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Research Article

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Design and Analysis of Unmanned Aerial Vehicles Wing

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Abstract—

Owing to the material differences in the natural and engineered systems, the design of a biological-inspired aircraft possesses considerable challenges to the aircraft designer. The birds employ a structure of hollow bones, flexible joints and muscles, and feathers to morph their wings to suit the desired flight condition. While the aircrafts use the rigid joints and structures to sustain the aerodynamic loading. With this underlying difference between the two systems and the aim of this research work being to understand the aerodynamic benefits of morphing wings, it is not desired to exactly emulate the bird wing kinematics. Rather, the objective is to devise a mechanism to emulate the bird wing shapes and aspect ratios for quasi-steady aerodynamic analysis using computational and experimental setups. In this project, we propose mechanisms to continuously morph a wing from a lower aspect ratio to a higher and to further extremities of a gull and an inverted-gull configuration. The mechanism comprises of a linear actuator for the extension of the wing and the servo motors to obtain the gull and inverted gull configurations. The design process includes conceptual sketch of wing structure followed by detailed design with suitable constraints and design of 3D model in SOLIDWORKS. It is then imported to ANSYS for computing impact of loads occurring due to combined operation of servo motors and actuators.

Keywords— morphing, gull configuration, invert gull configuration** [1], **aspect ratio, mechanism, actuators.

I. INTRODUCTION

Aircraft systems are continually evolving to expand their capabilities and mission effectiveness. Some of the missions which are now being conceived include short distance surveillance, local target acquisition, biological agent detection and operation within an urban environment. Two evolutions which are particularly relevant to these missions *[2]* are the design of micro air vehicles (MAV) and the design of morphing structures. The concept of morphing is generally envisioned as changing, potentially dramatically, the shape and structure of an aircraft in a manner somewhat analogous to variations seen by birds and insects. The adoption of morphing *[3]* is generally being considered for fighter size aircraft and small- size or medium-size unpiloted air vehicles (UAV).Theoretically studies clearly indicate an increase in metrics, such as agility and lift-to-drag ratio, proportional to the amount of morphing; however, actuation mechanisms do not exist to achieve the desired morphing for these vehicles. Similarly, micro air vehicles are being designed *[4]* along sizes and scales observed in biological systems. A MAV is essentially a flight vehicle with small wing span, less than 6 inches for a recent DARPA project, that may encompass traditional fixed–wing and rotary-wing designs along with flapping wing designs. Flight tests have demonstrated mission capability; however insufficient control authority often limits maneuvering performance.

II. SCOPE OF THE PROJECT

Unmanned Aerial Vehicles (UAVs) are unpiloted aircraft that are utilized mainly in intelligence, surveillance, reconnaissance and target acquisition missions where human life could be at risk. These UAVs *[5]* can be remotely controlled or can fly autonomously based on pre-programmed flight plans. Since UAVs are not limited by human pilots' physiological necessities or fatigue, they can be designed for maximized on-station times. Therefore, high endurance UAVs are very popular. This type of aircraft requires excellent loiter capabilities in order to achieve flight durations over 24 hrs. As a result of their widespread popularity, this paper mainly deals with endurance UAVs. In order to improve performance of these aircraft it is necessary to develop structures that can optimize each flight phase. Therefore, this thesis project focuses on the development of actuated structures applied to morphing wing design for UAVs.

III. DESIGN REQUIREMENTS

The primary hindrance is the structural and vibration considerations due to the unsteady nature of the airflow during the flight. The preliminary construction was tested in the low speed subsonic wind tunnel and as such based upon the tunnel dimension (width – 36 inches, height – 24 inches and length – 72 inches) the maximum semi-wingspan of the wing was limited to 30 inches to avoid the wall effects of the wind tunnel. The outer wing thus measures up to 20 inches and the inner (telescopic/extendible wing) measures 10 inches span wise. Thus the wing would span 40 inches for the first case of un-extended configuration and would approximately span 60 inches for the extended configuration. The wing loading for model aircrafts of this size is typically about 18 - 24 oz/sq. ft. A value of 20 oz/sq. ft. is assumed initially for design consideration.

IV. WING DESIGN CONSIDERATIONS

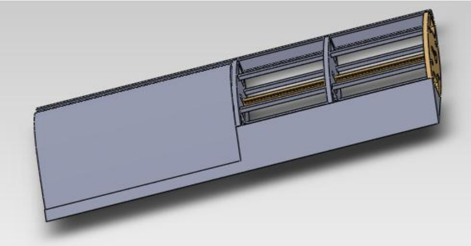
From an aerodynamics perspective, the overall shape of the wing is the most important design parameter for an aircraft. When a specific type of mission is required, there is usually an ideal configuration [6] of the aircraft to accomplish it. Therefore, an aircraft's performance is greatly improved with the addition of morphing elements that allow it to achieve that ideal configuration for various flight *[7]* conditions and missions. The effect of changes in wing geometric parameters was summarized by Jha and Kudva as:

- Increasing the Wing Plan Area and the Wing [8] Aspect Ratio increases lift, L/D ratio, loiter time, cruise distance, turn rates, load factor capability and parasitic drag, while decreasing engine requirements and maximum speed.
- Increasing the Wing Dihedral, increases rolling moment capability and lateral stability, while decreases maximum speed.
- Increasing the Wing Sweep, increases the critical Mach number and dihedral effect, while decreasing high-speed drag and maximum coefficient of lift.
- Altering the Wing Taper Ratio affects the span-wise lift distribution.
- Altering the Wing Twist Distribution [9] prevents tip stall behavior.
- Altering the Airfoil Camber affects the zero-lift angle of attack, the airfoil efficiency and the separation behavior.
- Increasing the Airfoil Thickness/Chord Ratio and the Leading Edge Radius improves the low-speed airfoil performance [8] but worsens the high-speed airfoil performance.

Parts are to be designed name as

- Ribs
- Spars
- C-clamp
- Rack base
- Leading edge
- Trailing edge
- Extension wing support
- Extension wing
- Rod

V. ASSEMBLY



VI. ANALYSIS

The material selection for the UAV was derived from an analysis of various materials. The materials that focus on were Aluminum, Carbon epoxy and Steel. Both materials are extremely popular in Aircraft industry due to their suitable qualities. Aluminum is an abundant low cost material, with characteristics that make it perfect for our UAV construction. It is a versatile material with super corrosion resistance, good formability, flexibility, and strength *[10]* Composites are often overlooked when cost is an important consideration. However, with such advanced characteristics, including great fatigue resistance, good damping characteristics, and very light weight they came out on top for best performance. In some cases this performance resulted in an actual cost saving. Analysis is performed on both un-extended and extended wing and the results are comparing with previous results.

VII. RESULTS

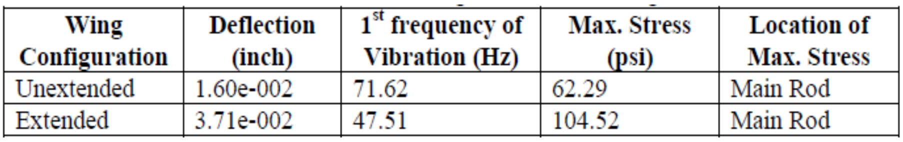
Table: Un-extended Wing Configuration

MATERIAL	FREQUENCY	DEFLECTION (inch)
Aluminium	0-80HZ	0.0013364
Carbon fiber	0-80HZ	0.00095138

Table: Extended Wing Configuration

MATERIAL	FREQUENCY	DEFLECTION (inch)
Aluminium	0-80HZ	0.0043139
Carbon fiber	0-80HZ	0.0029039

Previous Results:



Wing Configuration	Deflection (inch)	1st frequency of Vibration (Hz)	Max. Stress (psi)	Location of Max. Stress
Unextended	1.60e-002	71.62	62.29	Main Rod
Extended	3.71e-002	47.51	104.52	Main Rod

VIII. CONCLUSIONS

The main objective of the project was to design and analyse a morphing structure with applications to morphing wing design for endurance of UAVs. In order to improve energy efficiency, flight control and mission control, concepts for morphing aircraft must be developed. Quite a number of concepts have been generated, many of which are too complex to be implemented in the near future. Most of these concepts employ multiple degrees of freedom and have proven to be too bulky or too difficult to control.

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