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REVIEW PAPER

Computer Simulation of an Armoured Battalion Swarming

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ABSTRACT

Swarming is a tactical approach considered in modern armies combat activities conceptualisation. More intensive research of military application of swarming began after 2000, mostly in the areas of unmanned air, underwater, and ground vehicles, as well as in air force, navy and some special ground force units. In spite of relative inconveniences of contemporary main battle tanks to act as swarmers, some of initial results of the armoured mobile platforms swarming research have been presented. The motivation for the research is that adaptation of contemporary tanks for swarming could prolong their working life until the new generation comes, and could be the best investment in medium and smaller countries armies' modernisation. Brief survey of the till date research, description of the simulation model and the results of experiments simulating swarming of the battalion-sized group of armed mobile platforms, defending territory from superior adversary unit, have been considered in the paper.

Keywords: Swarming, armed mobile platform, armoured battalion, computer simulation

NOMENCLATURE

AMP	Armed mobile platform
A_{ij}	AMP-*i* to *T*/*T-j* assignment coefficient [0/1]
D_{ij}	Distance between AMP-*i* and *T*/*T-j*.
D_{MW-i}	Effective range of AMP-*i* main weapon
Δt	C^4ISR system reporting interval
G_{AMP}	Territory occupancy density by AMPs
K_{ij}	AMP-*i* to *T*/*T-j* compatibility cofficient [0/1]
KU_j	Total cumulative effect of AMPs on *T*/*T-j*
L	Number of conflicts in sample size
M	Number of threat/target units in the defended territory
MW-i	Main weapon of AMP-*i*
N	Number of AMPs in the group
N_{ssw}	Number of successful swarmings in the sample of *L* conflicts
N_{usw}	Number of unsuccessful swarmings in the sample of *L* conflicts
P_{C^4ISR-i}	Preciseness of the C^4ISR system
PKU_j	Threshold of the critical cumulative effect on *T/T-j*
p_{ssw}	Successful swarming probability
R_{WTT-j}	Effective range of *T*/*T-j* weapon
S	Defended territory area
SZ	Synchronisation zone
T/T-j	Threat/target unit *T*/*T-j*
T_{m-j}	Mission time of *T*/*T-j*
U_j	Effect of individual AMP against *T*/*T-j*
V_i	AMP-*i* maximal velocity
V_{tt}	*T*/*T* unit maximal velocity

1. INTRODUCTION

Originating from biology, a swarm is a large group of insects or small organisms, particularly when they are in motion. Swarm or swarming has recently become word à la mode, due to its extensive use as an analogy or the basis of other uses of the term, in various areas of science and technology.

In military sense of the word, swarming[1] is a tactics by which military forces attack an adversary from many different directions, and then regroup. Repeated actions of many small, manoeuvrable units are going on, circling constantly through the phases of swarming:

- Disperse deployment of units in battlefield;
- Gathering (concentration) of many units on common target;
- Action (strike or fire) at a target from all directions;
- Dispersion of units.

The way of swarming application is depicted in Fig. 1, and its basic characteristics are as follows:

(i) Autonomous/semiautonomous units, engaged in concentrated attack at common target.
(ii) Amorphous, coordinated attack from all directions by continuous fire/shock assaults.
(iii) Many small, space dispersed mutually networked units.
(iv) Integrated surveillance, sensors, and C^4ISR systems for upper level situation assessment.
(v) Units' action capabilities, from distance as well as in direct contact.
(vi) Continuous attacks aiming to break adversaries cohesion.

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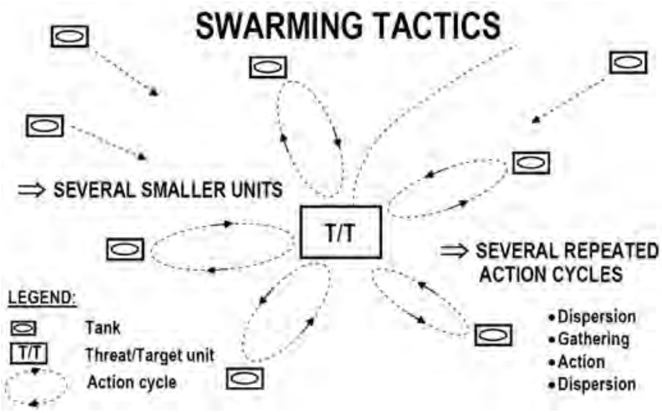

Figure 1. Swarming of armoured units.

Although numerous examples of successful swarming application have been recorded in history[2], the significance of this tactics did not reach its full measure until our days, due to brisk development of information technologies and merging of computing and telecommunications[3]. The swarming tactics is applied by units much smaller than target/threat, but their use is far more efficient, so in their actions as a whole, they can often defeat many times superior adversary.

More intensive military swarming research began after 2000, and attained first results mainly in the areas of unmanned vehicles[4-7] (in the air, underwater and on the ground), air force, navy and some special ground forces units. A common point to all those research efforts is that they have emphasised the need for changes of contemporary armies organisation and tactical principles.

As for military hardware, it seems that the existing air force and navy equipment could be used for swarming on the as is principle, at least in the near and foreseeable future. Until now there are not many published results of the armoured and mechanised units swarming research, especially those on main battle tanks.

Tanks have been metioned in such publications rather as the objects of swarming attack than being the swarmers themselves. The main reason for that lies in fact that the best known contemporary tanks in service have been conceived to be dominant over classical opponents on the ground. That means, heavy, large-calibre main armament and a huge amount of extra equipment for protection, both active and passive. The consequences are huge mass, large silhouette, less capability of fast manoeuvring and extensive logistic requirements. All these factors have impact to prevailing use of existing tanks according to former well known tactical principles, meaning that there will still be tendency to engage tanks in great joint formations, and that main swarmers in ground forces will probably be some other kind of units, perhaps cooperating with medium and light armoured combat vehicles.

A huge mass represents particular problem for the existing main battle tanks attacking swarmings, extremely limitting their fast deployment in the combat action territory by means of air transport. That problem could be somewhat lessen in defence, because in many cases the defender's tanks are supposed to be already deployed in the defended territory.

Because of all afore mentioned reasons, armies of more developed countries still rely mostly on firepower supremacy achievement and massive force concentration, along with airspace superiority, conducting the so called air-land battle.

However, attack to the units of such heavy armed and technologically extraordinary equipped army, from all directions and close distances could result in extremely good effects. Numerically strong units and their fire and strike power can be successfully opposed by psychological effect, achieved on adversary, attacked suddenly and from all directions. Besides, small units manoeuvrability and their capability to disperse after sudden attack prevent technologically superior adversary to react on time.

Such an approach brings major changes, both in modern armies organisation and equipment, and has a praticular influence on the principles of use and the bare prospects for tanks survival on the 21st centuries battlefields. New generations of tanks will surely differ from those developed up to now, intended for totally different style of warfare. They should be smaller, faster and more agile, better armed and with incorporated elements of the C^{4}ISR systems.

A development of new generation of tanks is going on for quite some time now. However, their introduction in service of the producer countries armed forces is expected not until the middle of next decade, and for the rest of the world, even later. Besides, such procurements require enormous financial costs, not to mention actual industry problems, for there is a huge number of contemporary tanks, conceptually quite different, still in service, and nobody would like to question the existing production and logistic sectors, being the important economy factors of the most developped countries.

The problem is even more outstanding for the medium and smaller countries armed forces. What to do with the existing tanks of previous generations, for example, many thousands of T-72 and similar tanks, still in active service of numerous armies, for which procurement and maintenance huge amount of money has been, and still is invested?

One of the approaches to that problem solving is to investigate adaptation possibilities of the existing tanks for swarming, so that their active life time can be prolonged until the new generation comes into service, and they could in the best way be used in the changing conditions of modern warfare.

Adaptation of armed forces for swarming, existing armoured and mechanised units in particular, could be one of the best investments for smaller countries and their armies, as it is the case with Serbia[8]. That is the basic motivation for the research of swarming at Union University School of Computing (UUSC) in Belgrade. Some of the results have been presented in this article.

2. BACKGROUND RESEARCH

The approach to computer simulation of swarming, new tactics which members of armoured battalion, as a group of armed mobile platforms (AMPs) can apply in conflicts with numerically and technically superior adversary units, has been presented[8,9]. The approach of the research takes into account every single tank in the simulation, and the armed mobile platforms group is considered at the level of an armoured battalion.

The simulation model and the algorithm for the armed mobile platform group swarming (Fig. 2), implemented by means of the discrete events system simulation language GPSSWorld[10,13].

The realised simulator of swarming, which members of an armoured battalion, as a group of armed mobile platforms, can apply in conflict with numerically and technically superior adversary units[11].

In this paper, they present some results of the experiments with the realised simulator, which have been executed to explore

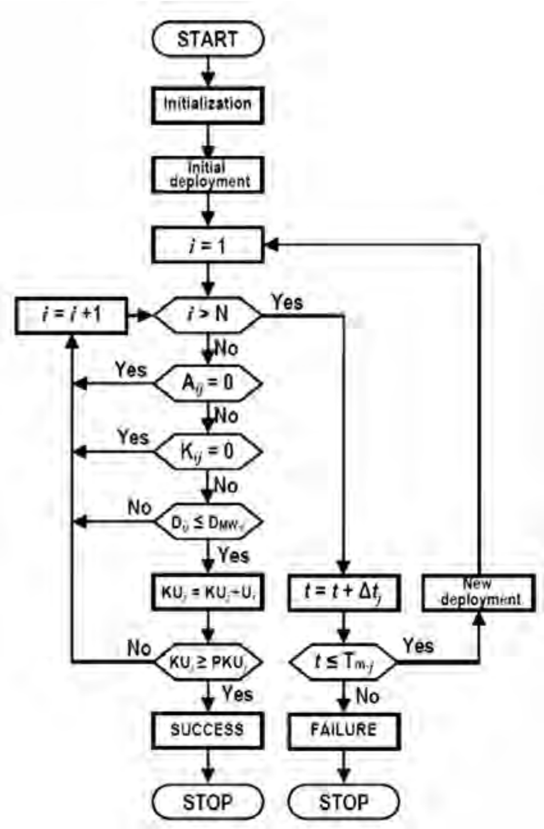

Figure 2. Basic swarming simulation algorithm (monotarget/threat).

the impact of three different kinds of *T*/*T* units and the defended territory dimensions on the swarming success of the group of N = 43 randomly deployed armed mobile platforms.

3. THE SIMULATED SYSTEM

The system being simulated consists of: group of N armed mobile platforms (AMP-i, where i = 1,..., N), one threat/target unit (*T*/*T*), C^{4}ISR system and the defended territory – the theatre of combat actions (swarming).

Armed mobile platforms AMP-i, can move at velocities V_i. Each of them has main weapon (MW-i), characterised by range ($D_{MW\text{-}i}$) and compatibility with *T*/*T* (K_{ij}), which determines its total effect in swarming against *T*/*T* (U_{ij}). Every AMP is active member in the C^{4}ISR system and disposes appropriate equipment (GPS receiver, computer and radio transceiver for data transmission at speed V_{RU}).

T/*T* can move at maximal velocity $V_{t/t}$. It is superior to every single AMP of the group, so for the successful swarming it is necessary that the critical cumulative effect of several AMPs, specific to such threat/target, should be exceeded.

The primary function of the C^{4}ISR system is regular informing of every user on its actual position and other data of interest:

- About the T/T, based on the data acquired by the territory multi-sensor surveillance network[12], individual AMPs of the group and other friendly forces;
- About every single AMP of the group, based on the regular reports of the AMP-i about changes in its own position.

C^{4}ISR system works successfully if it dispatches regular reports about *T*/*T* and every single AMP-i motion before their expirations. Time of expiration of the report about every threat/target unit or AMP of the group is defined by the expression:

$$t_{\exp-i} = \frac{P_{c^4 ISR-i}}{V_i} \tag{1}$$

where $P_{C^4 ISR\text{-}i}$ is the preciseness of the C^{4}ISR system[8] (prescribed relative distance from the previous known position, due to further motion, which can be tolerated as no motion at all), and V_i is its velocity in the period of the report.

Combat actions take place in territory which is presented in the model by means of two-dimensional rectangular coordinate system.

4. THE SIMULATION MODEL

The simulation model of the AMP group swarming is discrete and dynamic, oriented to events. In the model, system activities are represented by pure time delays. The moving entities in the model are: units of the group (AMP-i, i = 1, 2…N), *T*/*T* unit and messages of the C^{4}ISR system.

The initial deployment of the AMP group is random, which is the worst case, because the occurrence of *T*/*T* is unexpected, and the AMP group is prepared for it by no deployment intended for defending territory under such specific circumstances.

The simulation goal is to explore impact of the variable defended territory occupancy density by the AMP group to success of its swarming. It has been achieved by changing the dimensions of the territory in experiments, along with retaining fixed number of AMPs in the group. In the simulation, the group of the armoured battalion size has been considered, consisting of 43 AMPs.

The AMPs of the group get information of the *T*/*T* units and other AMPs of the group motion in time intervals Ä*t*, and give reports about their own current positions. Based on that information, AMPs direct themselves toward

T/*T*, with the goal to reach, as soon as possible, the position enabling them to perform successful swarming, for the sake of destroying, disabling, or preventing the adversary in accomplishment of its mission.

The graphical representation of motion of the part of the system, consisting of 1 *T*/*T* and 4 AMPs (1, 2, 3 and 4), manoeuvring to accomplish the swarming is depicted in Fig. 3.

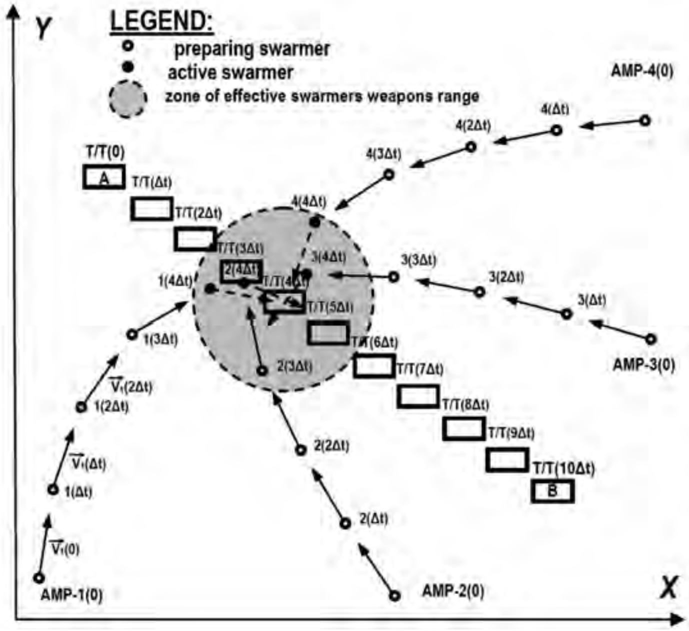

Figure 3. Swarming example: Motion of target/threat *T* and AMP-1, 2, 3 and 4.

The *T*/*T* unit is accomplishing its own mission and, contrary to AMP-*i*, has no access to information of the C[4]ISR system, so its primary goal is to fulfil its own task, which has been represented by motion on given trajectory between points *A* and *B* in the model, according to functional dependencies of its coordinates of time, $x_{t/t}(t)$ and $y_{t/t}(t)$. When the period Ä*t* elapses and C[4]ISR system dispatches the report of the new *T*/*T* position (*t* = Ä*t*), *T*/*T* has moved to its new position, *T*/*T* (Ä*t*). Until then, AMP-*i* have moved to their new positions, 1(Ä*t*), 2(Ä*t*), 3(Ä*t*) and 4(Ä*t*), following the directions from the previous time interval, directed their velocity vectors towards new position of *T*/*T*, and then the process continues.

In order that individual swarming participating AMP-*i* could act upon *T*/*T* unit (to become active swarmer, Fig. 3), the following three conditions must be fulfilled:

(a) AMP-i must dispose of the main weapon MW-i, compatible with the adversary unit.

(b) The distance between AMP-*i* and the adversary unit *j* must be in the main weapon MW-*i* range limit, i.e.:

$$D_{ij} = \sqrt{(y_j(t) - y_i(t))^2 + (x_j(t) - x_i(t))^2} \leq D_{MW-i} \quad (2)$$

(c) The a. and b. conditions must be satisfied by enough AMPs of the group, so that their total cumulative effect on *T*/*T*, KU_j should be equal or greater than critical threshold of the multiple AMPs cumulative effect, PKU_j, specific to *T*/*T*:

$$KU_j = \sum_{i=1}^{N} A_{ij} \cdot K_{ij} \cdot U_{ij} \geq PKU_j \quad (3)$$

- A_{ij} is the assignment coefficient (0/1), which is intended to assignment of *T*/*T-j* unit to AMP-*i*, in the multitarget swarming models;
- K_{ij} is the main weapon MW-*i* compatibility coefficient with the *T*/*T-j* (0/1);
- U_{ij} is the possible effect of the main weapon MW-*i* on the *T*/*T-j*.

Two issues of swarming simulation are possible:

(a) Success: AMPs of the group have succeeded to fulfil all necessary conditions and by means of swarming have prevented the threat/target to accomplish its mission (it has not reached the point B, which happened in time *t* = 4 Ä*t* in the example in Fig.3).

(b) Failure: AMPs of the group have not succeeded to fulfil all necessary conditions, so the threat/target has accomplished its mission (it has reached the point B).

The swarming simulator has been realised by means of 87 Block entities of the GPSS World simulation language[13]. The user enters input data: number of conflicts in experiment and the user-controllable system parameters, listed in section 5. Individual swarming is represented by one sole GPSS transaction entity[13], which passes through the main program loop, according to the algorithm in Fig. 2, as many times as the number of necessary individual swarmings in the experiment.

Threat/target unit, *T*/*T*, is represented by means of coordinates of its initial, final and all intermediate positions during the simulation (current coordinates). *T*/*T* current coordinates change according to chosen law of its motion, which has been uniform and rectilinear in the experiments considered in this article. Coordinates change is a discrete event which happens at every time interval Ä*t* of the simulated C[4]ISR system. The change of the *T*/*T* law of motion can be made by replacement of the program module in which it has been implemented.

All individual AMPs of the group applying swarming are represented by total deployment of their current coordinates, by means of MATRIX GPSS entity[13]. Matrices are also used for representing other AMP attributes in the simulator (A_{ij}, K_{ij}, D_{MW-i}, U_{ij}, etc.).

During the simulator initialisation, the user enters appropriate contents in the matrices. In the experiments considered in this article, the AMPs initial deployment has been generated at random, in the quadratic area of the side $a \in \{500, 1000, \ldots, 10000\}$.

T/*T* has been assigned to every AMP, and all AMPs have been equipped with main weapon MW-*i* with effective range D_{MW-i} = 2500 m, and compatible with *T*/*T* (K_{ij}=1). Every MW-*i* could produce effect on *T*/*T*, expressed by coefficient of U_i = 0.15.

Threshold of the cumulative effect (*KU*) of several AMPs on *T*/*T*, *PKU*, represents critical value for successful swarming. If *PKU* is set to 3, it means that for successful swarming at least 20 AMPs of the group, with individual effect coefficients of 0.15, have to reach the distance from *T*/*T* equal to or less than their main weapons range.

Besides reaching *PKU*, it is necessary that it happens before *T*/*T* fulfills its mission, which is represented by time T_{m-j}, needed for *T*/*T* to go from initial to final position, and calculated on its motion law basis.

After initial deploying of the group of AMPs and entering *T*/*T* initial and final positions coordinates in the simulator, every AMP-*i* is checked whether *T*/*T* has been assigned to it, and whether it has the compatible main weapon MW-*i*. If the distance from AMP to *T*/*T* is $D_{ij} \leq D_{\text{MW-}i}$, the cumulative effect of all such AMPs is calculated, and if $KU \geq PKU$, swarming is successful.

If, after all AMPs have been checked, *PKU* has not been reached, the simulation clock advances for Ä*t*, and then the simulator checks whether the time T_{m-j} has been exceeded, in which case it would result in unsuccessful swarming in the given time frame.

If the critical time T_{m-j} has not been reached yet, the simulator moves *T*/*T* to the next position that it will occupy after time interval Ä*t*, and generates new deployment of all AMPs. The new deployment is generated by individual calculating of a new motion direction for every AMP towards the currently known *T*/*T* position; in the next time interval Ä*t*, AMP-i continues to move in that direction by its velocity V_i, till the Ä*t* elapses, and AMP gets information of the *T*/*T* next position.

After each swarming issue (success or failure), the reinitialisation is made, by generating new initial deployment of the *T*/*T* and all AMPs of the group, and resetting all internal data relating to that individual simulation pass.

At the end of the experiment, the simulator returns the successful swarming probability and other data of interest, for given number of conflicts, under the conditions defined by the user.

5. SYSTEM PARAMETERS AND PERFORMANCE MEASURES

The following are the parameters of the simulated system in the experiments considered in this paper:

(a) Threat/target parameters:
- Number of *T*/*T* units: $M = 1$
- Initial position of the *T*/*T* unit: A ($x_j(0)$, $y_j(0)$)
- Final position of the *T*/*T* unit: B (a, a), $a \in$ {500, 1000,…, 10000 m}
- Law of motion of the *T*/*T* unit *P-j*:
  X-axis: uniform motion, $x = X_o + V_{t/t}$ cosát
  Y-axis: uniform motion, $y = Y_o + V_{t/t}$ sinát
- Maximal *T*/*T* unit velocity: $V_{t/t} = 15$ m/s
- Threshold of the critical cumulative effect on the *T*/*T* unit: PKU_j {1.5, 3.0, 4.5}

(b) Parameters of the AMPs group:
- Number of AMPs in the group: $N = 43$
- Maximal AMP-*i* velocity: $V_i = 15$ m/s
- Range of the main weapon MW-*i*: $D_{MW-i} = 2500$ m
- Effect of individual AMP-*i* against *T*/*T* unit: $U_i = 0.15$
- Compatibility coefficient of main weapon MW-*i* with *T*/*T* unit: $K\text{-}i = 1$

(c) Parameters of the territory of swarming:
- Shape: quadratic
- Dimension: a {500, 1000, … , 10000 m}

(d) Parameters of the C4ISR system:
- Preciseness (prescribed relative distance from the previous known position of *T*/*T* unit or AMP-*j*, for which the previous position data are not obsolete): $P_{C^4ISR-i} = 150$ m
- Data transfer rate: $V_{RU} = 16$ kb/s.

The primary performance measure is the probability of successful swarming:

$$p_{ssw} = \frac{N_{ssw}}{N_{ssw} + N_{usw}} \tag{4}$$

where: N_{ssw} is the number of successful swarmings and N_{usw} is the number of unsuccessful swarmings in the sample of L conflicts.

6. ANALYSIS OF THE RESULTS

Total of 60 experiments have been executed by means of the realised simulator. Each experiment involved L = 10000 conflicts of 1 *T*/*T* unit and the group of N = 43 AMPs, so total of 600000 conflicts have been simulated. The experimental factor involved:

- Kind of *T*/*T*, expressed through the critical threshold of successful swarming, PKU_j {1.5, 3.0, 4.5}
- Dimension of the quadratic defended territory, a {500, 1000, … , 10000 m}

The results of the experiments have been presented in the Figs. 4, 5, and 6. For given size of the group of N = 43 AMPs, the successful swarming probability p_{ssw} has been considered, depending on the defended territory area S [km^2], the front width a [m] and the defended territory occupancy density by the AMPs of the group, G_{AMP} [AMP/km^2]:

$$G_{AMP} = \frac{N}{S} \tag{5}$$

where, N is the number of AMPs in the group, and S is the defended territory area in km^2.

The simulation has been executed for 3 kinds of *T*/*T*s, attacking the territory defended by the group of N=43 AMPs, applying the swarming tactics: *T*/*T*-1, *T*/*T*-2 and *T*/*T*-3, for which 10, 20 and 30 AMPs respectively are necessary for successful swarming.

The successful swarming probability curves, p_{ssw} [%], as function of the defended territory area, S [km^2], have been presented in Fig. 4.

The simulated system behaves as expected: the successful swarming probability in smaller defended territories is initially 100 per cent, and after that it decreases as the territory

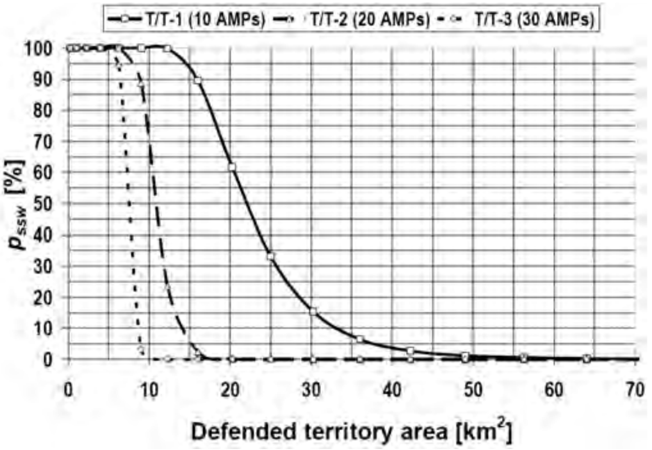

Figure 4. Successful swarming probability as function of the defended territory area.

area increases, until becoming negligible. The fastest change is for the *T*/*T*-3 (which needs at least 30 AMPs for successful swarming), slower for *T*/*T*-2 (20 AMPs), and the slowest for *T*/*T*-1 (10 AMPs).

If the probability p_{ssw} > 90 per cent is adopted as the criterion for the successful system, one can see that the group of 43 AMPs can satisfy it in the territory which area is about 16 km^2 for the threat/target unit *T*/*T*-1, 9 km^2 for *T*/*T*-2 and 6.5 km^2 for *T*/*T*-3.

One of the usual ways of dealing with the territory defending issues is by considering the defending front width, which has been presented in the Fig. 5. The dependency curves are similar in shape to those in Fig.5, with somewhat more moderate change, due to one-dimensional independent variable in the later case, expressed in linear metres.

If the same criterion is considered, i.e. that p_{ssw} must be > 90 per cent, it can be seen that the group of 43 randomly deployed AMPs can satisfy it at the front width of about 4000 m for *T*/*T*-1, 3000 m for *T*/*T*-2 and 2600 m for *T*/*T*-3.

Both ways of the results interpreting considered so far require knowledge of the exact number of AMPs in the group (N = 43). Somewhat different way has been presented in Fig. 6, where the swarming success probability has been considered as function of the defended territory occupancy density by AMPs of the group, i.e. of the number of AMPs per km^2. That probability starts from 0 per cent for empty territory, and increases with the occupancy density up to 100 per cent. Such change is the fastest for *T*/*T*-1, which requires at least 10 AMPs for successful swarming, slower for *T*/*T*-2 (20 AMPs), and the slowest for *T*/*T*-3 (30 AMPs).

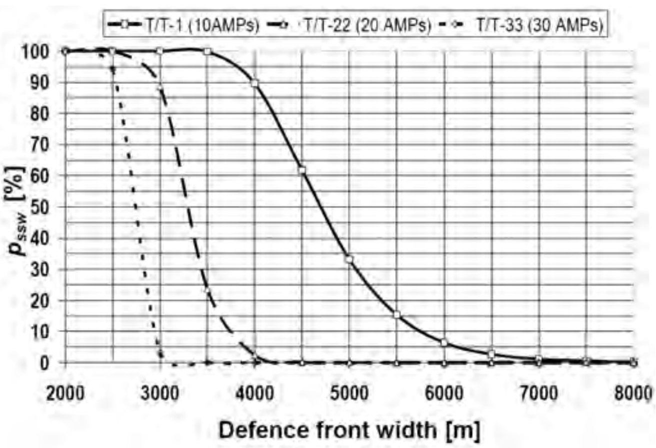

Figure 5. Successful swarming probability as function of defence front width.

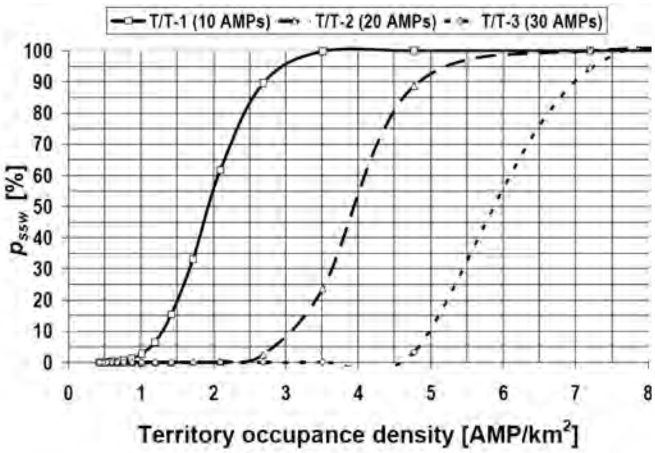

Figure 6. Successful swarming probability as function of territory occupancy density.

It can be seen the AMP group satisfies the criterion that the p_{ssw} probability should be greater than 90 per cent at the defended territory occupancy density G_{AMP} = 2.7 AMP/km^2 for *T*/*T*-1, G_{AMP} = 4.8 AMP/km^2 for *T*/*T*-2 and G_{AMP} = 7 AMP/km^2 for *T*/*T*-3.

The results produced by means of the realized AMP group swarming simulator could be used for armoured and mechanised units' engagement in territory defence planning. If the characteristics of the *T*/*T*, the appropriate density achievement, i.e. number of AMPs per unit of territory area, will result in the value of successful swarming combat action issue.

7. FURTHER SIMULATOR IMPROVEMENTS

The AMP group swarming simulator realised so far is limited to the case of a single *T*/*T* and no synchronisation procedure among the swarming AMPs. Those limitations are not a problem when considering relatively smaller AMP groups, which are often engaged in combat action against one *T*/*T*, and/or when the number of AMPs in the group is large enough to let the swarming develop in an unsynchronized way.

However, even an armoured battalion, as the basic tactical unit, has opportunities to apply swarming against *T*/*T* which is near, or even beyond its capabilities, or simultaneously against 2, 3 and even more different *T*/*T*s. This imposes some new issues related to AMPs synchronisation, *T*/*T* selection, priorities, and the capabilities of the group for the self-organising in such situations. That is the reason why the research is currently focusing on two main directions:

- Swarming synchronisation
- Swarming against multiple *T/T*s simultaneously present in the combat actions territory.

The synchronisation problem arises if AMPs applying swarming against *T/T* don't reach the distance from it within the range of their main weapons in approximately same time and in a number large enough to achieve critical threshold of their cumulative effect PKU. In that case there is a probability of swarming failure, because *T/T* could destroy AMPs one by one, as they appear within the range of its own weapons. To solve this problem, we have proposed in the paper[14] introducing of synchronisation zone (SZ), circular ring around *T/T*, defined by the expression:

$$SZ = R_{WTT-j}(1 \pm q) \qquad (4)$$

where $R_{WT/T\text{-}j}$ is the effective range of weapon of *T/T-j*, and $0<q<1$.

Such a mechanism enables, while there are not enough AMPs for successful swarming, that:

- AMPs far from *T/T* continue to approach it by the shortest possible way;
- AMPs in the *SZ*, move parallel with *T/T* at relative safe distance, ready to move towards *T/T* again, when enough AMPs gather for successful swarming;
- AMPs near *T/T* move away from it towards *SZ*, in order to avoid individual destruction and swarming failure.

Possibility of multiple *T/T* introduction in the swarming simulation model is the most important direction of the current research. An improved simulator algorithm and corresponding implementaion mechanisms have been proposed by Jankovic[14].

Finally, certain attention is going to be paid to different initial deployments of the AMPs of the group. The results obtained in simulation of swarming of the group of AMPs with random initial deployment will be the reference (the worst case), whereas the results obtained for the chosen specific initial deployments should be compared to, for the sake of getting knowledge of advantages that could be achieved by alternative solutions considered.

8. CONCLUSIONS

- Swarming, as a tactical approach, is becoming inevitable when considering the future combat activities conceptualization.
- Some of initial results of the armoured mobile platforms swarming research have been presented in this article. The motivation is that adaptation of contemporary main battle tanks, in spite of their relative inconveniences to act as swarmers, could prolong their working life until the new generation, more suitable for swarming comes, and could be the best investment in medium and smaller countries armies' modernisation.
- The simulation model of swarming of the battalion-sized armed mobile platforms group, defending a territory from the threat/target unit superior to any individual AMP of the group, has been developed and the programme-simulator has been implemented by means of the GPSS World discrete events system simulation language.
- A total of 60 experiments have been executed in order to explore the kind of threat/target unit and the defended territory size impacts on success of swarming of the group of armed mobile platforms, initially deployed at random.
- Finally, there is a brief regard to limitations of the simulator realised so far and the further research directions. The transfer to synchronised multitarget swarming is expected, as well as different initial deployments of the armed mobile platforms in such situations.

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