The Building of Naval Gun Dynamics Simulation Model Based on Adams

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***Abstract*—Because of conditions limit and expensive, the method of gun firing research naval gun system shooting dynamics equation generally less used. The paper carry simulates calculation based on Adams, analysis the character of naval gun system dynamics. And draw support from parts of test data checkout the dynamics model, achieved satisfactory results.**

Key words: Naval Gun, Dynamics analysis, Simulation Model, Adams

I OVERVIEW

There are two main ways research the dynamics process of gun firing process: One way is through the pilot test firing live ammunition artillery kinetic data, study the structure and dynamics of the model parameters, in this way, it would be cost too much, general in the case of the shooting conditions; the other way is to get guns dynamics data then analysis system through simulation and experimental data by means of the dynamic part of the model validation, this method is more economical.

Naval Gun is a mechanical and electrical integration, rigid coupling complex artillery systems. The establishment of numerical simulation models, including the model of rigid body dynamics, rigid body dynamics model coupled electromechanical system integration model. Adams dynamics calculations using simulation software for complex dynamic systems software algorithms Adams Gear predictor-corrector algorithm can effectively overcome the effects of these pathological matrix calculations.

Let launch state artillery system consists of n rigid bodies, the generalized coordinates of system whichever rigid body can be expressed as: $q_i = [x, y, z, \varphi, \theta, \psi]_i^T$, generalized coordinate system is expressed as: $q = [q_1^T, q_2^T, \ldots, q_n^T]$. Create a system dynamics using Lagrange multipliers [1]:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_k}\right) - \frac{\partial T}{\partial q_k} + \phi_q^T \rho_k + \vartheta_{\dot{q}}^T \mu_k = Q_k$$

$$k = 1,2,\ldots,n$$

n : generalized coordinate

$$T = \sum_{i=1}^{N} \left(\frac{1}{2} m_i \cdot \vec{\dot{r}}_i \cdot \vec{\dot{r}}_i\right)$$

$$Q_k = \sum_{i=1}^{N} F_i \frac{\partial \vec{r}_i}{\partial q_k}$$

Where: T-Systems kinetic energy; N-the number of rigid body systems; $\vec{r}_i$ -the i-th rigid body centroid radius vector; q_k -generalized coordinates; $\dot{q}_k$ -generalized velocity; Q_k -generalized force; ρ_k -complete constraint corresponding Lagrange multipliers; μ_k -corresponding non- integrity constraints Lagrange multipliers .

II NAVAL GUN RIGID BODY DYNAMICS SIMULATION MODELING

Various parts of the gun movement weapons systems include: azimuth rotation bracket cradle level sport, the automaton sat recoil movement and rotation, automatic machine movement sport, playing the drum rotates, bombs / shells exercise.

Servo motion analysis system with a gun:

Automatic machine motion parameters analyzed:

$\vec{\omega}_3 = \dot{\psi}_1 \vec{k}_1 + \dot{\theta}_2 \vec{i}_2 + \dot{\beta}_3 \vec{j}_3 \theta_2 \vec{k}$, $\vec{\varepsilon}_3 = \frac{d\vec{\omega}_3}{dt}$

As the 11 groups doing high-speed rotating barrel clockwise during the gun firing process, around double drum while playing for the bomb, in the first and second quadrant the barrel is loaded with live ammunition (projectile and propellant), and the third or fourth quadrant barrel only installed free shells or individual no firing of live ammunition. Set automatic machine centroid as C_3, the automatic machine centroid always within one or two quadrants, it is not as automatic machine for around automaton rotary for rotation, only with automatic machines for the back seat movement.

The eccentric amount $\left| C_3' C_3 \right|$, which C_3' is the centroid C_3 of the projection y_3 axis to the O origin of the inertial coordinate system $O-xyz$ anchored centroid radius $\vec{r}_3$ vector is C_3, the projection points C_3 implicated velocity $\vec{v}_{e3}$:

$$\vec{v}_{e3} = \vec{\omega}_3 \times \vec{r}_3 = (\dot{\psi}_1 \vec{k}_1 + \dot{\theta}_2 \vec{i}_2 + \dot{\beta}_3 \vec{j}_3) \times (\left|OO_1\right| \vec{k}_1 + \left|O_2O_3\right| \vec{j}_2 + \left|O_3C_3'\right| \vec{j}_3 - \left|C_3'C_3\right| \vec{i}_1)$$

Under the effect of powder gas, since the recoil movement resulting automaton centroid C_3 (or a projection point C_3', because C_3' is the projection of C_3 in the axial direction y_2 、 y_3 axis) the relative velocity $\vec{v}_{r3} = \frac{d\left|O_2O_3\right|}{dt}$, the speed of the center of mass C_3:

$$\vec{v}_3 = \vec{v}_{e3} + \vec{v}_{r3}$$

Automata kinetic parameters analysis, the center of mass C_3 acceleration:

$$\vec{a}_3 = \frac{d\vec{v}_{r3}}{dt} + \frac{d\vec{v}_{e3}}{dt}$$

Anti- recoil device after sitting resistance analysis:

$$\sum \vec{F} = \vec{f}_p + \vec{f}_r + \vec{f}_q + \vec{f}_f = 0$$

Where: $\vec{f}_p$ -gun barrels of gunpowder gases together, including the validity of the process of reaction, and $f_p = Sp_{pt}$.

III GUNS RIGID COUPLING BODY DYNAMICS SIMULATION MODELING

Assuming mechanical components guns for linear elastic body, by the action bore the load force, inertial force, driving torque and so on. Represented by physical degrees of freedom of the mechanical components guns linear elastic finite element dynamic system of equations [2]:

$$\begin{bmatrix} M_{ii} & M_{is} \\ M_{si} & M_{ss} \end{bmatrix} \begin{Bmatrix} \ddot{x}_i \\ \ddot{x}_s \end{Bmatrix} + \begin{bmatrix} C_{ii} & C_{is} \\ C_{si} & C_{ss} \end{bmatrix} \begin{Bmatrix} \dot{x}_i \\ \dot{x}_s \end{Bmatrix} + \begin{bmatrix} K_{ii} & K_{is} \\ K_{si} & K_{ss} \end{bmatrix} \begin{Bmatrix} x_i \\ x_s \end{Bmatrix} = \begin{Bmatrix} F_i \\ R_s \end{Bmatrix}$$

Where: subscript i indicates the degree of freedom is not constrained; subscript s indicates the degree of freedom constraint; F_i said external force is applied; R_s said reaction force; M, C, K denote the mass, damping and stiffness matrices.

The method of modal acceleration calculates the acceleration of structural displacement effect by taking the static response. Displacement can be calculated by the following formula out:

$$[K_{ii}]\{x_i\} = \{f_i\} - [M_{ii}]\{\ddot{x}_i\} - [C_{ii}]\{\dot{x}_i\}$$

$$\{\dot{x}_i\} = [\Phi_s]\{\dot{x}_s\} + [\Phi_n]\{\dot{X}_n\}$$

$$\{\ddot{x}_i\} = [\Phi_s]\{\ddot{x}_s\} + [\Phi_n]\{\ddot{X}_n\}$$

Where: $[\Phi_a]$-the force corresponding to the applied force units attached to freedom modal matrix; $[\Phi_{aa}]$ -corresponds to the forced vibration acceleration equivalent modal matrix adhesion; $[\Phi_{av}]$-forced velocity corresponding to the equivalent modal matrix adhesion; $[\Phi_s]$-corresponding to freedom of movement constraints forced modal matrix.

$$[\ddot{\Phi}_n] = \left[\left(\frac{-1}{\omega_1^2}\right)\{\phi_1\}, \left(\frac{-1}{\omega_2^2}\right)\{\phi_2\}, \cdots, \left(\frac{-1}{\omega_m^2}\right)\{\phi_m\}, \cdots\right]$$

$$[\dot{\Phi}_n] = \left[\left(\frac{-2\xi_1}{\omega_1^2}\right)\{\phi_1\}, \left(\frac{-2\xi_2}{\omega_2^2}\right)\{\phi_2\}, \cdots, \left(\frac{-2\xi_m}{\omega_m^2}\right)\{\phi_m\}, \cdots\right]$$

Where: ω_m -the m -th free vibration modal frequency; ξ_m-the m -th modal damping ratio; ϕ_m - the m -th modal vibration mode.

Modal displacement method, system response calculated by the following formula:

$$\{x\} = [\Phi_n]\{X_n\} + [\Phi_s]\{x_s\}$$

$$\{\dot{x}\} = [\Phi_n]\{\dot{X}_n\} + [\Phi_s]\{\dot{x}_s\}$$

$$\{\ddot{x}\} = [\Phi_n]\{\ddot{X}_n\} + [\Phi_s]\{\ddot{x}_s\}$$

IV Naval gun servo system modeling output movement

Assuming shooting servo system error is normally distributed random process.

Using a computer program to produce a number of uniformly distributed in [0, 1] and mutually independent random variables ξ_1, ξ_2 . The composite sampling methods are:

$$\begin{cases} X_1 = \sqrt{-2\ln\xi_1}\cos 2\pi\xi_2 \\ X_2 = \sqrt{-2\ln\xi_1}\sin 2\pi\xi_2 \end{cases}$$

Two-dimensional normal random variable denotes the level of shooting servo system error, the error position shooting, which mean, respectively as μ_1, μ_2 , the covariance matrix is:

$$[K] = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$

In the formula

$$K_{ij} = E[(Y_i - \mu_i)(Y_j - \mu_j)] = \frac{1}{4}\sum_{p=1}^{2}\sum_{q=1}^{2}(y_{ip} - \mu_i)(y_{jq} - \mu_j)$$

; $Y_i = (y_{i1}, y_{i2})$ $Y_j = (y_{j1}, y_{j2})$.

Servo system pilot test was shot error curve in Figure 2.

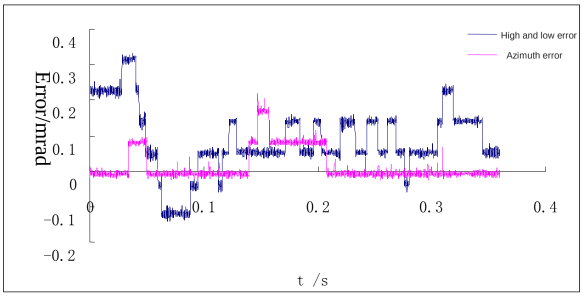

Figure 2 Shots error curve follower

V Naval simulation model calibration experiment

Using result of Modal testing and analysis calibrate the models. Experimental modal testing and analyzing equipment including: hammers, acceleration sensors, charge amplifiers, filters, instrumentation and modal analysis software [3]-[5]. The test diagram is shown in Figure 3.

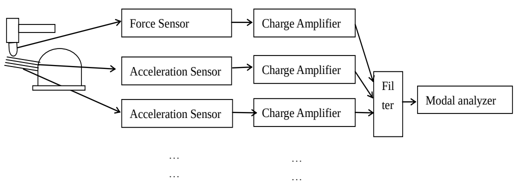

Figure 3 modal testing and analysis of experiments schematics

Using the method of hammer test to test the level of vibration mode, excitation position is automatically selected at the top of the unit on a barrel, near the muzzle ferrule position, vertical knocking down the barrel. Azimuth test vibration mode, the excitation position selected a barrel on the far left of the automatic unit, near the muzzle ferrule position, horizontal right percussion barrel.

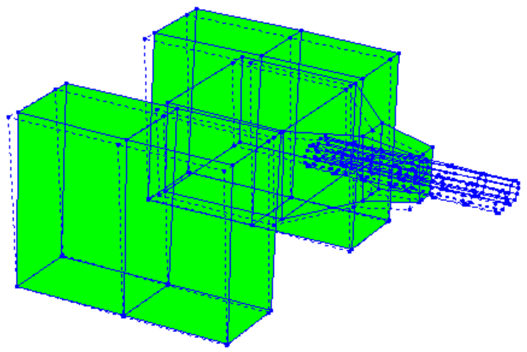

Figure 4 guns orientation mode (first mode)

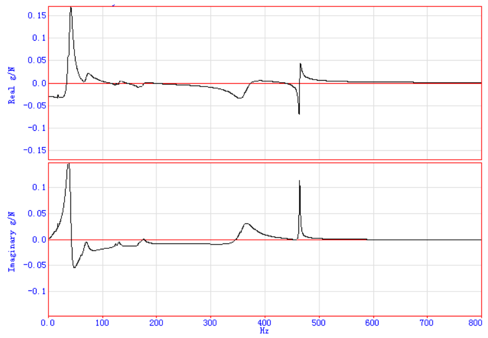

Figure 5. 4-6 azimuth gun barrel vibration frequency response function integrated

VI Conclusions

The paper carry simulates calculation based on Adams, analysis the character of naval gun system dynamics. And draw support from parts of test data checkout the dynamics model, achieved satisfactory results. Solved the problem of limit and expensive, the method of gun firing research naval gun system shooting dynamics equation.

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