COMBAT OPERATION SIMULATION OF A HELICOPTER FORMATION

V.A. Gorshkov, A.M. Volodko

State Research Institute of Aircraft Maintenance

Moscow, Russia

Abstract

The developed mathematical model simulates the environmental factors (such as human and natural ones, or hitting by ammunition), tactics and dynamics of combat operations, unsteadiness of the system elements, also of the other systems connected with the main one (logistics, manufacture, combat operations command), various processes of the flying unit operation, i.e. management, technology, training, or the social process, etc.

The model of the helicopter squadron (division) operation includes six main units:

- evaluation of the combat damage tolerance and survivability of the helicopters;
- evaluation of helicopter repairability;
- evaluation of the operating-tactical situation;
- purposed application of the helicopters;
- organization of the damaged helicopters repair;
- logistic support.

Interaction of the units is simulated by means of several limitations dwelt upon in the paper.

The authors gained detailed information on the operation of the helicopter flying units during the war in Afghanistan, where helicopters were involved into a vast number of combat operations of various duration. The reliability of the method was estimated by comparison of the calculated results with the real statistical data on the repairs made during the Pandgsher's combats in May-June, 1984. The confidence intervals for the integral dependence, which reflects variation of the number of the simulated repairs in the helicopter flying unit do not exceed the boundaries of the confidence level of γ=0.85.

Simulation of the helicopter flying unit operation allows estimation of their potentialities and development of helpful administrative and technical measures in advance.

Introduction

Diverse and complex missions the helicopter flying units have to perform under various environmental conditions require an analysis of theoretical solutions based on the advanced scientific methods. The simulation model of a helicopter flying unit operation, which is the result of the analysis the authors have completed considers for the following factors:

- environmental conditions, i.e. influence of natural and human factors;
- combat tactics and dynamics;
- unsteadiness of the components of the system, such as the helicopters themselves, the field repair system, supply, manufacture, and combat operations control.

The simulation model of a helicopter flying unit operation includes:

- limitations and assumptions assumed to formalize the operation of a helicopter unit and combat conditions;
- a measure of effectiveness, which characterises the operation of the flying unit, namely whether it succeeds in supplying the flying units with serviceable helicopters. Either the number of serviceable helicopters available during an operation or the field repair rate serve the simulation measure of effectiveness;
- initial data and their order of priority;
- the model structure, which illustrates communication of the model with the environments;
- the simulation algorithm, which contains easy-modified units;
- the simulation software.

The simulation model allows estimation of the following principal characteristics:

- combat damage tolerance and survivability of the helicopters (under the fire of bullets, bombs, or missiles), and the rate helicopters get under various repairs;
- recoverability of the damaged helicopters, that allows prediction of necessary force and aids to fulfil the repairs;
- operability and combat readiness of the helicopter flying unit - repair team system under different initial conditions, such as in time of peace, at complete readiness for action, or deploy;
- effectiveness of the helicopter flying units (from a squadron to division) combined with the repair teams for a number of various logistics situations;
- the influence of the number of specialists involved, their skill, the logistic support, spare parts available, etc. on the effectiveness of the combat helicopter flying units (different natural environments are considered);
- the need for strengthening the helicopter flying unit in course of combats.

The generalized distribution laws, bar charts, statistical series and tables, etc., i.e. statistics available on the operational & combat damage tolerance, survivability of the helicopters, flight preparation, repair time-taking and labour expenditures, logistics characteristics of the flying units and field repair teams serve the initial data for the simulation. All the data on the Russian helicopters have been accumulated at recent local armed conflicts.

<u>Structure of the model</u>

Six *main units comprise* the model of operation of the helicopter flying unit -repair team. Let us consider the input-output information characteristic of every unit.

The helicopter combat damage tolerance and survivability unit accepts the following information:

- design characteristics of the helicopters the unit is armed with;
- the helicopter compartments file as it follows from the exploded view drawing;
- fire aspect angles of the helicopter estimated for different ammunitions;
- the compartments laws of survivability;
- the ammunition specifications and hitting accuracy.

The output data :

- the nomenclature and number of ammunitions hit the helicopter compartments;
- hitting coordinates;
- helicopter areas hit with the fragments of the bombs;
- helicopter hitting probability;
- helicopter damage probability.

The helicopter repairability unit accepts as an input information:

- the output data come from the previous unit;
- characteristics of the minor, current, medium and overhaul repairs;
- the helicopter arrangement.

The output data:

- an option of the field repair;
- time consumed to fulfil the field repair;
- the amount and nomenclature of the spare parts required;
- the trades and number of specialists necessary to fulfil the repair;
- time for shooting the troubles revealed at the pre-flight preparation after the repair.

The combat situation unit accepts:

- time consumed for the field repair;
- the option of the field repair;
- the front displacement average rate;
- the repair team and facilities distance-to-go;
- distance from the spare parts depots to the place where the field repair team and facilities are located at the beginning of the operation;
- the distance from the initial front line to the repair team and facilities;
- an average speed of the repair team and facilities motion.

This unit supplies the following data:

- current distance from the spare parts depots to the repair team;
- current distance from the repair team to the front line;
- time when the enemy hits the repair team facilities.

The helicopter combat unit accepts:

- the types of helicopters the flying unit is armed with;
- the initial number of helicopters in every flying unit of the division;
- the combat performance of the helicopters;
- the helicopter hit probability;
- the damage probability of the helicopters;
- time for shooting the troubles revealed at pre-flight preparation after the repair.
- the number of helicopters mended.

Information supplied by the unit:

- the helicopter fire aspect;
- a number of helicopters hit by ammunition;
- the damaged aircraft flying time;
- a number of sorties;
- a number of helicopters lost.

Repair logistics unit input data:

- the damaged aircraft flying time;
- the number of damaged helicopters;
- the number of specialists of the trades in need;
- time consumed for repair of the damaged helicopters;
- time when the enemy hits the repair team facilities.
- current distance from the repair team to the front line;
- time necessary to deliver spare parts or materials to the repair team;
- a number of specialists in every repair team;
- the skills of the specialists;
- equipment of the repair teams with machinery and appliances;
- provision with spare parts and materials needed for repair.

The output data are the following:

- the number and rate of sorties ensured by the field repair intensity;
- a number of helicopters mended by the field repair teams immediately in the places of the forced landing;
- a number of serviceable helicopters available;
- a speed at which the repair teams move;
- the distance from the initial front line to the repair team and facilities.

The logistic support unit accepts:

- the amount of the spare parts and

materials required;

- an average speed at which they are delivered;
- initial distance from the spare parts depots to the place where the field repair team and facilities are located at the beginning of the operation;
- the number of the spare parts depots.

The output information supplied by the unit:

- time of delivery of spare parts and materials required for the repair;
- current distance from the spare parts depots to the place where the field repair team and facilities are located at the beginning of the operation.

The enlisted data running between the units of the model show what is happening in real combat conditions of the helicopter operation.

The following limitations are assumed to formalize interaction of the model units:

1. An input signal $X(t)$ accepted by a unit is considered to be a sum of simple signals $x_1(t), x_2(t), \ldots, x_m(t)$, supplied to the unit simultaneously. On the other hand an output signal $Y(t)$ comprises a number of simple signals $y_1(t), y_2(t), \ldots, y_n(t)$.

2. Simple signals are transmitted through independent channels.

3. The input contact of every unit of the model is connected with only one independent channel.

4. Any number of independent channels can be linked up with the output contact of a unit.

The environmental influence (time of day, pressure, humidity, dust in the air, etc.) can be considered by means of signals transmitted from the environments to the units of the model and vice versa. Every signal supplied to the environments consists of simple signals from one or several units. The simple signals, which comprise the environmental signal are accepted by one or several units. Thus the environments can be considered to be a fictitious unit of the model, the signal supplied by the model to the environments serves the input signal

$$X^{(0)}(t) = [x_1^{(0)}(t), x_2^{(0)}(t), \ldots, x_{m0}^{(0)}(t)],$$

whereas the signal supplied by the environments to the model serves the output signal of the fictitious environmental unit. It consists of the simple signals

$$Y^{(0)}(t) = [y_1^{(0)}(t), y_2^{(0)}(t), \ldots, y_{n0}^{(0)}(t)].$$

Thus every unit of the model (as well as the described fictitious environmental unit) accepts a variety of the input contacts:

$$[X_j^{(i)}]_1^{mi} = (x_1^{(i)}, x_2^{(i)}, \ldots, x_{mi}^{(i)}),$$

and a variety of the output signals:

$$[Y_j^{(i)}]_1^{ni} = (y_1^{(i)}, y_2^{(i)}, \ldots, y_{ni}^{(i)}).$$

If $Y_\Theta^{(k)} = R(X_j^{(i)})$ is the function statement,

$$X_j^{(i)} \in \bigcup_{i=1}^{N} [X_j^{(i)}]_1^{mi}; Y_\Theta^{(k)} \in \bigcup_{i=1}^{N} [Y_j^{(i)}]_1^{ni},$$

which connects an input contact $X_j^{(i)}$ with an output contact $Y_\Theta^{(k)}$.

The interface operator is assigned as a table where the lines contain ***i*** contacts of the model, and columns contain ***j*** unit numbers. The ***k-e*** sets in the intersections show the unit ***k*** and the contact ***e*** linked up with the contact $X_j^{(i)}$.

<u>Simulation algorithm</u>

The algorithm is based on the assumption of the discrete time variation of the state of the helicopter unit during certain time interval (Δt).

If $\Delta t \to 0$ (the algebraic step), the operation of a helicopter flying unit (squadron, division) can be considered to be a continuous process in discrete time, while the relationships between the model units allow formalization of the operation.

The simulation algorithm consists of blocks, each one being a complete operating piece. This building-block principle allows modifying of separate processes under simulation without rebuilding the whole algorithm. The memory size required amounts to approximately 300 Kb. Computation time depends on the simulation step Δt, duration of the operation being simulated, the number of helicopters in the flying unit and the field repair teams.

The central limit theorem of the probability theory and the average value of the chosen measure of effectiveness of the helicopter flying unit are the base to estimate the number of computations necessary for ensuring accurate simulation results. The sample size required to ensure the desired computational error of the measure of effectiveness can be estimated through the influence a change in the input parameters exerts upon the number of simulations, the significance level and relative error being assigned. Calculations have proved, that an accurate determination of the measure of effectiveness (at a relative error of $\pm 5\%$) requires approximately 30 simulations independently of variation of the measure of effectiveness.

On the whole the algorithm and simulation itself are realized by means of the well approved Monte-Carlo technique.

<u>Verification of the simulation</u>

The confidence interval of the sample X_m , obtained from simulation allows estimation of the simulation adequacy through checking whether the points that correspond to the data characteristic of the real operation of a helicopter unit belong to the calculated confidence interval.

The war in Afghanistan brought most reliable and complete information on the helicopter combats for helicopters were used there on the large scale in over 150 combat operations of different duration [1]. Let's apply the statistics gained at the Pandgsher combats in May-June of 1984 to verify the model under consideration.

The statistical analysis enables us to determine the confidence intervals for the integral dependence of change in the repairs of the helicopter flying unit being simulated for every section (fig.1, curve 1). The real data (curve 2) do not appear to reach the limits of the confidence interval (curves marked 3) for a confidence level of γ=0.85.

The reliability of the estimation has been improved by tracing the curve paths, checking the extremes, applying the Wald approximation method and the Tale coefficients technique.

As a result of verifying the adequacy of simulation by means of several well-known procedures the developed model has been approved to be reliable for evaluating the effectiveness of the helicopter combat operations. An average difference between the number of the helicopter repairs and sorties does not exceed ~13%, which is good enough for the practical purposes.

Reliability of the developed model also implies its stability, which has been verified by determination of a set of admissible values for the input disturbance vectors. These values ensure stable results for each simulation. The procedure includes determination of the measure of effectiveness distribution law and makes up a special algorithm, that allows evaluation of the measure of effectiveness stability region along the combat factors space.

A real helicopter flying unit located in the mountain-desert area and taking part in the combats has been used to make a complex verification of the developed model. This enabled the authors to obtain the following relationships:

- the dependence of the helicopter flying unit measure of effectiveness (the number of repairs and sorties) on the variation of the number of specialists in the repair teams;
- on provision of the repair teams with spare parts and repair materials;
- on the equipment with machinery and appliances;
- on the skills of the specialists.

The results obtained agree well with the ones known from the practice of using the Mi-8, Mi-24 helicopter flying units in both Afghanistan and recent armed conflicts on the territory of the former Soviet Union.

References:

1. A.M. Volodko, V.A. Gorshkov *Helicopter in Afghanistan* Vojenizdat, Moscow, 1993

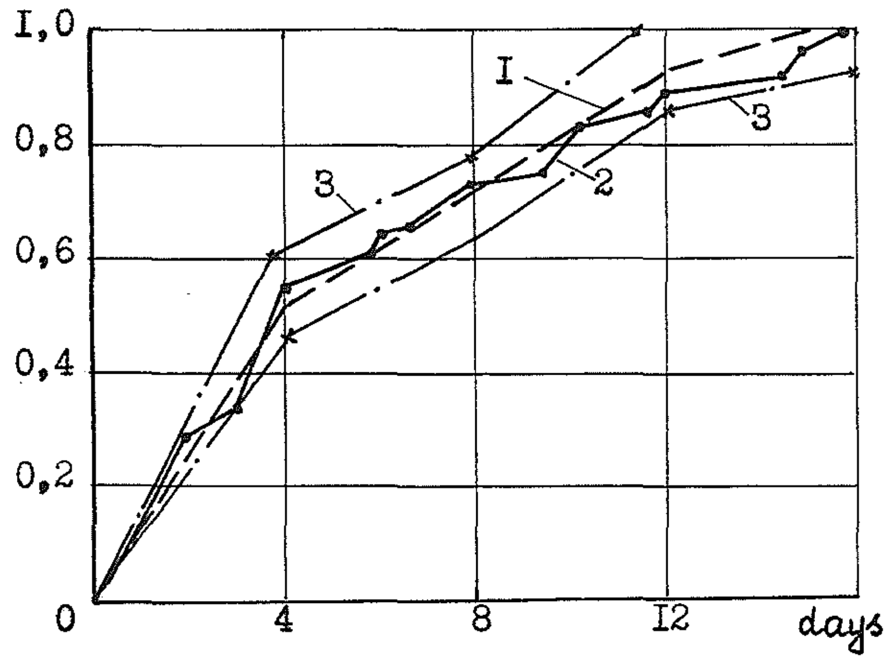

Fig. 1. Dependence of the relative number of the helicopter repairs during the Pandgsher combats