GOAL: Design of a new and unique flapping wing mechanism with improved performances

CURRENT MECHANISM: Patented design, differential with complex control required, rust problem, limited angle of flapping, cable management required in rotation

REQUIREMENTS: Flapping of 180° with a frequency of 2Hz, main rotation with a frequency of 0.25Hz, change of angle of attack with a frequency of 1Hz, small size, waterproof, stable, accurate, engines away from water, decoupled motions for easier control implementation

THE MECHANISM
• 3 degrees of freedom
• Stainless steel 3D printing
• Functional under-water
• Outer casing for torque transmission
• Bevel gears for flapping motion (a)
• Innovative spherical gears, for change of angle of attack (b)

STRUCTURE
The main structural characteristics are rigidity and guidance. Four plates (2) are added to the initial structure (1) in order keep the motors, which drive the mechanical transmission through the use of belts and pulleys (3), at rest and away from the water tank (5), while guiding the tubes and inner shaft with ball bearings. The 8mm inner shaft, and the outer tubes with diameters of 12mm and 20 mm (4), actuate the mechanism (6), and allow for three degrees of freedom motions (roll, pitch and yaw respectively). A fourth tube, which is not rotating, has been added to avoid Magnus effect.

A GREAT IDEA: THE SPHERICAL GEAR
• Constant (cross-sectional) number of teeth
• Constant gear ratio of 1
• Spherical shape: modulus at any point function of initial radius, angle and number of teeth:
\[ m(r_0, \theta) = \frac{2R_0 \cos \theta}{z_0} \]

CASING
• Keep the whole mechanism in one part
• Used for torque transmission
• Sphere-shaped to avoid flow separation
• 3D printed in nylon using laser

ACTUATION
• 3 powerful 48V motors
• T2.5 pulleys and belts
• Tensioning pulleys for well driven movement

FURTHER DEVELOPMENTS
• Implementation of a load cell
• Automatic motion
• Industrialize production process
• Patent the mechanism

STATIC AND MODAL ANALYSIS BY FINITE ELEMENTS METHOD
The structure is clamped and subject to maximum lift force of 3.5N, and drag force of 2.1N :
• Assembly well below plastic domain
• Maximum displacement under load of 0.006mm
• First mode at 70Hz, 35 times greater than working frequency

CONCLUSION
• Main goals reached
• Innovative design
• Demonstrating 3D printing power
• Great team work