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MODELING AND SIMULATION FOR THE TIME CONSTRAINT DAMAGE EFFICIENCY OF MLRS

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ABSTRACT

Aiming at the shortcomings of the present damage efficiency model of multiple launch rocket system(MLRS) that ignores factors such as targets movement and viability while considers factors like shooting accuracy, target characteristics, and amount of ammunition only, a time-constraint damage efficiency model of MLRS was presented based on artillery firepower theory and firepower counterwork theory. The damage efficiency of MLRS in scenarios that containing time-constraint factors was computed based on the new model. Simulation results show the effectiveness of the model, and demonstrate that factors like targets maneuver and survival demand play an important role in damage efficiency of MLRS battalion and make the damage efficiency time sensitive.

Keywords: *Time-Constraint, Damage Efficiency, Shooting Accuracy, Ammunition Consumption, Target Maneuver*

1. INTRODUCTION

The MLRS is a long-rang surface-suppressing weapon with fierce firepower and good mobility. The damage efficiency of MLRS is determined by factors such as shooting accuracy, targets characteristics, and amount of ammunition. Both military and civilian scholars have done a lot of fruitful work in damage efficiency, and presented some methods for calculating the damage efficiency under different conditions[1-6], but the time-constraint caused by the target maneuver and survival needs, have not been paid enough attention and given in-depth studying. With the advances of military technology, target characteristics have changed dramatically, especially in the target dimensionality, and the target distribution characteristics and target maneuver, which have a direct impact on the combat effectiveness of the weapon systems and tactical choices. In addition, with modern reconnaissance technology improving, the ability to get information is distinct from the past. The increasing transparency of the modern battlefield brings convenience to the commanding and information transporting[7] of the MLRS while brings viability test too. Therefore, in order to improve the viability of MLRS, the hostile counterattack speed[8,9] and firepower preparing time must be taken into account while computing the damage efficiency of MLRS.

A new damage efficiency model was set up based on used static model in this paper. The new time-constraint model takes into account the change of target characteristics and ammunition consumption caused by time factor. The application to the classic scenarios shows the validity of the time-constraint model in damage efficiency calculation.

2. THE USED DAMAGE EFFICIENCY MODEL OF MLRS[10,11]

Each MLRS needs to be assigned its target when the MLRS battalion fires at the grouping targets, but in the damage efficiency calculating, the blast points are distributed evenly instead of actual blast points. The damage efficiency is:

$$R_N = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \varphi(X,Z)R(x',z')dXdZ \qquad (1)$$

$R'(x',z')$ is conditional damage probability, gained by formula below:

$$R(x',z') = 1-[1-P'(x',z')]^N$$

For blast points obey uniform distribution, so:

$$P'(x',z') = \begin{cases} \dfrac{S_M}{4L_{xS}L_{zS}} & when |x| \le L_{xS} and |Z| \le L_{zS} \\ 0 & otherwise \end{cases}$$

The damage probability of any single target when shooting at gathering targets is:

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$$R_N = \hat{\Phi}(\frac{L_{xS}}{E'_d})\hat{\Phi}(\frac{L_{zS}}{E'_f})(1-e^{-\frac{NS_M}{4L_{xS}L_{zS}}}) \quad (2)$$

Which is equals to the damage probability of the group targets, so the damage efficiency can also be written as:

$$M(k) = \hat{\Phi}(\frac{L_{xS}}{E'_d})\hat{\Phi}(\frac{L_{zS}}{E'_f})(1-e^{-\frac{NS_M}{4L_{xS}L_{zS}}}) \quad (3)$$

In which, L_{xS}, L_{zS} is half of the bombing point uniform distribution in depth and front;

$$L_{xS} = \sqrt{\frac{3B_d^2}{2\rho^2} + \frac{k^2-1}{4}h_x^2}$$

$$L_{zS} = \sqrt{\frac{3B_f^2}{2\rho^2} + \frac{n^2-1}{4}h_z^2}$$

k, n is rear sight amount and direction number (gun number within a company) when firing.

h_x, h_z is the graduation of the adjacent rear sight and the graduation in direction.

E'_d, E'_f is error on behalf of intermediate error when firing at group targets.

$$E'_d = \sqrt{E_d^2 + 0.152L_x^2}$$

$$E'_f = \sqrt{E_f^2 + 0.152L_z^2}$$

$\hat{\Phi}(\frac{L_{xS}}{E'_d})\hat{\Phi}(\frac{L_{zS}}{E'_f})$ is probability that error which obey the normal distribution falls in the evenly distributed blasting area($|x'| \le L_{xS}$ and $|z'| \le L_{zS}$), actual, means the coverage probability of the units target in the area in which evenly distributed blast points evenly distributed.

$\left(1-e^{-\frac{NS_M}{4L_{xS}L_{zS}}}\right)$ is conditional damage probability.

3 THE TIME-CONSTRAINT DAMAGE EFFICIENCY MODEL OF MLRS

3.1 Time-Constraint Factors And Its Influence On The Damage Efficiency Model Of Mlrs

Being a surface suppressing weapon, the MLRS has many battle objects such as gathering effective, armored vehicles and self-propelled artillery. In the changeful battlefield situation, both the density of targets and the coverage of blast points are subject to the target maneuver. Clearly, the change of target dimensionality will cause damage efficiency to change.

To the gathering targets maneuver, we discuss the simple case in this paper. Assuming that the MLRS battalion commander obtains the target information at moment t_0 and organizes objectives to be assigned and fired at (the gathering target dimensionality is rectangular and its size is $2L_d \times 2L_f$, the target group move away form the MLRS position at speed v at the moment t_0. The rocket arrives at the target area at moment t_1). The target dimensionality at moment t_1 is changed comparing with its initial state, as shown in fig. 1:

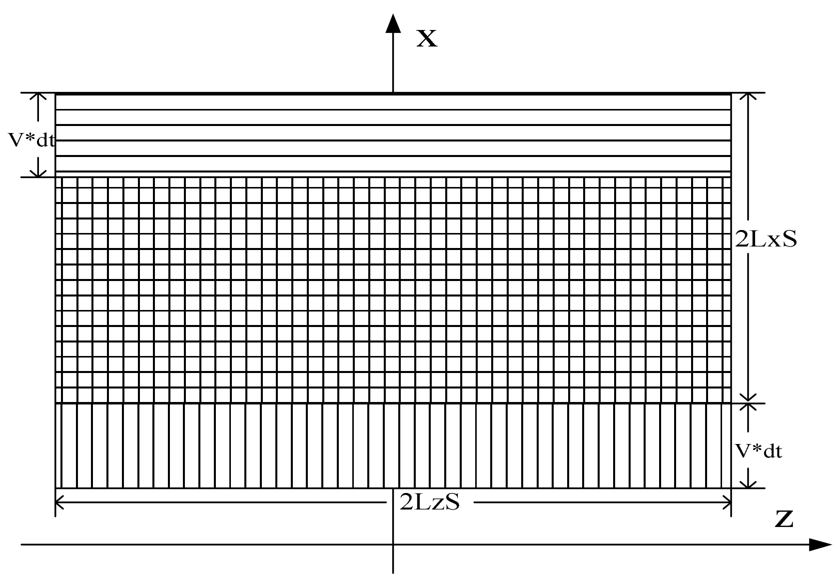

Fig. 1 The Change Of Gathering Targets Position

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Area with horizontal lines and panes is the original dimensionality at the moment t_0, after some time dt, the dimensionality becomes to be the area with vertical lines and panes. Obviously, the area with panes is the area that belongs to both original dimensionality and new dimensionality. In the actual shooting, the commander issues operational commands that should be mostly possible to make blast points evenly distributed in target dimensionality, so it's clear that the blast points can't cover the dimensionality entirely as shown in figure 1. Damage efficiency in this case, is lower compared to the conditions that group targets resting. By the formula (2) or (3), the first two items are the probability of blast point falling into the target dimensionality, and the last item is the conditional probability of coverage and damage. In the illustrated case, it is clear that the gathering target maneuver has no impact on the conditional probability, while has influence to the probability of coverage. From the physical sense, the change in probability of coverage of the target is equal to the change in probability of the burst points falling in the dimensionality. As illustrated in the case of group target maneuver, to get the best damage efficiency, the blast points distribution should has the corresponding maneuver. The effective blast point distribution is the overlap zone in fig. 1.

As shown in fig.1, L_{xS} changes into $L_{xS} - Vdt/2$ with the group targets maneuver, while parameters such as E'_d, E'_f and L_{zS} are the same as those when group targets in still condition. The probability function $\hat{\phi}$ is a approximate proportional function, so it is reasonable to change the whole damage efficiency according to the change of effective blast points distribution area.

So we can solve the damage efficiency of gathering target with maneuver characters as the following formula:

$$R_{Nt'} = \frac{S'}{S} R_N = \frac{L'_{xS} * L'_{zS}}{L_{xS} * L_{zS}} R_N$$

S' (L'_{xS}, L'_{zS})is the overlapped size of blast points distribution, the difference compared with original S (L_{xS}, L_{zS}) demonstrates the influence of the group targets maneuver on the effectiveness of blast points distribution.

When the group targets move along other directions, the method is the same as above, it is necessary to calculate the overlapped area size and multiply the original damage efficiency by the ratio of the overlapped area to the original blast points distribution area.

3.2 Time Constraints Caused By Opposed Factors And Its Influence On Damage Efficiency

The viability of MLRS faces serious test in modern warfare with the use of a large number of high-tech reconnaissance means, and threats come from aerial reconnaissance, moving target surveillance radar, emplacements radar and so on[8]. This paper discusses only the change of damage efficiency caused by viability need.

One of the important mobile operations means of MLRS unit is receiving the mission and managing to fire in maneuver. The progress is maneuver-fire-maneuver-fire. At the present time, the phased array emplacements radar equipped in foreign army has a 90° searching angle-range and 25km~50km reconnaissance distance against MLRS, and has the capacity of capturing multiple trajectory synchronously. This equipment can work about 25s once boot-strap, and determine the coordinates of emission emplacements according to the rising arcs ballistics, and has higher positioning accuracy to position single artillery. Multi-gun salvo can introduce interference and cause reduced positioning accuracy. Phased array emplacements radar has a high positioning accuracy to MLRS because of its big configuring size and distance, especially in the case of multi-radar networking.

Assume that for a MLRS, it needs t_s to complete one single shoot, needs t_{total} to complete one volley, needs t_r to complete a filing, needs t_c to change from marching state to battling state. To the phased array emplacements radar, It needs T_p to capture the ballistic trajectory and complete positioning. To the firepower chain of command and artillery units of enemy, it needs T_a to complete a shoot. According to the current MLRS tactical and technical criterion, it is unrealistic to fill for the next wave of firepower after completing a volley at one position.

Obviously, The MLRS firing is subject to the time constraints as follows because of survival considering:

$$t_{fire} + t_c < T_p + T_a \qquad (4)$$

The constraints in the formula (4) determines how much ammunition used of the MLRS, one shoot or multiple charge shooting. In other words, the constraints determine the N in the coverage and damage probability. With the advance in military technology, such constraints will be more demanding in future.

Considering the actual situation, the constraint is

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$$t_{total} + t_c < T_p + T_a \quad (5)$$

The MLRS unit can not be implemented a volley on the target without converting the position if the relationship exits in formula (5), therefore the maxim ammunition a single MLRS unit can fire must be decided before calculating the damage efficiency, as shown in formula (6)

$$n = \mathrm{int}[\frac{T_p + T_a - t_c}{t_s}] \quad (6)$$

If the MLRS battalion fire in time-constraint condition, the total ammunition can be obtained by multiply the n by the number of vehicles in the battalion. In particular, the MLRS should, as far as possible, arranged in a large area land for security considerations. To gain the abrupt effect of firepower and improve the viability, the MLRS battalion should synchronize the emission to the greatest extent to form multiple ballistic trajectories to avoid the accurate positioning of the phased array emplacements radar.

3.3 Damage Efficiency Model With Time-Constraints

According to the analysis in 3.1 and 3.2, to solve the damage efficiency in actual battlefield environment, the influence of group target maneuver on target coverage and the constraints of firepower density due to viability needs should be considered. So the damage efficiency of the MLRS battalion can be defined as follows:

$$R_T = \eta R_{N_{\max}} = \frac{L'_{xS} * L'_{zS}}{L_{xS} * L_{zS}} \hat{\Phi}(\frac{L_{xS}}{E'_d}) \hat{\Phi}(\frac{L_{zS}}{E'_f})(1 - e^{-\frac{N_{\max} S_M}{4 L_{xS} L_{zS}}}) \quad (7)$$

η is the covering coefficient, which equals the ratio of overlapped area to the original area when group target maneuver.

$N_{\max}$ is the maximum ammunition the MLRS can launch in actual action.

4 SIMULATION

4.1 Simulation Conditions

A MLRS battalion carry out a suppress fire towards group armored vehicles that 20000m away from the MLRS position. The battalion has three companies and includes 18 MLRS units totally. The group target dimensionality is 1000m • 1000m and the destroy area of the armored vehicle is 80m^2. The battalion error is $Ed = 60\,m, Ef = 40\,m$, the spread error is $Bd = 60m, Bf = 40m$.

The MLRS's conversion between fighting and marching consumes 120s, and the first volley consumes 30s, single shoot consumes 0.5s, and one volley launches 60 rockets. The emplacements radar consumes 40s for capturing the ballistic trajectory and positioning. The group target moves apart from the position for extra 100m. it needs 100s for the hostile firepower to complete the counterattack after positioning. The shooting parameters obey the favorable firepower allocation method.

4.2 Results And Discussions

According to the most favorable fire distribution calculation method [12], the shooting parameters such as fired intervals, difference in distance and damage efficiency was calculated without considering the time-constraints first. In time-constraints conditions, the maximum ammunition a single MLRS can launch is 40 according to the formula (6). The graduation of the adjacent rear sight and the graduation in direction need to be determined again with the new ammunition amount. Simulation results is shown in table 1 and fig. 2.

Tab. 1 Simulation Results Contrast

	Interval in direction/m/	Difference in distance/m	Ammunition amount/piece	Damage efficiency/%
Without time-constraint	116	66	1080	10.74
Target maneuver	116	66	1080	9.67
Confront condition	94	57	720	7.65
With time-constraint	94	57	720	6.88

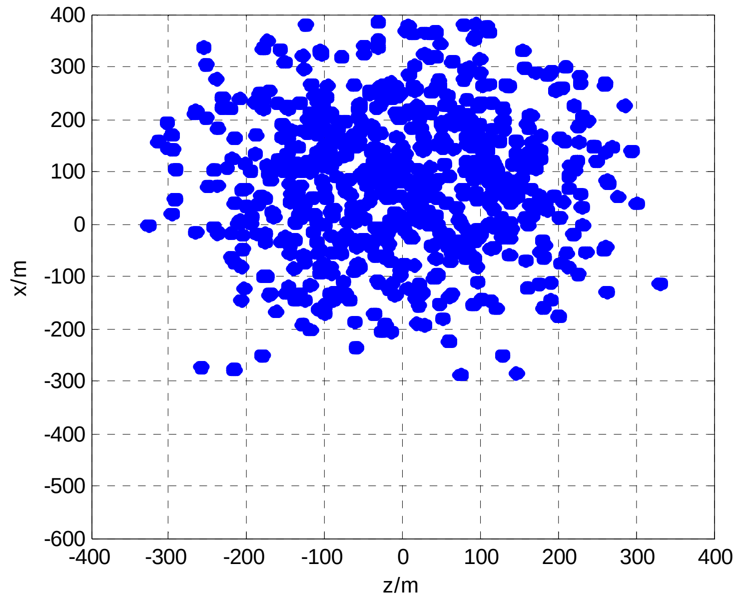

Fig. 2 The Distribution Of The Burst Point

As can be seen from fig.1, the actual target dimensionality in portrait is between -600m-400m instead of -500m-500m, the rockets fall in 400m-500m district make no sense. This is coincident with formula (7) in physical meaning. The blast point didn't show the well-proportioned distributing in fig.2 because of the randomicity of distribution.

As can be seen in tab.1, adjusting the shooting parameters is not necessary when consider the group target movement only, and the change of blast points coverage to target dimensionality caused the damage efficiency decline obviously. Under the condition of considering the survival demand, the limit of shooting time reduced the ammunition amount, and to gain the best damage efficiency, the shooting parameters must be adjusted, compared to the condition that not considering time-constraints, there were obvious changes in the shooting parameters, of course the damage efficiency changed obviously also.

The demand of viability restricts the ammunition amount that the MLRS battalion can launch in a salvo, and the ammunition amount determines the best firepower management indirectly. Furthermore, the change in gathering targets dimension plays an important role to the change of damage efficiency.

5 CONCLUSIONS

The time-constraint damage efficiency model was presented and applied to a scenarios, simulation results showed the rationality and availability of the model. A conclusion can be drawn that the MLRS battalion commander should consider not only the information of the target but also the information of the counterwork ability of hostile army to improve the damage efficiency and viability.

To the change of damage efficiency caused by the target maneuver, only simple case was analyzed in this paper. In actual battlefield, the change of target position caused by maneuver is more complex, and how to accurately measure changes of it worthy of further in-depth study.

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