航空学报
ACTA AERONAUTICA ET ASTRONAUTICA SINICA
ISSN 1000-6893
CN 11-1929/V

航空学报 » 2013, Vol. 34 » Issue (3) :509-516 DOI: 10.7527/S1000-6893.2013.0086

多因素耦合复杂飞行情形风险定量评估方法

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Quantitative Risk Evaluation Methods for Multi-factor Coupling Complex Flight Situations

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摘要

多不利因素耦合诱发飞行事故具有隐蔽性强、因素关联复杂及状态"不可逆"性等特点,对其进行定量建模及风险评估研究难度较大。为此建立了典型装备故障和恶劣环境两类不利因素的定量数学模型。基于飞机六自由度全量运动方程、不利因素数学模型和人在环的操纵方式,应用MATLAB/Simulink、C语言和Flightgear软件开发了用于多因素耦合飞行情形研究的虚拟试飞安全性分析系统。建立了基于改进粒子群算法的极值分布风险评估模型,通过广义极值分布参数优化自动找到最为符合的极值分布模型。提出了随机自适应进化粒子群优化算法(RAE-PSO)对拟合过程进行优化,提高了评估精度和收敛速度。建立了多因素耦合复杂飞行情形的综合评估模型,以GJB 626A-2006中的试飞风险科目为例进行风险评估与结果分析,验证了方法的可行性和有效性。

关键词： 飞行安全 虚拟试飞 建模与仿真 多因素耦合 粒子群算法 风险评估

Abstract:

In multi-factor complex flight situations, factors' coupling is secluded, complex and always has the characteristic of irreversibility. Thus, it is difficult to research the modeling and risk evaluation of such flight situations. Representative disadvantage factors' models including aircraft malfunction and atrocious weather are established. Based on the six-DOF non-linear differential equations of aircraft motion, models of disadvantage factors and pilot-in-loop manipulation, a virtual flight testing system for multi-factor flight situation research is developed using MATLAB/Simulink, C language and Flightgear software. Generalized extreme value risk evaluation model based on an improved particle swarm pptimization algorithm is proposed. The most appropriate type of extremum distribution can be found by this model. A random adaptive evolutionary particle swarm optimization (RAE-PSO) is proposed to optimize the fitting process, and the precision and constringency speed are improved. An integrated risk evaluation model for multi-factor coupled complex flight situations is put forward. And a flight test subject in GJB 626A-2006 is used as an example to validate the method's feasibility and validity.

Keywords: flight safety virtual flight test modeling and simulation multi-factor coupling particle swarm optimization risk evaluation

Received 2012-06-18;

Fund:

国家自然科学基金(60572172,61074007)

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引用本文:

刘东亮, 徐浩军, 张久星. 多因素耦合复杂飞行情形风险定量评估方法[J]. 航空学报, 2013, 34(3): 509-516.DOI: 10.7527/S1000-6893.2013.0086

LIU Dongliang, XU Haojun, ZHANG Jiuxing. Quantitative Risk Evaluation Methods for Multi-factor Coupling Complex Flight Situations[J]. Acta Aeronautica et Astronautica Sinica, 2013, 34(3): 509-516.DOI: 10.7527/S1000-6893.2013.0086