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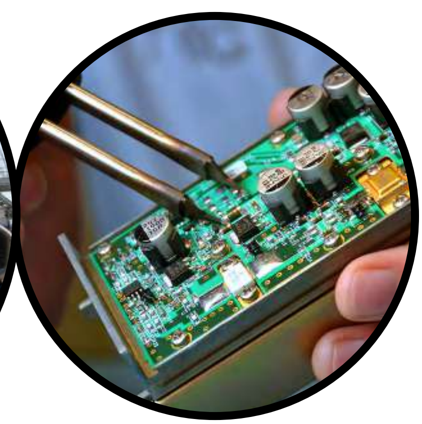
AVIATION MAINTENANCE TECHNICIAN CERTIFICATION SERIES

AIRCRAFT AERODYNAMICS
STRUCTURES AND SYSTEMS

13





COMPLIANT WITH EASA PART 66/147

EASA 2023-989 COMPLIANT

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VERSION	EFFECTIVE DATE
005	2024.12

To order books or for customer service, please call +1 (970) 726-5111, or visit us online at www.actechbooks.com

ISBN-13: 978-1964302102

Update notices for this book will be available online at www.actechbooks.com/revisions.html
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VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2016.01	Module creation and release.
002	2017.02	Format updates and minor type corrections.
003	2019.11	Submodule 3 revisions. Typo corrections in Submodules 3, 4 and 8.
004	2020.02	Enhanced or modified content within the following Submodules: 13.3: Added Autopilot Modes of Operation 13.4: Reorganized based on Part-66 2018 changes; added content: ADS-B and Datalink; Corrected Figures 4-78 and 4-79. 13.7: Added Fly-By-Wire Failsafe and Fly-By-Wire operation.
004.1	2021.04	Enhanced or modified content within the following Submodules: 13.4: Corrected 150 Mhz to 150 Hz. 13.8: Corrected Figure 8-12; Engine Pressure Ratio (EPR) 14.7 psi to 14.5 psi.
004.2	2022.10	Inclusion of Measurement Standards for clarification, page iv. Minor appearance and format updates.
004.3	2023.04	Minor appearance and format updates.
005	2024.12	Regulatory update for EASA 2023-989 compliance.

Module was reorganized based upon the EASA 2023-989 subject criteria. Enhancements included in this version 005 are:

13.1A *High Speed Flight* - moved to Module 8 Basic Aerodynamics.
13.4A *Satellite Communication Systems* - topic added.
13.4A *Controller Pilot Data Link* - topic added.
13.4A *Satellite Based Augmentation* - topic added.
13.4B *VLF Navigation* - topic was removed per EASA 989-2023.
13.6 *Inflight Entertainment* - topic was removed per EASA 989-2023.
13.7D *Rotorcraft Flight Controls* - topic added.
13.8 *Avionics Test Equipment* - topic added.
13.9 *Light Sources* - topic added.
13.20 *Integrated Modular Avionics*- complete rewrite.
13.21 *Cabin Systems* - complete rewrite.
13.22 *Information Systems* - complete rewrite.
Questions and Answers updated.

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Figure 1-35. Aerospatiale Fenestron tail rotor system (left) and the McDonnell Douglas NOTAR® System (right).

blades. Changing the angle of attack changes the drag on the rotor blades, and the power delivered by the engine must change as well to keep the rotor speed constant.

The weight that must be supported is the total weight of the helicopter and its occupants. If the amount of lift is greater than the actual weight, the helicopter accelerates upwards until the lift force equals the weight gain altitude; if thrust is less than weight, the helicopter accelerates downward. When operating near the ground, the effect of the closeness to the ground changes this response. An important consequence of producing thrust is torque. Newton's Third Law states that for every action there is an equal and opposite reaction. Therefore, as the engine turns the main rotor system in a counterclockwise direction, the helicopter fuselage tends to turn clockwise. This tendency for the fuselage to rotate is called torque. The amount of torque is directly related to the amount of engine power being used to turn the main rotor system. The greater the engine power, the greater the torque effect. The force that compensates for torque and provides for directional control can be produced by various means. The defining factor is dictated by the design of the helicopter, some of which do not have a torque issue. Single main rotor designs typically have an auxiliary rotor located on the end of the tail boom. [**Figure 1-32**]

This auxiliary rotor, generally referred to as a tail rotor, produces thrust in the direction opposite the torque reaction developed by the main rotor. A pilot can vary the amount of thrust produced by the tail rotor in relation to the amount of torque produced by the engine. As the engine supplies more power to the main rotor, the tail rotor must produce more thrust to overcome the increased torque effect. Other methods of compensating for torque and providing directional control include the Fenestron® tail rotor system, an SUD Aviation design that employs a ducted fan enclosed by a shroud. Another design, called NOTAR®, a McDonald Douglas design with no tail rotor, employs air directed through a series of slots in the tail boom, with the balance exiting through a 90° duct located at the rear of the tail boom. [**Figure 1-35**]

Basically, these units do the same things, regardless of the type of helicopter on which they are installed; however, the operation of the control system varies greatly by helicopter model.

VERTICAL FLIGHT

Hovering is actually an element of vertical flight. Increasing the angle of attack of the rotor blades (pitch) while keeping their rotation speed constant generates additional lift and the helicopter ascends. Decreasing the pitch causes the helicopter to descend. In a no wind condition, when lift and thrust are less than weight and drag, the helicopter descends vertically. If lift and thrust are greater than weight and drag, the helicopter ascends vertically. [**Figure 1-36**]

FORWARD FLIGHT

In steady forward flight with no change in airspeed or vertical speed, the four forces of lift, thrust, drag, and weight must be in balance. Once the tip-path plane is tilted forward, the total lift-thrust force is also tilted forward. This resultant lift-thrust force can be resolved into two components - lift acting vertically

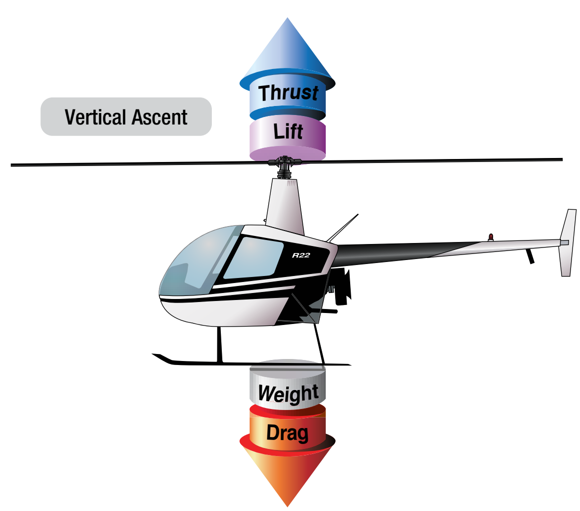

Figure 1-36. To ascend vertically, more lift and thrust must be generated to overcome the forces of weight and drag.

upward and thrust acting horizontally in the direction of flight. In addition to lift and thrust, there is weight (the downward acting force) and drag (the force opposing the motion of an airfoil through the air). [**Figure 1-37**]

In straight-and-level (constant heading and at a constant altitude), unaccelerated forward flight, lift equals weight and thrust equals drag. If lift exceeds weight, the helicopter accelerates vertically until the forces are in balance; if thrust is less than drag, the helicopter slows until the forces are in balance. As the helicopter moves forward, it begins to lose altitude because lift is lost as thrust is diverted forward. However, as the helicopter begins to accelerate, the rotor system becomes more efficient due to the increased airflow.

The result is excess power over that which is required to hover. Continued acceleration causes an even larger increase in airflow through the rotor disk and more excess power. In order to maintain unaccelerated flight, the pilot must not make any changes in power or in cyclic movement. Any such changes would cause the helicopter to climb or descend. Once straight-and-level flight is obtained, the pilot should make note of the power (torque setting) required and not make major adjustments to the flight controls.

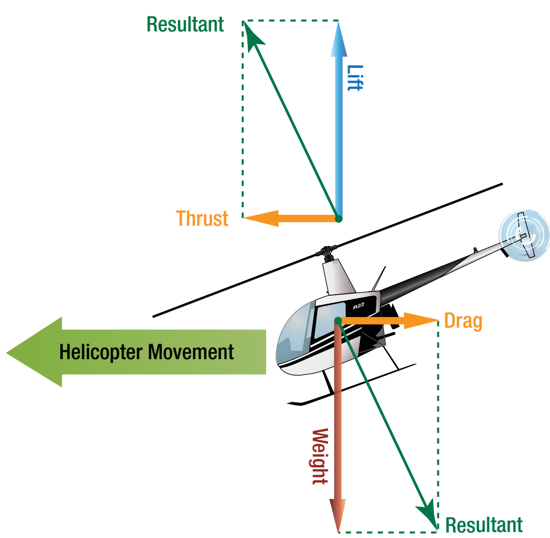

Figure 1-37. The power required to maintain a straight-and-level flight and a stabilized airspeed.

AUTOROTATION

Autorotation is the state of flight in which the main rotor system of a helicopter is being turned by the action of air moving up through the rotor rather than engine power driving the rotor. In normal, powered flight, air is drawn into the main rotor system from above and exhausted downward, but during autorotation, air moves up into the rotor system from below as the helicopter descends. Autorotation is permitted mechanically by a freewheeling unit, which is a special clutch mechanism that allows the main rotor to continue turning even if the engine is not running. If the engine fails, the freewheeling unit automatically disengages the engine from the main rotor allowing the main rotor to rotate freely. It is the means by which a helicopter can be landed safely in the event of an engine failure; consequently, all helicopters must demonstrate this capability in order to be certificated. [**Figure 1-38**]

OPERATION AND EFFECT OF ROTORCRAFT CONTROLS

FLIGHTS CONTROLS CONFIGURATION

The flight controls of a helicopter differ slightly from those found in an aircraft. The control units located in the flight deck of all helicopters are very nearly the same. There are three major controls in a helicopter that the pilot must use during flight. They are the collective pitch control, cyclic pitch control, and antitorque pedals or tail rotor control. In addition to these major controls, the pilot must also use the throttle control, which is mounted directly to the collective pitch control in order to fly the helicopter. [**Figure 1-39**]

SWASH PLATE ASSEMBLY

The purpose of the swash plate is to transmit control inputs from the collective and cyclic controls to the main rotor blades. It consists of two main parts: the stationary swash plate and the rotating swash plate. [**Figure 1-40**]

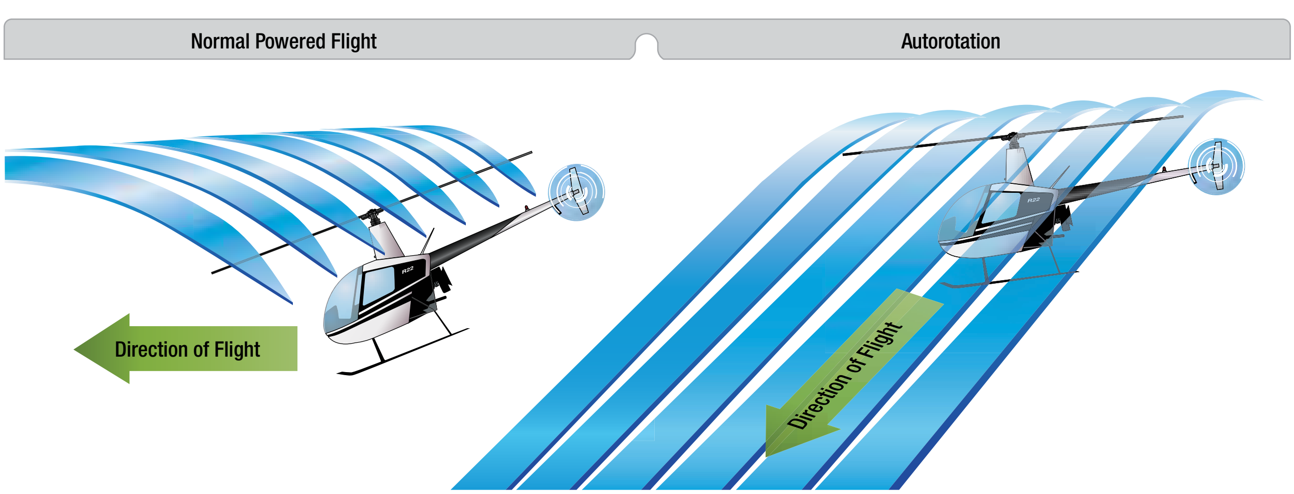

Figure 1-38. During an autorotation, the upward flow of relative wind permits the main rotor blades to rotate at their normal speed. Ineffect, the blades are "gliding" in their rotational plane.

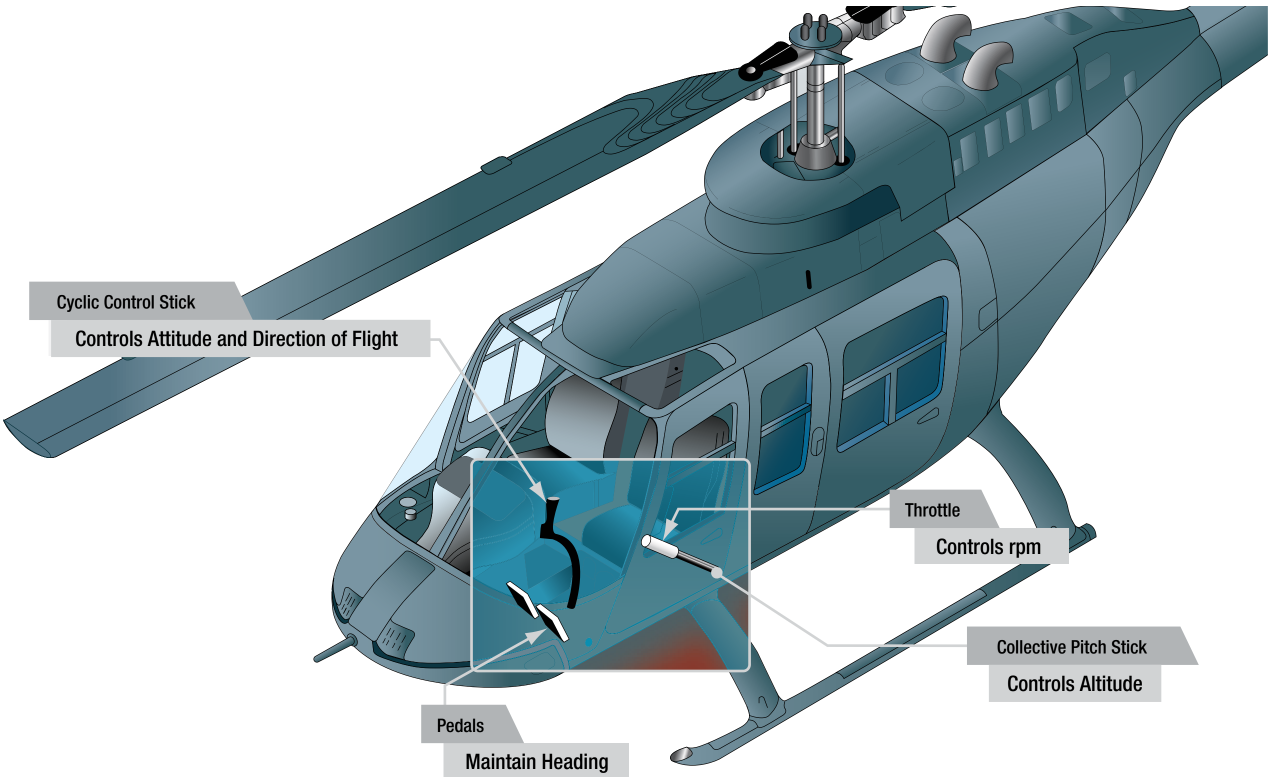

Figure 1-39. Controls of a helicopter and the principal function of each.

The stationary swash plate is mounted around the main rotor mast and connected to the cyclic and collective controls by a series of pushrods. It is restrained from rotating by an anti-drive link but is able to tilt in all directions and move vertically. The rotating swash plate is mounted to the stationary swash plate by a uniball sleeve. It is connected to the mast by drive links and is allowed to rotate with the main rotor mast. Both swash plates tilt and slide up and down as one unit. The rotating swash plate is connected to the pitch horns by the pitch links.

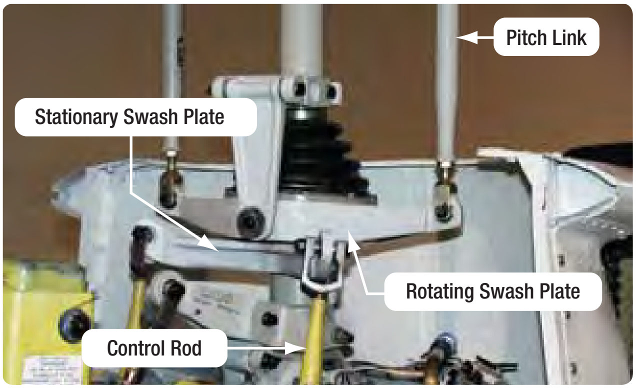

Figure 1-40. Stationary and rotating swash plate.

COLLECTIVE PITCH CONTROL

The collective pitch control is located on the left side of the pilot's seat and is operated with the left hand. The collective is used to make changes to the pitch angle of all the main rotor blades simultaneously, or collectively, as the name implies. As the collective pitch control is raised, there is a simultaneous and equal increase in pitch angle of all main rotor blades; as it is lowered, there is a simultaneous and equal decrease in pitch angle. This is done through a series of mechanical linkages, and the amount of movement in the collective lever determines the amount of blade pitch change. [**Figure 1-41**]An adjustable friction control helps prevent inadvertent collective pitch movement.

THROTTLE CONTROL

The function of the throttle is to regulate engine rpm. If the correlator or governor system does not maintain the desired rpm when the collective is raised or lowered, or if those systems are not installed, the throttle must be moved manually with the twist grip to maintain rpm. The throttle control is much like a motorcycle throttle, and works almost the same way; twisting the throttle to the left increases rpm, twisting the throttle to the right decreases rpm. [**Figure 1-42**]

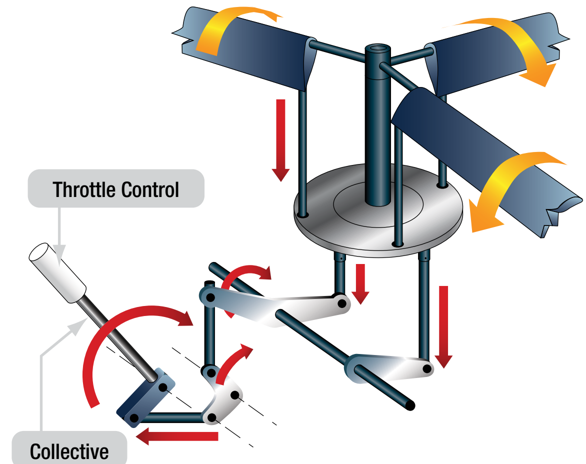

Figure 1-41. The collective changes the pitch of all of the rotor blades simultaneously and by the same amount, thereby increasing or decreasing lift.

GOVERNOR/CORRELATOR
A governor is a sensing device that senses rotor and engine rpm and makes the necessary adjustments in order to keep rotor rpm constant. Once the rotor rpm is set in normal operations, the governor keeps the rpm constant, and there is no need to make any throttle adjustments. A correlator is a mechanical connection between the collective lever and the engine throttle. When the collective lever is raised, power is automatically increased and when lowered, power is decreased. This system maintains rpm close to the desired value, but still requires adjustment of the throttle for fine tuning. Governors are common on all turbine helicopters (as it is a function of the fuel control system of the turbine engine), and used on some piston-powered helicopters. Some helicopters do not have correlators or governors and require coordination of all collective and throttle movements.

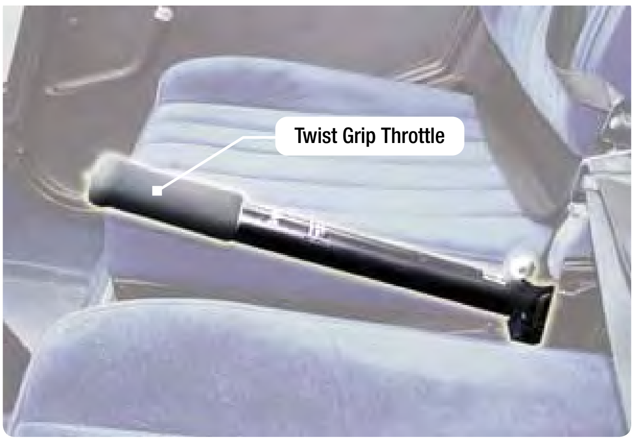

Figure 1-42. A twist grip throttle is usually mounted on the end of the collective lever. The throttles on some turbine helicopters are mounted on the overhead panel or on the floor in the cockpit.

Figure 1-43. The cyclic pitch control may be mounted vertically between the pilot's knees or on a teetering bar from a single cyclic located in the center of the helicopter. The cyclic can pivot in all directions.

CYCLIC PITCH CONTROL
The cyclic pitch control is mounted vertically from the cockpit floor, between the pilot's legs or, in some models, between the two pilot seats. [**Figure 1-43**] This primary flight control allows the pilot to fly the helicopter in any horizontal direction; fore, aft, and sideways. [**Figure 1-44**] The total lift force is always perpendicular to the tip-path place of the main rotor. The purpose of the cyclic pitch control is to tilt the tip-path plane in the direction of the desired horizontal direction. The cyclic control changes the direction of this force and controls the attitude and airspeed of the helicopter.

The rotor disk tilts in the same direction the cyclic pitch control is moved. If the cyclic is moved forward, the rotor disk tilts forward; if the cyclic is moved aft, the disk tilts aft, and so on. Because the rotor disk acts like a gyro, the mechanical linkages for the cyclic

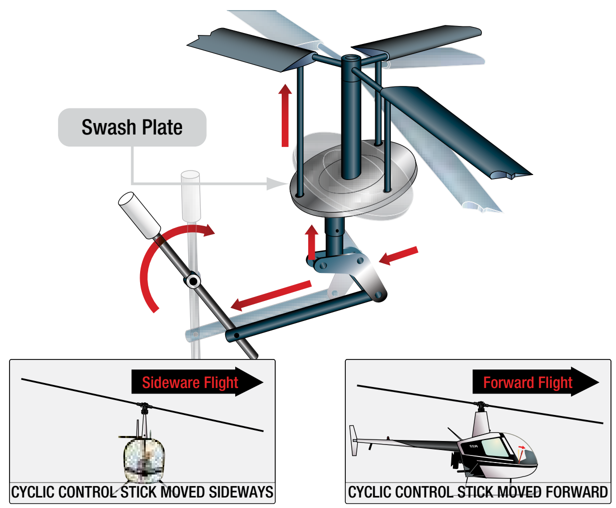

Figure 1-44. The cyclic changes the angle of the swash plate which changes the plane of rotation of the rotor blades. This moves the aircraft horizontally in any direction depending on the positioning of the cyclic.

Figure 1-45. Antitorque pedals compensate for changes in torque and control heading in a hover.

control rods are rigged in such a way that they decrease the pitch angle of the rotor blade approximately 90° before it reaches the direction of cyclic displacement, and increase the pitch angle of the rotor blade approximately 90° after it passes the direction of displacement. An increase in pitch angle increases angle of attack; a decrease in pitch angle decreases angle of attack. For example, if the cyclic is moved forward, the angle of attack decreases as the rotor blade passes the right side of the helicopter and increases on the left side. This results in maximum downward deflection of the rotor blade in front of the helicopter and maximum upward deflection behind it, causing the rotor disk to tilt forward.

ANTITORQUE PEDALS

The antitorque pedals are located on the cabin floor by the pilot's feet. They control the pitch and, therefore, the thrust of the tail rotor blades. [**Figure 1-45**]

Newton's Third Law applies to the helicopter fuselage and how it rotates in the opposite direction of the main rotor blades unless counteracted and controlled. To make flight possible and to compensate for this torque, most helicopter designs incorporate an antitorque rotor or tail rotor. The antitorque pedals allow the pilot to control the pitch angle of the tail rotor blades which in forward flight puts the helicopter in longitudinal trim and while at a hover, enables the pilot to turn the helicopter 360°. The antitorque pedals are connected to the pitch change mechanism on the tail rotor gearbox and allow the pitch angle on the tail rotor blades to be increased or decreased.

Helicopters that are designed with tandem rotors do not have an antitorque rotor. [**Figure 1-33**] These helicopters are designed with both rotor systems rotating in opposite directions to counteract the torque, rather than using a tail rotor. Directional antitorque pedals are used for directional control of the aircraft while in flight, as well as while taxiing with the forward gear off the ground. With the right pedal displaced forward, the forward rotor disk tilts to the right, while the aft rotor disk tilts to the left. The opposite occurs when the left pedal is pushed forward; the forward rotor disk inclines to the left, and the aft rotor disk tilts to the right. Differing combinations of pedal and cyclic application can allow the tandem rotor helicopter to pivot about the aft or forward vertical axis, as well as pivoting about the center of mass.