A PREDICTION ON DISPERSION ACCURACY OF THE GUN-VEHICLE SYSTEM IN SELF-PROPELLED ANTI-AIRCRAFT GUN

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Abstract: From vehicle, gun, projectile and charge system, a basic principle has been presented for the first time in the paper by making use of the random-simulation technology based on the theory of interior ballistic, automat, vibration of self-propelled gun system, initial disturbing and external ballistic etc. The basic principle is achieved by simulating a movement procedure of the gun-vehicle system on firing and by predicting dispersion accuracy on targets with computer. According to this basic principle, we programmed the predicting software about dispersion accuracy of the gun-vehicle system in self-propelled anti-aircraft gun, finally by comparing the result from computer simulation with the data of firing practice in shooting range. Hence the identical result in testing proves that the principle of this researching method is correct and practical. The method can be used in research on dispersion accuracy of other guns or artillery as well and possesses a certain reference value.
Key words: Self-propelled Anti-aircraft Gun, Dispersion Accuracy, Prediction.

The research on artillery system dynamics has become more and more active in China and other countries, which is one of the most efficient technological ways of increasing the dispersion accuracy of gun and has been a new studying direction and one of study focuses on modern ordnance. According to the domestic and abroad documents consulted, most of papers carried research through certain models, not random models[1-2].

Presently methods of studying artillery dynamics by using random models are classified into three kinds: the first is to use the theory related to random vibration and spectrum analysis to figure out dynamical responsibility of gun[3]; the second is to make use of parsing function method of covariance to resolve to dynamical problems [4]; the third is to get the result of system's dynamical response through Monte Carlo and random load from random number generator [5-6]. Based on known excited property, the front two ways figure out system dynamic responsibility and are not involved with the simulation of random load; the back one is to figure out the dynamical responsibility of gun from random load, not involved with fired projectiles dispersion. This paper thinks that to predict the projectiles dispersion it need set up a synthetic dynamics model and randomly simulate the overall process of gun firing with computer.

1 Basic Concept and Theory

Because of projectiles and charges having some errors in the manufacturing process and different density of loading charge before gun firing, a series of fired projectiles' bore pressure maximum and pressure curves have few random errors. With regard to some self-propelled anti-aircraft gun's pneumatic floating automat, these errors directly affected the range and shape of the pressure curve inside the pneumatic cylinder and caused the random change of recoiling and counter-recoiling movement. Thus load on the gun will have few random changes while firing. Random barrel-firing vibration resulted from this, makes projectiles' initial disturbing have random errors, which is got at the moment when they fly out of the muzzle. Thereby, projectiles deviate the predicted orbit, which resulted in dispersion of a series of fired projectiles. So, dispersion of projectiles is decided by a few random elements.

The theory of probability provides the mathematical basis for prediction of gun's dispersion accuracy. Those elements affecting dispersion of fired projectiles and dispersion accuracy are random variable and assumed a normal multidimensional distribution. To simulate the firing process and predicting dispersion accuracy, it is essential to set up the theory equation between designing parameters of gun and ammunition affecting dispersion accuracy, which is the equation of initial disturbing theory. According to the document [7], this equation can been written:

$$\dot{d}_{?} = f(A, B, l_b, l_R, R_S, \text{ß}_D; q, V_O, P_g; \text{ß}_O, \dot{b}_O, \dot{y}_O, \ddot{y}_O; e) \quad (1)$$

The meanings of symbols in the equation are seen in Document [7].

The mean values and mean-square deviation A, B, l_b, l_R, R_S, ß_D show the effect which structural parameters of projectiles have on dispersion of projectiles; the mean values and mean-square deviation of q, V_0, P_g reflects the effect which charge structure and interior ballistic parameters have on the dispersion; the mean values and mean-square deviation of ß_O, $\dot{b}_O$, $\dot{y}_O$, and $\ddot{y}_O$ mirror the effect which gun's vibration has on the dispersion. By function equation (1), are designing parameters of vehicle, gun, projectiles and charge and the initial disturbing related. Considered from the gun, equation (1) relates the gun's vibration and the initial disturbing; from the process of simulation, the equation (1) links the gun's vibration simulation and the external ballistic simulation. Thus, the theory of initial disturbing is the basis of predicting dispersion accuracy, which makes it possible to simulate the whole firing process of the gun-vehicle system in self-propelled anti-aircraft gun.

2 The Basic Principle of Predicting Dispersion Accuracy

As well as we know, to finish the effective firing, the self-propelled anti-aircraft gun must undergo loading ammunition, igniting primer, the burning and exploding of power, the movement of projectile in the gun barrel by propellant gas, the movement of automat, projectile flying in the air out of muzzle and hitting the target. Flying out of the muzzle, the projectile's orbit and posture in the air, which are mainly affected by the initial disturbing beside the whether condition, decide the accuracy of hitting the target. A number of researches' results show that the most important element of affecting the dispersion accuracy of small caliber anti-aircraft gun, is muzzle's vibration and the condition of atmosphere and weather can be neglected. Seen from the analysis of some self-propelled anti-aircraft gun's load excitement, the most main exciting source of gun's vibration is the composite force by power's burning inside the bore and the movements of the automat and barrel.

To realize the simulation of the whole firing process of the gun-vehicle system self-propelled anti-aircraft gun, first, it need to put the charge structure parameters and the random value of initial interior ballistic parameters into the interior ballistic model before getting the result of interior ballistic equation to simulate the curve of bore pressure; second, it is to make a dynamical kinetic and analysis of a floating automat by using two degree-of-freedom model, and then simulate the exciting force function essential to computing the muzzle's vibration; according to designing paper, it is to set up multi-body model as the gun's dynamical one, randomly simulate the result with interior ballistic and floating automat and use interactive method to simulate the gun's vibration and compute the muzzle vibration parameters; it is to make use of the theory of initial disturbing to randomly simulate the initial disturbing parameters caused by the gun's vibration, the static and kinetic imbalance of projectile, projectile weight, the muzzle velocity, the muzzle pressure and the clearance between projectile and barrel; at last, it is to use external equation to simulate the flying orbit and impact point of projectiles and then count the result of dispersion accuracy. At the same time, it is to find the part that affects most the dispersion accuracy through analysis of designing parameter's sensitivity and provide structural designing of the gun-vehicle system with guiding suggestion. This is the basic principle of simulating the firing process of the gun-vehicle system in self-propelled anti-aircraft gun and predicting the dispersion accuracy, shown as the Fig.1.

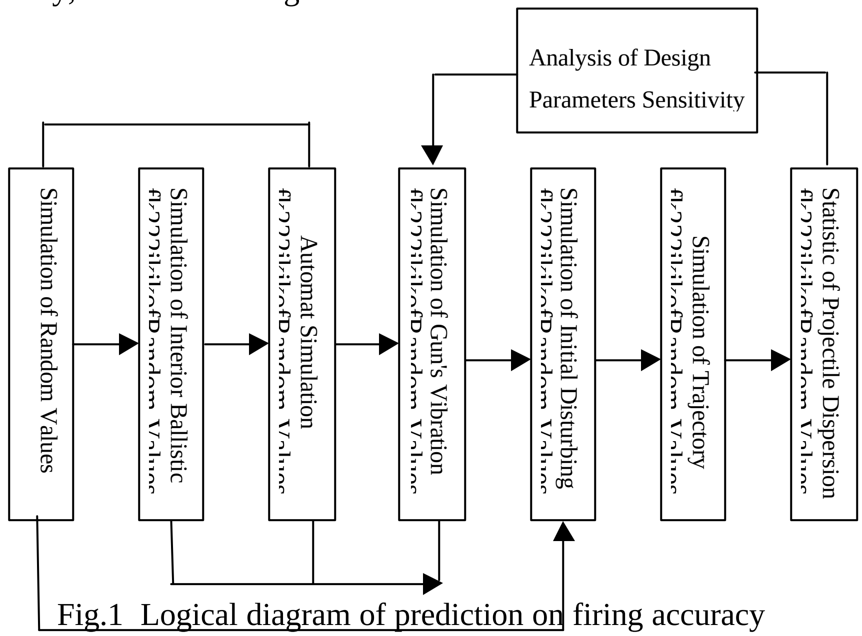


Fig.1 Logical diagram of prediction on firing accuracy

3 Software Structure and Predicting Result

According to the theories of gun's interior ballistic, automat, gun vibration, initial disturbing and trajectory, and random simulation by computer is used to program the software of simulate the firing process and dispersion accuracy of the gun-vehicle system in a self-propelled anti-aircraft gun. The software is composed with a general control module, an interior ballistic module (including random variant module), a floating automat module, a muzzle's vibration module, a trajectory module (including initial disturbing computation and analysis of firing dispersion), a displaying or printing and demonstrating module of figure and curve. The data es. Figure 2 displays the logical diagram of th

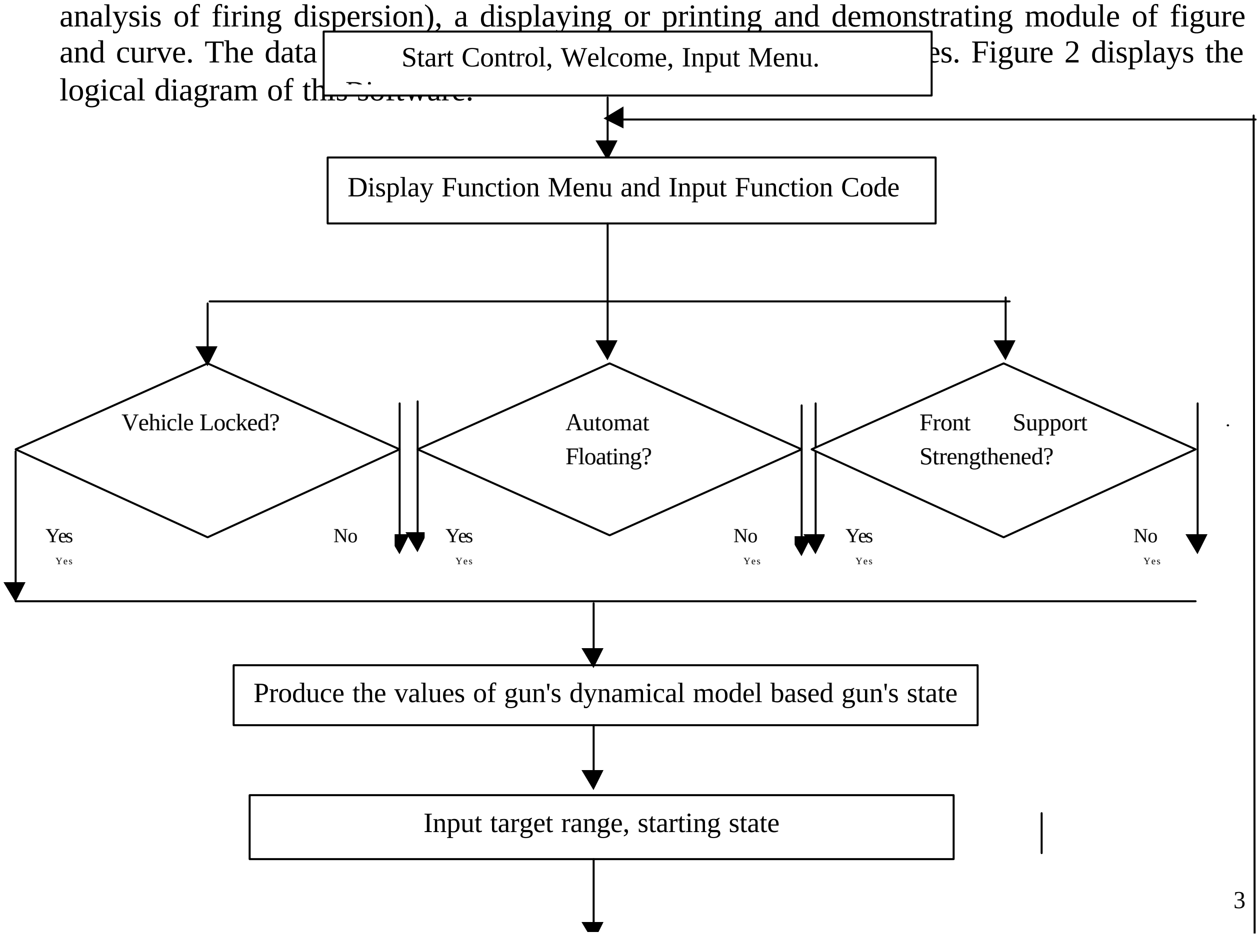
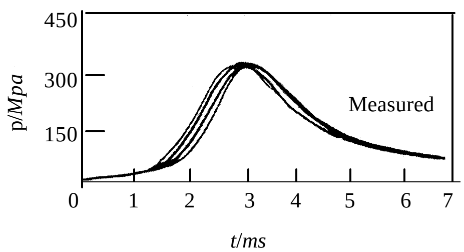


Fig.2 Logical diagram of the software

3.1

3.1 Random Simulation of Interior Ballistic

Based on the design and testing data of ammunition, we compute the mean values of projectile weight, charge volume and the half of annulus thickness of some self-propelled anti-aircraft gun and get random parameters of covariance matrix； assumed that these parameters take on normal distribution, mathematical statistic is used to generate the valued of these random parameters essential for each shell, which will be further put into simultaneous equations of interior ballistic to get the curves of p-t and v-t. Figure 3 shows the real testing data and computing simulation of the time curve of some self-propelled anti-aircraft gun's bore-pressure.



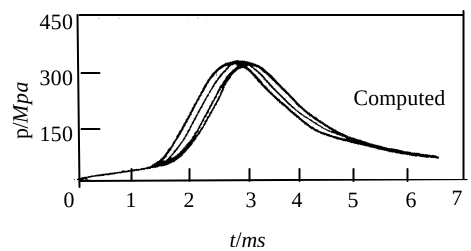


Fig 3 The p-t curve of the bore-pressure

3.2 Random Simulation of a Floating Automat

Random simulation of interior ballistic provides random simulation of a automat with p-t curve, projectile weight, charge volume, velocity, the time and bore-pressure of exit of shot and the time and bore-pressure which projectile moves to the exhaust and ignition time, etc. Find the structure and dynamic parameters of the automat in the designing paper and set up relevant data files as required by software, and then run the automat module to carry dynamical and kinetic computation of the floating automat and keep the result. The curves of floating displacement time of a automat are shown as Figure 4.while actually testing and simulating 7-round automatic fire.

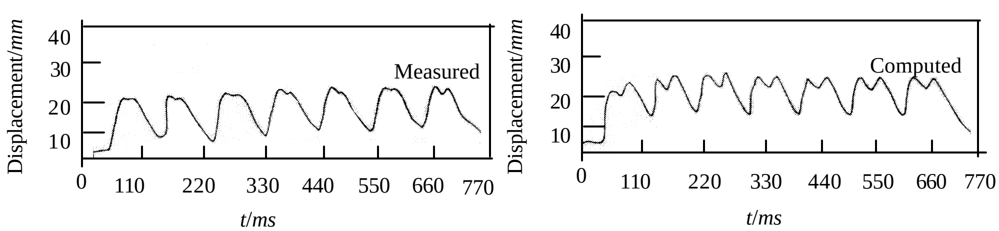


Fig.4 The curve of automat movement

3.3 Simulating Muzzle Vibration Parameter

Proved by a number of researches, the size and change of muzzle vibration parameter reflects the effect that gun's vibration has on dispersion accuracy. In order to make simulated result meet the actual situation as much as possible, we divide some self-propelled anti-aircraft gun into 12- freedom multi-body system dynamical model of gun that could be consisted of various kinetic pair (rotating pair, translation pair) and spring-damper elements and then examine and improve the model step by step by using simulating experiments and actually tested data.

We developed the software that is fit with the response computation of gun's vibration, which consist of one master control module and sixteen sub-modules. It is to take as excited function the load simulated with interior ballistic and a automat and compute the curve of muzzle vibration by using interactive method? The curves of gun muzzle vibration displacement actually measured and computed are as Figure 5.

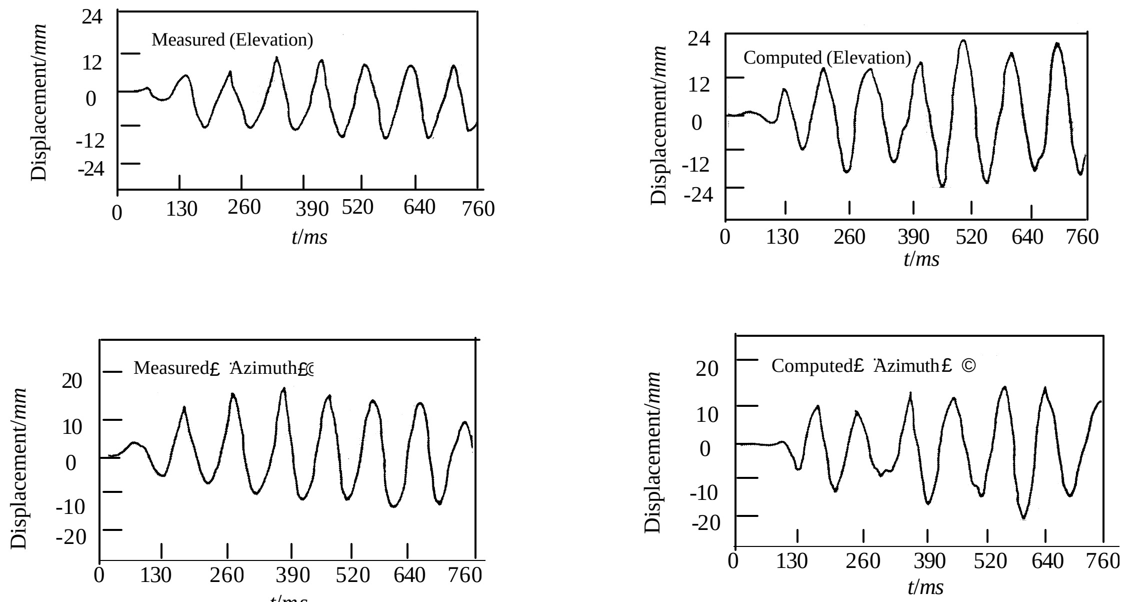


Fig.5 The muzzle vibration movement

3.4 Trajectory Simulation

In the first place, it is to randomly simulate part of parameters essential for the generation of projectile system and other files to produce relevant data; use the effect parameters of gun's vibration having on dispersion, angular displacement, angular velocity, linear velocity, linear acceleration to compute initial disturbing; and taking initial disturbing as the initial value, simulate the coordinate impact point of every shell on the basis of the initial disturbing theory and simultaneous equations of trajectory and then count and analyze the simulated result to trajectory. The mean result of simulation and prediction is listed on Table 1 through a number of computations of differential structures' states.

Tab. 1 Simulated and measured results

System State	Predicting Result (mil) (azimuth × elevation)	Measured Values (mil) (azimuth × elevation)
Vehicle locked, floated, front support strengthened	4.22 × 2.97	4.21 × 2.07
Vehicle locked, floated, front support not strengthened	6.10 × 3.79	5.69 × 2.58
Vehicle locked, not floated, front support strengthened	6.37 × 5.20	No measured values
Vehicle unlocked, floated, front support strengthened	7.51 × 7.95	Missing target

4 Conclusion

Computing result with the software programmed in the light with the theory in this paper is mostly identical with the data from the live fire test. This proves that the basic principle of predicting the dispersion accuracy of the gun-vehicle system in self-propelled anti-aircraft gun is correct and practical. If the way of data between modules exchanges through compatible database instead of files, it will speed up the running of the software and economize the save time and at the same time, provide auxiliary designing and structural optimization of a gun-vehicle system with the theoretical basis. In the phase of dispersion accuracy of the self-propelled anti-aircraft gun, the software correctly analyze why the dispersion accuracy goes beyond the designing standard is that the roll frequency of gun cradle is almost identical with the firing frequency--- resonance is generated on gun while firing. The software gave a suggestion to strengthen the horizontal hardness of cradle's front support and the problem was solved after master control system was improved and we succeeded only once time in developing the prototype of guns (mechanical part). To other guns' dispersion accuracy study, the research method is referential too.

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