Risk Modelling

Approach for Analysis of Components Failure Rate Used for System Maintenance and Risk Decision Making

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ABSTRACT

Reliability, numbers of spare parts and repair time have major impact on system's availability. In this chapter we have observed a repairable system under maintenance contract. Maintenance contracts serve to improve system's availability and they have been studied extensively in recent times. These studies showed that inventory level does not impact system's availability as much as component reliability, failure time and repair time in a system operating under maintenance contracts. Thus, this paper aims to set a framework for repair rate by emphasizing its stochastic nature. A model for statistical analysis of the critical components' repair rates and failure rates are presented herein. The final equation for probability density function of components' repair rate enables precise modeling of repair process for related values of availability and mean time to failure. Then, based on the presented model, the approach for calculation of probability density function of maximal and minimal repair time for a system comprised of observed components was developed. The obtained information can be useful for making decisions in which time interval repair or replacement should be done in order to maintain the desired level of system and component availability. In addition to planning of maintenance activities, the presented models could be used for planning of inventory, service capacities and dynamic forecasting of system characteristics.

Preventive maintenance implies periodical checking of system's conditions and parameters in order to prevent occurrence of failure. This concept of preventive maintenance is based on supervision and control of system's conditions while it is still in function, and on undertaking of those activities which delay occurrence of failure and keep system in operational state. Since the occurrences of unplanned failures and damage to the system are almost unavoidable, even in cases when a system is regularly maintained, the corrective maintenance should not be disregarded. When it comes to military aircrafts and weapon industry, the availability can be defined as a measure of degree to which an item is in an operable state and can be committed at the start of a mission when the mission is called for at an unknown (random) point in time. Conversely, reliability is defined as a probability that the equipment or the system will complete a specific task under specified conditions for a stated period of time. On the other hand, availability, in function of time, is a probability that the system will perform its function correctly in any instance of time t.

Inherent availability is the system's availability used in conditions of uncertainty, when only operational time and time required for correct maintenance of the system are observed. Also, time required for activities of preventive maintenance is not observed, as well as logistical or administrative delays. Also, it is anticipated that spare parts are available at all times.

Mean Time Between Failure (MTBF) is the average (expected) time between two successive failures of a component/system and it does not include repair time. It is a basic measure of the system's reliability and availability and is usually represented as units of hours. Mean Time to Repair (MTTR) is the time taken to

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repair a failed component or system. This time includes the time it takes to detect the defect, the time it takes to bring a repair man onsite, and the time it takes to physically repair the failed module. Just like MTBF, MTTR is usually stated in units of hours. We could define availability through MTBF and MTTR. In that case we would observe MTTR as a stochastic process and we would determine its characteristic PDF and other parameters for certain predefined availability but, according to our opinion observing 1/MTTR, rate of repair, as stochastic process, is more significant for the entire repair process planning and managing. Due to complexity of process of estimating the components' failure rate in relation to time, as well as a stochastic nature of the observed process, the random variable x could also be considered as a random variable that changes significantly slower than random variable t described with the Rayleigh's model.

We assume that the failure rate is Rayleigh distributed and that the MTBF is a predetermined value. Also, after repairs, the unit returned to its original state and performed as new. By observing repair time as stochastic process, we present the exact expressions for repair rate's probability density function (PDF) and cumulative distribution function (CDF). Using this expression can result in exact repair rate sample values for corresponding values of availability. In this way, by simulating the repair rate process through generating its samples, we can predict system's dynamic characteristics. After determining the repair rate characteristics of single unit or subsystem, the statistical analysis of the system's repair rate was presented. Actually, we calculate probability density function of maximal and minimal repair rate of the system by observing repair rates of its components. The proposed model was applied to unmanned aerial vehicle (UAV) system comprised of three critical components: engine, propeller and avionics. The PDF of repair rate for each component was graphically presented as well as the PDF and CDF of maximal and minimal repair rate of the entire system. Based on this information we can conclude in which time interval maintenance action should be successfully completed in order to achieve the desired level of availability. Even though we set availability on certain levels, the numerical analysis can be repeated with different values of availability. This model can be applied in the same manner to other repairable systems with the alternating renewal process. The obtained results can be used in planning of maintenance activities, inventory, service systems and number of required employees, in the process of system maintenance. The observed system is an unmanned aerial vehicle (UAV). The concept of unmanned aerial vehicle (UAV) is not new but it has not been utilized in civilian sector due to the insufficient level of reliability of current solutions that leads to high probability of failure occurrence. The UAV is comprised of three critical components: aircraft engine, propeller and avionics. Each aircraft has 120 flight hours per month, i.e. 1440 (120*12) flight hours per year. Also, it is known that MTBF is 750 flight hours for the aircraft engine, 500 for the propeller and 1000 for avionics. Based on that it is possible to determine the MTBF as follows:

- for the aircraft engine $MTBF_e = 750 / 1400$
- for the aircraft propeller $MTBF_p = 500 / 1400$
- for the avionics $MTBF_e = 1000 / 1400$

Based on the model presented in previous section, a numerical analysis was conducted with the goal to calculate the annual expected time for repair in order to acquire availability of A=0.85, A=0.9, A=0.95 by emphasizing the stochastic nature of this process. A similar analysis can also be conducted for other values of parameter A. Also we can calculate the annual expected time for maximum and minimum repair rate of the UAV system. We have to take into consideration all three critical components of UVA system: engine, propeller and avionics. The presented figures show probability that the repairs conducted in certain time frame will provide the desired level of system availability. That information can be useful for planning of system's maintenance activities, number of service stations, spare parts as in and manpower required for maintenance.

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