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Influence and analysis of escape posture for different launch tube spiral angles*

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Abstract. Flexible interaction model of a certain 122mm MLRS in launching process is established basing on non-linear transient dynamics theories. Launching dynamical simulation and analysis of this model are simulated and analyzed using numerical simulation methods. the feasibility of the model and method is verified. at meantime, Influence and analyse of escape parameters about different launch tube spiral angles is analyzed. The results and methods in this paper have offered theory reference and basis for the improvement research of this type 122mm MLRS.

Keywords: non-linear transient dynamics, collision contact, MRLS, structure dynamics, escape parameters

1 Background

In the rocket weapons, the intensive degree of non-revolving empennage type rockets is very bad because of the serious eccentricity influence of thrust. Turbine type rockets fly steadily because of its rotating, but meantime because the limitation of rocket length, it is difficult to receive larger range. So, the demand for development of rocket launching technology at present are reducing eccentricity influence of thrust and utilizing spiral angle of launch tube to produce a reasonable rotational speed, which can ensure the purpose of flying steadily and increasing range. The research purpose of this paper is to use the ripe numeric methods to calculate the escape parameters of the flexible interaction model about rocket in launch tube, also analyze the influence of escape posture for two kinds of spiral angles ($2.5°$ and $4.0°$) of the launch tube in a certain 122 mm rocket weapon modification research work .

2 Basic theories

2.1 Basic theories of non-linear transient dynamics

Analysis of transient dynamics is also called the time history analysis, which is a kind of method to confirm structure dynamics responds of bearing variational load.

For solving the questions of non-linear dynamics, we can adopt the method of direct time differential, its dynamic equation can be described as the following format.

$$M\ddot{u} + C\dot{u} + f_{int} = f \tag{1}$$

In this equation: f_{int} is the internal force vector, which is the nonlinear function of displacement. The matrix M and C also correlate with displacement or velocity. We only take account of the non-linear internal force in this equation.

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We can convert equation (1) into equation (2) by taking time differential.

$$M\ddot{u} + C\ddot{u} + K^t\dot{u} = \dot{f} \tag{2}$$

In this equation: K^t is the rigidity matrix of tangent. If it can suppose that equation is valid at finite time region , then, equation (2) can have equation be described as the following format:

$$M \cdot \Delta\ddot{u} + C \cdot \Delta\ddot{u} + K^t \cdot \Delta\dot{u} = \Delta f \tag{3}$$

This equation can be solved by using an iterative formula. If we use Newmark formula to solve equation (3), we will get the following equation (4). Further more, we can also get the linear format of equation (4).

$$(4\frac{M}{\Delta t^2} + 2\frac{C}{\Delta t} + K) \cdot \Delta u = \Delta f + (4\frac{M}{\Delta t} + 2C)\dot{u}^n + 2M\ddot{u}^n \tag{4}$$

$$M \cdot \ddot{u} + C\dot{u} + K^t u = f - f^n_{int} + K^t u^n \tag{5}$$

Adopting Newmark formula, we can get the recursion relation.

$$(4\frac{M}{\Delta t^2} + 2\frac{C}{\Delta t} + K^t)\Delta u = f^{n+1} - f^n_{int} + (4\frac{M}{\Delta t} + 2C)\dot{u}^n + M\ddot{u}^n \tag{6}$$

3 Method and calculation

3.1 Basic assumptions of simulation

For reducing the difficulty and time of calculation, we do the following assumptions:

(1) In the course of launching, the vibration effect of whole rocket system is made up of the flexible vibration effect of flexible model between rocket and launch tube and the rigid vibration effect of whole rocket system;

(2) The mutual force in flexible vibration effect of flexible model between rocket and launch tube can be put on the rigid body dynamics model of whole rocket system;

(3) In the course of computing, deformation of launch tube and interactive influence between rocket and launch tube caused by vibration of rigid body dynamics model can be neglected;

(4) The start time of Calculation is the moment of rocket release from launch tube;

(5) In the flexible model, rocket and launch tube are flexible bodies, which have elasticity contact each other;

(6) In the course of contact, the function of friction is not considered.

3.2 Establishment of flexible interaction model

The flexible interaction model is set up as Fig. 1. Fig. 2 shows the FEA model, which have 24487 shell elements.

For the convenience of calculation, the following coordinate system is set up: The positive direction of Z axis parallel to the axis of launch tube; The positive direction of X axis parallel to the paper plane and also is perpendicular to the axis of launch tube; The positive direction of Y axis is established by the right hand law.

In this model, the rocket is a free body, which touches with the launch tube, contact type is ASTS (Auto surface to surface contact). Three positions that launch tube touches clapboards of launch container restrain all degree of freedoms. Numerical simulation method in this paper is FULL method. Considering the real working condition between rocket and launch tube and the test result of rocket thrust, the load of this analysis model is divided into three phases, the form of load is a slope load, its first loads time is 0 second(s), its second loads time is 0.01 second (s), its third loads time is 2.5 second (s), the maximum of rocket thrust is 28000 Newton (test date).

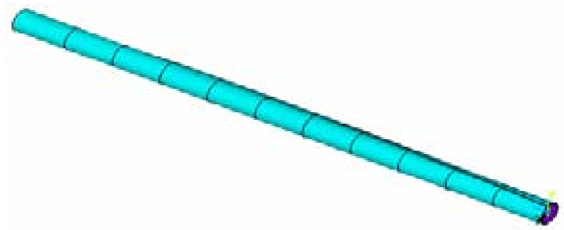

Fig. 1. Structure of rocket & launcher

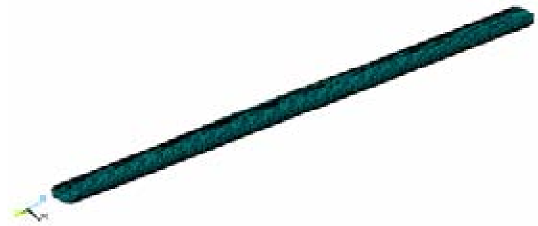

Fig. 2. SFEA model of rocket&launcher

4 Result and analysis

The results of calculation are shown as Fig. 3 and Fig. 4. From the comparison of results of calculation and results of real rockets (Tab. 1), the flexible interaction model is feasible. The maximum of error is 7.63%which can be regarded as without taking friction into account.

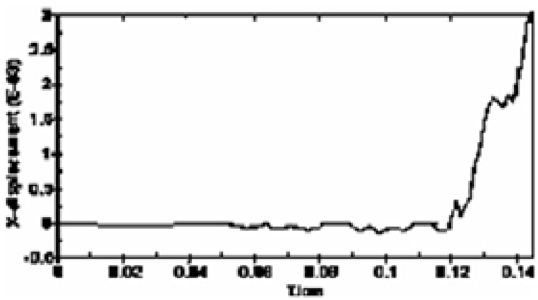

Fig. 3. X direction displacement of end part (2.5°)

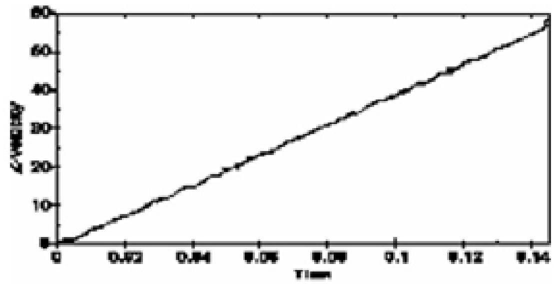

Fig. 4. Z direction velocity of end part (2.5°)

Table 1. Comparison about results of simulation and test

	Calculating value	Testing value	Error
Escape time	0.127s	0.132s	3.03%
Escape velocity	48.94 m/s	45.47 m/s	7.63%
Angular velocity of rotation	33.12rad/s 32.59rad/s	1.63%	

By the calculation, some other results are received, such as the movement characteristics and the mechanics characteristics of the flexible interaction model (shown as Fig. 7 to 10). Because of the length restriction of this paper, the results such as gyration displacement, gyration velocity, the movement characteristics and the mechanics characteristics of rocket about 4.0° spiral angle of launch tube were not shown in this paper.

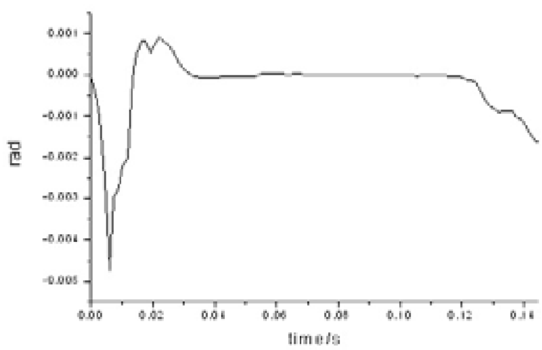

Fig. 5. Pitching angle displacement of rocket (2.5°)

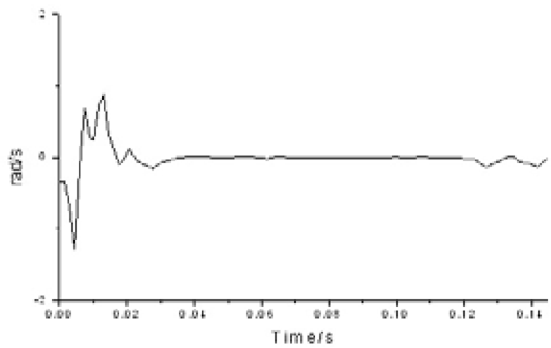

Fig. 6. Pitching angle velocityof rocket (2.5°)

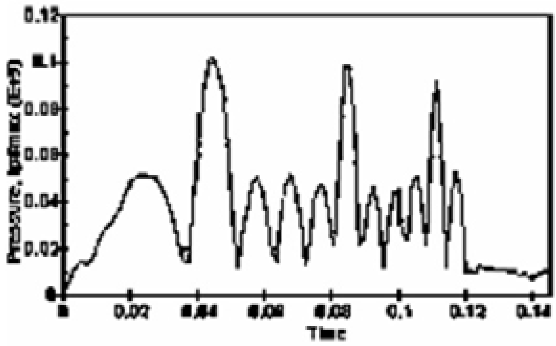

Fig. 7. Pressure distribution of directional button (2.5°)

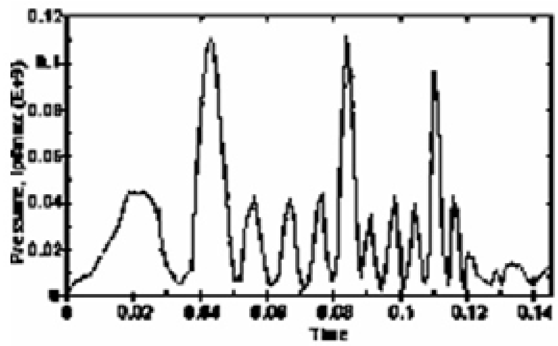

Fig. 8. Pressure distribution of back centering device (2.5°)

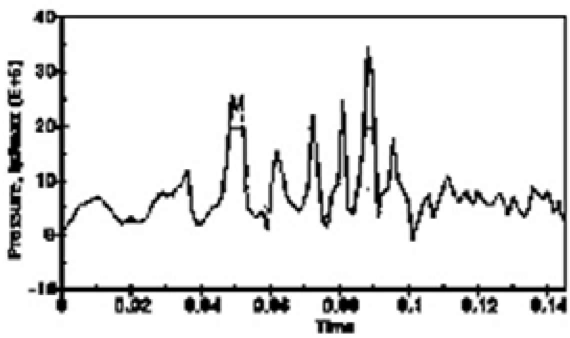

Fig. 9. Pressure distribution of middle centering device (2.5°)

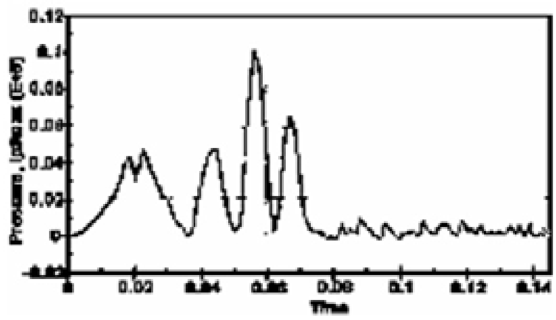

Fig. 10. Pressure distribution of front centering device (2.5°)

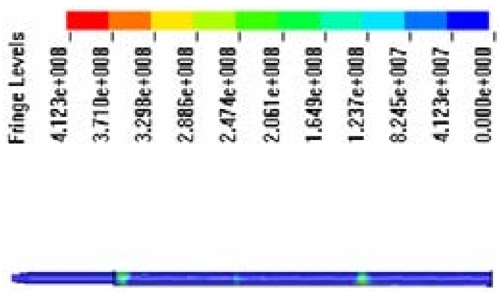

Fig. 11. Stress distribution when front centering device escaping(2.5°)

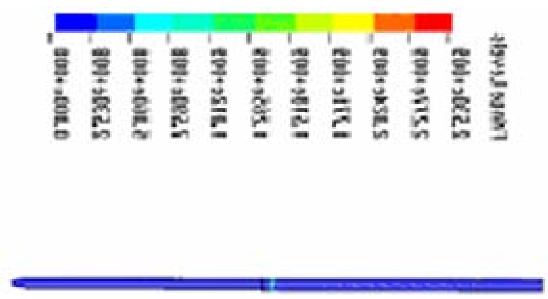

Fig. 12. Stress distribution when back centering device escaping(2.5°)

Tab. 2 and Tab. 3 are the comparison of the movement parameters and the mechanics parameters about two different spiral angles in course of launch.

5 Conclusion

(1) Flexible interaction model of a certain 122mm MLRS in launching process is established basing on non-linear transient dynamics theories. Launching dynamical simulation and analysis of this model are simulated and analyzed using numerical simulation methods, which examined the validity of the flexible interaction model and the numeric method in this project.

(2) The slide time of whole rocket escaping from launch tube about 2.5° spiral angle is less than that of 4.0° spiral angle;

Table 2. Comparison result of simulation (at escape time)

	2.5°	4.0°
Angular velocity of rotation	33.1248rad/s	50.9544rad/s
Pitch angle	-1.18E-4rad	9.14E-5rad
Angular velocity of pitch	-1.73E-2rad/s	6.02E-2rad/s
Round angle	9.187E-5rad	-7.479E-4rad
Angular velocity of round	0.005rad/s	-0.0801rad/s
Synthesis angular velocity	0.0180rad/s	0.1002rad/s

Table 3. Comparison result of simulation (in the course of launching)

	2.5°	4.0°
Maximal pressure of directional button	0.108E+3Mpa	0.271E+3
Mpa Maximal pressure of front centering device	0.100E+3 Mpa	0.260E+3
Mpa Maximal pressure of middle centering device	0.035E+3 Mpa	0.275E+3 Mpa
Maximal pressure of back centering device	0.106E+3 Mpa	0.580E+3 Mpa
Maximal contact stress	4.132E+2 Mpa	2.530E+3 Mpa
Maximal strain	2.376 mm	10.440 mm

(3) The angular velocity of rotation of whole rocket escaping from launch tube about 2.5° spiral angle is less than that of 4.0? spiral angle, which indicates obviously that flight stability after whole rocket escaping from launch tube about 4.0° spiral angle is better than that of 2.5° spiral angle;

(4) From the strength situation of rocket, it is obviously that the strength of 4.0° spiral angle is bigger than that of 2.5° spiral angle. Meanwhile, the oscillation frequency of 4.0° spiral angle is also higher than that of 2.5° spiral angle;

(5) From the strain situation of rocket, it is obviously that the strain of 4.0° spiral angle is bigger than that of 2.5° spiral angle;

(6) According to the influence factors of the intensive degree, the comprehensive value of initial disturbance of rocket about 2.5° spiral angle is obviously better than that of 4.0° spiral angle.

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