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Design and Development of a Nature-Inspired Bird Flapping Mechanism

Moiz Shaikh[1], Nikhil Nikam[2], Tushar Tuse[3], Saurab Nigal[4], Om Nagre[5]

[1]Assistant Professor of Department of Mechanical, Santosh N Darade Polytechnic, Yeola
[2]Student of Department of Mechanical, Santosh N Darade Polytechnic, Yeola
[3]Student of Department of Mechanical, Santosh N Darade Polytechnic, Yeola
[4] Student of Department of Mechanical, Santosh N Darade Polytechnic, Yeola
[5]Student of Department of Mechanical, Santosh N Darade Polytechnic, Yeola

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Abstract - Bird flight is one of the most efficient natural motions, where lift and thrust are generated simultaneously through wing flapping. This paper presents the design and development of a **nature-inspired bird flapping mechanism** developed as a student research project. The main objective is to convert rotary motion from an electric motor into synchronized oscillatory motion of wings using a simple mechanical linkage system. The mechanism emphasises simplicity, low cost, and ease of fabrication while demonstrating fundamental concepts of engineering mechanics, applied physics, and engineering mathematics. Logical design considerations such as symmetric linkage arrangement, torque-based motor selection, and controlled flapping amplitude ensure smooth and stable operation. Experimental observations confirm uniform wing motion, making the system suitable for educational demonstrations and preliminary research on flapping wings.

Key Words: *Bird flapping mechanism, Nature-inspired design, Ornithopter, Linkage mechanism, Mechanical motion.*

1. INTRODUCTION

Nature has always guided engineering innovation by providing efficient and optimised motion systems. Among these, bird flight is a remarkable example where wings perform a continuous flapping motion to generate lift and thrust simultaneously. Unlike conventional fixed-wing aircraft, birds can take off in limited space, manoeuvre easily, and adapt their motion dynamically.

Inspired by this natural principle, engineers have explored flapping-wing mechanisms, commonly known as ornithopters. However, many existing designs involve complex aerodynamics and electronic control systems, making them unsuitable for diploma-level learning. This research focuses on developing a **simple mechanical bird flapping mechanism** that demonstrates natural wing motion using basic engineering principles.

2. LITERATURE REVIEW

Previous studies on flapping mechanisms include crank-rocker systems, slider-crank arrangements, and cam-based mechanisms. Researchers have emphasized that symmetric wing motion reduces vibration and improves stability. Lightweight materials and simple kinematic chains are preferred for academic prototypes. The present work adopts a purely mechanical linkage-based approach to minimize complexity while retaining effective flapping motion.

3. PROBLEM STATEMENT AND OBJECTIVES

3.1 Problem Statement

To design and fabricate a mechanically simple, economical, and reliable bird flapping mechanism that demonstrates natural wing motion using fundamental engineering concepts.

3.2 Objectives

- To convert rotary motion into oscillatory wing motion
- To achieve symmetric flapping of both wings
- To apply diploma-level concepts of physics and mathematics
- To develop a working prototype suitable for academic research

Fig -1: Electrical-to-Oscillatory Energy Conversion

4. DESIGN LOGIC AND METHODOLOGY

4.1 Design Logic

The mechanism is based on three important engineering principles:

Symmetry: Equal link lengths on both sides ensure balanced motion and reduced vibration.

Controlled Motion: Proper selection of link length and pivot location controls flapping amplitude.

Efficient Force Transmission: Gear-driven motion increases torque and prevents motor stalling.

4.2 Methodology

A DC geared motor provides rotary motion, which is transmitted through a spur gear to a crank-link mechanism. The linkage converts rotary motion into oscillatory motion, producing synchronized wing flapping.

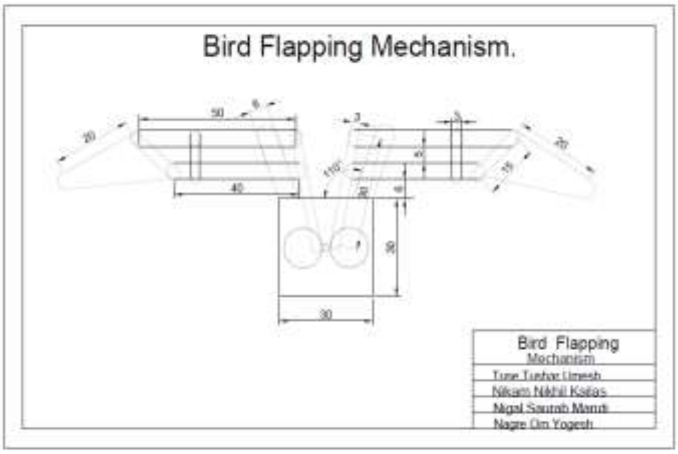

Fig -2: Assembly Drawing

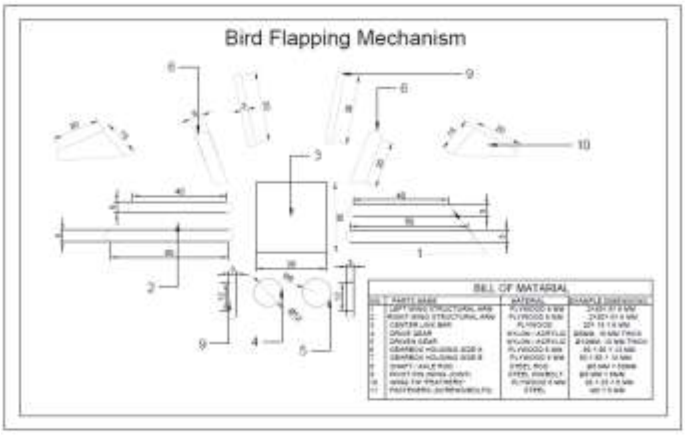

Fig -3: Detail Drawing

5. WORKING PRINCIPLE

When the motor rotates, the spur gear transfers motion to the crank. The crank moves the connecting link, converting rotary motion into oscillatory motion. This oscillation causes the wing arms to move upward and downward, creating flapping motion. A mirrored linkage arrangement ensures both wings flap simultaneously and symmetrically.

6. APPLIED PHYSICS CONCEPTS

6.1 Rotational Motion

Angular velocity of the motor is given by:

$$\omega = \frac{2\pi N}{60}$$

For motor speed N=300N RPM:

$$\omega = 31.4\, rad/s$$

6.2 Oscillatory Motion

The wing motion is periodic and resembles simple oscillatory motion similar to simple harmonic motion.

7. ENGINEERING MATHEMATICS CONCEPTS

7.1 Angular Displacement

$$\theta = \omega t$$

7.2 Linear Velocity of Wing Tip

$$\vartheta = r\omega$$

Engineering Insight:
Increasing wing length increases linear displacement but also increases torque requirement on the motor.

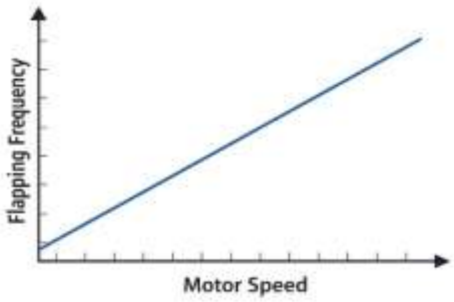

Chart 1: Motor Speed vs Flapping Frequency

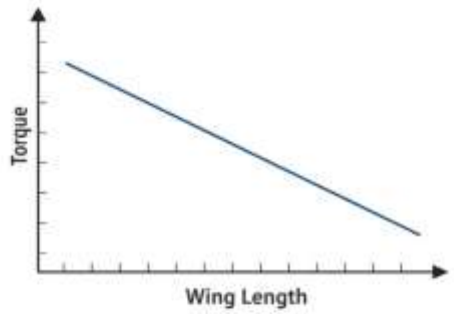

Chart 2: Wing Length vs Required Torque

8. RESULTS AND DISCUSSION

The fabricated prototype demonstrated smooth and continuous flapping motion. Symmetric wing movement minimized vibration and mechanical stress. Flapping amplitude was controlled by linkage geometry and motor speed. The observed results validate the design logic and confirm effective conversion of rotary motion into oscillatory motion.

9. LIMITATIONS

- No aerodynamic lift generation
- No active electronic control system
- Vibration at higher motor speeds

10. FUTURE SCOPE

Future improvements may include lightweight wings, aerodynamic profiling, electronic speed control, flexible wing materials, and sensor-based control systems for advanced flapping-wing research.

11. CONCLUSIONS

This research successfully demonstrates that natural wing motion can be replicated using simple mechanical logic. The bird flapping mechanism integrates engineering mechanics, applied physics, and mathematics effectively. Its simplicity, low cost, and educational value make it highly suitable for diploma-level student research and laboratory applications.

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