MASTER OF SCIENCE
IN
AERONAUTICAL ENGINEERING

SYSTEM ENGINEERING ASPECTS OF VTOL ROTORCRAFT: AN EXTENSION OF THE SIKORSKY ASSET CONCEPT DESIGN TRADE STUDY FOR THE UNITED STATES COAST GUARD DEEPWATER PROGRAM

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This thesis develops and uses systems engineering methods for the selection of vertical takeoff and landing (VTOL) rotorcraft for a specified mission. It proposes a general process for performing design trade studies as they apply to the selection of the Medium Range Rotorcraft (MRR) and Ship Based Unmanned Air Vehicle (SUAV) assets that are best suited in fulfilling the United States Coast Guard's Integrated Deepwater System (IDS) Concept of Operation (CONOPS). This thesis defines the phases that encompass a comprehensive trade-off analysis process. This thesis also describes an example of this process as used in the MRR and SUAV asset selection for the Sikorsky Deepwater Phase IA proposal. A method of validating the affordability criteria of the trade study through a derived life cycle cost (LCC) cost estimating relationship (CER) is formulated through the use of multiple variable regression analysis. A method of validating the flight performance criteria of the trade study is proposed using mission profile modeling and simulation (M&S). The Taguchi Method is used to analyze parameter sensitivity effects in the LCC model, and a selection criteria weight factor sensitivity analysis is conducted on the Trade Study Element Matrix.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Trade-off Analysis Process, Deepwater, Cost Estimating Relationship (CER)

UH-60 BLACK HAWK DISTURBANCE REJECTION STUDY FOR HOVER/LOW SPEED HANDLING QUALITIES CRITERIA AND TURBULENCE MODELING

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Helicopters operate in an environment where task performance can easily be affected by atmospheric turbulence. This paper discusses the airborne flight test of the Sikorsky UH-60 Black Hawk helicopter in turbulent conditions to determine disturbance rejection criteria and to develop a low speed turbulence model for helicopter simulation. A simple approach to modeling the aircraft response to turbulence is described by using an identified model of the Black Hawk to extract representative control inputs that replicate the aircraft response to disturbances. This parametric turbulence model is designed to be scaled for varying levels of turbulence and utilized in ground or in-flight simulation. Flight control cutoff frequency data are also analyzed to support design criteria for gust rejection handling qualities.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Low Speed Helicopter Handling Qualities, Turbulence Modeling, Cutoff Frequency, Flight Control Design Requirements

A COMPUTATIONAL AND EXPERIMENTAL INVESTIGATION OF FLAPPING WING PROPULSION

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Flapping-wing propulsion is studied experimentally and numerically. The objective of the research is to provide further insight into the aerodynamics of flapping-wing air vehicles. Experimental work is conducted in the NPS 1.5 m x 1.5 m (5 ft x 5 ft) in-draft wind tunnel. A previously constructed long-span flapping-wing model suspended by cables is used to approximate the two-dimensional nature of the numerical simulation. For this experiment, the model is configured with two wings executing plunge-only motion. Thrust is indirectly determined by using a laser rangefinder to measure streamwise displacement of the model. Results are compared with previous experimental tests. A numerical analysis is conducted using USPOT, a locally developed unsteady panel code that models two independently moving airfoils with three degrees of freedom and non-linear deforming wakes. Thrust and efficiencies are computed for harmonically oscillating airfoils. Direct comparison is made between experimental and numerical thrust measurements.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Flapping Wing, Low Reynolds Number, USPOT, Panel Code, Laser Doppler Velocimetry, LDV

QUALITY FUNCTIONAL DEPLOYMENT AS A CONCEPTUAL AIRCRAFT DESIGN TOOL

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Quality Functional Deployment (QFD) methodology was applied as a possible system integration tool for use during the conceptual configuration design phase of low speed High Altitude Long Endurance (HALE) UAVs. A four-level QFD model was used to identify important design variables and prioritize those that impact customer attributes. The customer attributes were deployed into performance parameters. The performance parameters were deployed into UAV part characteristics. The part characteristics were deployed into manufacturing processes. The manufacturing processes were deployed into process controls. Based on QFD, the research effort showed that to achieve the customer attributes of high endurance, range, cruise altitude and payload, the important performance parameters are low gross weight, low $C_{D,0}$, high $C_{L,max}$ and a low life cycle cost. The part characteristics considered for the conceptual HALE UAV configuration were maximum utilization of composites, thick airfoil (to increase fuel capacity), high wing fatigue strength and low wing sweep. To achieve the part characteristics, the manufacturing methods considered were autoclaving and filament winding for composites components; milling and precision forging were considered for aluminum alloy components. Manufacturing process controls were also identified. In each QFD matrix, the technical correlations “roof” provided an effective mechanism for comparing each design parameter against other design parameters in order to determine conflicting design requirements.

DoD KEY TECHNOLOGY AREA: Other (Aircraft Design)

KEYWORDS: Quality Functional Deployment, Aircraft Design, Uninhabited Aerial Vehicle

FULL NONLINEAR SIMULATION OF HELICOPTER COUPLED ROTOR-FUSELAGE MOTION USING MATLAB® AND DYNAMIC SIMULATION

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This thesis formulates the full nonlinear equations of motion for determining the stability of helicopter coupled rotor-fuselage motion utilizing MATLAB®'s Symbolic Math Toolbox. Using the extended symbolic processor toolbox, the goal of this work was to eliminate the time consuming process of converting Fortran or C code generated by the symbolic processor, MAPLE® into a MATLAB® useable format where it is further incorporated into an 'S-function' to be used in the dynamic simulation environment.

The formulation of the equations of motion utilized in this process is unique in that it uses the complete set of nonlinear terms in the equations of motions without utilizing ordering schemes, small angle assumptions, linearizing techniques, or other simplifying assumptions. After derivation, the equations of motion are numerically integrated using the dynamic simulation software SIMULINK® and a time history plot is generated of blade and fuselage motion. The equations of motion are regenerated with each time step allowing the adjustment of characteristic structural, blade and dampening properties. These time traces can be used to explore the effects of damping nonlinearities, structural nonlinearities, active control, individual blade control, and damper failure on ground resonance.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Modeling and Simulation

KEYWORDS: MATLAB® Symbolic Processor, Helicopter, Ground Resonance, Nonlinear Simulation, Computer Modeling