Design on the Theoretical Breechblock Operating Force of Shock Test Bed for Gun Breechblock System

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Abstract. Breechblock operating force is one of the key test parameters of the shock test bed for gun breechblock system. With the design principle determined, the dynamics principle model of the shock test bed is established based on the virtual prototype technology. The kinetic energy theorem is used to calculate the minimum theoretical force F, a standard value for shock test bed to open breechblock. As both the mass of breechblock operating cam and the breechblock operating distance are fixed, the simulation experiment is performed based on the principle model when the breechblock operating force is F.. The results show that the test bed fails to open breechblock under the working condition for energy loss during the impact. By the research, it is better to grasp the dynamics characteristics of test bed before the physical entity experiments, which is benefit to choose a suitable breechblock operating force.

Introduction

At present, scientific research personnel developed gun recoil test machines by advanced theories and technologies [1][2] . The machines could simulate gun shooting, which provided convenience for capabilities test and study.

However, breechblock system is a part of a gun and the gun recoil test machine is a very great equipment, just studying performance of the breechblock system through the equipment would reduce the cost-effectiveness. As a result, treating the breechblock system separately to establish test bed is put forward. Using the test bed to do experiments and examine design indexes will go well.

Virtual Prototyping(VP) technology has been applied more and more to gun research, such as dynamics analysis[3], structural parameter design[4], fault analysis[5] and reliability studying[6] and so on. So such technology is beneficial to design shock test bed for breechblock system before establishing physical test bed. In this paper, VP technology is used to design shock test bed and perform simulation experiments, so as to analyze the influence of breechblock operating force on breechblock operating parameters of shock test bed, which will lay the foundation for developing physical entity experiments.

Design of shock test bed for breechblock system

Breechblock opening principle of breechblock system

The breechblock system comprises of gun breech, breechblock and other parts installed on the two parts. It is shown in Figure 1.

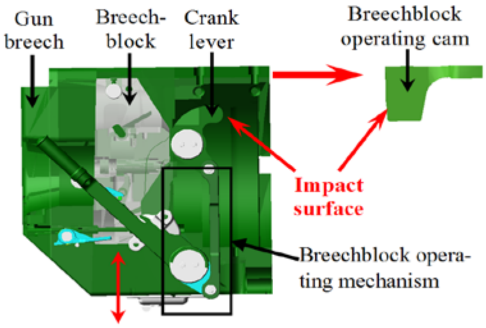

Fig.1. Breechblock system composition.

The process of opening and closing breechblock is breechblock moving down and up along gun breech, which is shown as a double-headed arrow. The other parts use the motion to complete their design actions. After gun shooting, gun breech moves forward. The crank lever on gun breech impacts breechblock operating cam fixed on the other part without motion. Then the crank lever rotates and drives the breechblock operating mechanism to open breechblock. The breechblock will fall to the lowest position, which prepares for the next shell filling. A spring is pressed in opening breechblock and stores up energy of closing. The motion of gun breech is shown as an arrowhead in Figure 1.

Design principle and model establishment of shock test bed

While establishing shock test bed for breechblock system, simulation for practical movements of gun breech will consume a lot of energies on account of its great mass. In addition, it is necessary to use a lathe bed with greater mass and intensity to support and fix the gun breech.

Moreover, heavy object is prone to deflection and overturn in the process of impacting if out of control. Cushioning safety must be taken into consideration. Many researchers have tried to figure out how to simulate the same movement just as the gun shooting only on the platform, but this is an ambitious aim that has proven difficult to realize. And the test bed will have low stability and cost more on that condition.

Based on research, design principle of shock test bed is adopting breechblock operating cam, the moving part, to impact crank lever, with gun breech fixed on the test bed. In this way, it is availably to reduce the mass and driving energies, which can facilitate the construction of shock test bed. During test bed designing, breechblock operating cam is fixed on a case. The case is loaded with mass bodies. The total mass to impact crank lever will be changed through varying the numbers of mass bodies. The force, on the breechblock operating cam, is supplied by hydraulic pressure, which is the breechblock operating force to open breechblock.

The principle model of shock test bed is established based on virtual prototype technology. The three-dimensional solid model is established by CAD software Pro/E. Then it is imported into the dynamic software ADAMS and added some constraints and forces. In the model, gun breech is fixed on ground without motion. The breechblock operating cam is defined a motion and a force on it. Then the breechblock operating cam can move along the opposite direction of gun breech to impact crank lever under the force. The motion is shown as an arrowhead in Figure 2.

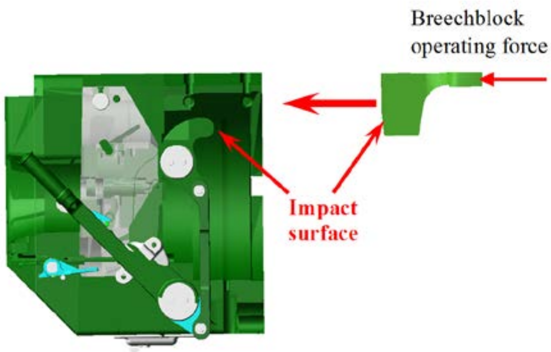

Fig.2. Principle model of the shock test bed.

The theoretical value of minimum breechblock operating force

In the test bed, breechblock operating cam is the moving part to impact crank lever being revolute pair with gun breech, so the mass and speed of breechblock operating cam play an important part during impacting. According to law of conservation of momentum, the product of mass and speed must achieve a definite value, so that breechblock operating cam is able to drive crank lever to open breechblock. The speed results from outside force, so the cooperation of mass and speed could be described that of different mass and different force defined on breechblock operating cam. Therefore, it is necessary to determine the minimum breechblock operating force in theory first.

According to kinetic energy theorem

$$T_2 - T_1 = W_{12} + W_{12}^{'} \tag{1}$$

Where T_1, T_2 are initial kinetic energy and end kinetic energy, W_{12} is work of conservative force, and $W_{12}^{'}$ is work of nonconservative force. Substituting $W_{12} = V_1 - V_2$ into formula(1), what is obtained is

$$(T_2 + V_2) - (T_1 + V_1) = W_{12}^{'} \tag{2}$$

Where V_1, V_2 are initial potential energy and end potential energy, Formula(2) expresses that mechanical energy variation should equal work of nonconservative force.

In the shock test bed, the hydraulic pressure, namely breechblock operating force, is main nonconservative force without regard to friction. Then

$$W_{12}^{'} = FS \tag{3}$$

Where F is the breechblock operating force, S is breechblock operating distance, the displacement from the original position of breechblock operating cam to crank lever coming into contact with the bottom surface of breechblock operating cam. Then

$$(T_2 + V_2) - (T_1 + V_1) = FS \tag{4}$$

During opening breechblock, breechblock operating cam is pushed by hydraulic pressure to impact crank lever. As crank lever comes into contact with the bottom surface of breechblock operating cam, breechblock descends to the lowest position. At the moment, as long as the speed is not zero, breechblock operating cam will move forward to break away crank lever and complete opening breechblock.

To calculate the minimum energy to open breechblock, on the assumption that the speed of breechblock operating cam falls to zero at the moment. That is to say, the kinetic energy of whole system is zero.

Definition：the first movement of breechblock operating cam is initial time, the last time is the crank lever coming into contact with the bottom surface of breechblock operating cam. The potential energy is zero when the breechblock descends to the lowest position. Then

$$\begin{cases} T_1 = T_2 = 0 \\ V_1 = mgh_1 + \frac{1}{2}k_1 l_{11}^2 + \frac{1}{2}k_2 l_{21}^2 + \frac{1}{2}k_3 l_{31}^2 \\ V_2 = mgh_2 + \frac{1}{2}k_1 l_{12}^2 + \frac{1}{2}k_2 l_{22}^2 + \frac{1}{2}k_3 l_{32}^2 \end{cases} \tag{5}$$

In the formula, h_1 is the initial height of breechblock compared with h_2, where the potential energy of system is defined as zero. m is the mass of breechblock and other parts on it. k_i is spring's stiffness coefficient. l_{i1}, l_{i2} are the initial and last deformation of spring. $i = 1, 2, 3$ represent three springs in the system. The values of each quantity could be obtained from design instruction of the gun.

With the definite breechblock operating distance(S=300mm), the theoretical value of minimum breechblock operating force is obtained by calculation. That is

$$F = 690.9 \text{ N}$$

The minimum breechblock operating force provides a standard for choice of breechblock operating force. That is to say, when the breechblock operating force is smaller than *F*, the test bed can not open breechblock.

Simulation experiment

Based on the principle model of shock test bed, simulation experiment is carried out as the breechblock operating force is F and the mass of breechblock operating cam is 10 times the original mass. The rotation angle of crank lever is tested, which is shown in Figure 3.

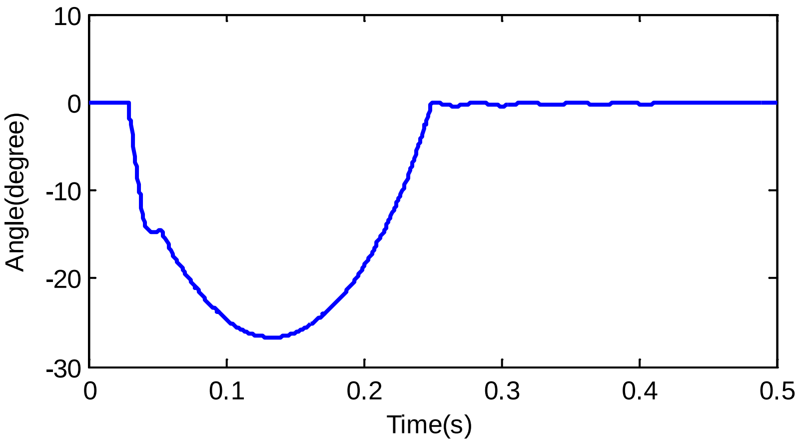

Fig.3 The rotation angle of crank lever

Under the minimum breechblock operating force *F*, while the mass of breechblock operating cam is 10 times the original mass, the maximum rotation angle of crank lever is only 26.7°. The angle does not achieve the breechblock opening index 111.4°. So the test bed can not open breechblock. And breechblock operating cam is pushed back. As the impact times increase, breechblock operating cam moves back and forth until breechblock operating force balanced with spring counterforce. Then breechblock operating cam and crank lever keep into contact without moving. At the moment, crank lever has a very small rotation angle.

In practice, the impact between parts, the friction during relative motion, spring damping and so on, have dissipated system’s energy. As a result, to open breechblock, the actual value of breechblock operating force is greater than *F*.

Summary

In this paper, as both the mass of breechblock operating cam and the breechblock operating distance are certain, simulation experiments are performed based on the principle model when the breechblock operating force is *F*. The results show that the test bed fails to open breechblock under the working condition. During impacting, there is energies loss. So the test bed could not open the breechblock under the minimum breechblock operating force(*F*). The study provides theoretical reference for experiments with the test bed.

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