Aerodynamics 2- Rotorcraft Aerodynamics

Lecture 8

High Speed Flight, Noise and Hub Drag

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High Speed Flight - The Limitations

The problems of compressibility and stall for the edgewise flight of a rotor prohibit speeds much above 240 mph. At these relatively high speeds the rotor has insufficient reserves of thrust to be particularly agile. Unlike the fixed wing aircraft where available lift is proportional to velocity squared, the helicopter has a reduced thrust availability at high speed. This is primarily due to the retreating blade operating near to stall. There are a number of ways of improving this situation:

∗ Off-load the rotor lift demands by employing a conventional wing to provide lift. This has the attraction that it becomes more effective at speed. For stability considerations it has to be located near to the c of g so it is directly below the main rotor. Unfortunately, in the hover, rotor power is now being used to produce high levels of bluff body drag which opposes the thrust vector. This type of supplementary lift is called ***lift compounding.***

∗ Off-load the rotor thrust demands by employing a dedicated propulsive unit (usually a jet engine) so that the rotor thrust vector need only oppose the aircraft's weight. The retreating blade stall is thus delayed and a marginally higher speed can be achieved. This is known as ***thrust compounding***.

∗ A combination of lift and thrust compounding can be used.

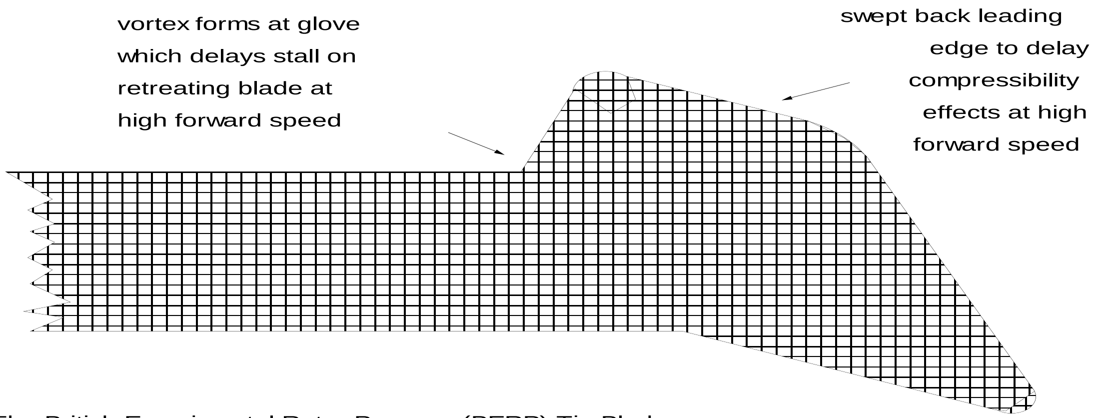
∗ The deficiencies of the retreating blade can be accepted as inevitable and a coaxial rotor employed with <u>very stiff</u> blades. The lateral lift balance is met by having two advancing blades. The rotor speed can be reduced so as to limit the onset of compressibility and extend the operational speed of the aircraft. This is known as the ***Advancing Blade Concept***.

X2 Sikorsky Helicopter (adapted from www.airliners.net)

The main advantage of the ABC concept is that the retreating blade (and its associated stall problems) are of little consequence and a laterally balanced production of lift is achieved from the advancing sector of the rotor. The advancing blades have a very high dynamic head (increasing with translational speed) so a rotor designed for efficiency in the hover is even more efficient at speed. The disadvantage is that the rotors, by virtue of their closely coupled coaxial contra-rotational configuration, must be very rigid in flap. This induces very severe levels of vibration that is prohibitive for anything less than short endurance for manned flight. A further disadvantage of the ABC is that the offloading of the retreating side of the discs reduces blade drag here, which would otherwise contribute to thrust.

∗ Two rotors can be employed at the tips of a conventional wing and with (or without) the wing can be tilted at high speed so as to attain axial , propulsive flight (propellers) and this is known as ***tilt wing*** (or ***tilt rotor***). The tilt rotor compromises the hover performance as does the lift compounded helicopter.

The onset of compressibility can be delayed by using leading edge sweep back (this is used on all high speed fixed wing aircraft) and this was done by Westland Helicopters in the early 1980’s. The paddle tip that incorporated the sweep also produced (unexpected) delayed stall characteristics for the retreating blade. This work was carried out under the **B**ritish **E**xperimental **R**otor **P**rogram and has come to be known as the **BERP** tip. On the 11th August 1986 a Westland Lynx with a BERP tipped rotor set a new speed record for a conventional helicopter of 249.1mph.



The British Experimental Rotor Program (BERP) Tip Blade

Rotor Noise

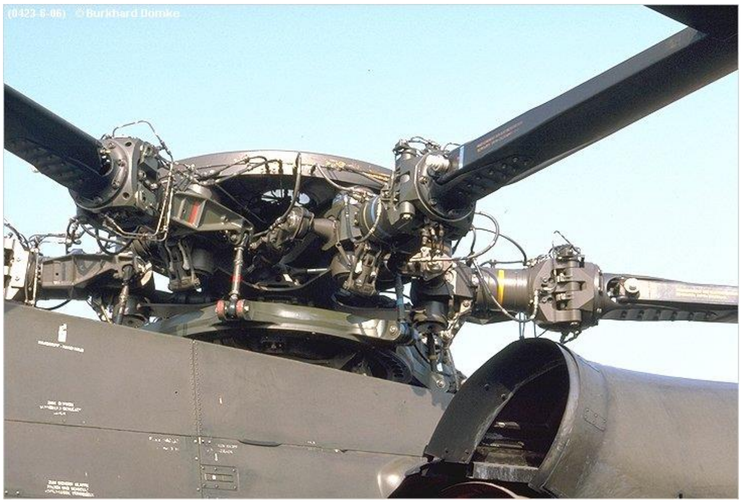
The most audible noise emanating from a lifting rotor is due to Blade Vortex Interaction (BVI) which is more commonly referred to as “blade slap”. It is caused by the rapid pressure changes as a rotor blade passes through the trailing vortex generated by a neighbouring rotor blade. In the conventional single rotor helicopter, this occurs whilst manoeuvring at low speed. This is often whilst the aircraft is about to land which is one reason why city centre heliports have not been too popular. The two rotor tandem helicopter need only perform moderate manoeuvres for the rear rotor to be heard operating in the wake of the forward rotor. This is one reason why the rear rotor is mounted so much higher than the forward one.

If the strength of the tip vortex is reduced, so will be the noise. Thus lightly loaded rotors emit less energy in BVI than the more highly loaded rotors.

The direction of rotation of the main rotor has no effect upon the noise generation but the direction (and position) of the tail rotor relative to the main rotor is important. To avoid BVI for the tail rotor, it should be positioned so as to be outside of the main rotor wake in hover. In forward flight, the main rotor wake will pass through the tail rotor and tests at Westland has shown that the BVI noise from the tail rotor is less when the tail rotor rotates anticlockwise when view from port.

Rotor Hub Drag

The early rotor hubs were fairly simple and as helicopter translational speeds were low the major drag penalty was associated with the rotation of the hub. The moment arm was very small so the losses were not significant. As rotors became larger with 4, 5 or even 8 blades, the complexity and size of the hubs became extensive. For the fully articulated hub with three discrete hinges per blade, lead~lag dampers, oil lubrication systems and blade anti-icing plumbing, there was often a further complication. For ship borne operation, the blades required to be folded together along the helicopter tail for easy stowage below decks. This added to the size and therefore drag of the rotor hub at the much higher speeds that the aircraft were operating. The introduction of composite materials reduced this drag penalty significantly by removing the need for separate hinges and dampers. These rotors are not only smaller and lighter than articulated rotors but need less maintenance and adjustment.



Rotor Hub of an Articulated Rotor