RELATIONSHIP BETWEEN INDIVIDUAL INDICATORS OF DEPENDABILITY FLIGHT TECHNIQUE

Jozef Himič – Ján Kabát

The theme of the article is division of individual sort failures, relations between them and the demands for reliability of aviation equipment.

K e y w o r d s.: indices of dependability, safety, failure rate, classification of failures

1 INTRODUCTION

Among the important factors of improving sair transport safety is also the change of attitude to reliability, maintainance and renewal of aviation equipment. These problems are not of marginal value, because show how important it is to teach the technician and engineers the systematically discover the potentials for failures, to protect devices against subjective human errors from the onset – i.e. from projection over production, maintainance, activity and storage, to ecological phasing out the product from operations [2].

Very important aspect is safety and protection of the people against the prospective detrimental effects of the equipment. It means that the ecological qualities are a measure of human level and the ethical quality of creative worker. It is a way how an engineer gives way to humanistic morality in the designed technical solution. Such problems can be handled at a fair level only by creative specialists who prefer not only the narrow technical view, but with their education an breadth of views are able to appreciate and enforce a viable and safe solution also in view of the environment.

2 BASIC NOTIONS

Development of science and technology is resulting in gradually increase of the levels at which there is no longer a problem to manufacture and equipment capable of performing any kind of complex functions. However, the problem remains in term of manufacturing at a required level of reliability. At the present time, an operator is not evaluating a product only by its ability to perform the prescribed function and its reliability, but a fruther set of requirements are needed to me met. Based on them, a complex evaluation of the quality is products and equipment is needed, in terms of quality

Quality – a sum of characteristics, which best meet functional requirements the equipment is designed for. Among these characteristis are technical ones, expressed by technical parameters (service life, weight, volume, reliability, costs of operation, design, ergonomic and other features).

From the above it follows that i tis rather difficult to quantify quality, an ideal thing for the operator. Therefore, in practice, emphasis is put on certain characteristics of the product and equipment termed as efficiency.

Efficiency – a sum of characteristics, which enable the given product, equipment, system of means to meet and fulfill the functional requirements as deisgned, at the level of the parameters defined under the given conditions. Qualitiatively, efficiency is assessed in terms of probability, at which the given equipment fulfills its function featuring its parameters under the given conditons. Efficiency (E) is function of the following [7]:

$$E = f (R, R_{ž}, P_{pr}, W, C_1, C_2) \quad (1)$$

Where: R – reliability,
$R_{ž}$ – service life,
P_{pr} – static and dynamic precison,
W- weight,
C_1 – costs of manufacturing ,
$C_{2–}$ costs of operation.

Reliability – is a comprehensive notion that describes readiness and factors that affect it:

fault tolerance, maintanability and sustainability of and assurance of maintenance. The definition also expresses the fact that reliability is not only given by the object characteristics, but also by the result of renewal (maintenance). The notion reliability is used only for general description and cannot be quantified and expressed by any of numerical indicator. The separate partial indicators (readines, faultless operation and sustainability), however can already be quantified, evaluated by means of concrete indicators [6].

Reliabhility can be expressed by partial indicatiors such as:

- Fault tolerance,
- Reparability ,
- Readiness,
- Service life,
- Sustainability,
- Storability and other features.

Relations between the individual indicators of reliability are illustrated in Fig. 1.

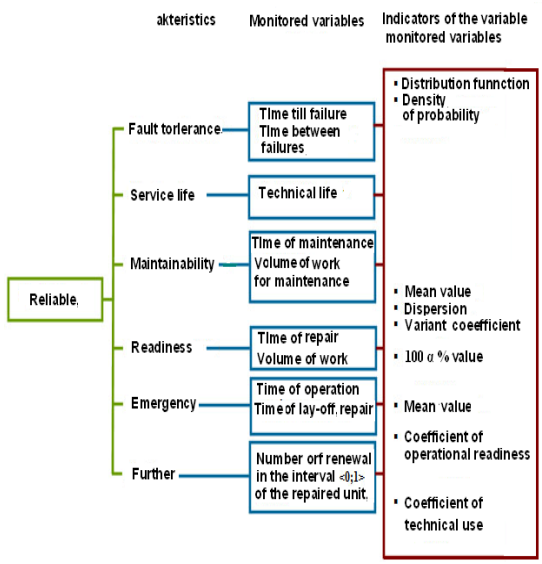

Fig. 1 Relation between the individual indicators of reliability

System – a set of mutually cooperating equipment designed for automated - independent fulfilment of tasks (function).

Element – part of the systeme designed to fulfill partial functions. When analysisng part of the system, no further subdivision applies to it.

Notions such as system and element are of relative value. An aircraft as a whole can be copnsidered as a system made up of five elements: airframe, power plant, electrical – special equipment, radio – electrical equipment, armament. Each of the elements represents to us a complex equipment also can be analysed as a system. The purpose of dividing a system into elements is principally given by the nature of the problem being solved.

Defect – is a variance from the characteristics of the equipment or the system from the required characteristics laid down in the technical documentation, and which bear no influence on the fucntional capability of the given equipment.

Genarally it holds that the more complex the technical equipment, the less reliable it is. As a result, reliability of an equipment to be considered already at its design and technological stages.

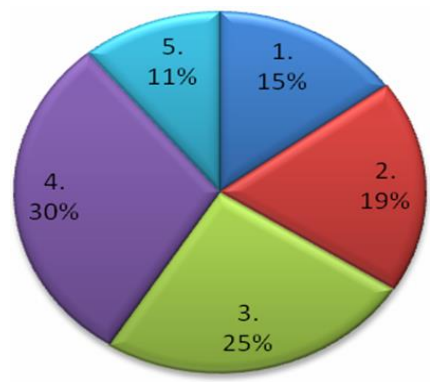

Fig. 2 Causes to failure states of equipment and in shared percentage estimates

Where:

1. unsuitable project,
2. non-adherence to work procedures
3. violating the priescirbed conditions of operation,
4. unsatisfactory level of reialibility of the parts,
5. other causes.

Fig. 2. makes it obvious that the issue of reliability must be handled in a complex way, if we are to obtain satisfatuory results. The decisive factor in achiving reliability for the given equipment is in the reliability of its individual parts. In aviation practice, failure is understood as any kind of losing operation capability (completely, partial or interim) of an aviation equipment both in the air on ground.

Failure an the air is termed from the beginning of take-off roll untill completion of the landing roll.

Failures in the air causing crash situation are considered precondition for extraordinary event.

Failures the resulted in abortion of flight (mission), causing time delay, or prevented takeoff for the given aircraft, are evaluated as failures with dangerous consequences.

The time when the failure occured is a random variable. This statement is the basis for the theory of reliability making use of the theories of probability and mathematical statistics to quantify the considerations. Applying the tools, one can reveal the law underlying the to causes and the conditions under which failures are generated. One of the preconditions of succesful use of the theory of reliabiltiy is thorough collection of information on the operation of the product.

Fault tolerance – is a characteristic of a given product that allows for fulfilling the required function for a stated period of time under the given conditions of operation.

Quantitatively, it is most frequently expressed by probability. It then follows that the random argument to this function is the time of failurless operation.

Operation of a given equipment sometimes proves that the period of operation is of no substantial weight in the occurence of failure and it is of more advantage to go for a a random argument, e.g. : time interval, number of cycles etc.

We distinguish fault tolerance – own (inherent) reliability R_1 (t), reliability in use R_2 (t) and reliability in operaton (involving both of the previous reliabilities):

$$R(t) = R_1(t) \,.\, R_2(t) \qquad (2)$$

Renewal – of the operational capability of the equipment is the recovery of the ability to filfill again the required function following a failure status. Quantitatively, it is defined by the period of renewal. The time of renewal is a random variable, whis is governed by the law of distribution- probability of renewal.

Probality of renewal – is defining reliability when the function of the system will be renewed, following the failure, within a required time interval, by an averagely trained staff using the necessary technology. Renewal is a highly ranked factor in terms of quality of reliability and at complex system it is of decisive value.

Failure – is a phenomenon of terminating the ability of a system to fulfill the required functions under the prescribed conditions within the determined time interval. Degradation of the equipment status is not achiving the level of breakdown.

During operation of a given equipment, two incompatible states can occur:

1. the given equipment is operational for the required time interval without failure,
2. a failure of the equipment will occur during the time interval monitored.

Probability of the first case is expressed by faultless operational probability R(t), and in the second case the probabiliy of failure is expressed as Q(t). For both cases it holds:

$$R(t) + Q(t) = 1 \qquad (3)$$

Important for determining the criterion of failure, as sum of symptoms characterizing the transition of the equipment, system, element from faultless status into faulty one. Failures that occure on aviation equipment can be divided into groups such as:

Periodical (occasional) failures – from the point of identification of causes, they are quite inconvenient. The word is about various symtpoms peculiarly appearing and disappearing in mechanical systems, eg.: unexpected oscillation of the needles of electronic instruments and pointers, etc. When checked, no apparent symptoms can be found, whereas the failure itself can be quite dangerous.

Abrupt failures – occur under heavy – duty operation, caused by vibrations, shocks, sudden changes in pressure, temperature, humidity an the like. They are also termed as catastrophic, as they are characterized by abrupt changes in one or several main parameters. Their causes might be in hidden defects in the manufacturing technology, or hidden defects of parameters that have accumulated throughout the operation of the equipment.

Gradual failures – occur under mild operational conditions as a result of gradual operational wear, degrading their parameters and arriving at unauthorized tolerances. They are characterized by abrupt changes or relatively slow changes, monotounous variations from the parameters. The time occurence of abrupt and gradual failures is an abrupt non-stationary process. In this case relability can be determined using the theory of probability and mathematical statistics.

Independent failures – occur indpendently of failures of the individual parts, they are primary in nature. Independent failures mostly occur only to a single element.

Dependent failures – voccure in one or several elements, as a result of a failure occured in other element or elements, they are secondary in nature. In some references, dependent failure can be termed as group failure.

Notions like partial or complete failures are used beacuse of the need to record the relative nature of the equipment function at different conditions of fulfiling their tasks (e.g. a failure of the equipment - instrument during an IFR flight, where as the failure, in view of the aircraft flying under standard conditions, is considered only as partia).

Complete failure – is a status when an equipment no longer can be used for the purpose it is designed.

Partial failure – is a status when the failure in the equipment is caused mostly by lessening one of the parameters, whereas, for a certain period of time the equipment can be used on without eliminating the causes of the failure.

Failures can have one or several causes. Most frequently, they can be traced back to technical reasons. When analysing failures related to poor quality of the technical staff maintenance, it is often difficult to find the proper boundary between the fault of the staff and the fault of the equipment. Based on the analysis we can sometimes arrive at technical innovations in design thereby preventing further failures to occure. Among external causes are mechanical actions, atmohspehirc conditions and the like. Falilures that occur on ground when working on the aviation equipment are to be separated from those occuring when in flight. It is mostly because of the possible consequences to be born.

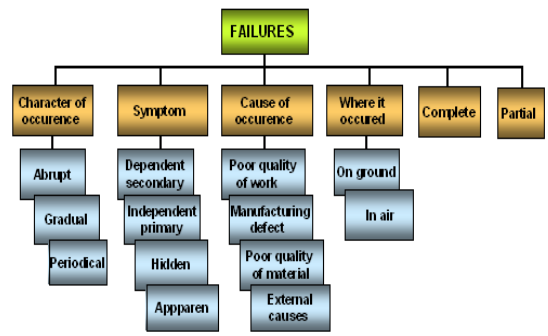

Fig. 3 Division of failures by groups

Failures that occur at aviation equipment can be divided into groups as illustrated in Fig. 3.

3 AT RELIABILITY CHARACTERISTICS

Reliability of the elements, systems and their quantitative characteristics are linked with their period of operation, working cycles, switching on, landings and the like. Based on these characteristics, one is not only able to assess the level of reliability of the technical equipments individually, but also solve a whole range of practical problems to ensure operational reliability [1].

When classifying the quantitative characteristics, it is logical and purposeful to introduce the notion of reparable (renewable) or irrepairable equipment. Correctness of such division is given on the one hand by the fact of differences in using the equipment following the failure, and on the pecularities of the

mathematical methods, mostly the theory of probability on the other.

Non-renewable equipment – from the point of the thory of reliability, considered are such equipments which once failed at operation are not repaired but replaced.

Renewable equipment – are the ones, which following a failure are immediately repaired and then continue in their operation, fulfilling their tasks.

Notions such as repairable irreparaible are rather relative. For example: for the operator, the number or hydraulic machine sets are from aircraft operational point of view, considered inreparable, whereas from the point of aiviation equipment repair company such machine set can be seen as repairable. With current aviation equipment there is a much higher number of renewable parts than those irrepairable.

Applicable characteristics of reliability of non-renewable equipment:

a) probalility of faultless operation,
b) distribution of distribution of time between failures,
c) intensity failures,
d) mean time between failures .

Characteristics of reliability applied to renewable equipment:

a) Probability of the occurence of just **n** failures,
b) parameter of the stream of failures,
c) time period of operation between failures,
d) probability of operation without failures (n=0).

4 AT RELIABILITY REQUIREMENTS

Determining the requirements on reliability of aviation technical equipment is a rather crucial problem as there is an understandable effort to achieve the highest possible reliability. However, there are neither equipment, systems elements nor products, which could maintain any level of high reliability in the course of a sufficiently long period of operation. Every product, in the end, will lose its quality also in terms of reliability. Efforts to improve reliability in via science and research are more and more demanding and costly.

Here comes a solution of optimization, which is to be adapted to concrete conditions. It is necessary to take into consideration the principal factors influencing reliability of equipment in terms of technology, economy, ecology an moral as well. For example: in relation to military aviation equipment, in determining the reliability, an inmportant role is played by the indicator of combat efficiency [3,5,6].

Aviation equipment have spoecific features whe determining the level of reliability. For this reason, they can be divided into three groups:

- elements, on which air safety depends; (namely the power plants- engines, controls, undercarriage, main rotors of helicopters and some kinds of special electronic special equipment,...),
- elements taht enable fulfilement of basic functions in line with the primary design of the aircraft;(instruments and aircraft systems of various kinds),
- elements, the role of which consists in fulfilling supplementary functions for aircraft operation; (for example systems of inlet or cover control).

Reliability of the element in the first group must be of the highest possible level, and is determined by the scientific and technological level applied to the conditions of both manufacturing and operation. The price in these cases is not of primary importance. When determining the reliability of these elements, it is necessary to base upon the existing state of the art and monitor tendencies that might lead tho higher reliability. It is obvious that with time reliability will improve both at aircrafts that have already been introduced and at those being introduced into operation. Improvement are reaqmarkable not only at elements, but entire systems and equipment. The nature of changes can be explained by gradual elimination of defects that occur during operation

The level of reliability of elements in the second group is no longer placed so high requirements. Important in improving level of reliability are the costs of manufacturing and operation. The less reliable the product, the higher the costs of operation. When raising the level of reliability requirements, costs of manufacturing

are increasing, too. Therefore, we do our best to find optimal solution.

When dealing with failures in the third group, no immediate cases of crash or aborting mission occur. For this reason, the reqirements on reliability of these elements, compared to group two, can be even lower.

5 CONCLUSION

Reliability in aviation equipment is a set of measures serving support to faultless operation, or minimilization the occurence of failures during operation.

Reliability of the separate technical equipment is a highly important element and the mark of quality. During operation, it is important to observe all the applicable douments when dealing with aviation equipment, and their renewal in line with the latest applicable technological procedures.

Once having started with the operation of eviation equipment, reliability must be monitored right from the onset. The goal is to obtain maximum possible information on operation of the product, equipment or element. Each failure, replacement or wear of partial element is recorded, then evaluated and processed as a follop-up. The information obtained in these ways are further used not only by the manufacturers but also those operating them.

Evaluation of the aviation equipment reliability from the point of quality is of priceless value in establishing systems of maintenance control, support of human resources and particularly for mesasures of maintenance to be take on time.

BIBLIOGRAPHY

[1] HOŠKO, J. - Základy spoľahlivosti, VVLŠ Košice, 1989, 180 s. ,
[2] CALABRO, S.R.: Základy spolehlivosti a jejich využití v praxi, Knihtisk, Praha,1963,309 s. (Reliability principles and practices),
[3] TŘÍSKA, V. - Provoz a údržba letadel, VAAZ Brno 1977, 93 s. ,
[4] POLSTEROVÁ, H. - Spolehlivost v elektrotechnice, VUT Brno, 2003, 86 s.,
[5] SCHINDLER, R.: Prevádzková spoľahlivosť lietadlových konštrukcií, VŠDS Žilina, 1983
[6] HOLUB, R., VINTR, Z.- Spolehlivost letadlové techniky, VUT Brno, 2001, 86 s.,
[7] LAZAR,T., BRÉDA,R., KURDEL, P. – Iištrumenty isrenia letovej bezpečnosti, TU v Košiciach, Letecká fakulta 2011. ISBN:978-80-553-0655-1

AUTHOR´ S ADDRESSES

Himič, Jozef, Ing.
Technical university of Košice
Faculty of aeronautics
e-mail: jozef.himic@tuke.sk

Kabát, Ján, Ing., PhD.,
Technical university of Košice
Faculty of aeronautics
e-mail: jan.kabat@tuke.sk