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Research on the High Safety Velocity of Detonator Flyer

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Abstract: *Flyer is the key part of the non-primary detonator, which determines whether the detonator could explode. In the present paper, the flyer plate model driven by explosive is applied to the flyer calculation of the excitation device. The velocity range of the detonation velocity and the flyer is determined by experiments, and compared with the numerical results.. Comparing the results, the conclusion is made that the unstable detonation happened in the excitation power, and Gurney energy is only 10%~30% of explosion heat, and some factors which could affect the flyer velocity are also given.*

Keywords: *mechanics of explosion, underwater explosion, Hilbert-Huang transform, metal detonating cord*

1. Introduction

Flying plate detonation [1-3] is a new type of detonator, the principle is the use of high-speed flyer motion compression detonator bottom loose charge, according to the hot theory, loose particles charge air is adiabatic compression, the temperature rises to more than the explosive, caused the DDT process. The type of detonator studied is based on the technology of the University of Science and Technology of China[4], as shown in Figure 1. The element producing the flyer is an excitation device consisting of an inner cap and an activating agent. The inner cap material is the same as the primer technique. The main component of the drug is RDX, and some oxidant is added. The reaction process is that the excitation powder after being ignited to produce high temperature and high pressure gas, and then the gas cap in the bottom shear to form a flyer; the flyer is accelerated by high pressure gas under the action of high explosive and downward movement, hit the bottom at a certain speed and then, make the initiation. Therefore, flying speed is a key factor to decide whether a detonated explosives. In the present paper, the velocity of flyer is studied, and by comparing the theoretical model calculation and experimental results with the numerical simulation results, the velocity range of the flyer is determined, and the relation between the Gurney energy and the detonation heat has been studied.

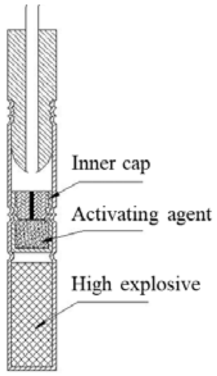

Figure. 1 The device without a detonator for a flyer (a nonel detonator)

2. Detonation driven flyer model

In 1947, Stanyukovich [5] established the classical analytic theory of explosive driven metal flyer on the basis of Newton's second law and C-J theory. Subsequently, scholars in various countries have carried out research on the problem of detonation driven flyer, and formed a theoretical model of many kinds of detonation driven flyer. In this paper, the speed of flyer is calculated according to the selected models, and compared with the experimental results.

2.1 Stanyukovich classical analytic theory

2.1.1 Basic assumptions

The classic analytic theory of the Stanyukovich dynamite-driven metal flyer is based on three basic assumptions [5]:

(1) Rigid body hypothesis: flyer conforms to rigid condition.

(2) Isentropic hypothesis: detonation wave in the flyer interface after the reflected wave is a weak shock wave, the detonation product similar to the entropy.

(3) Isentropic index: detonation product state equation of the isotope index is approximately taken as 3.

2.1.2 Basic formulas

The relationship between flyer velocity and time is shown as following.

$$u = D\left(1 + \frac{\theta - 1}{\eta\theta} - \frac{l\theta}{Dt}\right) \tag{1}$$

where u is the flyer speed; D is the explosive detonation velocity; t is the movement time; l is the charge length; $\eta=16m_c/27m_m$, and m_c and m_m are the charge quality and flyer quality, respectively; and $\theta = 1 + 2\eta\left(1 - \frac{l}{Dt}\right)^{-1/2}$.

In formula (1), if t takes infinite values, the ultimate velocity of the flyer can be obtained below.

$$\frac{u_{\max}}{D} = 1 + \frac{1}{\eta} - \sqrt{\frac{2}{\eta} + \frac{1}{\eta^2}}$$

2.2 Gurney model

2.2.1 Basic assumptions[6,7]

(1) Instantaneous detonation assumption: the wave reflection is not considered.

(2) Incompressible hypothesis: the density of detonation product gas is constant.

(3) One dimensional linear hypothesis: the velocity distribution is one dimensional linear.

(4) Energy conversion assumptions: all the energy of the explosives is converted to the kinetic energy of the metal and the detonation product.

2.2.2 Gurney equation

The Gurney equation is given below.

$$V_f = \sqrt{2E}\left(m_m/m_c + 1/2\right)^{-1/2} \tag{2}$$

where V_f is the maximum velocity of the metal flyer; E is the Gurney energy that is released in the thermal energy released by the explosion of a unit mass explosive and used for the product of gaseous detonation and metal flyer; m_m is the mass of the metal flyer; and m_c is the effective charge mass of the driving flyer motion, that is ,the effective mass of the excitant in the inner cap.

In the symmetrical charge structure, the cylinder charge is similar to the charge of the excitation device, and can be extended to the calculation of the flyer.

2.2.3 Open Sandwich model

According to the open Sandwich model developed by the Gurney method, the limiting velocity of the flyer is [8,9]:

$$V_{\mathrm{f}} = \sqrt{2E}\left[\frac{1+5\left(m_{\mathrm{m}}/m_{\mathrm{c}}\right)+4\left(m_{\mathrm{m}}/m_{\mathrm{c}}\right)^{2}}{3}\right]^{-1/2} \tag{3}$$

2.2.4 Kennedy improvements

Kennedy used the law equation of state of the detonation product to improve the Gurney equation, and obtained the bottom flyer velocity of the sandwich symmetrically packed structure:

$$V_{\mathrm{f}} = \left[2E\Big/\left(\frac{m_{\mathrm{m}}}{m_{\mathrm{c}}}\right)+\frac{1}{3}\right]^{1/2}\left[1-\left(\frac{x+l_{\mathrm{d}}}{l_{\mathrm{d}}}\right)^{-\frac{m_{\mathrm{m}}}{m_{\mathrm{c}}}\left(\frac{m_{\mathrm{m}}}{m_{\mathrm{c}}}+\frac{1}{2}\right)(\gamma-1)}\right]^{1/2} \tag{4}$$

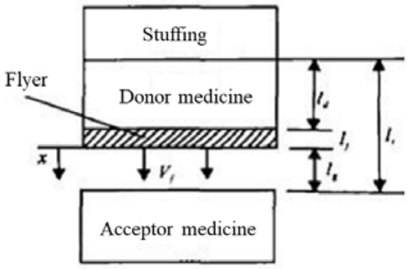

Figure. 2 Explosive driven flyer

2.3 The hydrodynamic model of Azis

2.3.1 Basic assumptions[6][7]

(1) Ignoring the impact of air movement in the plate.

(2) Only the rigid body motion of the plate under explosive load is taken into account and the strain of the plate itself is neglected.

(3) The explosive has large enough loading area and ignores the influence of lateral rarefaction wave on explosion load.

(4) The multi - index of detonation product is 3.

2.3.2 Azis equation

$$V_{\mathrm{f}} = D\left[\left(1+\frac{32m_{\mathrm{c}}}{27m_{\mathrm{m}}}\right)^{1/2}-1\right]\Big/\left[\left(1+\frac{32m_{\mathrm{c}}}{27m_{\mathrm{m}}}\right)^{1/2}+1\right] \tag{5}$$

2.4 Gurney mode

Gurney model and Azis model agree well with experimental data when $m_{\mathrm{c}}/m_{\mathrm{m}}$ is large, but there is a big difference between the measured data and theoretical calculation when $m_{\mathrm{c}}/m_{\mathrm{m}}$ is small. Yadav proposed a mathematical model established at smaller $m_{\mathrm{c}}/m_{\mathrm{m}}$ values [10].

Yadav model structure, there are two cases: (1) the thickness of the explosive layer is much smaller than the metal plate thickness; (2) explosive layer thickness is much greater than the metal plate thickness. As the excitation device in the amount of drugs to stimulate the amount of about 0.3g, the inner diameter of about 5.6mm, so the height of about 8~10mm excitant, and the bottom of the flyer thickness of only 0.4mm, visible layer thickness far greater than the fly thickness, it applies to Yadav (2).

According to the conservation of energy and conservation of momentum, the velocity equations of flyer in two different cases can be obtained:

$$V_{\mathrm{f}}^2 = \frac{2D^2}{\gamma^2-1}\left(\frac{\gamma}{\gamma+1}\right)^{\gamma} \Bigg/ \left(1+\frac{m_{\mathrm{m}}}{m_{\mathrm{c}}}\right) \tag{6.1}$$

$$V_{\mathrm{f}}^2 = E \Bigg/ \left(\frac{m_{\mathrm{m}}}{m_{\mathrm{c}}}+\frac{1}{6}\right) \tag{6.2}$$

2.5 One - dimensional Explosion Flow Field Model of Cylindrical Charges

2.5.1 Basic assumptions

Xie Xinghua simplified the detonation process of an industrial detonator into a one-dimensional flow field model. The model assumes that the axial flow field of the detonator is treated in one dimension, and its energy depends on the charge condition and explosive velocity of the charge; the explosion is completed in an instant; the energy of the flyer motion at the bottom of the detonator comes from the explosive gas and moves along the axial direction as a whole.

2.5.2 The basic formula [11]

Based on the above assumptions, the formula for calculating the velocity at the bottom of the detonator is deduced by using the "contribution parameter contribution method", taking into account the different layers of charge.

$$V_{\mathrm{f}} = 2\left[\alpha \sum_{i=1}^{n} \frac{\rho_{\mathrm{i}} l_{\mathrm{i}} D_{\mathrm{i}}^2}{\gamma_{\mathrm{i}}^2-1} \Bigg/ \left(\rho_{\mathrm{f}} l_{\mathrm{f}}\right)\right] \tag{7}$$

where $\alpha=2/[4l(\psi+\Delta)+2\psi^2]$, ψ is the detonator inner diameter, Δ is the shell side wall thickness, l is the detonator charge side closed cavity length; ρ_{i}, l_{i}, and D_{i} are the charge density, length and detonation velocity the detonator layer i, respectively; γ_{i} is the multi-index of the detonation product of charge in the i-th layer; ρ_{f} and l_{f} is the density and thickness of the bottom of the detonator, respectively.

The high-safety detonator has the same principle as the flapper at the bottom of the detonator. The formula(7) can be applied to the calculation of the excitation device flyer. Some parameters in the original formula can be compared with the inner cap: Φ is the inner diameter d; Δ is the inner cap side wall thickness; l that is within the cap to stimulate drug high h.

The excitation device only one kind of stimulant, and the density is uniform, so the formula can be changed to:

$$V_{\mathrm{f}} = 2\sqrt{\alpha \frac{\rho l D^2}{\gamma^2-1} \Bigg/ \left(\rho_{\mathrm{f}} l_{\mathrm{f}}\right)} \tag{8}$$

2.6 The Velocity Equation of Underfloor from Axial Symmetry Detonation Product Radial Flow Model

2.6.1 Basic assumptions [12]

When determining the driving velocity of the detonator charge to the bottom plate, Geng Junfeng uses a cylindrical symmetrical radial flow field model of detonation products, which is based on the following assumptions:

(1) The detonation of explosives inside the column symmetrical metal shell is completed instantaneously.

(2) the velocity of the detonation product is linearly distributed along the radial direction.

(3) The product state equation is described by $p=A\rho^{\gamma}$; where γ is the multiple index of the explosive gas; A is the constant associated with the explosive, p is the pressure of the product.

2.6.2 Basic equation

The velocity equation of detonator fragments is obtained as follows:

$$V_{\mathrm{f}}=\frac{D}{2}\sqrt{\frac{m_{\mathrm{c}}}{2m_{\mathrm{m}}+m_{\mathrm{c}}}\left[1-\left(\frac{\gamma_0}{\gamma_{\mathrm{s}}}\right)^4\right]} \tag{9}$$

where γ_0 is the radius of the detonator shell rupture; γ_s is the outer diameter of the detonator.

3. Flyer velocity calculation

According to the above models, the flyer speed of the excitation device is calculated, and several parameters need to be determined first. Because of the RDX and $KClO_3$ granulation products [13], $KClO_3$ can improve the detonation of RDX. However, after granulation, the porosity of the drug increases, the density decreases, and the RDX particles are wrapped around $KClO_3$. Therefore, the detonation wave firstly impacts compression $KClO_3$, causes it to be heated and decomposed, then generates hot spots in the RDX and produces detonation, which results in the detonation velocity of the explosive is different from that of RDX, and it needs to be determined by experiment.

3.1 Determination of the detonation velocity of the elicitor

3.1.1 The experimental protocol

In the experiment, the ZBS-10 intelligent explosive velocity measuring instrument developed by the Institute of Civilian Explosive Materials of Nanjing University of Science and Technology was employed. The experimental setup is shown in Figure 3, and probes 1 and 2 are disconnected. When the detonation velocity generator generates detonation, and the detonation wave passes through the probe 1 and 2, the instantaneous high temperature and high pressure ionize, so that the probe is conducted sequentially. The detonation velocity measuring instrument records the time difference between the two, and the average detonation velocity of the detonation wave between probes can be obtained according to the distance *S*. In order to ensure that the detonation wave at the probe has stabilized, the charge height *H* is at least 2 times the probe spacing *S*. Test results are listed in Table 1.

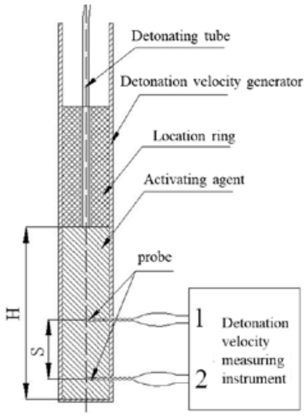

Figure. 2 Explosive driven flyer

Table 1 Test results of D test for explosive speed

Number	*S* (mm)	*H* (mm)	*T* (μs)	*D* (m/s)
1	20.25	42.00	23.3	869
2	27.50	55.02	15.3	1409
3	20.72	54.98	19.5	1062
4	10.82	27.00	30.6	353
5	20.70	39.70	30.7	674
6	21.06	63.90	9.9	2127

3.1.2 Results analysis

When the RDX density is 1.767g/cm^3, the detonation velocity is 8640m/s. When the density changes, the detonation velocity can be calculated according to the formula *D*=2.66+3.40 [14]. The density of RDX was 5465m/s, which was much higher than that in Table 1. It can be seen that the composition of the elicitor and the manufacturing process result in a detonation velocity below the

RDX detonation velocity at that density.

It can be seen from table 1 that the measured detonation velocity increases rapidly with the increase of the distance between the measuring point and the initiation surface of the initiating explosive. It is shown that when the measuring point is near the initiation plane of the initiating explosive, the detonation wave at the measuring point has not grown into stable detonation, and the recorded detonation velocity is actually unstable detonation velocity. With the increase of distance, unstable detonation gradually changes into stable detonation. Meanwhile, the detonation velocity increases rapidly. The measured detonation velocity 2127m/s may be the stable detonation velocity of the explosive.

But the length of the excimer within the cap is only about 5.0mm, according to Table 1, within this length range, it is impossible to form a stable detonation, so the trigger within the cap may occur deflagration, may also be unstable burst boom. In order to simplify the model, in the model calculation, the detonation velocity of the excitant is chosen to be 2127m/s in Table 1, and it is desirable to obtain the upper limit of the velocity of the flyer.

3.2 Stimulate drug burst thermal calculations

The RDX and $KClO_3$ granules were prepared by granulation of RDX and $KClO_3$ at a mass ratio of 1:1. Assuming that RDX and $KClO_3$ each is 1000g, the explosion equation for the elicitor is [15]:

$$4.50C_3H_6O_6N_6 + 8.13KClO_3 \rightarrow 13.50CO_2 + 13.50H_2O + 13.5N_2 + 8.13KCl + Q_p \tag{10}$$

The standard heat of formation of each substance in the equation [15,16] is shown in Table 2.

Table 2 Standard heat of formation Q(latm,298K)

Materials	$C_3H_6O_6N_6$	$KClO_3$	CO_2	H_2Og	N_2	O2	KCl
Q (KJ/mol)	65.4	397.7	393.5	241.8	0	0	436.5

Therefore, according to the law of Gass, can be calculated: Q_P = 8597KJ.

According to the formula $Q_V'=Q_P+2.478(n_2-n_1)$ [15], can be obtained constant volume detonation Q_V'=8710KJ.

For pure RDX, in the absence of constraints and basing on the Q_V and ρ relations: Q_V=4355KJ/Kg, the RDX heat of calculation ρ=0.825g/cm^3 is 5176 KJ/Kg. Compared with the detonation of 4355KJ/Kg, the effect of granulation process on the detonation of RDX

3.3 Flyer speed calculation

According to detonation-driven flyer model to calculate the flyer speed, the results in Table 3. The parameters involved in the model are shown in Table 4.

Table 3 Calculation value of flyer velocity

Model	Calculation value (m/s)
Stanyukovich Model (1)	701
Gurney Model (2)	2482
Open Sanwich Model(3)	2133
Kennedy equation (4)	1672
Azis Model(5)	701
Yadave quation (6.1)	583
Yadave quation (6.2)	2209
Xie Xinghua formula (7)	1024
Geng Junfeng equation (8)	719

Table 4 Parameters of the model

Parameters	m_c	m_m	γ	d	h	ρ
Value	0.104g	0.042g	3	5.4mm	5.5mm	0.825g/cm^3
Parameters	D	Q	$(2E)^{1/2}$	l_d	x	Φ
Value	2127m/s	4355KJ/Kg	2360m/s	5.5mm	2.0mm	5.4mm
Parameters	Δ	ρ_f	l_f	d_0	ds	
Value	0.038mm	7.8g/cm3	0.035mm	3.93mm	6.20mm	

Note: the flyer parameters are shown in Table 6

3.4 Factors affecting the velocity of flyer

According to the above models, the factors that affect the speed of the fly are:

(1) types of explosives

According to the Gurney equation, the velocity of the flyer depends mainly on the Gurney energy. E is mainly related to the detonation of explosives. Explosion refers to the unit mass of explosives in the explosion reaction of heat, is the embodiment of the explosive energy. According to the Gurney model, the energy of the explosive is the main factor determining the velocity of the flyer. Different types of explosives, different heat, such as the density of 1.5g/cm3 TNT heat to 4226KJ/Kg, the same density RDX heat of 5397 KJ / Kg.

The explosion heat of explosive is mainly affected by charge density [15]. As the charge density increases, the explosion heat increases. In addition, the shell of the detonator is also one of the factors that affect the explosion heat. The results show that the detonation heat increases when the explosive with negative oxygen balance is detonation in large density and solid shell. For example, when a TNT detonation in a brass enclosure is compacted, the energy released is 25% larger than that of a sample of the same weight and density in the case of a thin glass shell.

(2) the quality of explosives

Explosive quality determines the ability to produce high speed energy from the fly. In the formula of the above models, the effect of explosive mass on flyer velocity is embodied.

(3) degree of tightness between an inner cap and a detonator housing

The Gurney energy concept contains the notion of the proportion of energy that can provide the kinetic energy of the gas detonation product and the metal flyer. Experiments show that the inner cap with the detonator shell with the degree of tightness, to provide the production of flyer speed of energy accounted for within the cap in the proportion of energy generated by explosives have an important impact. When the two loosely cooperate with each other, the energy generated by detonation in the inner cap will first promote the movement of the inner cap. When the inner cap moves rapidly, the space inside the cap will increase rapidly and the detonation gas pressure will decrease, The minimum speed required to produce the hot spot, or less than the minimum pressure required to produce the flyer.

4. Experimental study on flyer speed of excitation device

4.1 Break-off method to measure the speed of flyer

On-off speed method is commonly used, the test principle is: when the object to be measured through the signal plate spacing, signal board sends a signal to the recording instrument, after the trigger signal board before a signal board as a benchmark, record the object to be measured through both the time required.

ZBS-10 intelligent explosive velocity measuring instrument developed by the Institute of Civil Explosive Materials of Nanjing University of Science and Technology was used in the experiment. In the experiment, the signal board consists of two aluminum foils and a spacer sandwiched between them. Aluminum foil conductive, low strength, will not have too much impact on the flyer speed; compartment using ordinary plastic tape, good insulation, strength is not high. The upper and lower layers of aluminum foil of each signal board are respectively connected with two trigger electrodes of one channel of the detonation velocity measuring instrument. When the flakes penetrate the signal board, the barrier is broken, the upper and lower aluminum foil conduction, the channel receives a trigger signal, the next channel to start recording the time until the channel corresponding to the signal board is turned on, recording stops. Figure 4 is the experimental device, Figure 5 is the experimental device schematic. Wherein the detonator shell is removed and the inner cap is fixedly connected with the actual connection, and the bottom of the inner cap and the end of the tube are flat, and are placed in a special lateral confinement device, that is, a flyer generator in the figure. The approximate formula for the velocity of the flyer is $v_1=S_1/t_1$; $v_2=S_2/t_2$.

Figure. 4 Speed measuring device for flyer

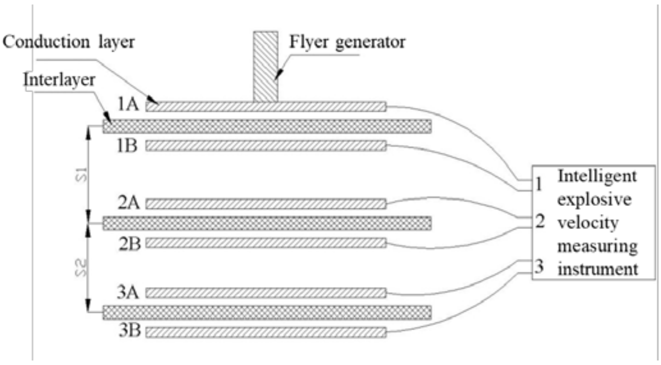

Figure. 5 Principle diagram of flyer velocity measurement

4.2 Experimental results

The experimental results are shown in Table 5.

Table 5 Experimental record of flyer velocity

Number	Inner cap (g)	Excitation drug (g)	S_1 (mm)	S_2 (mm)	t_1 (μs)	t_2 (μs)	v_1 (m/s)	v_2 (m/s)
1	0.845	0.108	10.0	11.5	14.0	23.0	714	500
2	0.845	0.101	10.6	\	20.0	\	530	\
3	0.844	0.102	12.6	\	23.8	\	529	\
4	0.850	0.111	10.8	9.4	33.6	13.8	321	681
5	0.852	0.104	11.4	\	18.2	\	626	\
6	0.829	0.104	100.0	\	244	\	410	\
7	0.832	0.109	13.6	\	8.9	\	1528	\
8	0.843	0.112	11.2	\	13.7	\	817	\
9	0.729	0.126	40.0	\	33.7	\	1187	\
10	0.844	0.102	50.0	\	51.1	\	978	\

Note: The first 5,6 experiments without lateral restraint device; 1-4 test lateral restraint diameter is too large, the tube side wall winding tape to strengthen; 7-10 times the use of small diameter copper tube constraints, and Shell with close.

4.3 Result analysis

To reduce the energy loss due to lateral expansion, the experiment uses copper tube as the lateral confinement of the tube shell. The diameter of the copper tubes used in groups 1 to 4 is too large, but the restraint strength is obviously lower than that of the 7th to 10th groups. The stronger the confinement intensity, the higher the flying speed, the more priming ability [17], 7 to 10 group experimental results were significantly higher than other groups. The fifth and sixth group experiments are the case that the detonator has no lateral confinement, and the data are in agreement with the first to fourth groups. The 1 to 6 sets of data can be used as the actual data with the excitation device to form a reliable piece of flying data, known as the actual speed of flyer. Although 7 to 10 sets of data are obtained with the addition of strong confinement, they do not represent the actual situation, but they represent the ultimate velocity of the flies that can be produced under the excitant composition and the dose, Has a certain value, it can be regarded as the limiting speed of flyer. The average value of the first set of data is 607m/s, the average value of the fourth group is 501m/s, the actual velocity of the flyer is 534m/s and the limit speed is 1528m/s.

Table 6 Parameters of the flyer

Number	Quality (g)	diameter (mm)	Thickness (mm)
1	0.042	3.70	0.50
2	0.041	3.74	0.50
3	0.043	4.20	0.48
4	0.043	4.00	0.48
5	0.042	4.00	0.50
Average value	0.042	3.93	0.49
Average value	0.042	3.93	0.49

5. Numerical Simulation of Flyer Velocity

The velocity of flyer was numerically simulated by Ls-Dyna software combined with combustion growth model. PETN, which is similar in nature to RDX, was used as the elicitor. Inner cap model size: medicine high 0.5cm, inside diameter of 0.73cm, the cap wall thickness and flyer thickness are 0.05cm, the distance from the bottom of the cap is 0.2cm. Numerical simulation of flyer speed of 934.4m/s, flyer velocity curve shown in Figure 6.

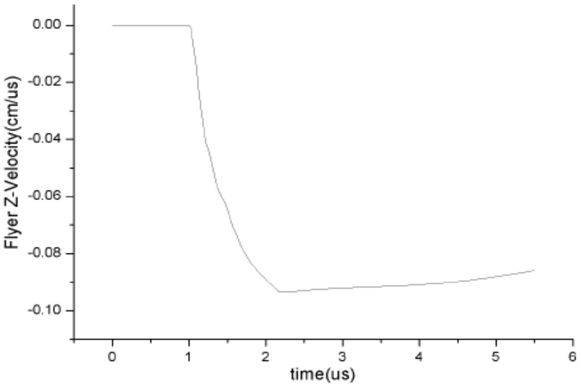

Figure. 6 Simulation curve of flyer velocity

6. Discussions

As the excitation within the cap of the drug is very small, the length is very short, the actual stimulant occurred in the unstable detonation (or deflagration), detonation speed is not only low, and unstable, resulting in the experiment with similar size within the cap The measurement results are very low and fluctuant. The velocity range of the flyer is 300~1500 m/s, the final velocity is 534 m/s, and the limit speed is 1528 m/s under the strong confinement, which is consistent with the numerical results.

Compared with the results calculated by the model, the Stanyukovich theory, the Azis model, the Yadav equation (6.2) and the Geng Jun-feng equation are in good agreement with each other. Gurney model, Open Sanwich model and Kennedy equation, Yadav (6.1) equation is too large, this is because these four models are Gurney model Gurney energy E is based on the establishment; other models are based on detonation velocity D, Independent of E. Characteristic velocity in model calculation $\sqrt{2E}$ is 2360 m/s[18], that is, the Gurney energy E is 2785 KJ/Kg. If the stimulant detonation 4335KJ/Kg to count, equivalent to 64.2% of the energy in the detonation to promote the fly. In fact, the formation of flyers, the inner cap and detonator shell expansion rupture, and the bottom is cut off from the inner cap, these processes have to consume a large part of the energy, actually used to promote the speed of the fly piece of energy to account for the heat The percentage may be less than 64.2%. If 10%~30% is used as the percentage of the contribution of the stimulant to the characteristic velocity, the results are in agreement with the other models (Table 7).

Table 7 The selection range of E value of flying plate and the calculation results

E/Q	E (KJ)	V_{Gurney}	$V_{Opensanwich}$	$V_{Kennedy}$	$V_{Yadav\ (6.2)}$ (m/s)
10%	433.5	979	842	659	872
20%	867.0	1385	1190	933	1233
30%	1300	1696	1458	1142	1510

7. Conclusions

In this paper, through the experiment to determine the high safety detonator excitation device formed by the flyer velocity range is 500m/s ~ 1500m/s, and according to the detonation velocity measurement experiments show that excitation occurs in explosive device cap is unstable detonation (or deflagration), the formation of the flyer velocity should be less than the application of stable detonation velocity calculated value. When the measured detonation velocity 2127m/s and the characteristic velocity 2360m/s are calculated, the results of the Stanyukovich theory, the Azis model, the Yadav equation (6.1), the Xie Xinghua formula and the Gunn equation are in good agreement. Thus, the Gurney energy E derived from the inverse method should be 10% to 30% of the explosion heat Q. At this point, the calculated values of the Gurney model, the Open Sanwich model and the Kennedy equation and the Yadav (6.2) equation are more in line with the actual conditions.

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