

Abstracts
of the 12th International Conference

RELIABILITY and STATISTICS

in TRANSPORTATION and COMMUNICATION

October 17-20, 2012
Riga, Latvia



Transport and
Telecommunication Institute

The K. Kordonsky
Charitable Foundation



Telematics and Logistics
Institute



Latvian Academy
of Sciences



Riga City Council



Latvian Operations
Research Society



Latvian Transport Development
and Education Association



Academic Park
Latvia



Latvian Transport Union



Laboratory of Applied
Systems



The 12th International Conference

The K. Kordonsky
Charitable Foundation

**RELIABILITY and STATISTICS
in TRANSPORTATION and COMMUNICATION
(RelStat'12)**

17–20 October 2012. Riga, Latvia

Organised by

Transport and Telecommunication Institute (Latvia)
The K.Kordonsky Charitable Foundation (USA)

in co-operation with

Latvian Transport Development and Education Association (Latvia)
Telecommunication Association of Latvia (Latvia)
Latvian Academy of Science (Latvia)
Baltic Operations Research Society

ABSTRACTS

Edited by

Igor V. Kabashkin

Irina V. Yatskiv

RIGA - 2012

THE PROGRAMME COMMITTEE

- Prof. Adolfas Baublys, *Vilnius Gediminas Technical University, Lithuania*
Prof. Maurizio Bielli, *Institute of System Analysis and Informatics, Italy*
Dr. Brent D. Bowen, *Purdue University, USA*
Dr. Vadim Donchenko, *Scientific and Research Institute of Motor Transport, Russia*
Prof. Ernst Frankel, *Massachusetts Institute of Technology, USA*
Prof. Igor Kabashkin, (Chairman) *Transport & Telecommunication Institute, Latvia*
Prof. Eugene Kopytov, *Transport & Telecommunication Institute, Latvia*
Prof. Zohar Laslo, *Sami Shamoon College of Engineering, Israel*
Prof. Andrzej Niewczas, *Lublin University of Technology, Poland*
Prof. Lauri Ojala, *Turku School of Economics, Finland*
Prof. Irina Yatskiv, *Transport & Telecommunication Institute, Latvia*
Prof. Edmundas Zavadskas, *Vilnius Gediminas Technical University, Lithuania*
Prof. Michael Bell, *Imperial College, United Kingdom*
Dr. Vincenzo Punzo, *Universita di Napoli "Federico II", Italy*
Prof. Andrés Monzón, *Politechnical University of Madrid, Spain*
Prof. Guido Gentile, *University of Rome, Italy*
Dr. Jacek Mazurkiewicz, *Institute of Computer Engineering, Control and Robotics, Wrocław University of Technology, Poland*
Prof. Eftihia Nathanail, *University of Thessaly, Greece*
Dr. Klaus Nökel, *Planung Transport Verkehr AG, Germany*
Prof. Yury Paramonov, *Riga Technical University, Latvia*
Prof. Alexander Grakovski, *Transport & Telecommunication Institute, Latvia*
Prof. Jurijs Tolujevs, *Transport & Telecommunication Institute, Latvia*
Prof. Alexander Andronov, *Transport & Telecommunication Institute, Latvia*

ORGANIZATION COMMITTEE

- Prof. Igor Kabashkin, Latvia – Chairman
Mrs. Inna Kordonsky-Frankel, USA – Co-Chairman
Prof. Irina Yatskiv, Latvia – Co-Chairman
Mrs. Elena Rutkovska, Latvia – Secretary

Transport and Telecommunication Institute
Lomonosova iela 1, LV-1019, Riga, Latvia
<http://RelStat.tsi.lv>

ISBN 978-9984-818-50-4

© Transport and Telecommunication Institute, 2012

RELIABILITY OF FLEET OF AIRCRAFT

Sergey Tretyakov¹, Yury Paramonov²

^{1,2}Riga Technical University, Aeronautical Institute
Gregora iela 8-64, Riga, Latvia

¹Ph.: 26732434. E-mail: sergejs.tretjakovs@inbox.lv

²Ph.: 67089990. E-mail: yuri.paramonov@gmail.com

Keywords: Monte Carlo, inspection program and approval test, fleet reliability

Review of the problem of elimination of aircraft fatigue failure can be seen in [1]. It is solved using two main methods: safe-life approach or fail-safe approaches. In this paper we consider the solution of this problem using second approach. In previous investigation [1] the reliability of one aircraft was studied usually. Here we consider the reliability of a fleet of aircraft of the same type taking into account that if fatigue crack is discovered in any aircraft then any fatigue failure in the fleet will be eliminated because this and all other aircrafts in the fleet will be discarded from service. Redesign of this type of aircraft will be made before new attempt to continue the service will be made. In [1] really the fatigue failure of one aircraft, p_{f1} , was studied, but reliability of fleet of N aircraft was calculated using equation of probability of independent events: $1 - p_{fN} = (1 - p_{f1})^N$, where p_{fN} was probability of any failure in the fleet of N aircraft. This calculation corresponds to assumption that after discovery of fatigue crack in any aircraft we make redesign (repair) only of this specific aircraft but the service of all other aircrafts in the fleet will be continued without any changes, as if we do not do any exchange of information. In this paper we take into account the exchange of information about the crack discovery in any aircraft and take into account the human factor also. This mean that we take into account that the fatigue crack will be discovered only with probability w , $w \leq 1$, even if during inspection it has detectable size. The reason of this can be the low level of labour discipline or any other combination of circumstances (human factor). The human factor also was not taken into account in [1].

We make assumption that some structurally significant item, the failure of which is the failure of the aircraft, is characterized by a random vector (T_D, T_C) , where T_C is a critical lifetime (up to failure), T_D is a service time, when some damage (fatigue crack) can be detected. So if inspection will be made in interval (T_D, T_C) , then the fatigue crack will be discovered with probability w . We suppose also that a required operational life of the aircraft is limited by specified life when aircraft is discarded from service.

As it is shown in (Paramonov *et al.*, 2011), the following simple exponential model of fatigue crack could be used for approximation of its dependence on time: $a(t) = a_0 e^{Qt}$, where a_0 and Q are some parameters. In this paper we assume that Q random variable, which has normal distribution but a_0 is some constant (see more general assumption in [1]). Then it can be shown that random variables $T_D = (\log a_d - \log a_0)/Q = C_d/Q$ and $T_C = (\log a_c - \log a_0)/Q = C_c/Q$, where a_d and a_c are fatigue crack size when it become detectable and critical (correspond to failure), have lognormal distribution also. And we assume that parameter of these distribution are known [1]. This assumption allows calculating the probability of any fatigue failure in fleet of aircraft for specific inspection program.

To prevent the failure in the fleet with information exchange, it is enough to find at least one crack before the failure of any aircraft in the fleet. Let $T_{d_i}^+ = t_i + T_{d_i}$ and $T_{c_i}^+ = t_i + T_{c_i}$ be the calendar time moments when fatigue crack can be discovered and aircraft failure correspondingly for i -th aircraft, where t_i is time moment when service of i -th aircraft begins.

$t_1 < t_2 < \dots < t_N$, $i = 1, \dots, N$. And let $I_{SL} = \{i: T_{ci} < t_{SL}, i = 1, \dots, N\}$ be a set of indexes of aircraft the failure of which can take place if inspection is not provided. Let us define the calendar time of first failure in the fleet of aircraft without inspection: $T_f^+ = \min \{T_{ci}^+ : i \in I_{SL}\}$. Let us define also $T_{fi}^+ = \min(T_{ci}^+, T_f^+)$, $i \in I_{SL}$ and $R = \sum_{i \in I_{SL}} R_i$ is total number of planned inspections in aircraft fleet before T_f^+ , where $R_i = \max(\{(T_{fi}^+ - t_i)/D\} - \{(T_{di}^+ - t_i)/D\}, 0)$, $i \in I_{SL}$, is the random inspection number of i -th aircraft from the set I_{SL} for inspection interval D (it is supposed specific schedule of inspections for i -th aircraft: $t_i + D, t_i + 2D, \dots; i = 1, \dots, N$).

Random variable Q (it is the speed of fatigue crack growth in logarithm scale) has specific realization for each aircraft and Q_1, \dots, Q_N is independent random variables. So probability of any fatigue failure in fleet of N aircraft

$$p_{fNW}(D) = \int_{-\infty}^{\infty} \dots \int_{-\infty}^{\infty} (1-w)^{r(q)} dF_{Q_1}(q_1) \dots dF_{Q_N}(q_n), \quad (1)$$

where $r(q)$, $q = (q_1, \dots, q_n)$, is realization of random variable R .

Using this equation (and Monte Carlo method for calculation for large N) we can choose the inspection program (in considered case: inspection interval, D) under condition of limitation of this probability by some fixed small value.

Estimation of parameter distribution of random variable T_d and T_c can be obtained processing results of full scale fatigue test of airframe. Taking into account that these estimates are random variables the minimax approach should be used for final decision [1] but this is the subject of another paper. The necessary method and PC program are developed.

References

1. Paramonov, Yu., Kuznetsov, A., Kleinhofs, M. (2011). *Reliability of fatigue-prone airframes and composite materials*. Riga: Aviation Institute of Riga Technical University.