MODULE 12

FOR CAT-A3/A4 CERTIFICATION

HELICOPTER AERODYNAMICS STRUCTURES AND SYSTEMS

Aviation Maintenance Technician Certification Series

COMPLIANT WITH EASA European Aviation Safety Agency EASA PART 66/147

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This sub-module complies with Part-66 12.1 / CAT A

Objective	Part-66 Reference	Knowledge Levels	
		A	B1
Theory of Flight – Rotary Wing Aerodynamics	12.1	1	2
Terminology;			
Effects of gyroscopic precession;			
Torque reaction and directional control;			
Dissymmetry of lift, Blade tip stall;			
Translating tendency and its correction;			
Coriolis effect and compensation;			
Vortex ring state, power settling, overpitching;			
Auto-rotation;			
Ground effect.			

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MODULE 12.1 THEORY OF FLIGHT – ROTARY WING AERODYNAMICS

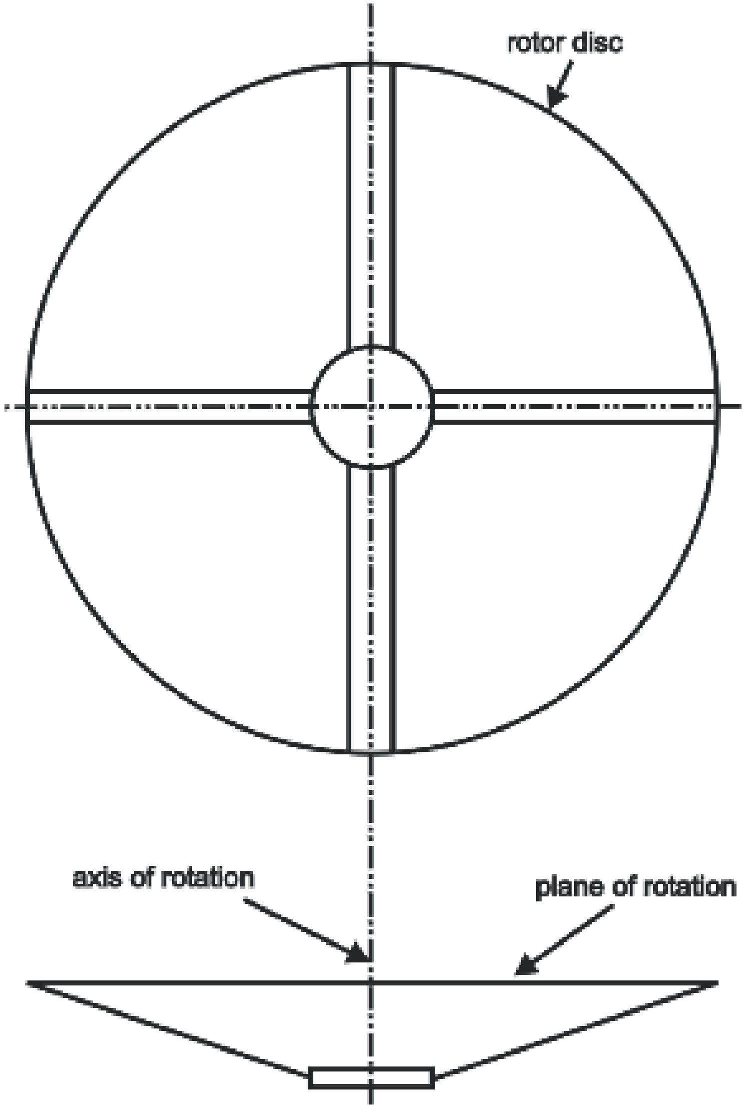
Terminology

Helicopter Rotor Blade and Disc Terminology

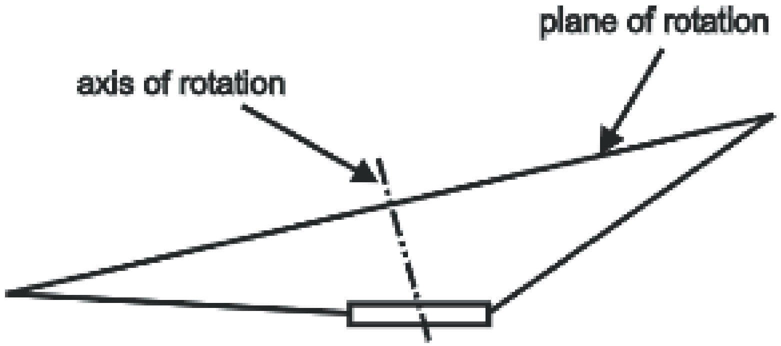
Rotor Disc
This is the area swept by the blades and is in the shape of a shallow inverted cone.

Plane of Rotation
A plane formed by the tip-path of the rotor blades and which is normal (perpendicular) to the axis of rotation. It is sometimes called the ‘tip path plane’.

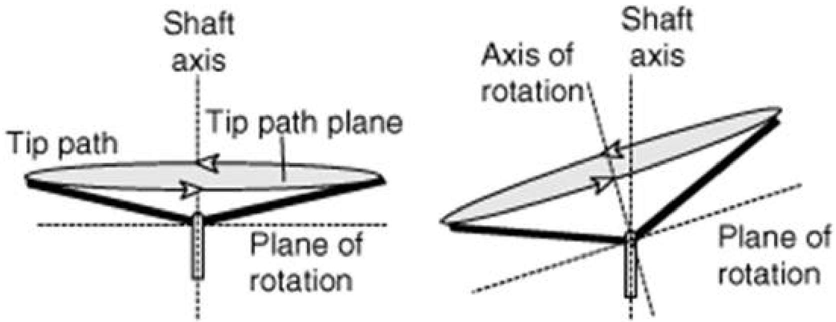
Axis of Rotation
A correct definition of this term is "an imaginary line which passes through a point about which a body rotates and which is normal to the plane of rotation".



Rotor disc



Axis of rotation



Axis of rotation

Blade Angle of Attack
Angle of attack is an aerodynamic angle and is illustrated below. It is defined as the angle between the aerofoil chord and its direction of motion relative to the air (resultant relative wind).

Several factors may cause rotor blade angle of attack to change. Some are controlled by the pilot and some occur automatically due to the rotor system design. Pilots can adjust angle of attack by moving the cyclic and collective pitch controls. However, even when these controls are held stationary, the angle of attack constantly changes as the blade moves around the circumference of the rotor disk. Other factors affecting angle of attack, over which the pilot has little control, are blade flapping, blade flexing, and gusty wind or turbulent air conditions. Angle of attack is one of the primary factors that determines amount of lift and drag produced by an aerofoil.

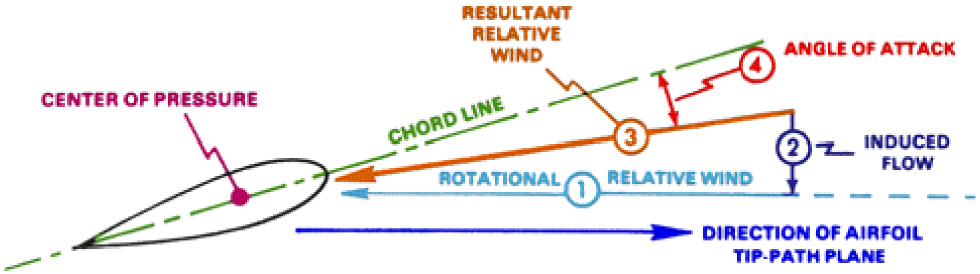
Blade Angle of Incidence
Angle of attack should not be confused with angle of incidence (blade pitch angle). Angle of incidence is the angle between the blade chord line and the plane of rotation of the rotor system. It is a mechanical angle rather than an aerodynamic angle.

Total Aerodynamic Force (TAF)
A total aerodynamic force is generated when a stream of air flows over and under an aerofoil that is moving through the air. The point at which the air separates to flow about the aerofoil is called the point of impact,

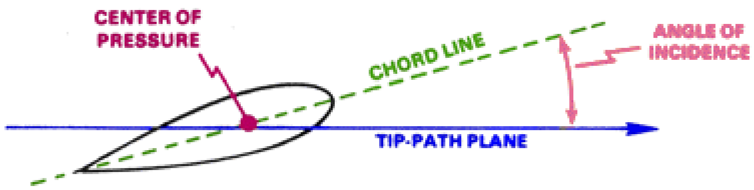
The figure below shows airflow lines that illustrate how the air moves about the aerofoil section. Notice that the air is deflected downward as it passes under the aerofoil and leaves the trailing edge. Remember Newton's third law which states "every action has an equal and opposite reaction." Since the air is being deflected downward, an equal and opposite force must be acting upward on the aerofoil. This force adds to the total aerodynamic force developed by the aerofoil. At very low or zero angles of attack, the deflection force or impact pressure may exert zero positive force, or even a downward or negative force.

Rotor Disc Incidence
This is the angle between the rotor disc and the relative airflow.

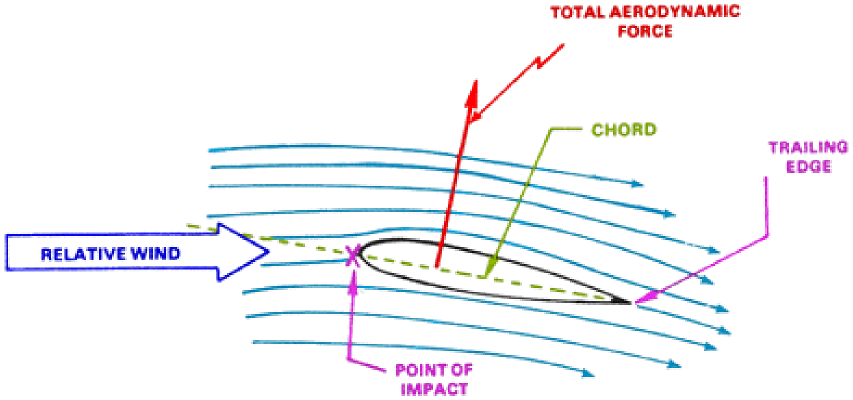
Coning Angle
This is the angle formed by the spanwise axis of the blade and the plane of rotation.



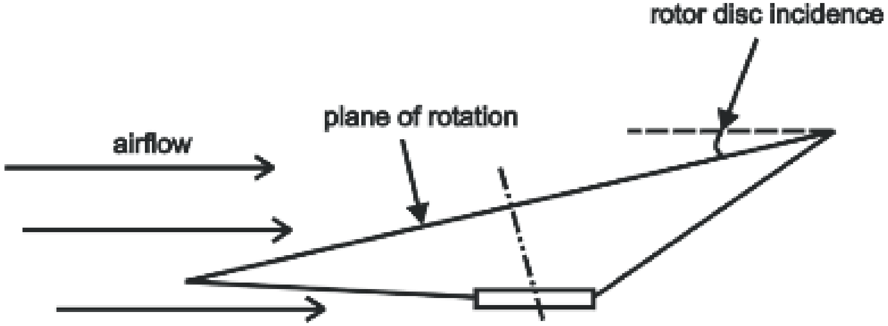
Blade angle of attack



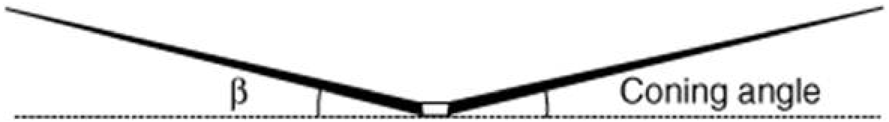
Blade angle of incidence



Total Aerodynamic Force (TAF)



Rotor disc incidence



Twisted and Tapered Blades

A considerable variation of lift will occur along the span of the blades because the tip of the blades is moving much faster than the root.

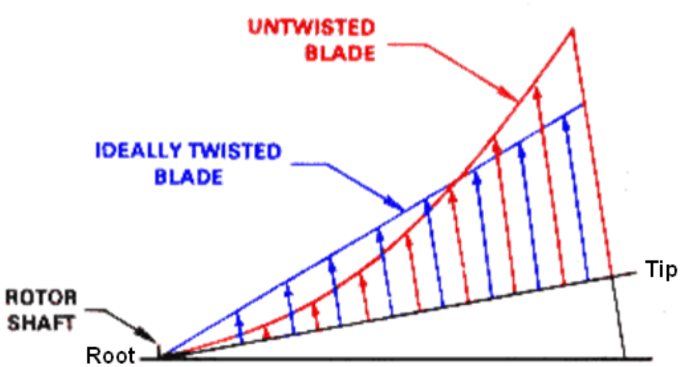
This situation would produce an uneven distribution of lift and a large bending moment on the blades. There are two ways of minimising this;

- Twist the blades, thus reducing the pitch angle lengthwise. This is known as 'washout'.
- Reduce the width of the blade lengthwise. This results in a tapered blade.

Rotor Speed and Maximum RPM

On some helicopters, the main rotor is large and heavy with considerable inertia and unable to make significant changes in RPM. In addition, the maximum rotational speed is limited by the tip speed - the tips must not go transonic or supersonic, otherwise control and vibrational problems would be encountered, especially in forward flight.

It is for this reason that rotor speed is kept constant, and an increase in lift is produced by increasing the pitch angle of each of the rotor blades collectively thus increasing the angle of attack and lift. However, with an increase of angle of attack there is always an associated increase in induced drag, therefore, to stop the rotor speed reducing, the engine power must be increased at the same time.



Lift distribution on twisted
and untwisted blades