Aerodynamics and control of next generation electric rotorcraft

Hyper Q Aerospace is driving a disruptive change in the understanding of helicopter aerodynamics and its implementation through the development of a hybrid electric rotorcraft.

This aircraft will use electric axial flux motors to rotate the rotorhead and attached rotor blades. The configuration will eliminate the need for gearboxes, transmissions and drive shafts as they currently exist in conventional helicopter design. Using an electric drive will offer a far more responsive RPM control of the rotorhead.

The rotorcraft will use small servomotors to replace the helicopter swashplate. This project will allow the functionality of a helicopter swashplate to be broken apart so that the properties of blade pitch angle control and rate of change of blade pitch angle become independent.

This project will enable Hyper Q Aerospace to build potentially the fastest helicopter style rotorcraft in the world.

<u>Configuration</u>

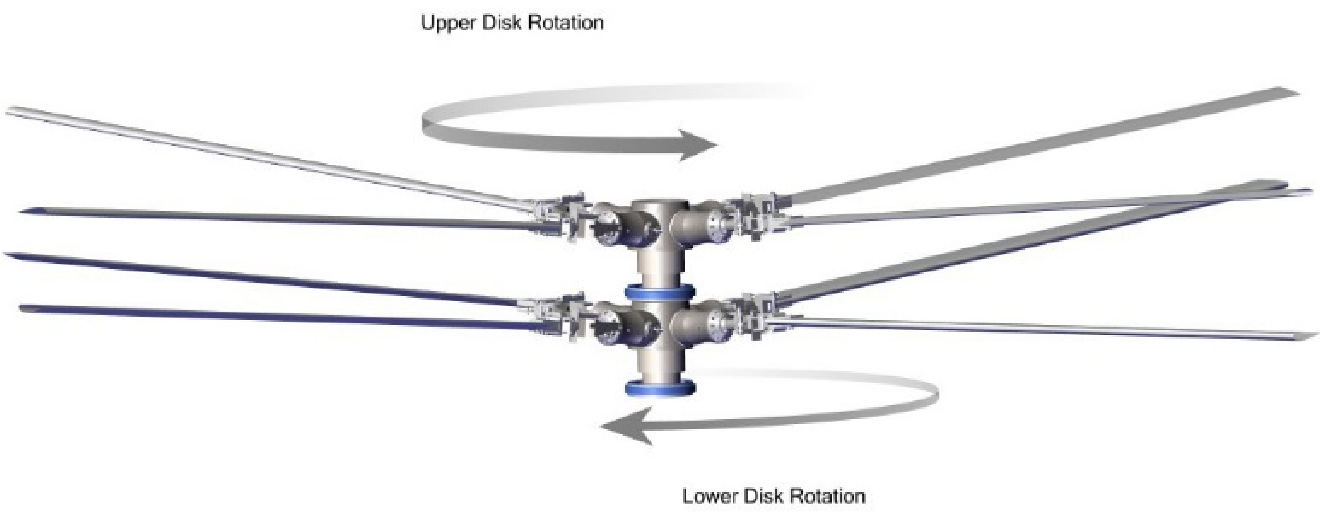
The rotorhead design is coaxial. Blade length is approximately 3m giving a rotor disk size of about 6.5m.

Typical angular velocity is 600RPM. Our design however will operate at angular velocities between about 250 RPM and 1500 RPM.

Aircraft velocity will vary from 0 to 300 kts or 550 km/hr.

Disk separation will be about 0.5m.

Concept Drawing

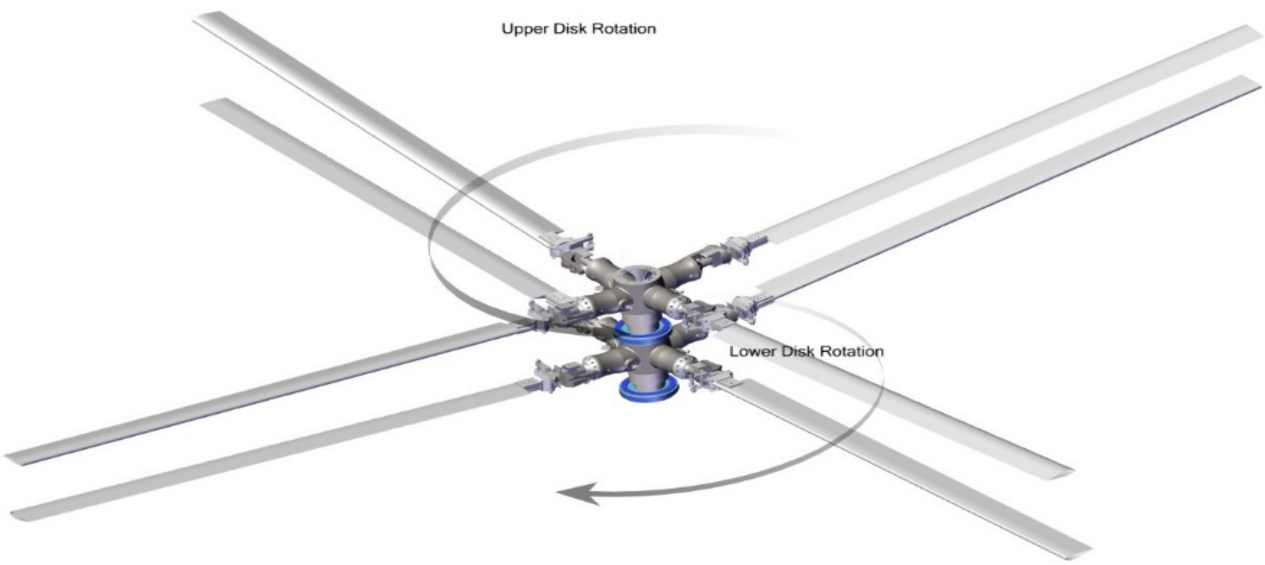


Aerodynamics

As the rotor blades rotate they generate lift. This is created by a lower pressure on the upper side of the blade. The faster the blade spins the greater the lift created. The amount of lift can be derived from general lift (L) equation

$$L = C_L \, 1/2 \, \rho \, V^2 \, S$$

https://en.wikipedia.org/wiki/Lift_(force)



For helicopters, typical blade profiles can be described by standard aerofoils such as NACA 0012, NACA 0015.

From this data it is possible to consider a point source as the calculus summation of all elemental chord slices of the blade to resolve the value and location of the centre of lift for a given blade at a particular angle of attack and rotational velocity.

If the aircraft is in equilibrium, i.e. in the hover, the total lift can be calculated by summing the lift created by each blade attached to the disk hub. This will be equal to the weight of the helicopter.

As the aircraft begins to move away from the hover, the value of lift is altered due to the change in the velocity of air over the blade. This assumes flying in still air. For the blades moving into wind, the advancing blades, the value of lift will increase. For the blades traveling in the same direction as the resultant airflow there will be a reduction of lift. However, from the lift equation it can be seen that the relationship to velocity is squared, therefore there will be more lift generated the faster the aircraft goes for a given blade angle of attack.

Questions

As our rotorcraft design will operate at a variable range of angular velocities:

1. What is the effect on lift as the blades on the upper and lower disk cross each other at various angular velocities? Is aerodynamic bump a problem?
    a. Variables:
        i. Angular velocity
        ii. Upper to Lower disk displacement
        iii. Blade load/Angle of attack
2. What harmonic effects occur
    a. For each blade as velocity changes;
    b. For the entire rotor disk with multiple blades;
    c. Between rotor disks; and
    d. At blade crossing.
    e. Variables:
        i. Angular velocity
        ii. Upper to Lower disk displacement
        iii. Blade load/Angle of attack
3. Are there specific angular velocities that should be avoided?
4. What combination of angular velocity and blade pitch angle will generate the lowest noise footprint?