A Research on The Model and Simulation Evaluation for Operational Availability

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Abstract—**The paper analyzes the conception and the measuring model of operational availability. For the restrictions of present models' assumptions, an instantaneous operational availability model and an average operational availability model for evaluating material availability together with a simulation method for the two models are put forward. The distinctions between the two models are also given by the simulation example. The analyzing of sensitivity factors shows that material reliability is the key factor affecting the operational availability, and the most effective way to improve operational availability is to increase reliability.**

Keywords- material; operational availability; simulation

I. INTRODUCTION

Operational availability is one of the important performance objective to materiel. It is the probability of which can work or can use when materiel at any time in mission, reflected reliability, maintainability and supportability integrated. Operational availability is the stratosphere objective of materiel development phase, the base of disassembling and transforming to other supportability objective. Otherwise, operational availability is the materiel ability objective which unit most care and the parameter of users measure operational readiness. So, evaluation for operational availability has the most important station in life cycle.

Since the concept of availability produced, it appeared many different measure models, but when referring to the concerned models, assumptions were neglected sometimes, leading to the operational availability's assessment results have long distance to the actual objective and lost the meaning of operational availability. So, before the text evaluate operational availability, it first analyze the assumptions of operational availability expressions, contraposing these limitation it give expressions and simulation method to evaluate materiel availability, at last using simulation to evaluate operational availability and analyze influence factor.

II. SUMMARIZATION OF OPERATIONAL AVAILABILITY

For single materiel ,if supposing (1)the frequency of fault happen is independence and failure rate fixedness, namely failure time obey the exponential distribution which random parameter is λ.(2)maintenance time is independency and obey the exponential distribution which maintenance probability parameter is μ.(3)repairing materiel timely, it isn't because waiting spares, maintenance person or other maintenance resource to dally over. So the probability of single materiel at any time is[1]:

$$A(t) = \frac{\mu}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu} e^{-(\lambda+\mu)t} \tag{1}$$

where A(t) is the rate of available material,λ is fault rate, u is maintenance rate.

For equation 1,if assumptions invariable, when t go to ∞, A(t) go to steady state, equation 1 translate to nether equation:

$$A_{ss} = A(t)\big|_{t\to\infty} = \frac{\mu}{\lambda+\mu} \tag{2}$$

where A_{ss} is the available rate when material at steady state.

If equation 2 existence[2], it must satisfy the assumptions which equation 1 demands.

If averaging equation 1:

$$A_{avg}(t_1,t_2) = \frac{1}{t_2-t_1}\int_{t_1}^{t_2} A(t)dt \tag{3}$$

where $A_{avg}(t_1,t_2)$ is average availability, t_1 is the beginning time of mission,t_2 is the end time of mission.

Using failure rate λ to replace MTBF, maintenance rate μ to replace MTTR, equation 2 can equal to :

$$A_{ss} = \frac{MTBF}{MTBF+MTTR} \tag{4}$$

For one operation unit which has many same material, for example, one armor corps has many same model tanks, if suppose (4)the failure event is independence between material, fault alternation time obey the exponential distribution which random parameter is λ, namely, it has the same reliability and mutual independence between material.(5) maintenance events are mutual independence between material, maintenance time obey the exponential distribution which random parameter is μ, namely, it didn't compete with many same systems for limit v resource, so equation 4 can evaluate availability of many material in the operation unit.

If considering management and support delay time more, supposing (6)the sum of mean-maintenance-time and mean-management and support delay-time obey the exponential distribution.(7)many same system in operation unit don't dispute spare or maintenance resource. So equation 4 transform to the standard formula:

$$A_o = \frac{\text{MTBF}}{\text{MTBF+MTTR+ALDT}} \tag{5}$$

For a long mission cycle in the material life cycle, maybe using preventive maintenance to assure reliability at a stated level. For these material which considering preventive maintenance , literature [3] give the operational availability formulae which calculate by MTBM and MDT:

$$A_0 = \frac{MTBM}{MTBM + MDT} \tag{6}$$

III. EXISTENT PROBLEM

Seeing from the definition of operational availability, the model of operational availability make some illogical hypothesis more or less:

1) because of wearing out or aging, fault rate maybe increase, so hypothesis 1 is not in reason.

2) Actual maintenance time obeys lognormal distribution,so hypothesis 2 is not in reason.

3) When material happen fault, it can not be repaired timely, because waiting spares, maintenance people or other resource ,so hypothesis 3 is not in reason.

4) If same material in mission unit happen fault at the same time, they will share in spares or maintenance resource, so hypothesis 5 and 7 is not in reason.

5) Manage and delay time influenced by many factors, they don't obey exponential distribution, so hypothesis 6 is not in reason.

So if using these formula to evaluate operational availability, not making proper disposal for illogical hypothesis, the result will have departure from real operational availability, it has no meaning.

Because mission is complex, availability relate to reliability, maintainability, supportability and so on, using math method has difficulty, So the paper use computer to simulate. Models simulate the actual process of using and maintaining, using simulation data to calculate operational availability. The paper aimed at armor material ,gave the method to evaluate operational availability by simulating.

IV. SIMULATION EVALUATION METHOD FOR OPERATIONAL AVAILABILITY

If limiting availability to a short time in the life cycle, or maintaining failure rate at a stated level in a long time, it can consider failure rate invariability. In the simulation, using random number which obey lognormal distribution to produce material maintenance time, it can simulate true material maintenance time really. About the problem of spare and maintenance resource share, in the simulation, it can solved by queueing theory.

A. *Fault Sample*

Material fault sample accord with fact to ensure simulation veracity. For a short mission time in the life cycle, failure rate can considered invariability. Many same model material in the operation unit, so it can suppose failure time of every material obey the exponential distribution which has the same parameter and mutual independence. For example, RAND company suppose the failure interval course of M1A1,M2A2,M3A3 obey the exponential distribution in the material availability and reliability simulation[4].In the process of simulation, it can suppose failure rate invariability, so the rate of material happen fault is :

$$P = 1 - \exp[-\frac{t}{MTBF}] \tag{7}$$

Where p is rate of material failure,t is work time of material,MTBF is mean-time-between-failures.

In the beginning of simulation, defining a uniform clock. When the mission begin, sampling fault isolation time of every material. At every step of clock, judging material whether happen fault, processing simulation statistics to find mean fault isolation time for every system.

B. *Sample Maintenance Time*

There are preventive maintenance and corrective maintenance. For a short time mission, it can not consider every preventive maintenance in the process of simulation. Maintenance time can be thought as random number which obey lognormal distribution. Maintenance time sample is[5]:

$$T_H = \exp\left[\mu + \sigma\sqrt{-2\ln\eta_1} \times \cos\left(2\pi \times \eta_2\right)\right] \tag{8}$$

where μ is mean value of logarithm, σ is normal difference,η1andη2 is random number.

C. *Support Delay Time*

Support delay time is the waiting time except repairing time in the process of maintaining material. Support delay time is the important fact to post-work, involving spares delay, management delay, there into, spares delay is the important fact to support delay. For a long time mission, spares turnover gained by real thing simulation, for a short time mission, because spares turnover need a long time, maintenance only relate to primary spares number.

D. *Model for Operational Availability*

According to these analysis, an instantaneous operational availability model and an average operational availability model for evaluating material availability together with a simulation method for the two models are put forward in the paper. The data which models use come from simulation result of real thing, have more practicality[6].

For one mission, instantaneous operational availability $A_O(t)$is the percentage of material which was avail in the all material at certain mission time t.

$$A_0(t) = \frac{\text{material which was avail}}{\text{all material which perform mission}} \quad (9)$$

For the mean availability of whole mission, it can be expressed by average operational availability $\overline{A}_o$ .Supposing the continue time of mission is t, average operational availability is[7]:

$$\overline{A}_o = \frac{\frac{1}{t}\int_s^{s+t} A_0(u)du}{M} \quad (10)$$

where s is beginning time of mission,t—continue time of mission,M is the number of material at the beginning of mission.

V. Example Analysis

A. Simulation for Operational Availability

For evaluating operational availability of material, the paper used a simple mission as the example in simulation. Mission profile was supposed as :there were 30 tanks in a armor corps to perform mission, state was in good condition, armor corps marched from the mass district to battle district, at the same time, maintenance unit took some spares to support. Some tank happen fault in the mission, maintenance unit made field maintenance quickly, tank perform the mission when they were repaired. Simulation parameter: mission time 100 hour, the number of tank is 30,mean-time-between-failures is 150 hour, maintenance time obey lognormal distribution which mean value of logarithm is 1.6, normal difference is 0.4, initial spares were 8.3 maintenance people, repair rate was 90%.

The paper made simulation using the Anylogic 6.5. over passing 3 times simulation, the change rule of operational availability shown in figure 1:

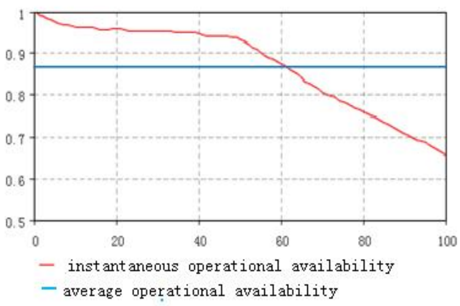

Figure 1. The change rule of instantaneous operational availability and average operational availability.

Seeing from the simulation result, in the foreside mission, because of enough spares, material can be repaired timely. Instantaneous operational availability was bigger than 90%.In the second half of mission, with the consuming of spares, material can not be repaired timely, the operational availability dropped quickly. The average operational availability of material was 87.3% in the whole mission higher than the instantaneous operational availability which was 65.7% in the end of mission.

B. Influence Factor Analysis

Operational availability as the stratosphere objective of material was influenced by reliability, maintainability, spares and so on. If making MTBF twice than before, spares twice than before, the number of maintenance people twice than before, mean-maintenance-time half than before, the result of instantaneous operational availability and average operational availability showed in figure 2 and figure 3:

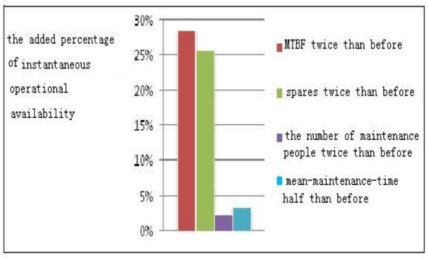

Figure 2. Influence factor analysis of instantaneous operational availability.

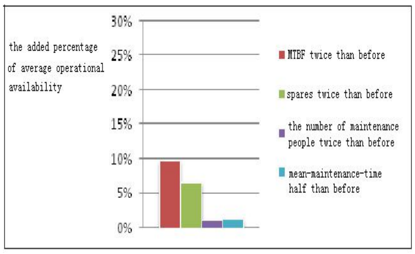

Figure 3. Influence factor analysis of average operational availability.

Seeing from figure 2 and figure 3,the important factor which influence operational availability was material inherent reliability. When increasing MTBF, instantaneous operational availability and average operational availability will increase obviously. The second factor which influence operational availability was initial spares. Increasing the number of maintenance people and decreasing mean-maintenance-time influence the operational availability inconspicuous, so, advancing the material inherent reliability was the most effective means to increase operational availability.

VI. Conclusion

The paper discusses the concept of operational availability, gives the simulation evaluation method for instantaneous operational availability and average operational availability. The result of simulation reveals the change rule of instantaneous operational availability in the mission. Average operational availability is different from instantaneous operational availability .It must see clearly when using. Simulation results indicate that materiel inherent reliability and the number of spares in the beginning of mission are the key factors which influence operational availability. The number of maintenance people and average maintenance time cannot have remarkable influence to operational availability. So improving materiel inherent reliability is the most effective way to enhance operational availability.

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