

Dynamic analysis and parameter matching simulation system of DTH Hammer

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Abstract: DTH hammer drilling in rock fragmentation has been widely used, but there is still a lack of effective computer-aided design tools. In this study, the dynamic analysis and parameter matching simulation system for down-the-hole hammer was developed. The dynamic process of down-the-hole drilling was elaborated, and the structural parameters of DTH drilling system were analyzed and studied. This work can provide the basis and reference for the economical and efficient design of DTH drilling system.

Introduction

Some predecessors have carried out a series of related work about the computer simulation study of dynamic process of DTH drilling^[1-4]. However, the research is mainly focused on the dynamic analysis of the DTH Hammer without yet established a more comprehensive computer simulation program^[5-7], and there is no a software for the evaluation and parameter optimization of the design scheme. So it is difficult to popularize and apply in the design of DTH impact drilling system^[8-10]. At present, the design of DTH impact drilling system is mainly based on experience and analogy.

In this case, a computer simulation system for dynamic analysis and parameter matching simulation system of DTH Hammer is developed in our study, which can be used as a computer-aided design method.

Principle of algorithm

DTH impactor piston movement equation:

$$M_P \frac{d^2 x}{dt^2} = F(t) = P_1 A_1 - P_2 A_2 - F_Q \quad (1)$$

Where: M_P —Piston quality; x —Piston displacement; t —Time; P_1 、 P_2 —Front and rear chamber pressure; A_1 、 A_2 —Front and rear chamber pressure area; F_Q —Tail force.

To divide the front and back cavity gas distribution process into 5 intervals (Fig. 1 input interface), the change of gas in the movement of the piston is a variable process, the equations of motion are second-order nonlinear differential equations, which can be solved by numerical methods, the quasi-stable state technique is used to determine the unit displacement S ., divide the piston motion into sufficiently short micro segments. In each micro segment, the gas state is constant then the force of the piston is a constant force, the motion of the piston can be regarded as acceleration, the values of the pressure in each zone are shown in Table 1.

Table 1: Each Section Pressure Value

Intervals	I	II	III	IV	V
$P_1(N)$	P_i	P_i	$P_1(N) = P_1(N-1) \left[\frac{L_D + x(N-1)}{L_D + x(N-1) + S} \right]^{1.3}$	P_0	P_i
$P_2(N)$	P_0	$P_2(N) = P_2(N-1) \left[\frac{LUL - x(N-1)}{LUL - x(N-1) - S} \right]^{1.3}$			P_i

P_1 and P_0 in the table are inlet and outlet pressures, according to the equation (1), the numerical solution is performed, and the calculation is performed step by step. Each cycle is obtained until the movement of the piston tends to a stable-state motion (approaching the limit cycle), and the calculation result and the stable-state motion curve are given (the output interface in Fig. 3).

Input Interface

The effect of the DTH hammer Can be study by changing the parameters.

Dynamic Analysis Input Interface

Gas Distribution Process

Parameter Input Interface of DTH Hammer

Exhaust Pressure (10 ⁵ Pa)	<input type="text" value="0"/>	Cylinder Diameter (cm)	<input type="text" value="6.1"/>
Inlet Pressure (10 ⁵ Pa)	<input type="text" value="5"/>	Back Cavity Area(cm ²)	<input type="text" value="34.68"/>
Piston Quality (kg)	<input type="text" value="7.8"/>	Front Cavity Area(cm ²)	<input type="text" value="35.72"/>
Tail Force (9.81N)	<input type="text" value="67.8"/>		
Initial Position Back Cavity	<input type="text" value="12.32"/>	Front Air Cushion Length(cm)	<input type="text" value="3.65"/>
Length of Front Cavity Inlet - Back Cavity Exhaust(cm)	<input type="text" value="2.15"/>	Length of Front Cavity Inlet-Back Cavity Compression Expansion(cm)	<input type="text" value="0.175"/>
Length of Front Cavity Compression Expansion-Back Cavity Compression Expansion(cm)	<input type="text" value="1.875"/>	Length of Front Cavity Exhaust-Back Cavity Compression Expansion(cm)	<input type="text" value="3.35"/>

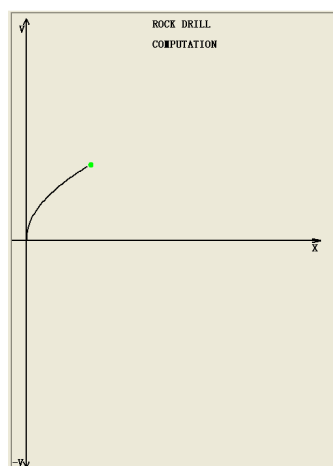
Fig. 1 Dynamic Analysis Input Interface

Fig. 1: L_1 ——Length of Front cavity Inlet- Back Cavity Exhaust, cm; L_2 ——Length of Front cavity Inlet- Back Cavity Compression Expansion, cm; L_3 ——Length of Front cavity Compression Expansion-Back Cavity Compression Expansion, cm; L_4 ——Length of Front cavity Exhaust- Back Cavity Compression Expansion, cm; L_5 ——Length of Front cavity Exhaust- Back Cavity Inlet, cm; L_D ——Front Air Cushion Length,cm; LU_4 ——Length of Back cavity at the end of phase IV, cm; LUL ——Length of Back cavity in the Beginning, cm; L ——Piston throw, $L=L_1+L_2+L_3+L_4+L_5$.

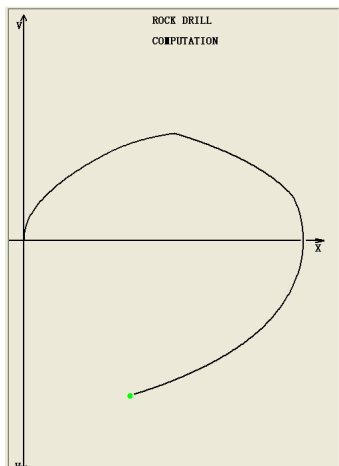
Output Interface

Fig. 2 (a) - (f) shows the gradual transition of the piston from the initial position to a stable state of motion. Fig. 2 (g) is the stable motion state of the piston, i.e., the reciprocating cycle of the piston in the limit circle of the outer ring. Fig. 2 (h) shows the displacement and time motion curves of piston in stable state motion. Fig. 2 (I) shows the calculation results of the relevant parameters of the piston in stable state motion.

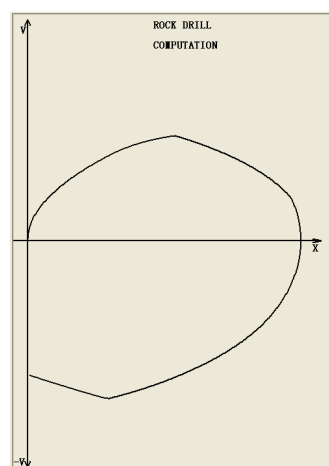
Fig. 3 shows the full output interface of the dynamic analysis and parameter matching computer simulation system of DTH hammer.



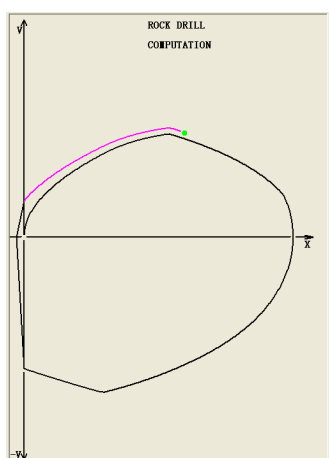
(a) Initial stage



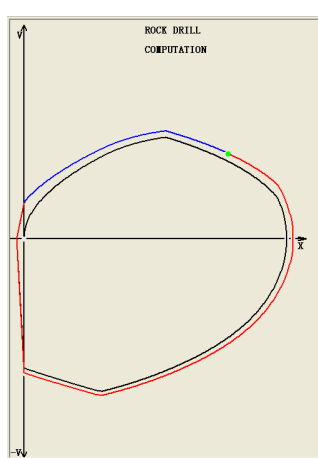
(b) Initial trajectory phase



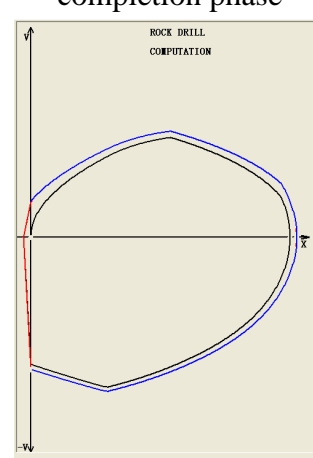
(c) Initial trajectory completion phase



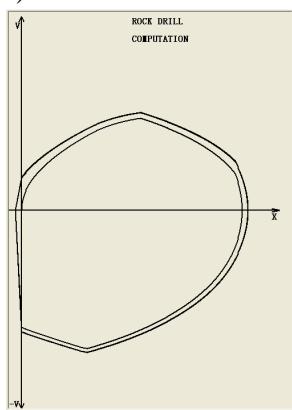
(d) Start the second track



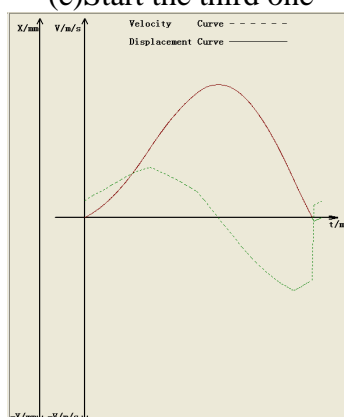
(e) Start the third one



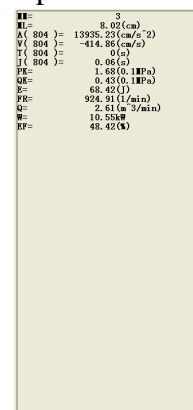
(f) Complete the third track



(g) Loop around the outside



(h) Stable state motion curve



(i) Calculate results

Fig. 2 Dynamic Analysis and Parameter Matching Output Interface Processes

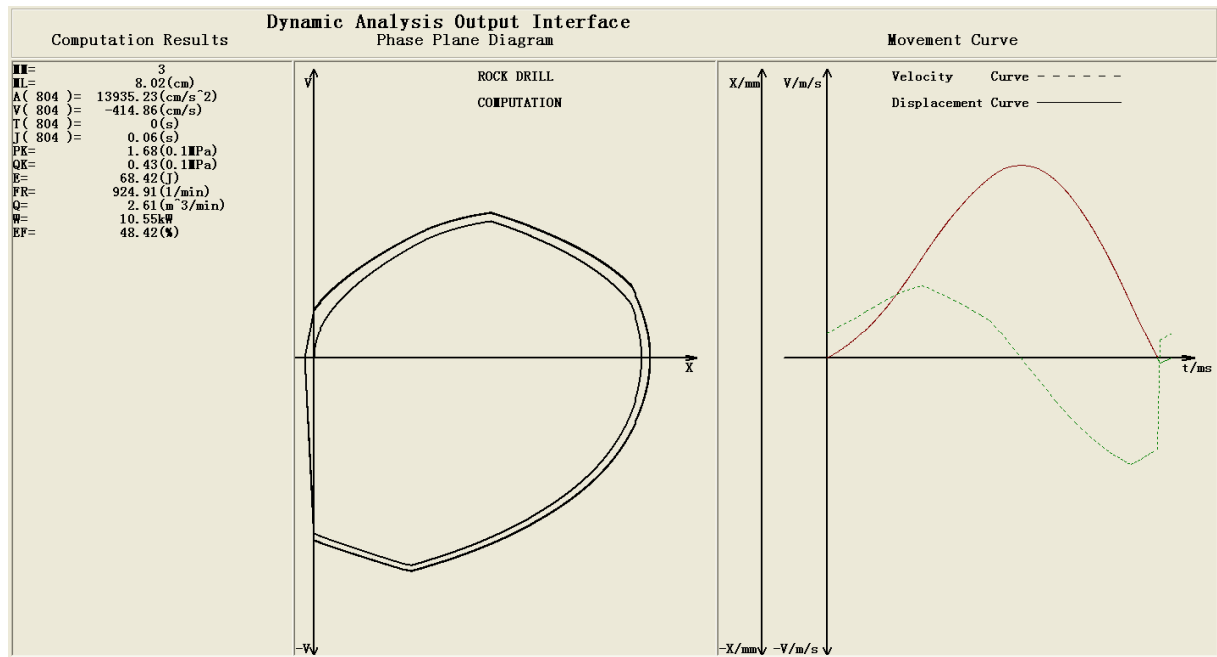


Fig. 3 Dynamic Analysis and Parameter Matching Output Interface

Conclusion

The simulation system uses the computer simulation method to comprehensively analyze the dynamics and parameter matching process of the downhole drilling system, which can give the influence of various parameters on the performance of the downhole drilling system. It can be used for the optimization design and efficiency evaluation of the product.

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