Design and Analysis of Flapping Wing Micro Aerial Vehicle using Magnetic Levitation Technique

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Abstract: *This research approaches the design and analysis of micro aerial vehicle with flapping wing mechanism by using magnetic levitation technique. Insects flight has created wide impacts in aerospace engineering due to its aerodynamic structure, flight control, endurance and efficiency. In the direction of understanding the effects and abilities of insects, it is quite challenging to study the shape, frequency and amplitude of the wing. Intending to obtain insect's capabilities like flapping amplitude, frequency and flight control, the Maglev technique is introduced. However, incorporating the Maglev technique into the flapping wing remains a challenge both in tethered-flight as well as in free flight condition. After a long experimental investigation NACA 23012 airfoil was chosen to design the wing in order to produce the reasonable thrust, lift and propulsive efficiency. The entire design work was carried over in Catia software and the final design was analyzed in ANSYS-Fluent for comparison. With the reference of all the analysis, this research has attained the net force and flapping frequency which is required to lift 600 grams aerodynamically designed object.*

Key Words: *MAGLEV, flapping wing, endurance, spur gear*

1. INTRODUCTION

Since the last decade, unmanned aerial vehicles have become an increasingly attractive option in many applications. Continuous research on micro aerial vehicle and unmanned aerial vehicle leads to understanding the aerodynamic structures and helps to analyze the

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design parameters of small scaled vehicle. Miniaturization offers exciting new options that cannot be possible with larger aircraft. MAV (Micro Aerial Vehicle-Used for Military Surveillances) using flapping wing technology offers the valuable properties when compared to the other flight style with minimum negative properties. Flying animal's observation suggests that even at very small sizes, extremely complex and specific maneuvers are possible with flapping wings. If an MAV would achieve the flight techniques utilized by flying animals, various new missions that are not yet available would become possible when compared to the rotorcraft and fixed wing, flapping wing has a favorable scaling that is an important benefit. With increased flapping frequency, flight becomes possible even with very small wings. Premature works on fluid flow, its performance, and active flow control have been studied [1]. Researchers at U. C. Berkeley obtained fabulous progress in making use of parallel mechanisms and piezoelectric actuators in biologically-designed wing flights [2], [3], [4]. MAVs have a tremendous role in many fields, particularly in military, air force and civilian areas. Previous studies showed that at low Reynolds numbers FMAVs (Flapping Micro Aerial Vehicles) have better aerodynamic characteristics than fixed-wing or rotor-wing aircraft for insect-size or bird-size aircraft [5], [6].

The concepts of a magnetic dipole and its interaction with an external magnetic field, torque on a magnetic dipole, magnetic flip and polarity of magnetic dipole have been studied [7]. To rise the aerodynamic stability with unsteady forces and moment, we can use flexible wing. More lift can be generated by using flapping wing technology [8].

To improve the fuel efficiency, we propose using a wing that has variations in its shape through flight to minimize the total mission drag. The wing morphing concept will give better results [9]. Designing the wing of MAV is more complicated and analyzing aerodynamic parameters is also tough. The lift and thrust can be generated by wing flapping so that MAV can be propelled through the air [10-12].

Aerodynamic load causes significant deformation of the wings, resulting in a large lifting surface. The main aim of this paper is to design and analyze a magnetic levitated flappable wing which has high performance and to find out the lifting capability of MAV. The overall process of this paper is as shown in Fig. 1

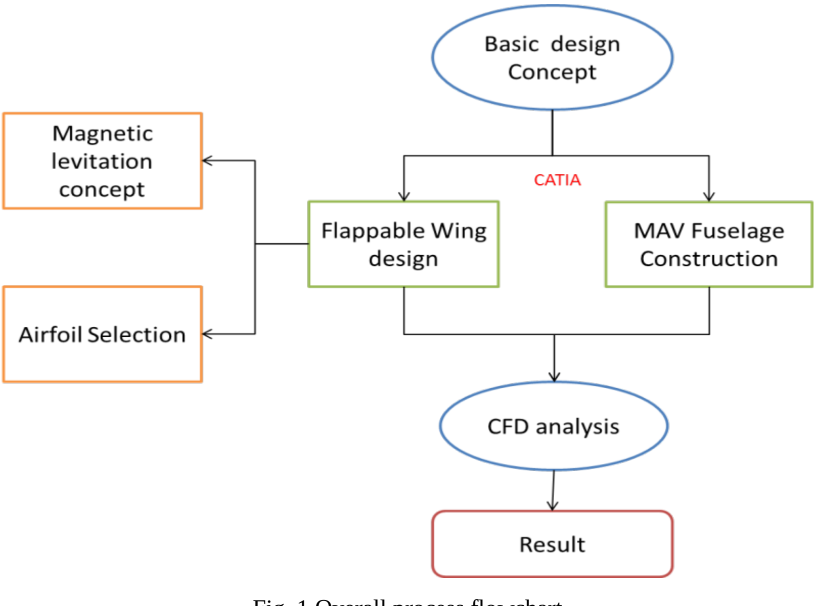

Fig. 1 Overall process flowchart

2. METHODOLOGY

2.1 Magnetic Levitation

It is a method in which the physical stuff of two magnetic bodies and the force produced between the two is keenly noticed, then the produced force is utilized for flapping technology.

To counterpoise the gravitational pull, here we can use the magnetic force and no contact interruption between a magnetic body and a fixed guide way may be obtained. Magnetic levitation is similar to magnetic interruption and it is used to swing (or levitate) vehicles.

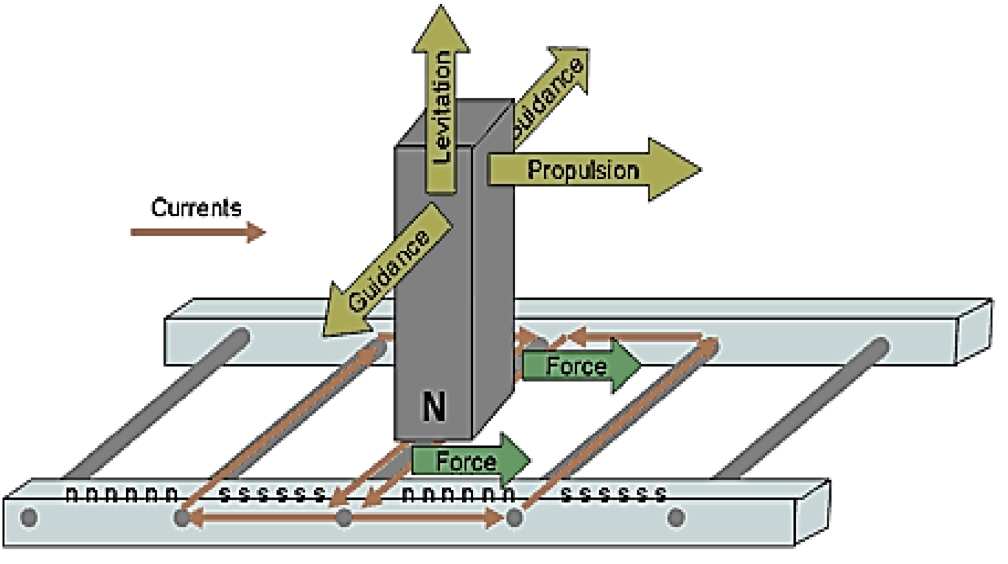

Fig. 2 Magnetic Levitation concept

In recent designs, magnetic forces are recommended to perform all three purposes while a nonmagnetic foundation of force might be used. No consensus exists on an optimum design to perform each of the functions. Fig. 2 portrays three primary functions of Maglev technology:

(1) Flying or suspension;
(2) Force
(3) Guidance.

2.2 Design of the MAV

The mechanism used to flap the wings used to propel the vehicle is designed in CATIA V5 tool and analyzed to determine the load acting on the wing during upstroke and down stroke. The design of all the components which are used in Maglev MAV is listed below.

3. FLAPPABLE WING MECHANISM

A simple 2D layout of the mechanism is shown in the figure below mentioning the dimensions. The airfoil used for the wing is NACA 23012. The MAV step by step design is shown in figures below.

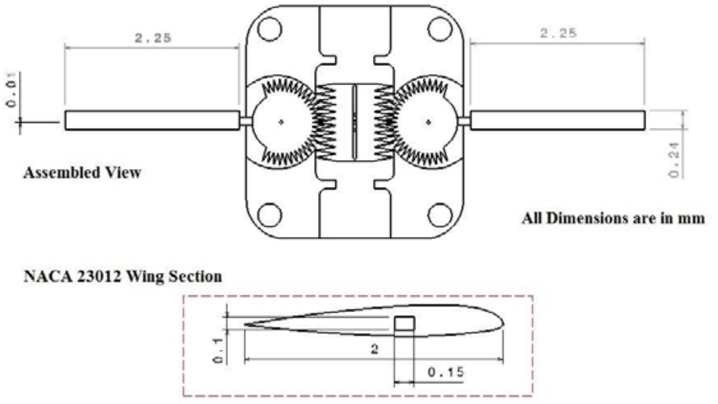

Fig. 3 Mav mechanism and airfoil

The magnet is attached with M.S rack (Mild Steel rack) to convert the linear motion of the magnet into angular motion. NdFeB (Neodymium Iron Boron) magnet is designed in the required dimension to work the mechanism. This kind of magnet is self-possessed with unusual earth magnetic material, and it has a high coercive force. It has a tremendously high energy creation range, up to 50 MGOe (Mega Gauss-Oersted). Due to high product energy level of Neodymium Iron Boron magnet, small and compact size can usually be produced. NdFeB magnets have low mechanical strength, tend to be brittle, and low corrosion resistance if it is left uncoated. It can be used in many applications if it is treated with gold, iron and nickel plating. It is a very powerful magnet and it is very hard to demagnetize.

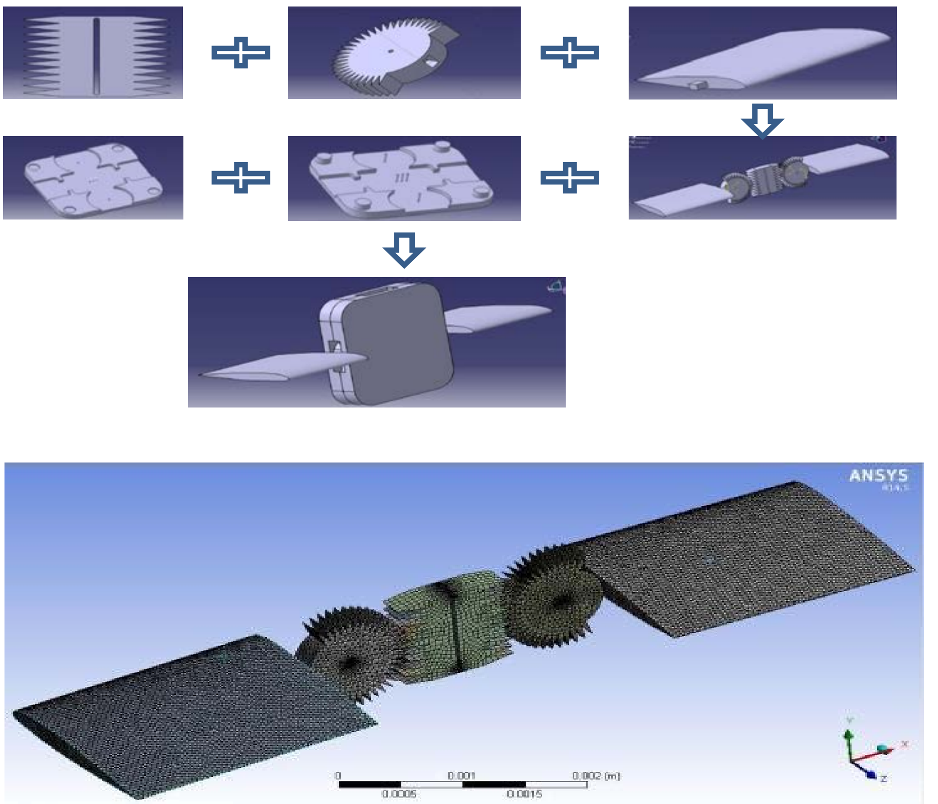

Fig. 4 Assembled parts of Mav

Spur gear is used to flapping mechanism, which is the most common type of gear and it is easy to design.

The general form of spur gear is a cylinder or disk. The teeth of this gear are project outward radially, and with these “straight cut gears”. The model of spur gear is shown in figure 4.

4. NUMERICAL SIMULATION

4.1 Grid generation

The designed MAV has been analyzed with the help of ANSYS Fluent software. Before the analysis, the grid has to be generated over the MAV, because the quality of the grid determines the accuracy of the results. For all the 3D components the mesh is generated using tetrahedron elements. The meshed components are listed below.

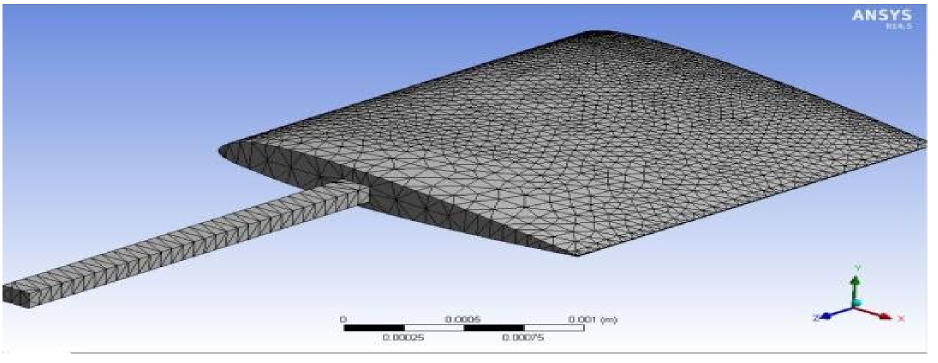

Fig. 5 Meshing image of MAV

Only the wing component alone was considered for analysis to estimate the payload that can be lifted by the MAV. Before starting the analysis the flapping speed of wing is assumed to be 100Hz. This frequency is used for all types of analysis.

Three types of flow field analysis are carried out to find the net flapping analysis. The three types are given below

- Horizontal flow field with free stream velocity of 5 m/s.
- Vertical upward direction flow field of velocity 0.2 m/s.
- Vertical downward direction flow field of velocity 0.2 m/s. l

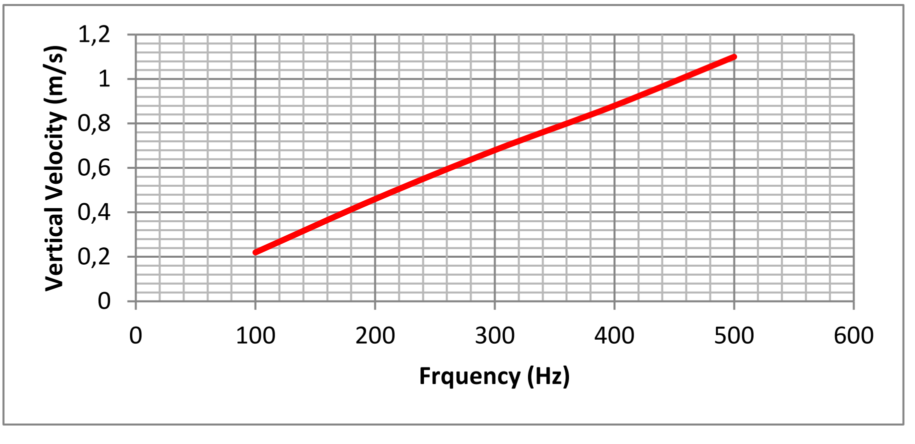

Fig. 6 Frequency Vs Vertical Velocity

The above Figure 6 shows the relation between the vertical velocity of the flapping wing to given frequency of MAV.

4.2 Boundary Conditions

In CFD, the boundary conditions play a vital role, because it includes the type of flow field and environmental conditions. PIESO solver is used to predict the flow performance over the wing. For this analysis the flow input is given as steady laminar inviscid flow without temperature effects and wall temperature as 300 K. The flow velocity in X-axis is 22 m/s and Y-axis as 5 m/s.

5. RESULTS & DISCUSSIONS

5.1 Vertical flow upward direction

The static pressure variation contour for vertical flow field on wing surface is shown in Fig. 7 below. The maximum obtained pressure on the upper wing surface is 1.95 Pa and the minimum obtained static pressure is -1.30 Pa on the lower surface in the reverse direction. As we can be seen in Fig. 8 the maximum pressure force on the wing surface is -1.004 N and the net force is -1.09 N, both in the reverse direction.

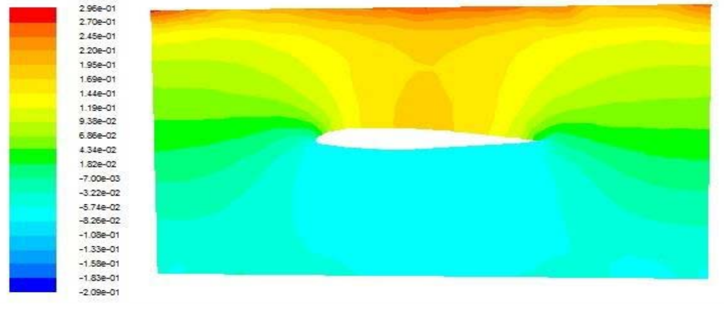

Fig. 7 Static Pressure variation contour

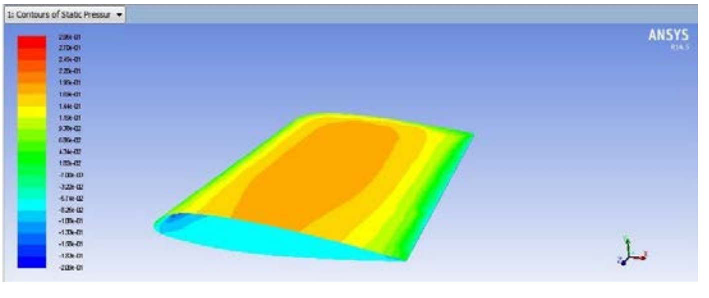

Fig. 8 Static Pressure Flow contour

5.2 Vertical flow downward direction

Vertical flow downward direction of flow velocity 0.22 m/s is applied for this analysis. The static pressure variation for vertical flow field on the wing surface is shown in Fig. 9. The minimum obtained pressure on the upper wing surface is -1.10 Pa in the reverse direction and the maximum obtained static pressure is 1.92 Pa on the lower surface.

From the flow contour, the maximum pressure force on the wing surface is 1.004 N and the net force is 1.09 N.

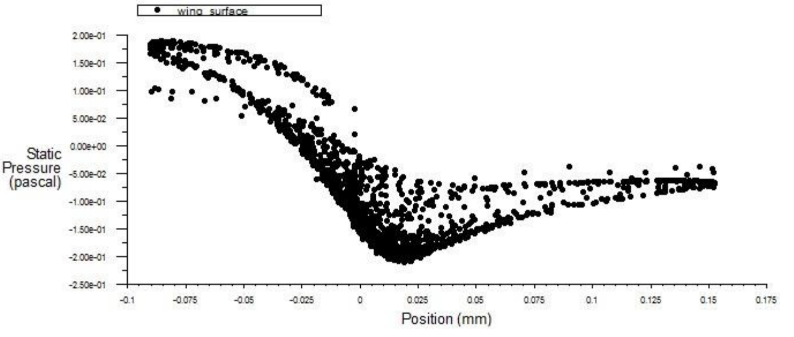

Fig. 9 Static Pressure variation for Vertical flow downward direction

5.3 Horizontal flow field

Horizontal flow direction of flow velocity 5m/s is applied for this analysis. The static pressure variation contour for horizontal flow field on wing surface is shown in Fig. 10. The maximum obtained pressure on the wing surface is 8.04 Pa and the minimum obtained static pressure is -4.53 Pa on the wing surface in the reverse direction.

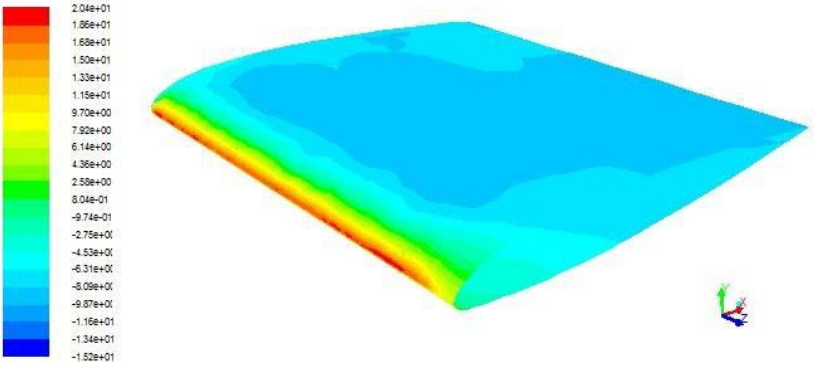

Fig. 10 Static Pressure variation for Horizontal flow direction

From all the three analysis it is easy to find the net force acting on this flapping wing surface. Due to 100 Hz frequency flapping of the wing the maximum lift produced is 6.786 N. It indicates that this model can lift up to 690grams for 100 Hz frequency flapping. If flapping speed increases the weight carrying ability will increase.

6. CONCLUSIONS

The flapping mechanism of the MAV is an important component of the complete system and is largely answerable for flight characteristics. Appropriate design of the flapping mechanism needs a detailed understanding of the forces produced by the wing flapping motion. The magnetic levitated concept is included in the flappable wing mechanism. It reduces the weight and increases the performance of MAV. The overall MAV was designed by using suitable modeling software. Finally, the wing was analyzed with the help of fluent software and the flow performance was also investigated. Due to 100 Hz frequency flapping of the wing the maximum lift produced is 6.786 N. It indicates that this model can lift up to 690grams for 100 Hz frequency flapping. If flapping speed increases the weight carrying ability will increase.

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