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Function failure and failure boundary analysis for an aircraft lock mechanism

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ABSTRACT

This paper analyzes the functional principle and functional hazard analysis for a landing gear cabin door lock mechanism, concluding that the unlocking function of the lock mechanism is the one at most risk. Then the failure probability of the unlocking process of the lock mechanism is calculated, based on the simulation model of the lock mechanism and the response surface method. At last, the failure boundary of the lock mechanism is studied, including: (a) A method for the failure boundary analysis of the lock mechanism is proposed; (b) The failure boundaries respectively with single-parameter and with double-parameter are obtained based on the simulation model; (c) With the lock mechanism's assembly error taken into consideration, the failure boundary of the lock-ring position is verified through the cabin door lock system test, which is quite helpful for the maintenance and management of the aircraft lock mechanism.

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1. Introduction

As aircraft performance is becoming increasingly demanding, more complex mechanisms are being used in new aircraft; for example motion mechanisms of the missile weapons bay, landing gear doors, and of multi-door and multi-locks in transport aircraft. The performance of these mechanisms is of great importance to aircraft safety. The lock mechanism of the landing gear door system is one of these new complex mechanisms, and its potential function failure and failure boundaries have been carefully studied in this paper.

There have been lots of researches on the mechanical failure problem. In 2011, Hui Wang [1] developed a hybrid experimental simulation system for mechanism motion reliability by using the LMS Virtual.Lab and Monte Carlo method. The multi-failure mode reliability analysis and sensitivity analysis of a lock mechanism are discussed. In 2012, Mingmin Lei [2] proposed a fault simulation analysis method for lock mechanism based on multi-disciplinary software collaboration. And fault simulation of lock mechanism is considered. In 2013, Zhongchao Sun [3] discussed a simulative trial method based on multi-factor coupling for the lock mechanism. And the reliability of cabin door lock mechanism is analyzed. In 2016, Dongyang Sun [4] presented a general methodology for kinematic accuracy analysis of planar mechanisms with clearance, involving random and epistemic uncertainty. Dongjie Zhao [5] investigates the application of a planar deployable structure with screw theory and discusses its possible

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applications in over constrained lift platforms via calculating its stiffness. Huafeng Ding [6] proposes an automatic method to synthesize planar non-fractionated kinematic chains with two multiple joints, which are generated from kinematic chains with one multiple joint by transforming a multiple link to a multiple joint. Huan Pang [7] studied the failure mechanism analysis and reliability assessment of the aircraft slat. T. Warren Liao [8] developed an integrated database and expert system for identifying the failure mechanism of mechanical components. C. Manfredi [9] analyzed three blowouts attributed to high pH SCC in different oil and natural gas transmission pipelines, which occurred by the sudden propagation of longitudinal cracks at the outer surface of the pipes. D.R.H. Jones [10] gave details of four cases in which internally pressurized tubes failed by creep bulging and ruptures (two boilers, one super heater and one reformer). Tim J Carter [11] discussed and illustrated the common failure mechanisms found in gas turbine blades. V. Infante [12] presented the analysis of two in service failures involving blades breakage belonging to different compressor stages. M. Sujata [13] reported the basic microstructural features in cast nickel base super alloys that control the failure mechanisms in gas turbine blades followed by analysis of two service failures.

For the lock mechanism, the limit state function cannot be expressed explicitly. So, response surface method (RSM) is always used for this issue. In 2001, Guan et al. [14] and Wu Qingxi [15] analyzed the change of model parameters on the impact of structural reliability analysis. In 2014, L.B. Jayasinghe [16] presented the response of pile foundations to ground shocks induced by surface explosion using fully coupled and non-linear dynamic computer simulation techniques together with different material models for the explosive, air, soil and pile. I.I. Cuesta [17] made use of the response surface methodology for the estimation of the creep parameters. In 2015, S. Selvi [18] developed a mathematical model to predict the wear rate of aluminum metal matrix composites and the adequacy of the model was verified using analysis of variance. Abdolreza Samimi [19] considered the mechanical strength of solid catalysts as an important factor in terms of ensuring the reliable performance of industrial reactors. In this work, a pelletizing method is used to form gamma alumina support for catalysts. Response surface method (RSM) is employed to analyze and model the effects of various manufacturing parameters on the crushing strength of the supports. In 2016, Yuan Gao [20] preferred scientific and efficient mix design method to enhance the quality of alkali-activated slag (AAS) materials, presented an optimization of AAS materials using Response Surface Method (RSM).

For the lock mechanism of the aircraft landing gear cabin door, its failure can impede the landing gear to go down safely, which threatens the safety of the aircraft and crew. Therefore, aiming at the lock mechanism of the landing gear door system, this paper firstly analyzes the functional principle and functional hazard of the lock mechanism and finds that the unlocking process of the lock is the most dangerous function. Then, in order to conduct the reliability analysis, the multibody dynamic model is built in the simulation software LMS; thereby the reliability of unlocking function is calculated based on the response surface method. However, the usual reliability analysis for the mechanical products can only provide guidance to the designers and producers, while it is not helpful for the customers. Hence, the research should be richened by analyzing the failure boundary of the mechanisms considering the key parameters, which is helpful for the customers to use and maintain the products. Accordingly, this paper proposes a method for obtaining the failure boundary of the lock mechanism of the landing gear door system; then the failure boundaries respectively with single parameter and with double parameters are obtained based on the simulation model; at last, considering the lock mechanism's assembly error, this paper verifies the failure boundary of the relative position between lock-hook and lock-ring through cabin door lock system test, which is quite helpful in the maintenance and management of the aircraft lock mechanism.

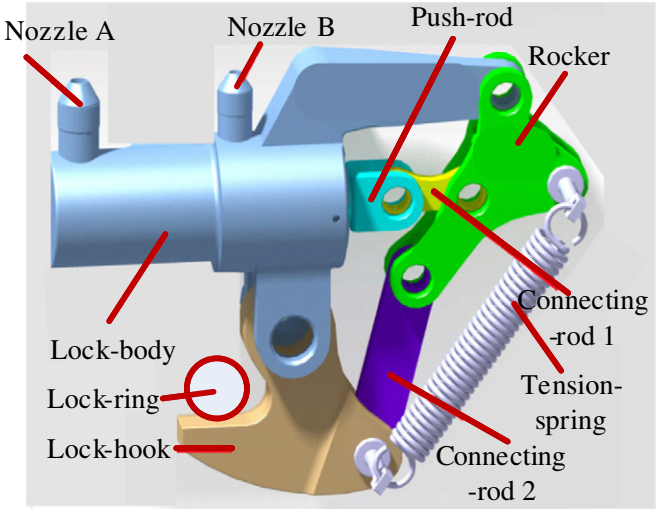

Fig. 1. The structure of the lock mechanism.

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