ITM Web of Conferences **7**, 09002 (2016) DOI: 10.1051/itmconf/20160709002
ITA 2016

Research on the Optimization in the Continuous-fire Strategy of the HPM-Bomb

Hui WENG[1,a], Xu-Chang ZHOU[2] and Chao MAO[1,b]

[1]*Dept. of Management Eng., Naval Univ. of Engineering, Wuhan, China*
[2]*Dept. of Weaponry Eng., Naval Univ. of Engineering, Wuhan, China*
[a]*26458711@qq.com*, [b]*hjklyuiop@126.com*

Abstract—The electronic damage feasibility and the operational characteristics of the high power electromagnetic pulse bomb shot by shipboard gun are analyzed. As the destruction of the electronic components caused by the high power electromagnetic pulse is hard to evaluate, the spatial distribution of the anti-ship missiles is analyzed, and the strategic model for the continuous fire is built. Aimed at the maximum damage effectiveness, the crux of the lasted shift shooting tactics is a TSP problem. The genetic algorithm is applied in the TSP problem. Simulation experiments demonstrate that the model and the algorithm are effective.

1 Introduction

For the development of the microelectronics technology, the large scale integrated circuit and the computer control technology, these technologies have been widely applied in the weapon system. The high technology weapons such as the flights, missiles and etc. have made great progress in the smart, intelligent, etc. However, with a growing reliance of the survival and combat capability on precision electronic equipment, they are more likely damaged and interfered with by the electromagnetic power. The theoretical and experimental studies have shown that the more sophisticated and more complex electronic system, it is more easily interfered with and damaged by the high power microwave (HPM) [1]. So, the HPM weapons have become the focus of the development of the weapons system in the military powers [2].

HPM-Bomb uses the electromagnetic vulnerability of the military equipment to attack electronic targets. The HPM pulse radiation gets through the antennas and apertures into the interior of the target electronic system. The breakdown of electronic components could cause the electronic system not to work indefinitely and then reduce the operational efficiency of the target.

2.Features of the Operation

2.1 Feasibility Analysis

Conventional HPM warhead is mainly composed by the primary power (electric energy or chemical energy), the excitation power supply, the explosive magnetic flux compression generator, the pulse power modulation system, the high power microwave source, the antenna system and etc.

The HPM-Bomb is composed by three major components which were shown as the structure diagram.

2.1.1 Microwave Tube and Antenna

Microwave tube is the microwave source which generates the electromagnetic radiation. For the dimensional restraint, the microwave tube which is used at the HPM-Bomb is the virtual cathode oscillator (VCO). The electromagnetic pulse (EMP) power generated by the VCO is over 1GW. The microwave generated by microwave tube is transmitted by the antenna. For strengthen the radiation direction, the antenna of HPM-Bomb is the spiral antenna.

2.1.2 Magnetic Flux Compression Generator (MFCG)

This is composed by primary energy (battery and capacitor), magnetic field of a current-carrying solenoid (stator), explosives and the metal casing for explosive charge (armature).

DOI: 10.1051/itmconf/20160709002

2.1.3 Pulse-forming Network

There are three main functions of the pulse-forming network. Firstly, it is a impedance-matching element, which transforms the low impedance into high-impedance. Secondly, it is a voltage changer, which transforms the low voltage of the MFCG output into a high voltage output, and loads on microwave source. Thirdly, it is a waveform rectifier, which transforms the slow rise pulse leading edge into a fast rising leading edge of the pulse output.

As the development of the explosive MFCG, the energy density of the explosive MFCG could arrive at 30J/cm3~60J/cm3, the energy conversion efficiency of the explosives energy to the load energy is close to 4.8%[4]。And as the development of the virtual cathode oscillator which is smaller volume among the high power microwave sources, the electromagnetic conversion efficiency increases from 1%~3% to above 12% [5]. As the motion of the electron of the coaxial virtual cathode oscillator is radial, the radial dimension should be reduced effectively. For the strong constraint of the radial of the gun firing HPM-Bomb, the coaxial geometry of the virtual cathode oscillator should help improve the efficiency of system integration. These developments of the HPM technologies should help HPM-Bomb to meet the electromagnetic operational requirements.

2.2 Operation Characteristics

HPM-Bomb emits the high power electromagnetic pulse, and it enters the weapon system through the front-door (such as the antenna, connector, and etc of the target) or the back-door (as the apertures, connect cables, ports). The high power electromagnetic pulse produces induced currents and voltage at the metal surface or metallic wire. The induced current and voltage cause the heating of the semiconductor medium and lead to the abnormal state or decrease the device performance. The normal function of target system is destroyed and the objective of electromagnetic operation is achieved.

The electronic attack by the HPM-Bomb has the following characteristics:

(1)For the mostly military equipment is not completely shielding, the electromagnetic pulse should enter the target system through the front-door or back-door.

(2)The coverage is so large that could cover several targets, so the location and tracking accuracy is reduced.

(3)Compared with the other directed energy weapons (such as laser weapons, particle beam weapons), the HPM weapon has the advantage of easy to spread, and independent of weather (such as fog, rain and etc.).

(4)Compared with the HPM radar weapons, the demand of the destroyed maximum peak power is lower for the approaching radiation, and the HPM-Bomb is far away from the friendly platform of avoiding electromagnetic accidentally injury to maximum extent possible.

(5)Compared the normal electromagnetic countermeasure (ECM), the high power electromagnetic pulse could cause the physical damage.

(6)The ultra-wide-band high power microwave should cover the working frequency band of the modern military radio equipment, such as radar, communication, navigation and etc., it has broadband electronic warfare features.

But the electromagnetic weapon damage effect evaluation especially real-time evaluation is hardly. Signal interruption cannot completely represent that the attack is effective. The target which is attacked effectively seems to work properly. Such as the receiver or data processor of the anti-ship missile is destroyed by the HPM attack, the radar seeker still emits electromagnetic waves. So, when HPM-Bomb shoots at several targets, there is no need to continue shooting at one target.

3 Strategy Model of Continuing Shooting

3.1 Saptial Distribution Model of the Missile Saturation Attack

For the saturation attack by anti-ship missile, the azimuth angle and pitching angle space distribution characteristics of single shipboard gun within the effective firing range are mainly discussed to provide the basis for the establishment of the continuing shifting firepower strategy.

3.1.1 ltitude angle (ε) Distribution of anti-ship Missile

The distance between the anti-ship missile and target and the flying height is the main influencing factors of the altitude angle (ε) distribution of anti-ship missile. For the shipboard gun range constraint, the space distribution of anti-ship missile is bound to the vertical plane at the maximum shipboard gun range constraint. Based on the analysis of all kinds of anti-ship missile route characteristic, at the maximum effective shooting range of the large and medium caliber naval gun (maximum effective shooting range of AK-130 shipboard gun is 18km); the anti-ship missiles are cruising at a constant altitude. To achieve coordinated attack, the anti-ship missile trajectories are high-low collocations. Assumed that the height of the cruise missile flying at high-altitude is 400m and the height of the cruise missile flying at low-altitude is 10m. In order to make full use of the height space, assumed that the cruise height distribution is Gaussian distribution. With the firing table, the cruise height distribution is available.

3.1.2 Azimuth Angle(β) Distribution of the Anti-ship Missile

For strengthen the attacking effectiveness of the anti-ship missile, especially penetrating the multi-level defense surface warship formation, saturation attack is frequently used in anti-ship missile penetrating. At the same time or within a certain time range, the penetrating anti-ship missiles exceed the available fire channels of the anti-missiles; this is called as anti-ship missile saturation attack. When the saturation attack is applied, to increase the penetrating possibility of anti-ship missile, multi-direction attack is usually chosen. The multi-direction attack should force greater dispersion of the shipboard defense system firepower. When the saturation anti-ship missiles attack from two or more directions, the chosen attack directions have a direct impact on penetrating possibility. For increasing the penetrating possibility, on the precondition to satisfy route planning principle, the different directions should be chosen by anti-ship missile attacking.

Obviously, the different direction chosen strategies should lead to different attack effectiveness. According to the direction chosen strategy proposed by the reference [6], when the saturation attack is being forced by several anti-ship missiles, the directions should be 90° attack angle pairings. For one side of the surface ship, it is just generate the azimuth angle distribution between 0~90° of signal side. As the analysis of altitude angle distribution, the azimuth distribution is even-distributed. When the number of the attack directions is odd number, the attack angle which is closest to 90° relative bearing is not need to pair.

The above analysis is based on the direction chosen strategy of the anti-ship missile route planning, and it is suitable for the normal anti-ship missile saturation attack situation.

3.2 Strategy Model of the Continuing Shifting Firepower

The following assumptions are made for the progress of the continuing shifting firepower.

(1)When the shipboard gun weapon shifts firepower, the aiming rotation speeds are constant, and equal to the maximum aiming speed.

(2)The damage probability of HPM-Bomb is static; the shifting firepower influence on the damage probability is neglected.

(3)The shifting firepower time from the fire control system of firing data to the gun pointing to the target is neglected, its influence is not considered too.

(4)The targets risk ranking is neglected, the target space distribution is considered only.

The shifting firepower distance is the larger between the abs of azimuth angles and the abs of altitude angles. Then the distance of shifting firepower between the (T_i, T_j) could be expressed as:

$$\theta_{i,j} = \max\left(\left|\varepsilon_i - \varepsilon_j\right|, \left|\beta_i - \beta_j\right|\right) \qquad (1)$$

Based on the above analysis, the continuing shifting firepower strategy could be described as below.

The coordinates of n targets and the shifting firepower distance between them is given. The optimal objective is the shortest path which is a closed path and travels every target only once.

3.3 Basic Simulation Process

The basic simulation process is shown as follows.

(1)Input the anti-ship missile number.

(2)According the space distribution of the incident anti-ship missile, the coordinates of the targets which meet the distribution characteristics are generated in the spherical coordinate system.

(3)Confirm the GA control parameters [7], and computing the optimal shifting firepower path with the GA.

(4)Determine the optimal shooting strategy.

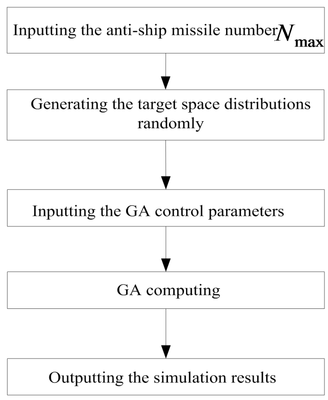

Figure 1. Simulation Flow Chart

The Genetic Algorithm control parameters are: using the tournament selection method, population size is 3, intensity of selection is 0.85, loss in the diversity is 0.385, and operation times of genetic algorithm are 500.

4 Simulation and Analysis

4.1 Initial Simulation Conditions Setting

Based on the spatial distribution model of the target, the target space position is generated randomly. The spatial position of 20 randomly selected targets is shown in the tab.1.

TABLE I. Spatial distribution of the target coordinates.

No.	ε (°)	β (°)	**No.**	ε (°)	β (°)
1	26.674	43.637	11	32.846	133.64
2	15.969	51.135	12	37.987	141.13
3	18.97	73.848	13	16.894	163.85
4	38.703	43.332	14	31.12	133.33
5	32.512	6.6634	15	24.712	96.663
6	17.659	37.317	16	29.171	127.32
7	22.892	62.232	17	31.13	152.23
8	20.795	53.43	18	38.352	143.43
9	33.679	82.451	19	29.45	172.45
10	39.351	14.106	20	19.307	104.11

4.2 Simulation Results and Analysis

The spatial angle distribution of the target can be obtained from the Tab.1 is shown as Fig.3. The strategy model of continuing shifting firepower is calculated by GA and the optimal shifting path is shown as Fig.4.

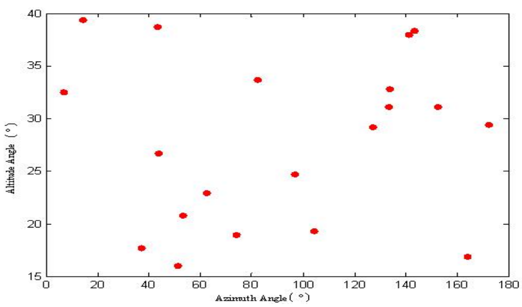

Figure 2. Target coordinates

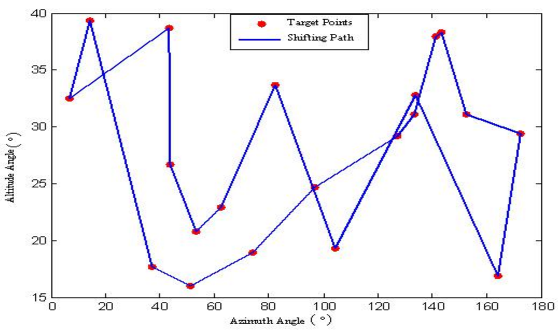

Figure 3. Optimal shifting firepower path

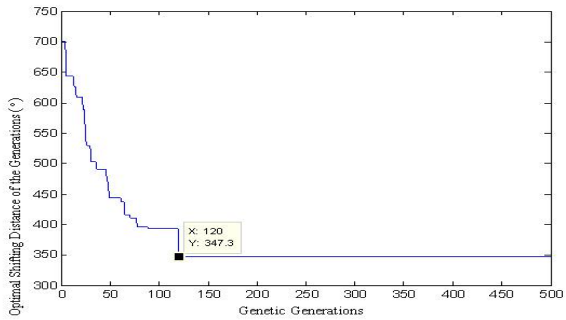

Figure 4. Optimal shifting distance

As Fig. 5 showed, the rotary angle of the unordered shifting firepower is about 700°. For the GA optimization, the GA convergence generations are 120, the rotary angle is 347.3°. Neglected the fire time influence and assume that the rotational speed of the shipboard gun 30°/s, the time of shifting firepower is reduced from 23.3s to 11.6s. From the simulation results, GA is feasible for the continuing shifting firepower model.

5 Conclusions

The large scale integrated circuit and the computer control technology are widely used in the modern military equipment. The electromagnetic vulnerability is exposed in combat with high power electromagnetic pulse. From the operational characteristic analysis of HPM-Bomb, the real-time damage evaluation of electromagnetic attack is very hardly. The continuing shifting firepower strategy is proposed in this paper. The continuing shifting firepower path is optimized by GA. The simulation result demonstrates that the GA is suitable for resolving the continuing shifting firepower path problem, and the shifting firing time is effectively reduced.

References

1. Clay W.High altitude electromagnetic pulse (HEMP) and high power microwave (HPM) devices: threat assessments[R].Washington, DC: Library of Congress,2006.
2. Xiao Jin-shi, Liu Wen-hua, Zhang Shi-ying, et al. Analysis and Simulation on Killing Ability of Cascaded Flux Compression Electromagnetic Pulse Bomb.Journal of Ballistics, 2009, 21(1):91-94.
3. Kopp C. The Electromagnetic Bomb – a Weapon of Electrical Mass Destruction. ADA332511. December 1997.
4. L. L. Altgilbers, M. D. J. Brown, I. Grishnaev, et al. Magnetocumulative Generators. New York: Springer-Verlag, 2000.

5. Liu Jing, Shu Ting, Li ZhiQiang. A novel configuration of vircator with coaxial waveguide. Acta Physica Sinica, 2010, 59(4): 2629-2633.
6. Zhou Lijun, Wang Changjin, Wang Jingheng.Analysis on selection tactic of attacking direction of anti-ship missile.Command Control&Simulation, 2008, 30(4): 44-47.
7. Wang Xiaoping,Cao Liming.Genetic algorithms-theory, application and software implementation.Xi'an: Xi'an Jiaotong University Press,2002.