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Shooting training method optimization research based on fluid mechanics and fuzzy theory

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ABSTRACT

In China, shooting always is the key sports event. But shooting training theoretical research doesn't yet go deeper, relative to current achieved performance, theoretical research is still in lagging state. Shooting before competition training aspect theoretical research hasn't yet formed into system. The paper mainly discusses sports events' shooting event, shooting event includes fixed target and clay-target two events. To clay-target, by making force analysis of clay-target, it gets clay-target makes constant deceleration both in horizontal and vertical directions. To fixed target event, by making force analysis of bullet, it gets bullet speed, ground included angle, front sight to fixed target distance equation. On that basis, it applies fuzzy theory comprehensive evaluation method to discuss fuzzy theory applied problems in selecting javelin training ways, in the hope of providing certain mathematical method and quantity evidence for selecting training ways.

KEYWORDS

Shooting training;
Fuzzy theory;
Mechanical model;
Training method;
Fluid mechanics.

INTRODUCTION

Shooting is derived from hunting and military activities as earliest. In 15th century, Switzerland has ever hosted matchlock shooting competition. Before 1st modern Olympic Games in1896, many European countries have already founded shooting associations and other organizations, and successively hosted shooting competitions. In 1897, it hosted first session world shooting championship. In July.15th, 1998, international shooting league was founded. Since 1968, it permitted women athletes to attend Olympic Games shooting event, but it didn't set special women event at that time, they can play together with men. Since Olympic Games in 1984, it started to found partial women's events, and in 1996, Olympic Games started to completely separate men and women's shooting competitions. Countries that take leading roles in shooting event in the world are China, America, Russia and Germany as well as other countries. Chinese shooting athletes have made brilliant achievements in Olympic Games, and totally achieved 14 gold medals in attended Olympic Games. It is worthy particular mentioned that in the 23th Olympic Games in 1984, shooter Xu Hai-Feng won the champion that achieved first gold medal in Chinese Olympic Games history.

By researching on shooting competitions, it is clear that bullet movement trajectory actually is projectile movement trajectory. Projectile movement is important part of mechanics, as early as more than 2000 years,

FULL PAPER

people has already started researching on projectile movement, the main representative personage are Aristotle, Galileo and others, and gained certain research achievements. For example, Aristotle thought reasons that projectile still moved after being out of hands is due to hands drove surrounding air to make movements, when it made projectile movement, projectile moved forward by air driving after out of hand. His research mainly carried out research from projectile movement reasons aspects, and the research are most deduction and reasoning without real data proofs. With physics further development and scientific levels further improvement, people have got new theory and research achievements. Projectile application is very widely, such as basketball shooting, rocket launching and so on. The paper on that basis, it establishes shooting dynamical equation, it hopes can provide more optimized schemes on previous shortcomings.

SHOOTING DYNAMICAL EQUATION

At first make force analysis of bullet and get its movement trajectory as following Figure 1.

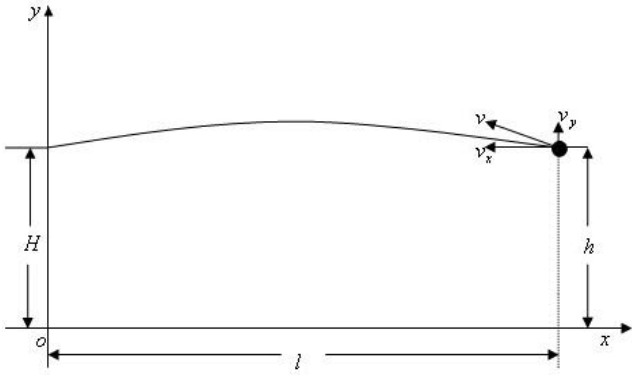

Figure 1 : Bullet movement trajectory

By above Figure 1, it is clear that initial speed v is decomposed into $v_x = v\cos\theta$, $v_y = v\sin\theta$. To the fixed target shooting, assume bullet movement process ignores resistance influence; front sight that gets shoot has equal height with bull's eye, and bullet vertical direction displacement $s = H - h$. The distance between fixed target and shooter is relative further, here only consider bullet across its parabola symmetry axis to fixed target corresponding time. Make discussion with vertical direction displacement s, and sole time t:

$$\begin{cases} t = -2\dfrac{v_y}{a} & H = h \\ t = \dfrac{-v_y + \sqrt{v_y^2 + 2a(H-h)}}{a} & H \neq h \end{cases}$$

And by displacement equation:

$$\begin{cases} l = v_x' t \\ s = v_y' t + \dfrac{1}{2}at^2 \end{cases}$$

it gets:

$$\begin{cases} l = -2\dfrac{v_y}{a} \times v_x' & H = h \\ l = \dfrac{-v_y + \sqrt{v_y^2 + 2a(H-h)}}{a} & H \neq h \end{cases}.$$

To sum up, it gets shooting angle θ and front sight to fixed target distance l relationship:

$$\begin{cases} l = \dfrac{v^2}{g}\sin(2\theta) & H = h \\ l = v\cos\theta\dfrac{[\sqrt{v^2\sin^2\theta - 2g(H-h)} + v\sin\theta]}{g} & H \neq h \end{cases}.$$

Therefore, after shooters testing front sight to fixed target distance, it can calculate best shooting angle.

The next, to clay-target shooting, similarly at first it makes force and movement trajectory analysis, as following Figure 2.

To resistance F, it maintains linear air resistance. Therefore $F = Av'r$, from which v' is clay-target speed, r is clay-target radius. By above figure, it is clear that clay-target movement trajectory is a parabola. Assume that bullet shooting time is t, Δt is difference between clay-target throwing time and bullet shooting time, so clay-target shooting time is $t + \Delta t$. Thereupon, it gets

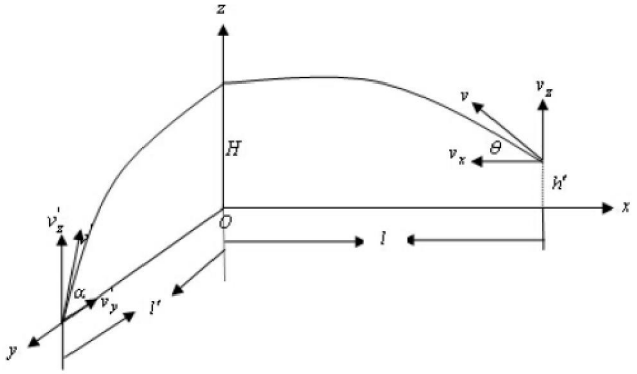

Figure 2 : Clay-target shooting force and movement trajectory graph

clay-target displacement equation is:

$$\begin{cases} l' = v_y'(t+\Delta t)+\frac{1}{2}a_y(t+\Delta t)^2 \\ H = v_z'(t+\Delta t)+\frac{1}{2}a_z(t+\Delta t)^2 \end{cases}$$

Among them, H and Figure 1 H are consistent, so $\left(\frac{a_z}{2}-\frac{a}{2}\right)t^2+(a_z\Delta t+v_z'-v_y)t+\frac{a_z}{2}(\Delta t)^2-h=0$, it solves:

$$\begin{cases} t_1 = \dfrac{-(a_z\Delta t+v_z'-v_y)-\sqrt{(a_z\Delta t+v_z'-v_y)^2-2(a_z-a)\cdot\left(\frac{a_z}{2}\cdot(\Delta t)^2-h\right)}}{a_z-a} \\ t_2 = \dfrac{-(a_z\Delta t+v_z'-v_y)+\sqrt{(a_z\Delta t+v_z'-v_y)^2-2(a_z-a)\cdot\left(\frac{a_z}{2}\cdot(\Delta t)^2-h\right)}}{a_z-a} \end{cases}.$$

When bullet initial speed v is larger than clay-target initial speed v', bullet movement trajectory will lie in the right of symmetric line, clay-target movement trajectory lies in symmetric line's front half or latter half, as following Figure 3.

Among them, A is shooter's position, D, E are respectively clay-target gets shoot position in the time t_1, t_2, the two point projection in the ground are C, D, therefore $l_3' = l_3$, $l_3 = l_3' = l_{t_2}' - l_{t_1}'$. Due to triangle ABC is right triangle, $l_2 = \sqrt{l_1^2 + l_3^2}$. And because v_z is vertical to ground, include angle with v is β, and v horizontal component is $v_{x1} = v\sin\beta$. $l_2 = v_{x1}\cdot t$. And then combines t_1, t_2 computing formula and get:

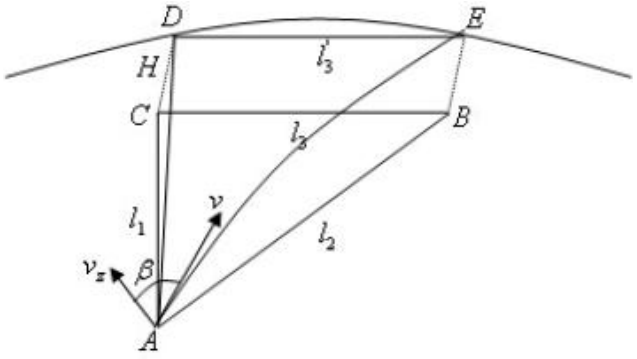

Figure 3 : Clay-target movement trajectory

$$\begin{cases} l_1 = v_x\cdot\dfrac{-(a_z\Delta t+v_z'-v_y)-\sqrt{(a_z\Delta t+v_z'-v_y)^2-2(a_z-a)\cdot\left(\frac{a_z}{2}\cdot(\Delta t)^2-h\right)}}{a_z-a} \\ l_2 = v_{x1}\cdot\dfrac{-(a_z\Delta t+v_z'-v_y)+\sqrt{(a_z\Delta t+v_z'-v_y)^2-2(a_z-a)\cdot\left(\frac{a_z}{2}\cdot(\Delta t)^2-h\right)}}{a_z-a} \end{cases}$$

To sum up, the paper gets:

$$l_1 = \frac{\left(v\sin\theta - v'\sin\alpha+\left(g+\frac{Av'r\sin\alpha}{M}\right)\cdot\Delta t\right)}{\frac{Av'r\sin\alpha}{M}}\times v\cos\theta -$$

$$\frac{\sqrt{\left(v\sin\theta - v'\sin\alpha+\left(g+\frac{Av'r\sin\alpha}{M}\right)\cdot\Delta t\right)^2 - \left(\frac{Av'r\sin\alpha}{M}\right)\cdot\left(\left(g+\frac{Av'r\sin\alpha}{M}\right)\cdot(\Delta t)^2-2h\right)}}{\frac{Av'r\sin\alpha}{M\times v\cos\theta}}$$

$$l_2 = \frac{\left(v\sin\theta - v'\sin\alpha+\left(g+\frac{Av'r\sin\alpha}{M}\right)\cdot\Delta t\right)}{\frac{Av'r\sin\alpha}{M}}\times v\sin\beta +$$

$$\frac{\sqrt{\left(v\sin\theta - v'\sin\alpha+\left(g+\frac{Av'r\sin\alpha}{M}\right)\cdot\Delta t\right)^2 - \left(\frac{Av'r\sin\alpha}{M}\right)\cdot\left(\left(g+\frac{Av'r\sin\alpha}{M}\right)\cdot(\Delta t)^2-2h\right)}}{\frac{Av'r\sin\alpha}{M\times v\sin\beta}}$$

Therefore shooters according to clay-target initial speed and vertical direction included angle, they can get bullet shooting to D, E initial speed v and ground included angle θ, β, and select best shooting angle.

BEST SHOOTING TRAINING METHOD

Due to fuzzy set theory judgment and selection on things are starting from membership thought, it is relative fit for fuzzy correlation degree description. And membership function establishment is easier to combine with people's experiences. Therefore use fuzzy comprehensive evaluation method can start from subjective experience and get objective best shooting training method, and make training plans to meet athletes' features. The paper takes fixed target shooting as an

FULL PAPER

example; firstly it classifies shooting motions into six motions, and gets motions set A as following: $A = \{a_1, a_2, \cdots, a_6\}$

Among them, a_1 is gun holding method a_2 is contracting eyes and staring even and straight motion, a_3 is aiming area entry motion, a_4 is gripping motion, a_5 is aiming motion and a_6 is competition rhythm.

Due to athletes' training time, technical applied degrees, physical state, psychological status are different, the paper endows different weights on these six motions, and get fuzzy subset $\underset{\sim}{A} = \{\mu_1, \mu_2, \cdots, \mu_6\}$, from which $\mu_1 = 0.1$, $\mu_2 = 0.2$, $\mu_3 = 0.1$, $\mu_4 = 0.1$, $\mu_5 = 0.2$ and $\mu_6 = 0.3$. And then take different training methods and compose set $B = \{b_1, \cdots, b_8\}$, from which b_1 is aimless shooting on target, b_2 is fixed target shooting, b_3 is disordered target shooting, b_4 is A type target shooting, b_5 is B type target shooting, b_6 is amplified aiming area target shooting, b_7 is diminished target shooting and b_8 is extended distance shooting. Utilize membership to describe different training methods effects on each technical motion, and divide it into seven grades: best is 1, better is 0.9, good is 0.7, qualified is 0.5, bad is 0.3, worse is 0.1, worst is 0. Establish technical motions and training methods fuzzy relational table, it can refer to TABLE 1.

By above, it gets relation matrix:

$$\underset{\sim}{R} = \begin{bmatrix} 1 & 0.5 & 0.3 & 0.5 & 0.3 & 0.1 & 0 & 0.5 \\ 0 & 0.9 & 0.1 & 0.9 & 0.7 & 0.9 & 0.7 & 0.3 \\ 0.7 & 0.7 & 0.9 & 1 & 0.9 & 0.3 & 1 & 1 \\ 0.5 & 0.7 & 0.5 & 0.3 & 0.7 & 0.1 & 0.1 & 0.9 \\ 0.7 & 0.7 & 0.7 & 0.9 & 1 & 0.5 & 0.7 & 1 \\ 0 & 0 & 0 & 0.7 & 0.9 & 1 & 0.3 & 0.3 \end{bmatrix}$$

And by $\underset{\sim}{B} = \underset{\sim}{A} \cdot \underset{\sim}{R}$, it gets evaluation result $\underset{\sim}{B} = (0.5, 0.56, 0.57, 0.78, 0.83, 0.67, 0.53, 0.67)$. Therefore use the fourth and fifth items training method are best.

TABLE 1 : Technical motions and training methods' fuzzy relations

Item	Aimless shooting on target	Fixed target shooting	Disordered target shooting	A type target shooting	B type target shooting	Amplified aiming area target shooting	Diminished Target shooting	Extended distance shooting
Gun holding method	1	0.5	0.3	0.5	0.3	0.1	0	0.5
Contracting eyes and staring even and straight motion	0	0.9	0.1	0.9	0.7	0.9	0.7	0.3
Aiming area entry motion	0.7	0.7	0.9	1	0.9	0.3	1	1
Gripping motion	0.5	0.7	0.5	0.3	0.7	0.1	0.1	0.9
Aiming motion	0.7	0.7	0.7	0.9	1	0.5	0.7	1
Competition rhythm	0	0	0	0.7	0.9	1	0.3	0.3

CONCLUSIONS

The paper firstly uses mechanics projectile kinematical theory to build good theoretical basis for two kinds of shooting, and then researches on shooting training methods, and gets better results that provides scientific evidence for shooters' training. Previous shooting training method generally applies traditional methods to screen with experiences. The method solves some problems in training, but the selected training ways by applying the method may let training periods extend or unnecessary repeat, let unit time training efficiency reduce. And, in improvement and implementation process, it always has certain blindness and randomness. In order to better summarize experience, the paper's fuzzy theory acts different ways or methods on different training objects, it should highlight main contradiction and also take secondary factors into account in training, which reduces blindness for shooting's training and let it more scientific and systematic.

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