A Usage Model of the Aeronautical Technical Equipment in Wartime of Local Armed Conflicts

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***Abstract*—The high-tech local war has become an important mode of warfare in the future. To cope with the ever-changing battlefield situation, it is necessary to make scientific and reasonable planning for the application of aero technical equipments in wartime. On the basis with Markov Random Process to analysize the actual process of using the aero technical equipment, the usage model is established for the aero technical equipment in wartime of the local armed conflict, and the preparation and combat utilization of the aero technical equipment are analyzed, then to enhance the planning and pertinence of using the aero technical equipment in wartime, which is conducive to full play the overall advantages of various aero technical equipment, to provide more scientific and powerful theoretical support for the formulation of support and combat plan and command decision-making.**

Keywords—aviation technical equipment; mathematical expectation; mathematical model

I. INTRODUCTION

The high-tech local war has become an important mode of warfare in the future,in local armed conflicts, aviation forces will play a key role in reconnaissance, search, air combat, elimination and attack of ground targets, and completion of special tasks. In the face of the battlefield situation rapidly changing, how to formulate scientific and reasonable support plans and combat plans for the aviation forces is the key to enhance the predictability of the war situation, better grasp the opportunity, and ensure victory. To ensure the scientificity of the preplan formulation,the application model of the aero technical equipment has been established, and the efficiency of aviation technical equipments used in combat has been evaluated.

II. DESCRIPTION OF THE APPLICATION PROCESS OF THE AVIATION TECHNICAL EQUIPMENT IN WARTIME

In the military struggle, the links included in the application of aviation technical equipment in wartime are shown in Fig. 1

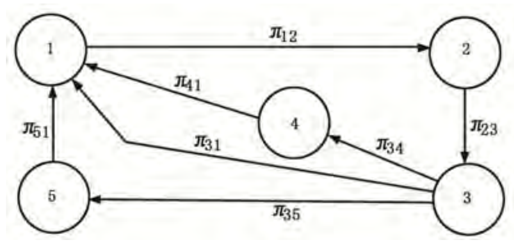
As shown in Fig.1, the actual usage process of aviation technical equipment is with characteristics as follows:

(1) The transition directions of the states directs to the usage states to be completed rather than the completed states;

(2) Following with random time θ, each state can be changed to any other states. From the state with the serial number i to the one with j, the probability is π_{ij}, it only depends on the properties of state i but nothing else factors. The time distribution law in a certain state depends on the serial number i or j of the state, the plane may be transferred to the next state during this time. The aircraft transition time ξ_n (n=1, 2, . . .) is equal to the sum of the duration of its stay in all of the above states;

(3) the residence time in each state can be determined or random;

(4) when the number of aircraft is reduced due to loss, the number shall be supplemented by intact aircrafts in the formation.



①Preparation before the use of aviation technical equipment in combat;② Operational exertion plan;③Operational exertion;④Load or unload of aerial weapons unused;⑤Loss and damage of aircrafts.

FIGURE I. FRAME SCHEMATIC OF THE LINKS OF THE AVIATION TECHNICAL EQUIPMENT USED IN WARTIME

III. ESTABLISHMENT OF THE USAGE MODEL OF AVIATION TECHNICAL EQUIPMENT IN WARTIME

The semi-markov process is called the jump process of discrete-continuous variables with two degrees of freedom, and its process is described as follows:

$$Z(t) = \{N(t), \theta(t)\} = \{N(t), \theta(t) : t \in [\xi_{n-1}, \xi_n], \xi_n = \xi_{n-1} + \min \theta_{ij}, n = 1,2,...\}, \tag{1}$$

The first component $N(t) \in \{1,2,...,m\}$ is a discrete markov process (markov chain) relativing to time $\xi_n, (n = 1,2,...)$, and its conversion probability:

$$\pi_{ij} = P(N(\xi_n) = j | N(\xi_{n-1}) = i); \ \sum_{i=1}^{m} \pi_{ij} = 1, \quad (2)$$

The second component $\theta(t)$ is a continuous random quantity, which is a distribution function with arbitrary form:

$$F_{ij}(t) = P(\theta(\xi_n) < t | N(\xi_{n-1}) = i; N(\xi_n) = j). \quad (3)$$

In this way, the single value $Z(t)$ of the semi-markov process determines the two-dimensional distribution {Π; F}, here Π= $(\pi_{ij})_{m\times m}$; F= $(F_{ij}(t))_{m\times m}$ are all matrices that conform to the distribution, and the contact points in the figure are that the used aviation technical equipment stay here in shortest time $\theta_i = \min\{\theta_{ij}\}$, while the lines with arrows represent the conversion probability π_{ij}.

Obviously, the probability π_{ij} met the following necessary conditions:

$$\pi_{12} = 1; \pi_{23} = 1; \pi_{31} + \pi_{34} + \pi_{35} = 1; \pi_{41} = 1; \pi_{51} = 1. \quad (4)$$

Assume that the process diagram studied by markov is called G, in which connecting lines between any node and other nodes is called connection, and in these connections some independent most basic trajectories (loops) may be separated. The number of these trajectories is called the loop number $\nu(G)$ of the graph, which can be obtained from the following formula:

$$\nu(G) = l(G) - r(G) + 1 \quad (5)$$

Here $l(G)$ is the number of lines in the graph; $r(G)$ is the number of nodes in the graph.

The following is the mathematical description of the usage process of aviation technical equipment, here semi-markov model with multiple discrete states is used:

For graph G shown in figure 1, the number of loops:

$\nu(G) = 7 - 5 + 1 = 3.$

The connection loops between nodes in figure 1 are as follows:

1-2-3-1;1-2-3-4-1;1-2-3-5-1.

The duration $\theta_э$ of the aircraft's first life cycle can be determined by the duration of each process along the loops in figure 1：

$$\theta_э = \begin{cases} \theta_1 + \theta_2 + \theta_3, 1-2-3-1; \\ \theta_1 + \theta_2 + \theta_3 + \theta_4, 1-2-3-4-1; \\ \theta_1 + \theta_2 + \theta_3 + \theta_5, 1-2-3-5-1. \end{cases} \quad (6)$$

The transition probability along any loop is equal to the product of the transition probabilities of each node. Thus, for example, the implementation probability of loop 1-2-3-1 is $\pi_{12}\pi_{23}\pi_{31}$; the implementation probability of loop 1-2-3-5-1 is $\pi_{12}\pi_{23}\pi_{35}\pi_{51}$.

To illustrate: the usage process is being advanced along the path in the figure,which is the same as the occurrence of random events with a certain probability, so we get the conditional mathematical expectation of the time $\theta_э$ relativing to the incompatible events in the whole formation:

$$\begin{aligned} t_ц = M(M[\theta_Э]) = \pi_{12}\pi_{23}\pi_{31}M[\theta_1 + \theta_2 + \theta_3] + \pi_{12}\pi_{23}\pi_{34}\pi_{41}M[\theta_1 + \theta_2 + \theta_3 + \theta_4] \\ + \pi_{12}\pi_{23}\pi_{35}\pi_{51}M[\theta_1 + \theta_2 + \theta_3 + \theta_5]. \end{aligned} \quad (7)$$

$$t_ц = \pi_{31}(t_1 + t_2 + t_3) + \pi_{34}(t_1 + t_2 + t_3 + t_4) + \pi_{35}(t_1 + t_2 + t_3 + t_5) = t_1 + t_2 + t_3 + \pi_{34}t_4 + \pi_{35}t_5 \quad (8)$$

Here $t_i = M(\theta_i)$ is the conditional mathematical expectation of the duration in state i of the usage process.

With the help of expression (8), it is not difficult to obtain the fixed probability of which the aviation technical equipment stay in different service states:

$$\rho_1 = \frac{t_1}{t_ц}; \ \rho_2 = \frac{t_2}{t_ц}; \ \rho_3 = \frac{t_3}{t_ц}; \ \rho_4 = \frac{\pi_{34}t_4}{t_ц}; \ \rho_5 = \frac{\pi_{35}t_5}{t_ц}. \quad (9)$$

In addition, the sum of the probability ρ_1 of the aircraft stayed in the operational readiness state and the probability ρ_2 of the aircraft stayed in the operational planning state determines the technical readiness coefficient $K_{ТГ}$ used in combat:

$$K_{ТГ} = \frac{t_1 + t_2}{t_ц} \tag{10}$$

And the probability ρ_3 obtained in the operational usage state determines the operational usage coefficient:

$$K_{БИ} = \frac{t_3}{t_ц} \tag{11}$$

IV. Application Analysis

In the following, by analyzing specific examples, we calculate the parameters (conversion probability π_{ij} and conditional mathematical expectation t_i) of the semi-markov model in aviation technical equipment used in a local armed conflict.

We propose a semi-markov process matrix $T = \left(\tilde{T}_{ij}\right)_{m\times m}$ of independent random variables, to illustrate the characteristics of the residence time of aeronautical technical equipment when $G_{ij}(t)$ is transferred from one state to another according to the allocation of functions.The random variable $\tilde{T}_{ij}$ illustrate the characteristics of the aircraft's stay time from state i to state j .

$$G_{31}(t) = 1(t - \tau_{пол}) = \begin{cases} 0, t < \tau_{пол}; \\ 1, t \geq \tau_{пол}; \end{cases} \quad G_{34}(t) = e^{\frac{1}{T_Ц}} ; \quad G_{35}(t) = 1 - e^{-\lambda_{Бп} t} \tag{12}$$

Among them, $\tau_{пол}$ is the average flight time of the aircraft; $T_Ц$ is the average of the existence time of the target; $\lambda_{бп}$ is the aircraft's irreparable loss of strength.

The relationship between conversion probability π_{ij} and distribution function $G_{ij}(t)$ is as follows:

$$\pi_{ij} = \int_0^\infty \underset{k\neq j,i}{П}\left[1 - G_{ik}(t)\right] dG_{ij}(t) \tag{13}$$

$$\pi_{34} = \int_0^\infty 1(t - \tau_{пол}) e^{-\lambda_{бп} t} de^{-\frac{1}{T_Ц}} = \frac{1}{T_ц \lambda_{бп} + 1}\left[e^{-\left(\frac{1}{T_Ц} + \lambda_{бп}\right)\tau_{пол}} + \lambda_{бп} T_Ц \right] \tag{14}$$

$$\pi_{35} = \int_0^\infty (1 - G_{31}(t))(1 - G_{34}(t)) dG_{35}(t) = 1 - e^{-\lambda_{бп}\tau_{пол}} - \frac{T_ц \lambda_{бп}}{T_ц \lambda_{бп} + 1}\left[1 - e^{-\left(\frac{1}{T_Ц} + \lambda_{бп}\right)\tau_{пол}} \right] \tag{15}$$

$t_i = M[\theta_i]$ is the conditional mathematical expectation of the time used in link i:

$$t_1 = M[\theta_1] = \tau_{ПОДГ} ; \; t_2 = M[\theta_2] = \tau_{бз} ; \; t_4 = M[\theta_4] = \tau_{рас} ; \; t_5 = M[\theta_5] = \tau_n$$

$$t_3 = M[\theta_3] = \tau_{пол}(1 - G_{34}(t))(1 - G_{35}(t)) + \int_0^{\tau_{пол}} t dG_{34}(t) + \int_0^{\tau_{пол}} t dG_{35}(t)$$

Among them, $\tau_{ПОДГ}$ is the average preparation time before the aircraft is used for combat; $\tau_{бз}$ is the average time to carry out combat missions; $\tau_{рас}$ is the average time to mount Airborne weapons; τ_{n} is the average time to prepare the plane again.

Through the expressions (7)-(9), (14)-(15), the fixed probability that the aircraft is in the main used link is determined, and at the same time, the readiness index and combat utilization of aviation technical equipment are also obtained.

V. CONCLUSION

The model has been established for the aviation technical equipment used under combat conditions,which can be used to calculate the transient process related to the aircraft usage, and to draw the relationship curves of the usage efficiency of aviation equipment technology,which relates to the characteristics of strategic and tactical situations in local armed conflicts. Through analysis and comparison on them, the war situation can be better grasped, comprehensively analyzed, the reasonable planning has been carried out for aviation technology equipment used in wartime of local armed conflict, to enhance the planned and targeted to the aviation technology equipment used in wartime, which is conducive to greater full play the overall advantages of various aviation technical equipmen,to provide more scientific and powerful theoretical support for the formulation of support and combat plan and command decision-making, so as to ensure to devise strategies within a command tent, to gain a decisive victory thousand miles away. Of course, due to the ever-changing battlefield conditions, the aviation technology equipment used in wartime will present different characteristics and requirements, to better guide the practice of war, the model still needs to be further improved.

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