# Research on Dynamic Load of Flexibility Sliding Rail

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Abstract: We propose a kind of plan with flexibility sliding rail for experimentation of the fuze in high speed condition. Analyzing characteristic and environment factors of the rail, we reckon kinds of parameter based on mechanics and material science. It is applied in the project. The result shows the method is effective.

## 1 INTRODUCTION

With the development of guided ammunition, fuze is no longer a single device, but a complex system, which is mainly composed of detection, signal control and actuating mechanism, etc. [1]. Whether the detonating time of fuze is coincident with the design requirements and how to find the best kill distance when ammunition is approaching arm. Those urgent problems are all solved in fuze design. These tests are usually completed under high speed conditions. At present, it is usually adopted two solutions to high-speed test: one is to use rigid slide rail which is laid on the ground, and the experiment is completed on rocket sleigh; the other is to use flexible slide rail that is set up on cableway in the air. The rigid slide raid can be used to achieve ultra-high speed test. However, the construction of the slide rail has very difficult. It has a rigorous condition to ground, so It's almost impossible to finish in mountainous and hilly areas. The use of flexible slide rail can achieve slower speed than rigid slide, but it is easier to build and lower in cost. Flexible slide rail is applied to fuze test which works in low speed, so the use of flexible slide rail is sufficient to solve the test environment problems.

## 2THE BASIC STRUCTURE OF FLEXIBLE SLIDE RAIL

The basic structure of the flexible slide rail is shown in Figure 1. It includes the flexible ropeway and the support device, the launching control platform, the stop device, the instrument cabin, the data recorder, the high-speed camera, the target and so on.

The target includes two parts: the ground target and the air target. A hanger is built on the ground target platform, and the target can be hoisted in air. The arresting net has four layers. The first layer adopts high strength arresting hook. The second layer are set up with high-intensity parachute behind the first layer a interval of 5m. Then, the third layer are set up with high strength parachute behind the first layer a interval of 3m. Finally, the sand bag is placed in stop platform.

## 3PARAMETER ESTIMATION OF INSTRUMENT CABIN

The equipment parameters are as follows in the analysis and calculation.

The weight of instrument cabin is 20kg. It is thrust forward by four engines of solid propellant, and it is pushed reversely by two engines of solid propellant too.

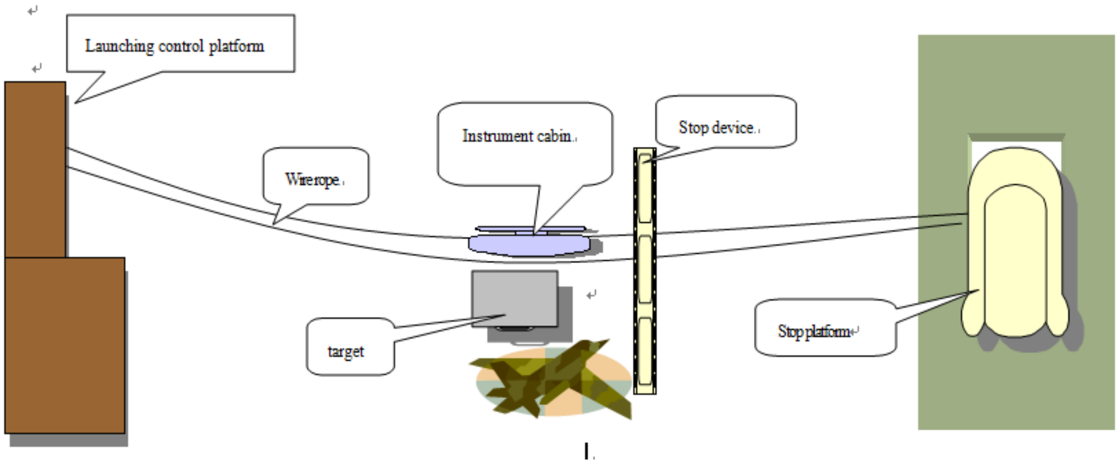


Figure 1The basic structure of flexible slide rail

### 3.1 Parameters of Engine

Parameters of thrust engine: thrust: 7889N; Working hours:0.893s; Weight:8.8kg.

Parameters of reverse thrust engine: thrust : 3136N; Working hours : 0.64~1.2s; Weight:3Kg.

### 3.2 Estimation of Driving Distance and Maximum Overload at Maximum Speed

The formulas used are as follows[2]:

$$\sum F = Ma \quad (1)$$

$$v = at = \frac{\sum F}{M} \cdot t \quad (2)$$

$$S = v_0 t + \frac{1}{2} at^2 = v_0 t + \frac{1}{2} \cdot \frac{\sum F}{M} \cdot t^2 \quad (3)$$

$$\text{Overload: } \Pi = \frac{\sum F}{M \cdot g} \quad (4)$$

Taking the engine parameters into (1), (2), (3), (4), and

$$M = 20 + 3 \times 2 + 8.8 \times 4 = 61.2 (kg)$$

$$v_{max} = \frac{7889 \times 4 \times 92\%}{61.2} \times 0.893 \approx 424 \ (m/s)$$

$$S_{v\,max} = \frac{1}{2} \times \frac{7889 \times 4 \times 92\%}{61.2} \times 0.893^2 \approx 189 \ (m)$$

$$\Pi \approx \frac{7889 \times 4 \times 92\%}{61.2 \times 9.8} \approx 48$$

## 4ESTIMATION OF CABLE TENSION

### 4.1 Analysis of Tension

When instrument cabin moves at high-speed, wire rope's deflection is generally 5%. If we ignore the elastic of wire rope, instrument cabin as a rigid body moves along an elliptical arc at high-speed (both points on ends of wire rope is the focus of the ellipse).Instrument cabin in moving generates a centrifugal force against the wire rope, so the wire rope sustain dynamic loading. Therefore, in order for the rigid body to stick to the wire rope reliably, the tension of the wire rope must be more than the resultant force of centrifugal force, weight of the wire rope and instrument cabin (as shown in Figure 2).

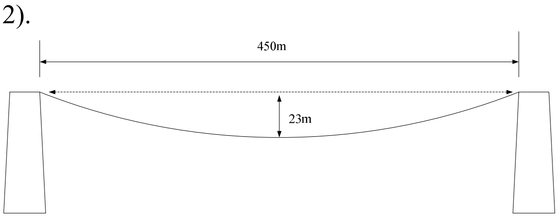


Figure 2 the wire rope

When calculating the tension of the wire rope, only one steel cable is analyzed to ensure more reliable and safe. The instrument cabin moves along the elliptical arc ADCB. The M and N are the focus of the ellipse and the pivot of the wire rope. A coordinate system is set up, and the center point of

MN is origin O. When the instrument cabin's displacement is S (that is, when moving to the D point), the force analysis is shown in Figure 3.

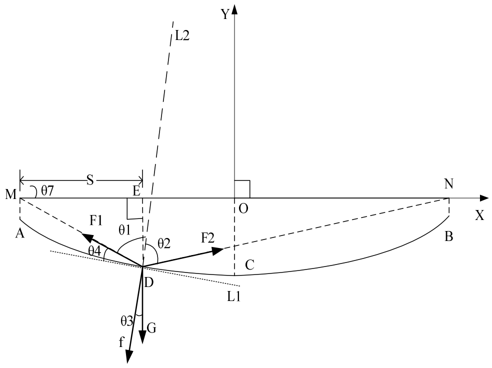


Figure 3wire rope force

The arc line ADC and the arc line CB are symmetrical, and the maximum velocity of the instrument cabin appears in the arc line ADC section, so the mast tension of the wire rope only appears in ADC section of the arc line. In the calculation, ignoring the self weight of the steel cable (considered by the constructor), when the instrument cabin's displacement is S, the straight line L1 isthe tangent line of the D point elliptical arc, and the straight line L2 is the normal line of the D point.

Suppose G is the instrument cabin's gravity; the F is the centrifugal force; F1 and F2 are the tension of the wire rope, and F1=F2.The short axis of the ellipse is b, and b=OC; the focal length is 2c, and 2c=MN. So the long axis is a[3].

$$a=\sqrt{OC^2+\frac{1}{4}MN^2}$$

Equation of ellipse is

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$$

Suppose the D point coordinate is $(x_0, y_0)$, and equation of the normal line of L2 is

$$y-y_0=\frac{a^2y_0}{b^2x_0}(x-x_0)$$

The slope of the normal line

$$k1=\frac{a^2y_0}{b^2x_0}$$

The radius of curvature of D is

$$R=\frac{b^2}{a\sin^3\theta 4}$$

The coordinate of M is (-c，0), and the equation of MD is:

$$\frac{x+c}{x_0+c}=\frac{y}{y_0}$$

The slope of a straight line is

$$k2=\frac{y_0}{x_0+c}$$

The resultant force of the wire rope in the direction of the normal line is 0, so

$$F1\cdot\cos\theta 1+F2\cdot\cos\theta 2=f+G\cdot\cos\theta 3$$

Because of

$$\cos\theta 1=\left|\frac{1+k1k2}{\sqrt{1+k1^2}\cdot\sqrt{1+k2^2}}\right|$$

$$\theta 2=\theta 1$$

$$\cos\theta 3=\frac{k1}{\sqrt{1+k1^2}}$$

$$\sin\theta 4=\cos\theta 1$$

$$F1=F2$$

$$f=M\frac{v^2}{R}$$

So

$$F1=\frac{f+G\cdot\cos\theta 3}{2\cos\theta 1}=\frac{aM}{2b^2}\cdot\frac{(1+k1\cdot k2)^2}{(1+k1^2)(1+k2^2)}\cdot v^2+\frac{G}{2}\cdot\left|\frac{k1\cdot\sqrt{1+k2^2}}{1+k1\cdot k2}\right| \quad (5)$$

In the ADC, the force of the instrument cabin in the tangent direction is similar to the thrust of the rocket engine, so

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$$v \approx \begin{cases} \sqrt{\frac{2SF_T}{M}} & \text{thrust working} \\ \sqrt{\frac{2S_{vmax}F_T}{M}} & \text{no thrust} \\ \sqrt{\frac{2S_{vmax}F_T}{M} + \frac{2F_R(S - v_{max} \cdot t_0 - S_{vmax})}{M}} & \text{counterthrust working} \end{cases} \quad (6)$$

The positive thrust of the instrument cabin is ;The negative thrust force for the instrument cabin is ; The displacement of the instrument cabin at the end of the positive thrust is $S_{v\max}$ ;The time between the positive and negative thrust is $t_0$ ; the maximum speed of the instrument cabin is $v_{\max}$ .

When $x_0 = -c + S$ so, $y_0 = -\frac{b}{a}\sqrt{a^2 - (S-c)^2}$ .

According to the formula (5) and (6), the function of F1 on S can be obtained.

$$F1 = \begin{cases} \frac{aSF_T}{b^2} \cdot \frac{(1+k1 \cdot k2)^2}{(1+k1^2)(1+k2^2)} + \frac{G}{2} \cdot \left| \frac{k1 \cdot \sqrt{1+k2^2}}{1+k1 \cdot k2} \right| & \text{thrust working} \\ \frac{aS_{vmax}F_T}{b^2} \cdot \frac{(1+k1 \cdot k2)^2}{(1+k1^2)(1+k2^2)} + \frac{G}{2} \cdot \left| \frac{k1 \cdot \sqrt{1+k2^2}}{1+k1 \cdot k2} \right| & \text{no thrust} \\ \frac{a}{b^2} \cdot \frac{(1+k1 \cdot k2)^2}{(1+k1^2)(1+k2^2)} \cdot [S_{vmax}|F_T| - |F_R|(S - v_{max} \cdot t_0 - S_{vmax}] + \frac{G}{2} \cdot \left| \frac{k1 \cdot \sqrt{1+k2^2}}{1+k1 \cdot k2} \right| & \text{counterthrust working} \end{cases} \quad (7)$$

## 4.2 Parameter Calculation

We can think that b is approximately equal to 23 and suppose $t_0$ is 0.1s, so

$$\begin{cases} c = 225 \\ b \approx 23 \\ a \approx 226 \\ F_T = 29032 \\ G = 600 \\ M = 61 \\ S_{vmax} = 189 \\ F_R = 5770 \\ t_0 = 0.1 \\ v_{max} = 424 \end{cases} \quad (8)$$

When the formula (8) inputs formula (7). The value of the function is solved by programming as shown in Figure 4.

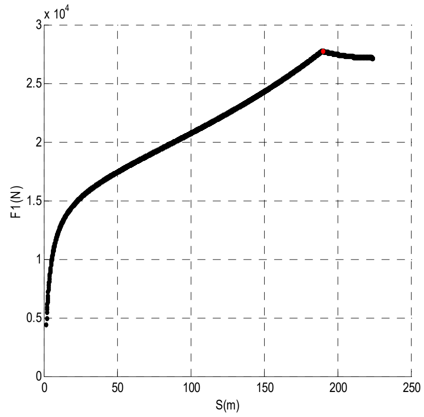


Figure 4Relationship between F1 and S.

So

$F1_{max} = 27634$, then, S=189.

Safety factor is 3, so

$T_{max} = 3F1_{max} = 82902(N)$

In the above calculation, the maximum dynamic tension of the instrument cabin is $T_{\max}$ . The self weight of the wire rope should be considered when the tensile strength of the wire rope is designed.

Tensile strength is

$$\sigma = \sigma_1 + \sigma_2$$

## 5 CONCLUSIONS

Based on the theoretical analysis of the instrument cabin and the wire rope, the dynamic pressure that is generated by the instrument cabin along the slide rail at the high-speed is calculated, so as to estimate the tension of the wire rope. It provide parameters for the strength design of the flexible slide rail. The results have been applied in the actual construction. When the weight of the instrument cabin or the engine is adjusted for the different exam, the method is also effective. However, friction and air resistance are ignored in the calculation, so the calculation parameters are not accurate enough. It will be gradually improved in the next study.


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