INVESTIGATION & SIMULATION OF BIRD FLIGHT KINEMATICS & DYNAMICS

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Abstract

Birds use a simple technique to get airborne. However, mankind is still not capable of using this simple technique successfully in any applications. In this project, it has been investigated about bird flight kinematics with respect to the different flying patterns of birds, with the intension of developing a mechanism for human applications which uses such kinematics. Motions of bird wing skeleton were examined and analysed using computer software. Virtual simulations of wing patterns were also done. In addition, an innovative simulation method has been developed to acquire flapping motion by manipulation of aerodynamic forces exerted, which has minimised the number of prime movers on board.

1. Introduction

Bird flight is commonly seen everywhere in the world. Man has used nature's solutions as inspirations to resolve his problems, but so far mankind is not able to use bird flight kinematics to get airborne instead of propeller and jet propulsion. Birds can fly following an accurate path in sub sonic speeds. Although a bird has 6 Degrees of Freedoms (DOF) in flight, manoeuvring requires control of lesser number of parameters than aircrafts. (1), (2), (3). Another very important aspect of bird flight is the capability of hovering. Therefore, it is clear that nature's solution to flying is far superior to manmade flight. Weight of the prime mover has created a great burden for imitating this kinematics up to date. Due to the low power to weight ratios of electrical motors and other actuators, previous researches has been limited only to the first biological linkage of birds' wing. But the addition of the second linkage would increase the efficiency of the wing by 25%. The third linkage or the hand of the bird's wing contributes towards the precision of following the intended path (4), (5), (6), (7). A birds' wing has six rotational DOFs but in previous researches, it has been simplified to one rotational DOF (8). However, this simplification has deviated intended flight from actual bird flight kinematics.

2. Methodology

2.1 Literature Survey

A comprehensive literature survey was performed thoroughly due to the breadth of the subject. The project itself carried out the studies on bird anatomy, mathematical modelling, aerodynamics of flapping motion, mechanical simulations, motor controlling, etc through various literature sources such as previous research, patents, video libraries, world wide web, etc.

2.2 Motion study

Wings of a bird, their functionality & their movements are one of the most sophisticated areas in the fields of aerodynamics. Different flying patterns were identified & categorised. The literature survey was the basis for simulating five wing motion patterns such as flapping, feathering, gliding, take-off and landing.

2.3 Conceptual designs

In an ideal model there should be 3 linkages in a wing and the two wings should work independently from each other along with the tail, especially when rolling or yawing the body in air. In this project scope was simplified to 2 linkage mechanism. It was evident that without trying to achieve control over wings independently, combining the wings to achieve a symmetrical wing pattern will cut down the number of motors required in half; thus bringing down the weight, but still leaving the ability of manoeuvre the bird using its tail. Several designs were developed and analysed with computer software.

2.4 Experiment on Fluid Dynamic Torque Exerted On the Flapping Axis of a Flapping Wing

An experiment was carried out to measure the torque exerted on the flapping axis of the flapping wing. Objective of the experiment was to find out the torque requirements of different flapping mechanisms and verify the results obtained by computational analysis and theoretical calculations. The basic principle of the experiment was the counter torque is exerted to the stator in opposite direction when the motor is rotating.

2.4 Computational Analysis

Computational analysis was used to verify the design calculations, fluid dynamic calculations, verified experimental results, and to avoid non critical complex cumbersome calculations. Design iterations were done with the results of these calculations. Computational analysis was carried out in Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD) analysis and kinematics analysis. *See Figure 1*

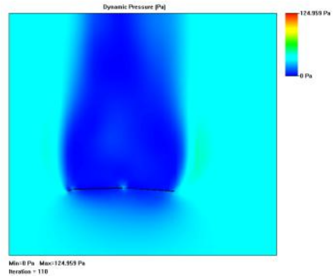

Figure 1-Pressure distribution analysis using COSMOSFloworks (*Original is in colour*)

2.4 Implementation

The manufacturing methods and techniques were highly concerned with respect to the implementation which should be used to manufacture the wing simulating mechanism with the desired conditions using the state of art technology. The design was fabricated with light weight materials with the required rigidity in order to cater the power to weight ratio of the design. Therefore Aluminium (Al) and plastics were used in the flapping wing design.

3. Results and Discussions

3.1 Computer simulations

Throughout this project computer simulations were heavily used. SolidWorks, COSMOSWorks, COSMOSFloworks software packages and Pro Engineer software package along with Animation application extension were used for computer simulations. At the studying stages of the project, computer simulations were used as studying tool. It was used to visualize and understand complex movements made by bird's wing. Kinematics modelled through these software packages were released as an outcome as well as a future guideline to the project.

3.2 Flapping wing simulating device

The flapping wing simulating model is capable of providing 3 DOF around the shoulder joint which are flapping around the shoulder, tilting around the shoulder, flapping the second link of the wing around the shoulder. A crank mechanism is used to get the desired motion profile while mechanizing the first link by means of a motor while the movement of the second link and tilting is accomplished by aerodynamic forces exerted on the wing. *See Figure 2*

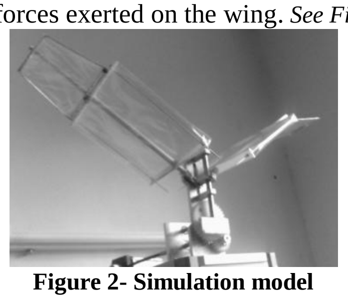

Figure 2- Simulation model

3.3 Discussion

In this project, Professor De Laurier's theory of calculating forces in a flapping wing has been referred for the calculations (4). The theory has contained 19 parameters and the parameters were set accordingly to suit the considered conditions. The basic movement of the birds' wing is the flapping. As this flapping motion is an oscillatory motion there are many different ways of imitating such motion. Previous attempts of simulating bird flight kinematics were limited to simulation of arm with twisting of the wing from the shoulder was overlooked. Therefore existing devices have only one DOF at the whole skeleton. All the previous attempts to simulate bird flight kinematics have been following the intension of mechanising a wing. This has created a barrier for further development in the field of Ornithopters as the development of low weight actuators is not up to the demand of the field. However in this project, methods for simulating of such kinematics were concerned without being limited to simulate using motor and such prime movers. This broader view of investigation has lead for a very innovative concept of manipulating of aerodynamic forces to obtain the desired motions. A novel concept is introduced and proven by the project. In this project two biological linkages with altogether 3 DOFs at 2 joints were successfully simulated. With this step forward in this field, this project has created a milestone in the history of Ornithopters; flapping wing aero vehicles. The project unveils a basis and a background for future work subsequently in this area together with the state of art technology with a scientific insight. Therefore with this favourable conclusion it is expected to continue the project in subsequent stages in coming years in order to achieve that ultimate goal to build a bird flying device which will be useful in explorations, scientific expeditions, rescue missions & surveillance.

References

1. *Modeling of bird flight animations using aerodynamics.* **Chaojiang ZHU, Kazunobu MURAOKA, Takeyuki KAWABATA, Can CAO, Tadahiro FUJIMOTO and Norishige CHIBA.** No.1 pp.1-10, s.l. : Tohoku Institute of Technology, Iwate University, Vol. Vol.5 .

2. **Kermode, A C.** *Mechanics of Flight* . s.l. : Longman Group UK Ltd., 1987. ISBN 0-582-42254-X.

3. *Bird Maneuvering Flight: Blurred Bodies, Clear Heads.* **D. R. WARRICK, M. W. BUNDLE, AND K. P. DIAL Department of Biology, Minot State University, Minot, North Dakota.** 42:141–148, s.l. : Intergrative & Comparative Biology, 2002. 59812.

4. *An Aerodynamic Model for Flapping-Wing Flight.* **DeLaurier, Professor James.** s.l. : Royal Aeronautical Society, April 1993.

5. *Flapping-wing flight in bird-sized UAVs for the ROBUR project: from an evolutionary optimization to a real flapping-wing mechanism.* **Emmanuel de Margerie, Jean-Baptiste Mouret,St´ephane Doncieux, Jean-Arcady Meyer.** Toulouse, France : s.n., 2007. Conference and Flight Competition (EMAV2007),. pp. 1 - 9.

6. **Tehran, Advanced Dynamic &Control Systems Laboratory (ADCSL) of school of Mechanical Engineering of University of.** Micro Aero vehicles. 2007.

7. **Wikimedia Foundation, Inc.** Ornithopters. *Wikipedia, the free encyclopedia.* [Online] Wikipedia®. [Cited: 28 06 2007.] http://en.wikipedia.org/wiki/Ornithopters.

8. *Realistic Modeling of Bird Flight Animations.* **Popovi´c, Jia-chi Wu Zoran.** s.l. : SIGGRAPH, 2003.