FLIGHT SAFETY AND THE SYNERGIC EFFECT

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Air laws and regulations set high demands on flight safety, which is of key importance for safe operation of civil aviation and one of the decisive factors of airline performances. The article is opening a intended series of papers, which the first one dealing with the basics of flight safety and analysis of the system of flying and flight safety as a result of combined acting of an ergatic system. The second part of the article is dealing with the synergic effect in terms of fight safety and prevention of aviation accidents.

K e y w o r d s: aviation, ergatic system, man-machine-environment, synergic effect, flight safety.

1 INTRODUCTION

The system of air transportation is made up of material and spiritual elements mutually interlinked by function. A system in which the man-aircraft – environment interact with one another. Each element of the system is rather sensitive to its own changes and to changes in mutual states of the given system. Any violation of the balance is fairly dangerous and can lead to surpassing the risk limit of the crew, threaten the lives of the crew, passengers or the aircraft, i.e. resulting in dangerous situation in the air.

2 BASIC NOTIONS

Safe flight – a flight performed by specified conditions, with no threats to health and life of the aircrew or the wholeness of the aircraft.

Unsafe flight – a flight, during which it comes to a dangerous situation posing threats to the life and health of the aircrew, passengers, or to the wholeness and operational capability of the aircraft.

Dangerous situation in the air – a phase of flight, with persistent threat to the aircrew, passengers and the aircraft. If it comes to threats to health and life of the aircraft – passengers or the damage of an aircraft, the flight is classified as dangerous.

Risk limit of flight safety – determined by operational condition, the flight turns into a dangerous one if conditions are violated.

Prerequisites of aiviation accident – such a dangerous situation, which can be solved by the aircrew of the air traffic control staff, either by termination of flight or by the changing for good by itself.

Aviation accident, crash - a dangerous situation in the air ending in an aircraft crash causing injuries to the aircrew or passengers, or both situations might have occurred.

Air fatality – a dangerous situation claiming human lives destroying aviation equipment.

3 SYSTEM OF FLYING - ERGATIC SYSTEM

The man-aircraft-environment represents the key factors of flight safety in the system of flying. Consequently, flight safety depends on the quality of mutual cooperation of these elements-factors of aircraft system reliability. From the aspect of flight engineering psychology, these factors are acting objectively making up a whole system, within which the components are functionally linked. Each factor of the system has its own level of safety upon which the level of flight safety depends.

Ergatic system a complex system, including man, environment wherein the object of action (technical equipment) is found. It represents a cybernetic system controlled by errors.

In wider context, it is a man-machine-environment relation. The system has lived up three periods of research over the period of more than 100 years.

- **Period 1 - adaptation of man onto technical equipment** (beginnings of aviation till WWI).The aim was to optimize the ergatic system of the kind.
- **Period 2 – adaptation of the technical equipment to man** – the aim was to design an aircraft and its flight characteristics, acceleration and operation altitude of flight (till the end of WWII).
- **Period 3** – **overall interpretation of human quality into the system.** The aim is in the research of the ergatic system in view of human factor analysis:
  - ***Automation of flight*** - unstressing the aircrew from physical and decision-making activities (50s – 70s of the 20h cent.
  - ***Complex notion of solutions to system and control*** (introduction of the information technology, 80s of the 20th century).
    - Increasing aircraft manoeuvrability;
    - Reducing aircraft visibility;
    - Complex automation of processes aboard of an aircraft;
    - Increasing athropo-technical requirements (cockpit adjustments, maximum visualization and rational presentation of data, colours ...);

Increase in the complexity and the amount of board instruments and the level of automation in flight control results in redistribution of functions between the aircraft systems and the aircrew and simultaneously to substantial changes in the contents of the aircrew activities, substantially conditioned by the psycho-physiological status and also the reliability of decisions when fulfilling tasks.

4 FLIGHT SAFETY

Grouping and adjustments of a wide variability of instruments with the elements of airframe structure towards improving its functionality and achieving the single goal of the man-operator forms the essence of ergatic complexes. Consequently, the level of flight safety and the efficiency of aircraft utilization is defined by the functional operation of target systems controlled by the operator.

Operational safety of the ergatic system ma- aircraft-environment is the demonstration of its equality. Estimation of the quality of the system functioning is developing in the course of flight tests by means of the characteristics, indicators of efficiency expressing the level of present goals achieved by the system..

Flight safety is determined by a great number of fairly complex elements of the air transportation system including the pilot-aircraft system, services of ensuring and controlling flights and on lots of organizational, technical, economic psycho-physiological, moral and ethical as well as other factors related to the development, manufacturing, servicing and maintenance of the aviation equipment.

The existing classification differentiates as much as 650 factors of the kind. Supposing that an aviation accident is a result of the interaction of coincidence of three factors, the number of variants as for the cause of aviation accidents is given by:

$$C_n^m = \frac{n!}{(n-m)!m!} \qquad (1)$$

Where:

m – number of jointly actuating actors

n- Number of coefficients linked to development manufacturing, operation of aviation equipment.

For m = 3 n = 650

$$C_{650}^3 = \frac{650!}{(650-3)!3!} = 45559800$$

Collection of statistical data and definition of the level of influence exerted by the threat of each coefficient, for the operative control of the levels of flight safety, is practically impossible. And this direct road to quantitative assessment of the flight level safety is even regarding a single systems is practically feasible.

Flight safety is a complex phenomenon, based on the fact, that no accident is supposed to take place when in flight. The probability of fulfilling the flight without catastrophe is considered the most acceptable for evaluation of flight safety. It is this this criterion that reflects the most precisely reflecting the essence of the matter, the general idea and offers direct answer to the question: What is the chance that the aircraft arrives in the destination, without an accident and the flight crew and the passengers remain in health?

Therefore, it is very important to establish criteria and methods, which could enable quantitative assessment of the level of flight safety by the known operational indicators of the man-aircraft system.

The need to assess efficiency at ensuring flight safety for the pilot-aircraft system is generated already at the stage of formulating the requirements and tasks for the development and design of new aircraft and further on in all the stages of projecting, manufacturing and operation.

The task must be solved in view of the potentials of the industry, prospects of the development in technology, achieved level and tendencies in the methods of air navigation, methods and means of aircraft servicing, planning for manufacturing and operation. Experiences from operation show that not all air incidents during flight turn into more complex situations and become aviation incidents.

Of the total number of in-flight emergency cases, 85 % of them have not proved influential in terms of programme fulfilment, or their influence remained negligible. Of Z n_y more complex flights only $n_{o.c}$ turn out to be a dangerous situation, and of z $n_{o.c}$ dangerous situation only $n_{a.c}$ develop into crash situations, however, only $n_{k.c}$ is transformed into catastrophic situations. The coherence between the emergency cases can be expressed by way of statistically determined coefficients of the transition of the man-aircraft system into dangerous, crash and catastrophic situations

$$k_{o.c} = \frac{n_{o.c}}{n_y};\ k_{a.c} = \frac{n_{a.c}}{n_{o.c}};\ k_{k.c} = \frac{n_{k.c}}{n_{a.c}}; \qquad (2)$$

Where:

$k_{o.c}$- coefficient of the transition of the man-aircraft system into dangerous situations,

$k_{a.c}$- coefficient of transition of the man-aircraft system into crash situations,

$k_{k.c}$- coefficient of the transition of the man-aircraft system into catastrophic situations,

Probabilities of arising four emergency cases is defined as the fraction of:

$$P_y = \frac{n_y}{N};\ P_{o.c} = \frac{n_{o.c}}{N};\ P_{a.c} = \frac{n_{a.c}}{N};\ P_{k.c} = \frac{n_{k.c}}{n_{a.c}}; \qquad (3)$$

Where:

N - the total number of flights for the assumed period of time

P_y - probability of arising of a complicated situation,

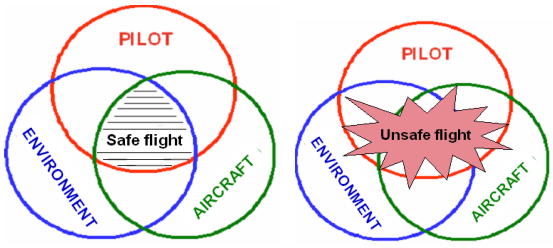
$P_{o.c}$- probability of arising a dangerous situation,

$P_{a.c}$ - probability of arising a crash situation,

$P_{k.c}$ - probability of arising a catastrophic situation.

Arranging the equation (3) with regard to (2), we obtain the expression of the linkage of the probability of arising a catastrophic situation along with the probability of arising complications in the conditions of flight,

$$P_{k.c} = k_{k.c}.k_{a.c}.k_{o.c}.P_y = k_c.P_y \qquad (4)$$



a) Safe flight b) Dangerous flight

Fig. 1. Ergatic system a) satisfies all the expressed values; b) expresses the deviations from the expected value.

Consequently, when justifying the establishment of the criteria of the efficiencies of ensuring fight safety in the man-aircraft system as a tool, enabling qualitative influence to be exerted upon the functioning of the basic manufacturing unit of the air transportation, it is necessary to take into account the existence of statistical rules applicable to accidents, incidents or emergency cases during flight.

5. SYNERGISTIC EFFECT, PREVENTION OF AA

Synergic effect is the effect of concentration generated by interaction and combination of several interventions at a single, final receiver. In our case it is the interaction of the environment and the aircrew, wherein the receivers are the passengers and the effect is the safe flight.

Synergic effect is an **added effect** of the simultaneous acting of several elements.

Synergic effect is the effect of social instrumentality, interoperation, interoperability of several elements, the result of which is usually larger and qualitatively at a higher level than the sum of the effects of the individual elements acting separately.

- Synergy in aviation arises in a group form of cooperation, with individuals assisting in achieving a goal – safe flight.
- Synergy arises at ensuring flights in that the individual apart from his individual approach is motivated by the action of the other elements of completing the flight, collective responsibility and the possibility of mutual help and influencing flight safety. Thanks to the cooperation, there is a greater chance to fulfil the mission in the time and quality as required.
- For synergy to be established in flight it is necessary to appraise the importance of prevention of aviation accidents, the task of which is to **actively** search for the risk factors in the individual areas of aviation activities, compensating for or eliminating them so as to ensure safe flight.
- Potential increase in the level of flight safety in the system of aviation accident prevention is available in increasing the **activity** of people within the **pilots and environment setting** - dispatchers, specialists of ground services, engineering and aviation services as well as another specialties supporting flight

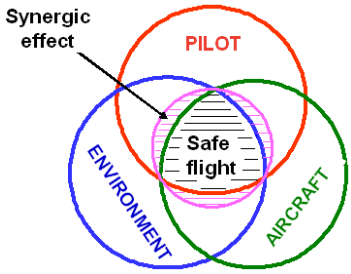


Fig. 2. Synergic effect coming into being

Prevention of Aviation accidents (AA) is a wide set of activities of all the persons involved in air operation. Prevention must be focused on all risk factors, of any kind.

Prevention leads to higher quality and making air operation more efficient, as it is **actively** seeking and offering remedy to errors and deficiencies at all levels and in time. All that way of looking for negative effects of objective factors is detrimental to reliability and flight safety.

Prevention of AA in air operation is aimed at:

- Maintaining the achieved level of reliability of flying;
- Ensuring reliable functioning of the system of successful solution of a flight situation;
- Minimizing the consequences of dangerous situations in the air;

Tasks of prevention of AA at aviation professionals are as follows:

- Foreseeing and identifying degradation of reliability (quality) of the existing systems;
- Revealing risk factors in these systems;
- Timely reacting to the degradation of aviation equipment and flight support services etc.;
- Compensating for the deterioration, or respecting it;
- Adjusting preparation to it, while performing flight and supporting services, or cancelling them if necessary.

CONCLUSION

Increasing flight safety is a complex technical and social issue, i.e. operational, organizational, economic and social issues related to aircraft reliability, aircrew, ground facilities, services, social environment and many other components as factors.

Systems-based approach in following the ergatic system in the process of ensuring safe flight is viable by way of adopting „foresee“ and prevent“ instead of the current principle adopted in aviation known as „reveal and repair“.

Introducing a systems-based analysis enables viewing the process as an active ergatic system in the space, subsequent revealing its true characteristics and potentials, making use of them to ensure flight safety.

BIBLIOGRAPHY

[1] PIĽOVÁ, E.: Súčasné problémy využívania ergatických systémov, Aeronautika 2013: Medzinárodná vedecká konferencia : 25. - 26. apríla 2013, Herľany. - Košice : TU, LF, 2013 S. 91-95. - ISBN 978-80-553-1416-7

[2] LAZAR, T. - BRÉDA, R. - KURDEL, P.: Inštrumenty istenia letovej bezpečnosti, Technická univerzita Košice : - 2011. – ISBN 978-80-553-0655-1

[3] LAZAR, T. - PIĽA, J. - KURDEL, P.: Aircraft asistence systems and flight safety, In: Acta Avionica. Roč. 13, č. 21 (2011), ISSN 1335- 9479

[4] KOZDRUK, V. V. – REBO, J. J. – Navigacionnye ergatičeskie komplexy samoľotov Moskva, Mašinostrojenie 1986

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