should be evaluated too. The current work is dedicated to finding of the best value of amplitude and the oscillation period that eventually can improve key performance indicators of existing impact machines. These indicators include [6]:

- good energy efficiency;
- formation of the applicable pulse curve;
- the highest peak efficiency.

The analysis of impact machines shows several drawbacks of existing impact machines, hence a new type of impact machine is described. This is a hydraulic-powered pulse machine without a pin, which is being developed in Tomsk Polytechnic University [1, 4]. The existing machines have energy losses on friction that occur among the pin, the anvil and the casing. The developed hydraulic-powered pulse machine without the pin is not only less affected by friction, but it also uses a resonance effect in the fluid power cylinder [3].

2. Mathematical modelling of the impact machine

Mathematical models describe the basic properties of an object, process or system, its parameters, internal and external communications with the help of logical-mathematical structures. At the current stage of research, a mathematical model of the developed machine is created to analyze the input signal effect on formed pulse parameters. All experiments are conducted in the MATLAB software. The software offers a variety of methods for finding a solution to Cauchy problem for differential equations: ordinary differential equation (ODE) solvers, special-purpose programs for the model investigation of controlled systems, SIMULINK as an analog simulation tool [2]. The scheme



generated in SIMULINK consists of units that simulate the process, its properties and construction parameters. The flow chart of the impact hydroimpulsive machine that depicts interrelationship of all machine units is shown in Figure 1. The mathematical model covers a hydro-pulsator, a high-pressure hose and impact machine parts.

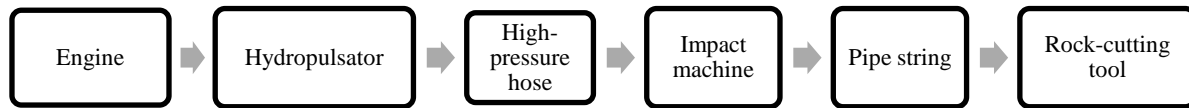


Figure 1. A flow chart of the impact hydroimpulsive machine.

DSP System Toolbox is used for mathematical modeling of the hydraulic-powered pulse machine; it allows predicting the system behavior under different conditions and then simulating it for a more precise system analysis.

3. Impact of input signal frequency on the formed pulse

It is important to determine the value of input pulse frequency, because the system work is based on resonance; therefore, the frequency of its oscillations matches the system's natural frequency of vibration [5]. It is also important to find resonance frequency for different input system parameters. Bode plot, one of the Matlab modules, is used for natural frequency determination. Bode plot itself is a graph of the frequency response of the system. It is usually a combination of Bode magnitude plot and Bode phase plot, both quantities are plotted against the same horizontal axis. Bode magnitude plot expresses the magnitude of the frequency response; ω -axis of the magnitude plot is logarithmic and the magnitude is given in decibels. Bode phase plot is the graph of the phase of the transfer function in degrees plotted logarithmically as a function of ω .

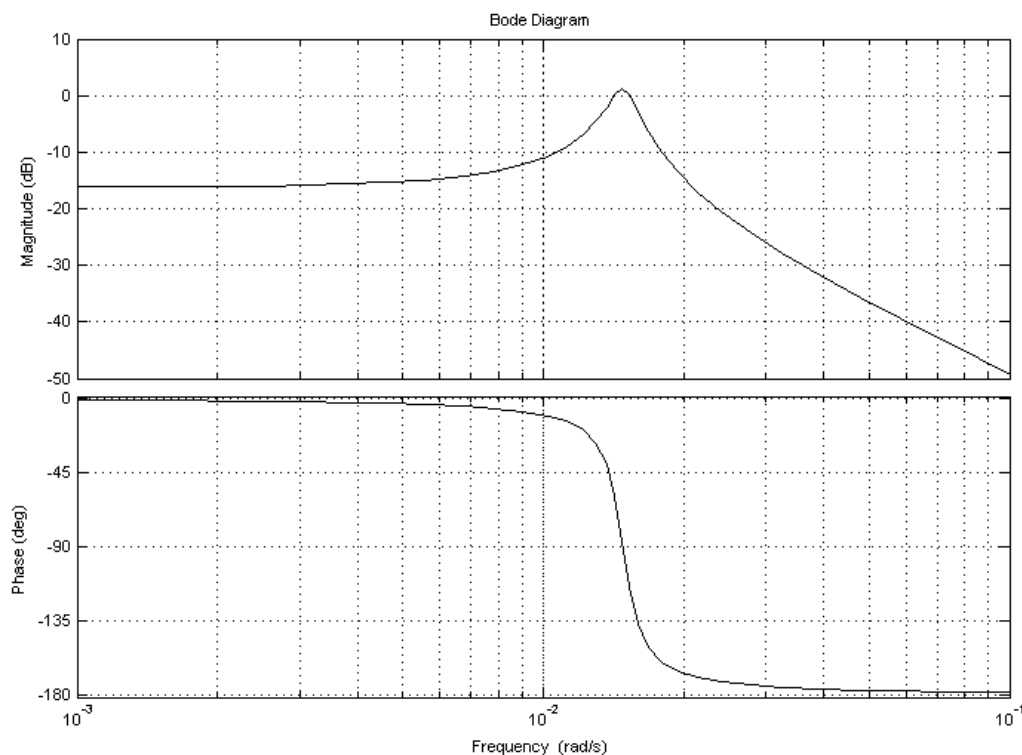


Figure 2. Bode plot of the hydraulic-powered pulse machine without the pin for initial parameters of the system.

The mathematical model is tested for the following system parameters, as depicted in Table 1.

Table 1. Impact machine parameters

	Parameter	Value
c	Spring stiffness	$18639 \frac{N}{m}$
m	Active mass	100 kg
Cv	High-pressure hose volume elasticity	$3.441 \cdot 10^{-9} \frac{m^3}{Pa}$
k_f	Coefficient of friction	0.2

The system base frequency is deduced from bode plot on the magnitude curve as a peak value on X axis. The system base frequency obtained from bode plot (Figure 2) is inserted into the mathematical model input parameters. The input signal curve is sine due to the specified motion law of the plunger [4]. ω_n stands for natural frequency; it depends on spring stiffness, high-pressure hose volume elasticity and active mass. ω_{in} stands for input frequency; it depends on the motion law of the machine drive and can be adjusted.

4. Results and Discussion

For coalescence of frequencies $\omega_n = 2.36$ mHz and $\omega_{in} = 2.36$ mHz, the hydraulic-powered pulse machine operates in a resonance mode as shown in Figure 3. The pulse amplitude reaches the peak value; no instability during the transient condition or deviation of the curve form are observed.

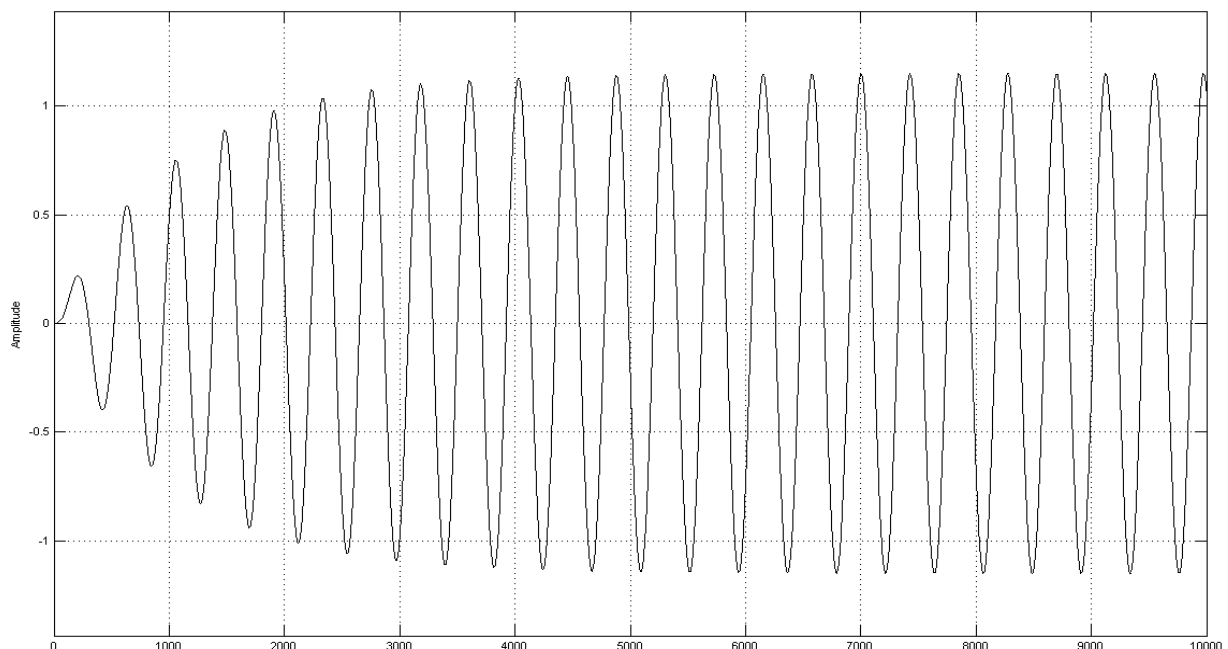


Figure 3. The formed output pulse curve for $\omega_{in} = 2.36$ mHz.

The input frequency value is set below the resonance value of 2.36 mHz. Calculations are made for $\omega_{in} = 1.6$ mHz (Figure 4). The output signal is periodic after some instability in the transient phase; its

oscillation period is increased. Though the frequency is slightly changed, the amplitude is almost 4 times lower than that in the resonance mode.

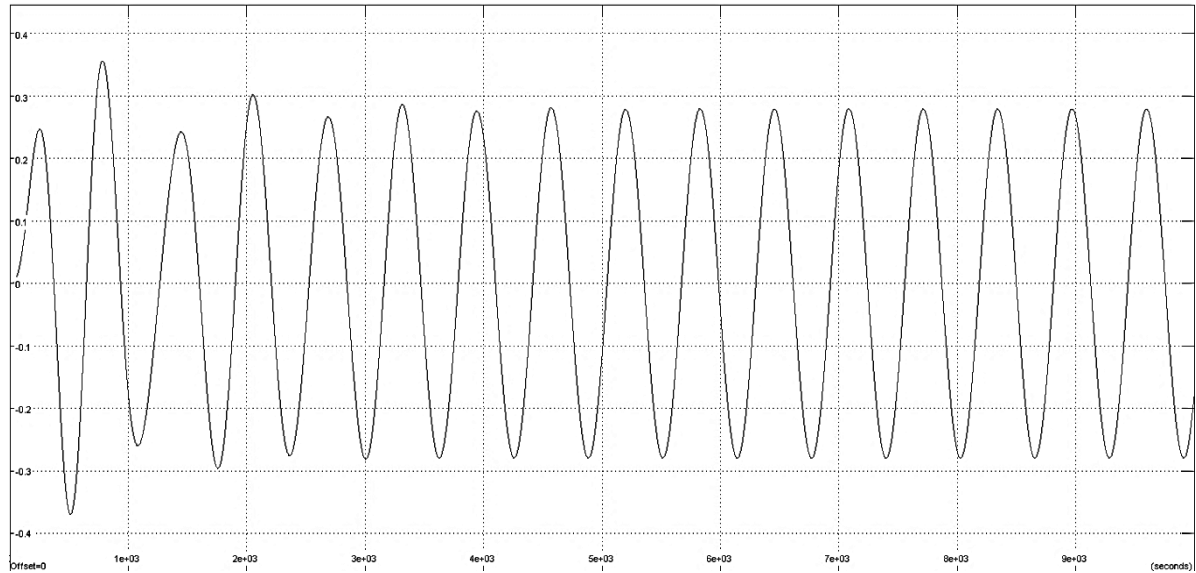


Figure 4. The formed output pulse curve for $\omega_{in} = 1.6$ mHz.

The input frequency value is set above the resonance value of 2.36 mHz. Calculations are made for $\omega_{in} = 3.2$ mHz (Figure 5). The output signal is periodic after apparent instability in the transient phase; its oscillation period is decreased. Though the frequency is slightly increased, the amplitude is almost 6 times lower than that in the resonance mode.

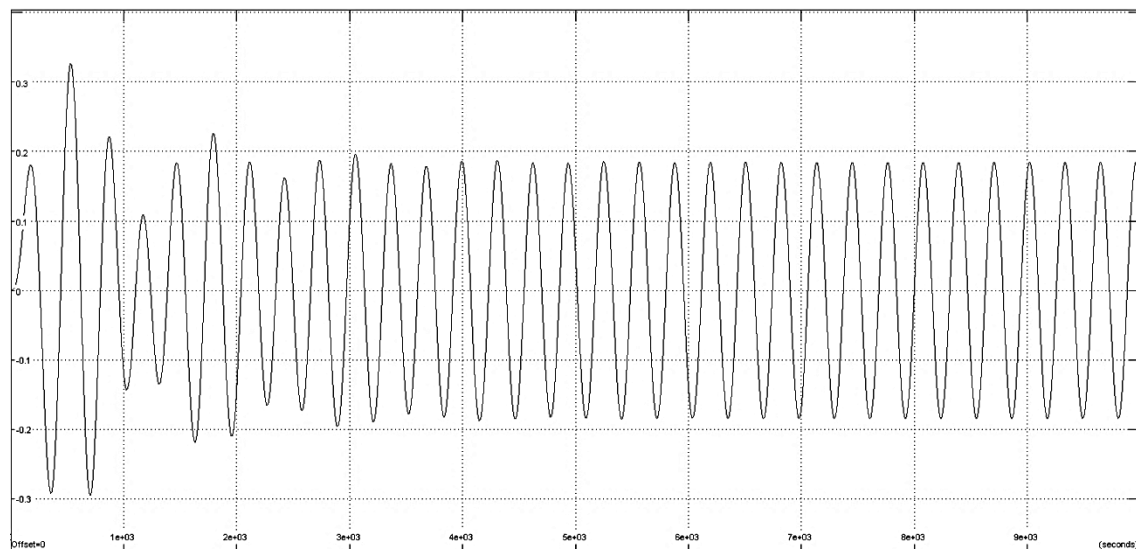


Figure 5. The formed output pulse curve for $\omega_{in} = 3.2$ mHz.

5. Conclusion

The machine mathematical simulation has shown the possibility to impact the pulse parameters in the calculated range by changing frequency as an input parameter. It is of great importance to operate the machine in the resonance mode, because slight changes in the input frequency strongly reduces the amplitude, i.e. reduces the overall machine efficiency. The conducted experiments show less

instability in the mode below the resonance one, which follows after the resonance mode; the amplitude is 1.5 times higher during the oscillation period, which is almost 2 times higher than that following the resonance mode and 1.4 times higher than that in the resonance mode.

References

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