

CHAPTER 7

HELICOPTERS AND TURBOSHAFT POWER PLANTS

The helicopter has become a vital part of naval aviation. Helicopters have many uses; some of these are antisubmarine warfare (ASW), search and rescue, minesweeping, amphibious warfare, and transferring supplies and personnel between ships. Transfer of supplies and personnel is made through internal loading or vertical replenishment (VERTREP). The advantage the helicopter has over conventional aircraft is that the helicopter's lift and control are relatively independent of forward speed. A helicopter can fly forward, backward, or sideways, or it can remain in stationary flight above the ground (hover). Helicopters do not require runways for takeoffs or landings; the decks of small ships or open fields provide an adequate landing area.

The main difference between a helicopter and an airplane is the source of lift. The airplane gets lift from a fixed airfoil surface (wing) while the helicopter gets lift from a rotating airfoil (rotor). The word helicopter comes from the Greek words meaning spiral wings. You may find it easier to understand how a helicopter operates by imagining the following: Remove the wings from a conventional aircraft and install them above the airplane. Rotating the wings causes a low-pressure area to form on the wings' upper surfaces and provides lift. This low-pressure area and resulting lift are the same as those formed by fixed wings on an aircraft.

The lift generated by a rotating wing enables the helicopter to accomplish its unique missions involving hovering and operating in confined areas. It also creates some unusual operating and control problems. Since rotor aerodynamics is the main difference between helicopters and fixed wing aircraft, let's first examine the rotor in detail. We will then look at helicopter controls, types of helicopters, engines, and finally, transmission and rotor systems.

LEARNING OBJECTIVES

When you have completed this chapter, you will be able to do the following:

1. Identify helicopter flight characteristics.
2. Discuss factors affecting helicopter flight.
3. Identify the factors affecting rotor blade lift.
4. Identify the types of helicopters and their powerplant systems.
5. Discuss the primary helicopter systems and components.
6. Discuss the helicopter transmission gearbox systems and maintenance procedures.
7. Discuss the helicopter rotor system and maintenance procedures.

HELICOPTER FLIGHT CHARACTERISTICS

The rotor is subject to the same physical laws of aerodynamics and motion that govern fixed-wing aircraft flight. However, the manner in which the rotor is subjected to these laws is much more complex. Fixed-wing flight characteristics depend upon forward aircraft speed and control surface movements. In a helicopter, the rotational speed and pitch variations of the rotor blades determine the flight characteristics. Since its flight is independent of forward speed, a helicopter is able to move in any direction at a controlled low speed.

Helicopter Theory of Lift

Rotor lift is explained by two theories. The first theory uses Newton's law of momentum. Lift results from accelerating a mass of air downward. This lift is similar to the jet thrust that develops by accelerating a mass of air out the exhaust. The second theory is the blade element theory. The airflow over the rotor blade acts the same as it does on the wing of a fixed-wing aircraft. The simple momentum theory determines only lift characteristic while the blade element theory gives both lift and drag characteristics. This comparison gives us a more complete picture of all the forces acting on a rotor blade.

The blade element theory divides the blade into parts (blade elements) (*Figure 7-1*). Engineers analyze the forces acting on each blade element. Then the forces of all elements are added to give the rotor characteristics. Each rotor blade element has a different velocity and possibly a different angle of attack. These differences make analysis a complicated problem.

If the helicopter hovers in a no-wind condition, the rotor's plane of rotation is parallel to the level ground. This attitude also makes the relative wind parallel to the ground. The angle of attack is the same on any blade element throughout the cycle of rotation. The lifting force is perpendicular to the plane of rotation.

If the helicopter is rising, there is a component of velocity parallel to the axis of the rotor. Then the relative wind is the result of the rotational velocity and the vertical velocity of the helicopter. Lift acts perpendicular to the relative wind. The relative wind is no longer parallel to the plane of rotation. Lift is not acting perpendicular to the plane of rotation. Then the vertical thrust, or the force acting to overcome gravity, is slightly less than the lifting force.

So far the discussion has been about the forces in the vertical direction. These forces support the helicopter, but do not give it any horizontal motion. Rotational and vertical velocities have already entered the picture. Any discussion of the principles of flight of the helicopter must specify the different velocities being considered, as well as such factors as torque, drag, and other forces.

Factors Affecting Helicopter Flight

Helicopters are subject to several rotary wing aerodynamic effects. These forces act independently. Their cumulative sums are factors that affect helicopter flight.

Torque

Although torque is not unique to helicopters, it does present some special problems for them. As the main rotors turn in one direction, the fuselage may rotate in the opposite direction. Newton's third law of motion states that "every action has an equal and opposite reaction." This tendency for the fuselage to rotate is known as torque effect. Since torque effect on the fuselage is a direct result of engine power, any change in power changes the torque. The greater the engine power, the greater

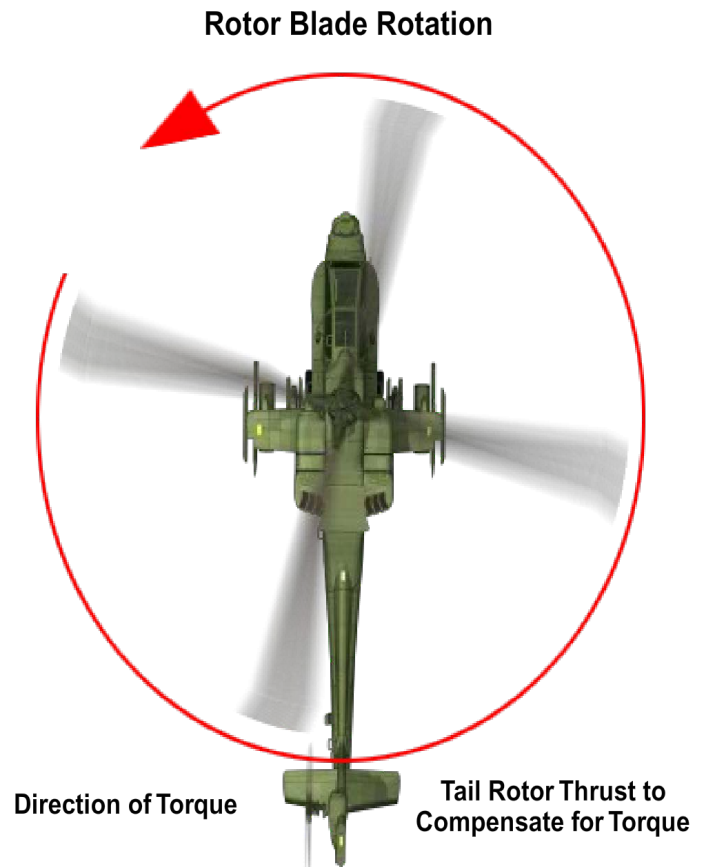


Figure 7-1 — Blade element theory.

the torque. There is no torque reaction when an engine is not operating. Therefore, there is no torque reaction during autorotation.

The usual method of counteracting torque in a single main rotor is by a tail (anti-torque) rotor. This auxiliary rotor is mounted vertically on the outer portion of the tail boom. The tail rotor and its controls counteract torque, and provide a means to control directional heading (yaw).

Dissymmetry of Lift

Dissymmetry of lift is the lift differences between the advancing blade half of the disk and the retreating blade half. The disk area is the area swept by the rotating blades. It is created by horizontal flight or by wind in a hover. You should be aware that hovering in a 20 mile per hour (mph) headwind is the same as flying forward at 20 mph. When hovering in a no-wind condition, the speed of the relative wind is the effective speed of the rotor. However, the speed is lower at points closer to the rotor hub (*Figure 7-2*). When the helicopter moves forward, relative wind over each blade becomes a combination of the rotor speed and forward movement. The advancing blade is then the combined speed of the blade speed and helicopter speed. On the opposite side, the retreating blade speed is the blade speed minus the speed of the helicopter. *Figure 7-3* shows dissymmetry of lift at 100 mph forward flight.

During forward flight, lift over the advancing blade half of the rotor disk is greater than over the retreating half. This greater lift would cause the helicopter to roll unless something equalized the lift. One method of equalizing the lift is through blade flapping.

Blade Flapping

Attachment to the rotor hub horizontal hinges permits the blade to move vertically. The blades actually flap up and down as they rotate. The hinge permits an advancing blade to rise, thus reducing its effective lift area. It also allows a retreating blade to settle, thus increasing its effective lift area. The combination of decreasing lift on the advancing blade and increasing lift on the retreating blade equalizes the lift.

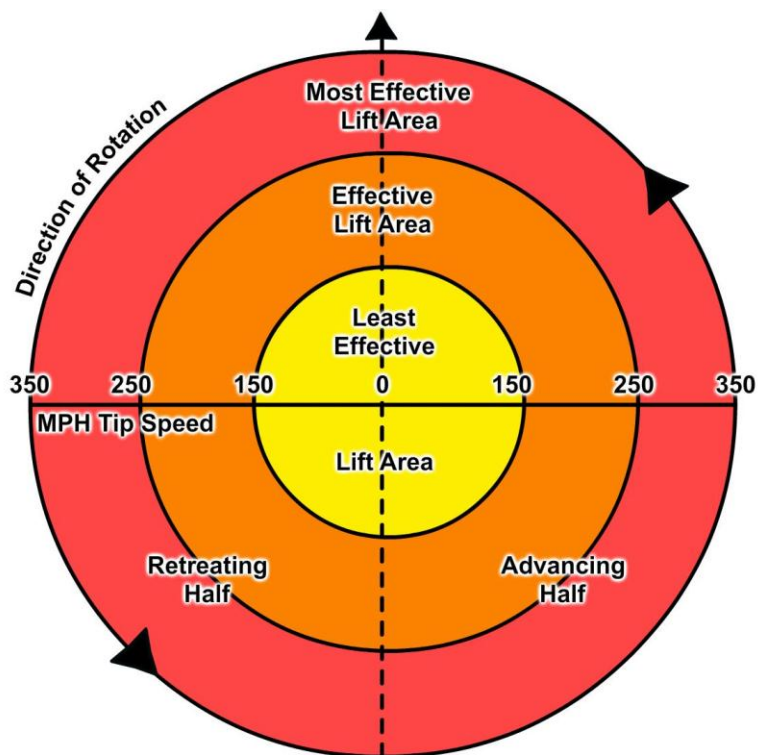


Figure 7-2 — Symmetry of lift.

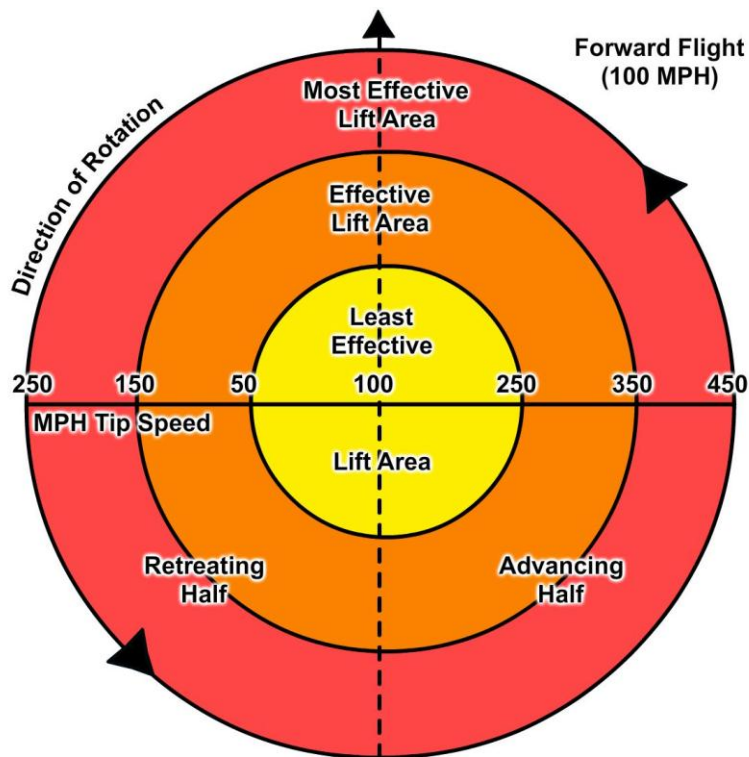


Figure 7-3 — Dissymmetry of lift.

Blade flapping creates an unbalanced condition, resulting in vibration. To prevent this vibration, a drag hinge allows the blades to move back and forth in a horizontal plane. A main rotor that permits individual movement of blades in a vertical and horizontal plane is known as an articulated rotor.

Coning

Coning is the upward bending of the blades caused by the combined forces of lift and centrifugal force. Before takeoff, due to centrifugal force, the blades rotate in a plane nearly perpendicular to the rotor hub. During a vertical liftoff, the blades assume a conical path as a result of centrifugal force acting outward and lift acting upward.

In a semi-rigid rotor, coning causes rotor blades to bend up. In an articulated rotor, the blades move to an upward angle through movement about the flapping hinges.

Gyroscopic Precession

The spinning main rotor of a helicopter acts like a gyroscope. It has the properties of gyroscopic action, one of which is precession. Gyroscopic precession is resulting action occurring 90 degrees from the applied force. Applying a downward force to the right of the disk area will cause the rotor to tilt down in front. This downward tilt is true only for a right-to-left (counterclockwise) rotor rotation.

The cyclic control applies force to the main rotor through the swash-plate. To simplify directional control, helicopters use a mechanical linkage, which places cyclic pitch change 90 degrees ahead of the applied force. Moving the cyclic control forward (right-to-left turning rotor) places high pitch on the blades to the pilot's left. Low pitch is then found on the blades to the pilot's right. Since every pitch change causes a flap, reaching its maximum at 90 degrees, this flapping causes the disk area to tilt forward.

If offset linkage were not used, the pilot would have to move the cyclic stick 90 degrees out of phase. The pilot would have to move the stick to the right to tilt the disk forward, and forward to tilt the disk area to the left, and so on.

Ground Effect

When a helicopter hovers close to the ground, the rotor directs air downward faster than it can escape. This builds up a cushion of dense air beneath the helicopter known as ground cushion or ground effect. It is effective to a height of one half the rotor diameter. Ground cushion effect does not occur at airspeeds greater than 10 mph.

Autorotation

Autorotation occurs when the main rotor is turned by air passing up through the rotor system instead of by the engine. The rotor disengages automatically from the engine during engine failure or shutdown. During autorotation, the rotor blades turn in the same direction as when engine driven. Air passes up through the rotor system instead of down. This air direction causes a slightly greater upward flex or coning of the blades.

Power Settling

Stalling will not occur in helicopters as it does in fixed-wing aircraft. However, power settling may occur in low-speed flight. Power settling is the uncontrollable loss of altitude. Heavy gross weights, poor density conditions, and low forward speed all contribute to power settling. During low forward speed and high rates of descent, the downwash from the rotor begins to recirculate. The downwind flows up, around, and back down through the effective outer disk area. The recirculating air velocity may become so high that full collective pitch cannot control the rate of descent.

Factors Affecting Rotor Blade Lift

Factors that affect rotor blade lift are the rotor area, pitch of rotor blades, smoothness of rotor blades, and density altitude.

Rotor Area

One assumption in figuring the lift of a rotor is that lift is dependent upon the entire area of the rotor disk. The rotor disk area is the area of the circle formed by the disk. The radius of the rotor disk is equal to the length of the rotor blade. The lift of a rotor increases in direct proportion not to the length of the rotor but to the square of the length of the rotor. The greater the rotor disk area, the greater the drag created. This drag results in the need for greater power requirements.

Pitch of Rotor Blades

If the rotor were to operate at zero angle of attack or zero pitch, no lift would result. When the pitch increases, the lifting force increases until the angle of attack reaches the stalling angle. To even out the lift distribution along the length of the rotor blade, it is common practice to twist the blade. Twisting the blade causes a smaller angle of attack at the tip than at the hub.

Smoothness of Rotor Blades

Tests have shown that the lift of a helicopter is increased by polishing the rotor blades to a mirror-like surface. Making the rotor blades as smooth as possible reduces the parasite drag. Any dirt, grease, or abrasions on the rotor blades may be a source of increased drag, which will decrease the lifting power of the helicopter.

Density Altitude

In formulas for lift and drag, the density of the air is an important factor. The mass or density of the air reacting in a downward direction causes the upward force or lift that supports the helicopter.

Density is dependent on two variables. One variable is the altitude, since density varies from a maximum at sea level to a minimum at high altitude. The other variable is atmospheric changes. The density of the air may be different, even at the same altitude, because of changes in temperature, pressure, or humidity.

FLIGHT CONTROL SYSTEM

The mechanical flight control system consists of mechanical linkage and controls (*Figure 7-4*). These linkages and controls transmit force to primary and auxiliary hydraulic system servo cylinders and to the rotary rudder. The mechanical flight controls have two independent systems. They are the rotary wing flight control and the rotary rudder flight control systems.

The rotary wing flight controls consist of cyclic and collective pitch control sticks, a mixing unit, a balance spring, and linkage. The cyclic controls give forward, aft, and lateral movement of the helicopter. The collective controls give vertical control of the helicopter.

The rotary rudder flight controls consist of pedals, pedal switches, and pedal adjusters for the pilot and copilot. Other system components are a negative force gradient spring and mechanical linkage. The rotary rudder compensates for the torque of the rotary wing. The controls provide a way to change the heading (direction) of the helicopter.

The cyclic pitch control system controls the forward, aft, and lateral movements of the helicopter. Control comes from the pilot's or co-pilot's cyclic stick. Control rods and bell cranks connect the stick to the auxiliary servo cylinders, then to the mixing unit and three primary servo cylinders. The primary servo cylinders control movement of the rotary wing blades through the swash-plate. The swash-plate changes the pitch of the blades.

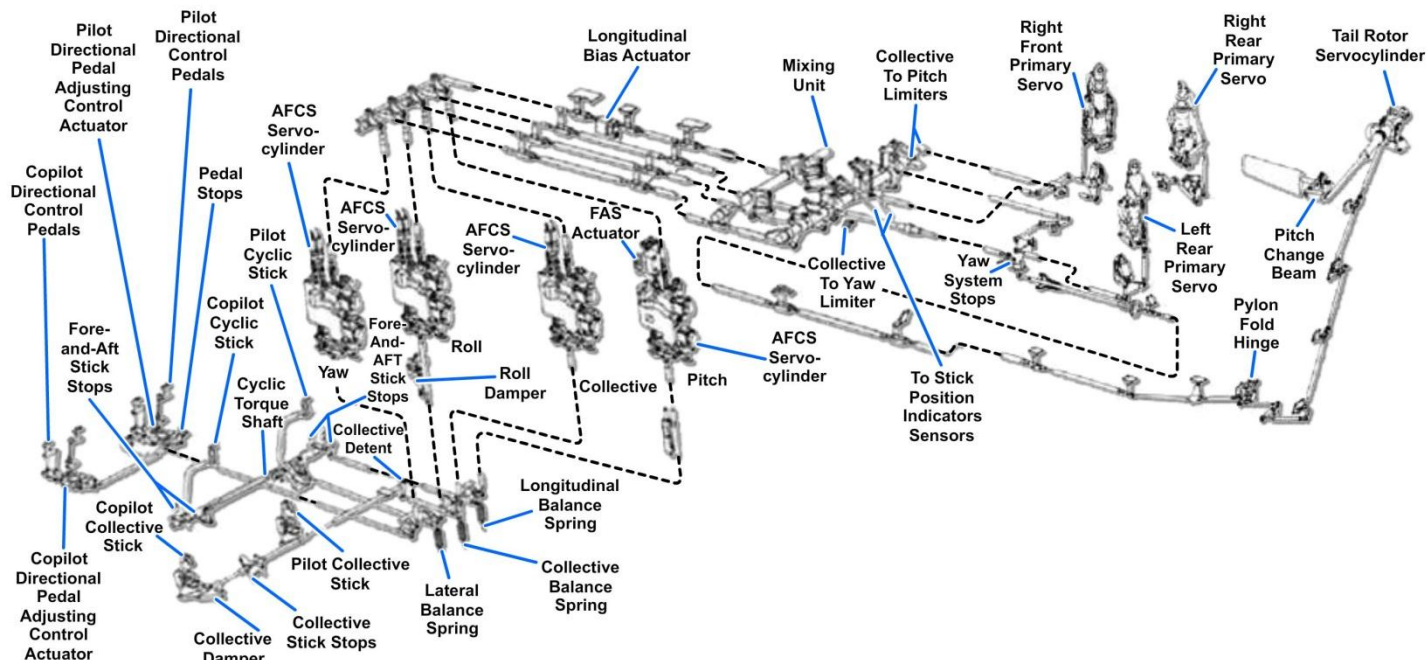


Figure 7-4 — Typical Flight Control System.

The collective pitch control system provides vertical control of the helicopter. Control comes from the pilot's and copilot's collective pitch control sticks. Control rods and bell cranks connect the stick to the auxiliary servo cylinder, then to the mixing unit. At the mixing unit, movements of the collective stick are sent to the primary servo cylinders and the swash-plate. The swash-plate increases or decreases the pitch of all blades equally and simultaneously. A balance spring on a control rod helps to balance the weight of the collective stick when the auxiliary servo system is off.

A collective-to-cyclic pitch coupling (fore-and-aft) is found in the mixing unit. The coupling automatically applies a nose-down pitching correction when the collective pitch stick is raised. Lowering the collective pitch stick makes a nose-up pitching correction. This action provides attitude control during transitions, especially during automatic stabilization equipment (ASE) system transitions.

A collective-to-yaw coupling provides automatic rotary rudder pitch changes to adjust for collective pitch changes. Rotary rudder blade angle changes result from both collective pitch stick and rudder pedal movement. The auxiliary servo's irreversible transfer of collective pitch motion will act to displace the rudder. The rudder pedal motion will not affect rotary wing collective pitch blade angle.

The rotary rudder control system controls helicopter heading by moving control rods and bell cranks connected to the auxiliary servo cylinder. The auxiliary servo cylinder connects to the mixing unit by control rods. At the mixing unit, a control rod operates a forward quadrant. From the forward quadrant, cables operate a rear quadrant in the aft fuselage. A control rod from the rear quadrant connects, at the pylon hinge line, to the control rods, bell cranks, and pitch control shaft. These units are found in the tail gearbox. A hydraulic pedal damper in the servo cylinder prevents sudden movements of the control pedals from causing rapid changes in blade pitch, which might damage the helicopter.

A typical helicopter flight control system consists of four subsystems. They are the cyclic pitch control sticks for directional flight, the collective pitch control sticks for vertical flight, the directional heading control (rudder) pedals, and the throttle. The throttle may be a motorcycle-type grip mounted on the collective pitch stick or a lever-type mounted on the center overhead console. Also included are an auxiliary servo cylinder, a mixing unit, primary servo cylinders, and mechanical linkage.

The cyclic pitch control stick controls forward, aft, and lateral helicopter movements. The collective pitch control stick controls vertical helicopter movement. The directional control pedals control helicopter headings (*Figure 7-4*).

Movement of the control sticks is sent by mechanical linkage to a hydraulically operated auxiliary servo cylinder for power boost. The boosted input is sent through a mixing unit for coordination with any heading directional control inputs. Stick movement is finally sent through the hydraulically actuated primary servo cylinders to the rotary wing head. At the rotary wing head, blade pitch changes.

Types of Helicopters

Helicopters are of two basic types, the single-rotor and the multi-rotor. The single main rotor with a vertical tail rotor is the most common type of helicopter. The SH-60 B/F, HH-60H, MH-60R/S (*Figure 7-5*) is an example of a single-rotor helicopter. Multi-rotor helicopters are classified into different categories according to their rotor configuration. Two types are the coaxial rotor and the tandem rotor.

The single-rotor configuration uses a vertical tail rotor to counteract torque and provide directional control. The advantages of this configuration are simplicity in design and effective directional control. Coaxial rotors are two rotors mounted on the same mast and turning in opposite directions. The torque produced by the two rotors balance each other out. Coaxial rotor systems have good ground clearance and are easy to maneuver, but their arrangement and controls are more complicated than

H-60



MH-53E

Figure 7-5 — Navy helicopter types.

single rotor systems. In the tandem rotor design, one rotor is located forward and the other located aft. Sometimes the rotor blades are in the same plane. The blades may or may not intermesh. The design offers good longitudinal stability since the fuselage hangs at two points, fore and aft. Like the coaxial rotor, the tandem rotor has little torque to overcome since these rotors rotate in opposite directions

Most Navy helicopters have a twin turbine engine powered, single rotor design like the SH-60 B/F, HH-60H, MH-60R/S. Some small trainer helicopters like the TH-57B/C have only one engine, and large helicopters like the MH-53E have three turbine engines.

NOTE

While procedures for specific engines or aircraft are included in this manual, many pertinent or mandatory references are left out. For this reason always refer to the applicable maintenance instruction manuals.

Helicopter Power Plants

The MH-53E uses three T64-GE-419 turboshaft engines; the SH-60 B/F, HH-60H, MH-60R/S uses two T700-GE-401C turboshaft engines, and the TH-57 B/C uses one Allison 250C-20J turboshaft engine. These engines all use the free turbine principle for power takeoff to the main transmission gearbox. Power takeoff comes from the power turbine section. This section is mechanically independent from the gas generator. Exhaust gases from the gas generator turbine drive the power turbine. The power turbine is connected to the main transmission gearbox through a coaxial main drive shaft.

NOTE

The T700-GE-401C turboshaft engine is one of a new generation of aviation propulsion systems with modular construction. Modular construction allows intermediate maintenance activities to replace major engine components, such as turbine sections, with basic hand tools, increasing the ability to replace parts at the lowest level of maintenance by decreasing down time.

T64-GE-419

The T64 turboshaft engine was introduced in 1964 and pioneered a number of technical innovations that influenced future generations of GE engines. These technical innovations included corrosion resistant and high-temperature coatings, front-drive free turbines and film air-cooled turbine blades and nozzles. Today's T64 incorporates new design and material technologies that have improved its performance and reliability and have doubled its original power rating.

Turbine Section

The turbine section is comprised of a two-stage gas generator turbine and a two stage power turbine.

Accessory Section

The accessory section is the primary structural member for the engine, as it provides mounting and support for the compressor and turbine assemblies. The accessory gearbox contains most of the lubrication system components and incorporates two separate gear trains.

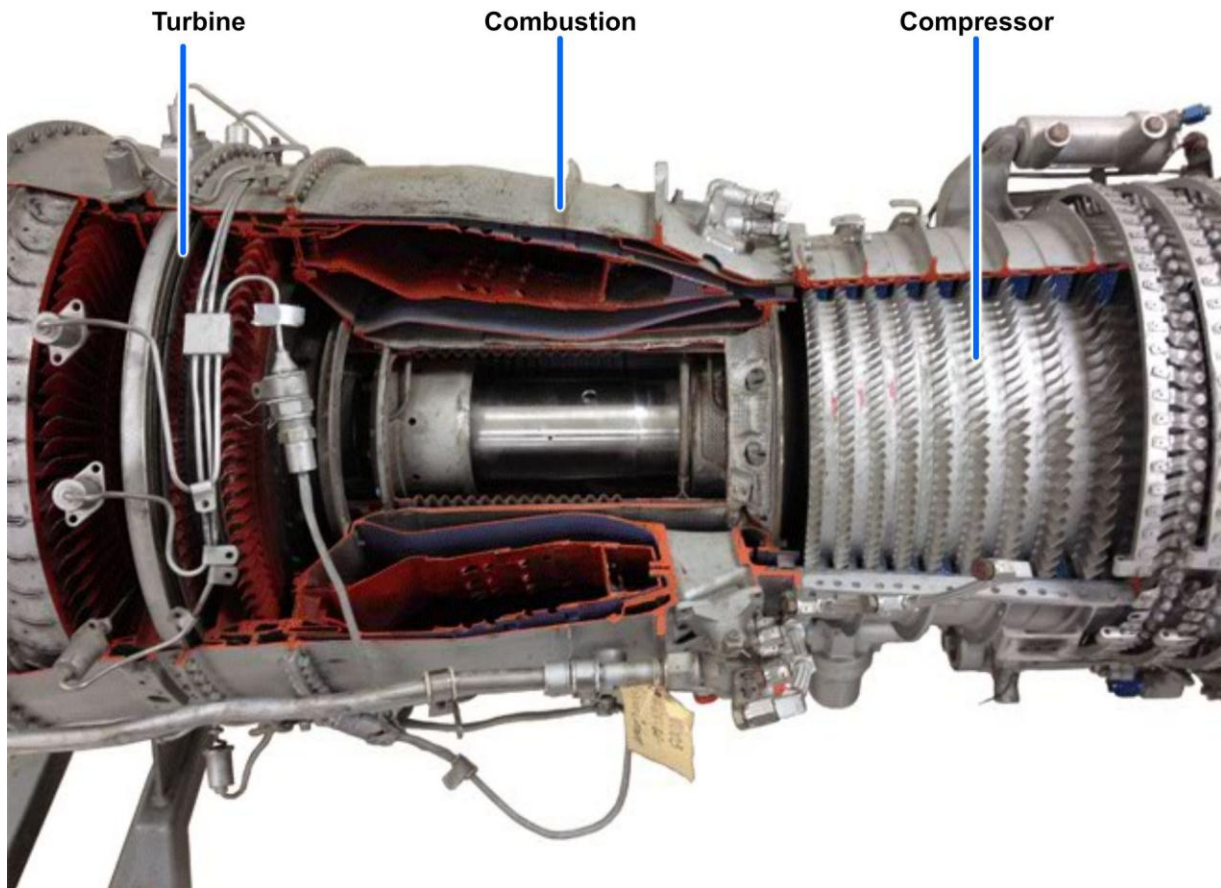


Figure 7-6 — T64-GE-419 turboshaft gas turbine engine cutaway view.

Compressor Section

The compressor is a 14-stage axial flow unit. The stages of an axial compressor consist of a set of rotors followed by a set of stators. The rotors accelerate the air while the stators slow it down and direct it to the next stage of rotors. Each stage of the axial flow compressor acts like a pump, moving air through the compressor as the cross-sectional area decreases once the air has passed through the 14 axial stages. The compressor ratio is determined by the decrease in area of the succeeding stages.

The T700-GE-401C Turboshaft Engine

The T700-GE-401C is a front-drive turboshaft engine featuring a single-spool gas generator section. The engine has a five-stage axial and a single-stage centrifugal flow compressor. It has a flow-through annular combustion chamber. The engine also has a two-stage, axial-flow gas generator turbine and a two-stage, axial-flow, free-power turbine. Some features of this engine include an integral inlet particle separator and self-contained systems incorporating modular construction.

The engine consists of five major sections. These sections are the inlet, compressor, combustor, turbine, and exhaust sections (*Figure 7-7*).

Inlet Section

The inlet section includes all the parts forward of the compressor. It directs airflow into the compressor and provides a mount for the accessory gearbox (AGB). The engine inlet uses an integral particle separator (IPS) to prevent foreign objects from entering the compressor. The IPS includes a swirl frame, scroll case, and engine driven blower. The 12 fixed-swirl vanes impart rotation to the airflow. Any particles are thrown into the collection scroll and dumped overboard by the blower (*Figure 7-8*).

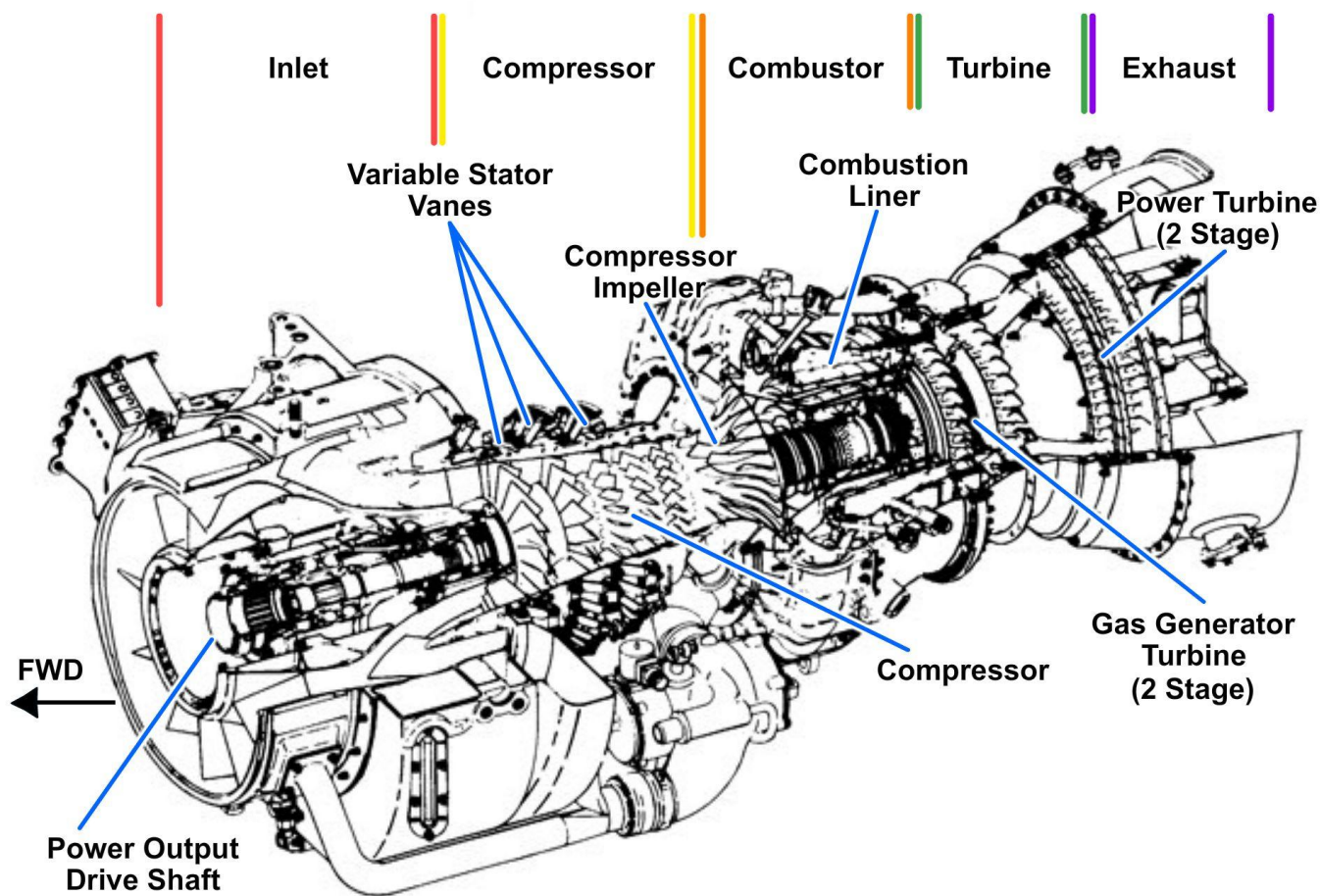


Figure 7-7 — T700-GE-401C turboshaft gas turbine engine cutaway view.

Compressor Section

The compressor section increases the mass airflow delivered to the combustor through a six stage compressor (five axial, one centrifugal). The inlet guide vanes and first two rows of stators have a variable geometry design.

Combustor Section

The combustor section houses an annular combustion liner. This section also contains 12 fuel injectors and 2 spark igniters.

Turbine Section

The turbine section has four axial flow turbine wheels. The first two wheels drive the compressor and AGB. These turbines are known as the engine's gas generator turbines. The last two wheels drive the main gearbox. These turbines are known as the engine's power turbines. The turbine section also houses the seven turbine gas temperature (TGT) thermocouples, which mount between the gas generator and power turbines.

Exhaust Section

The exhaust section is aft of the turbine section and contains two sensors that monitor power turbine (NP) speed and engine torque (Q).

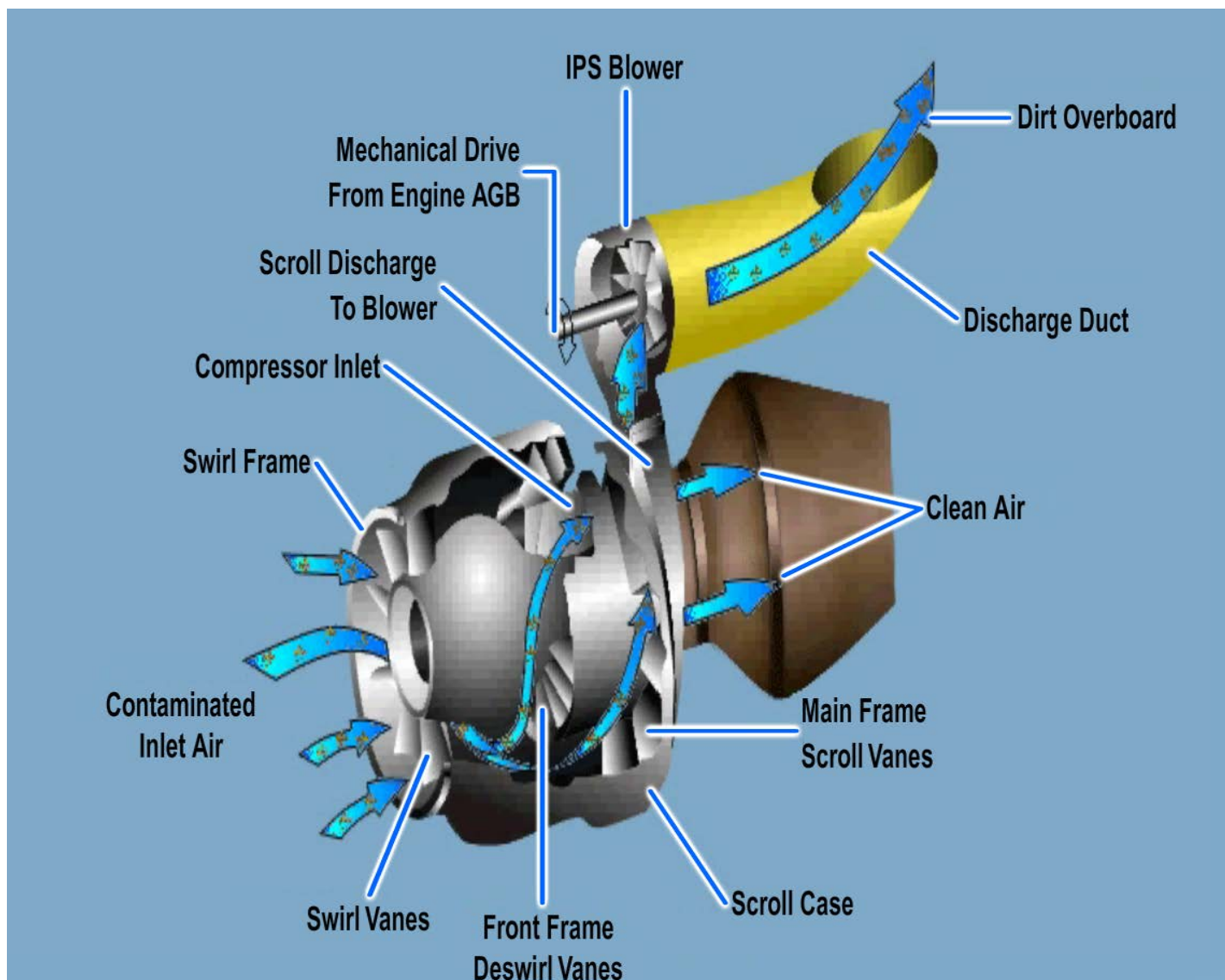


Figure 7-8 — Inlet particle separator (IPS).

Primary Helicopter Components

Because components vary in function and complexity on different models of helicopters, we will discuss only representative units. Refer to the aircraft maintenance instruction manual (MIM) for details on components for a specific helicopter.

NOTE

Always refer to the applicable MIM when attempting repair on helicopter systems.

Engine Control Quadrant

Figure 7-9 shows an engine control quadrant. It consists of two engine power control levers, two engine fuel system selector levers, and two engine emergency off T-handles. It also has a power control lever rotor brake interlock. Each power control lever has a starter button and four selectable positions. The positions are OFF, IDLE, FLY, and LOCKOUT.

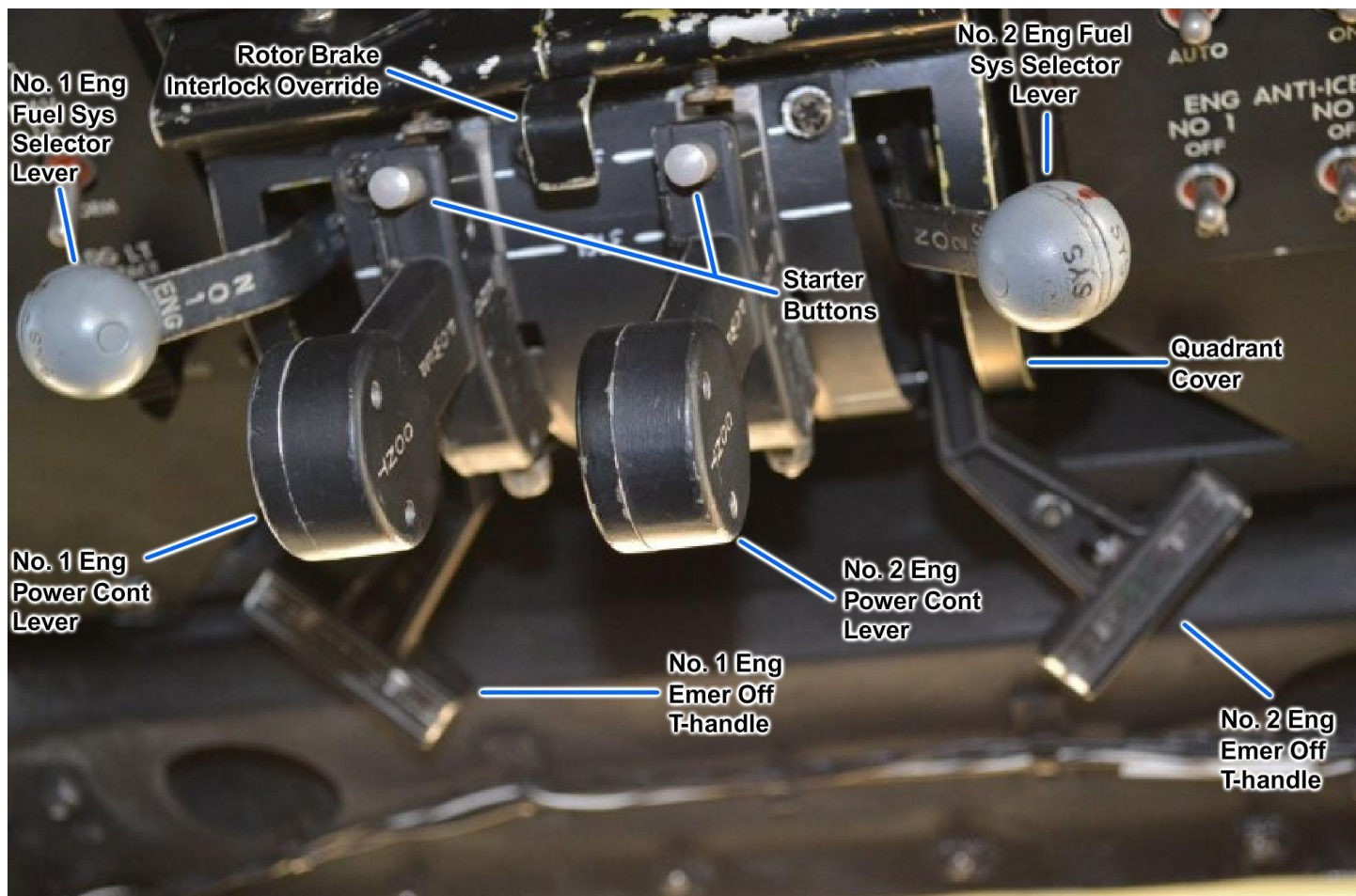


Figure 7-9 — Engine control quadrant.

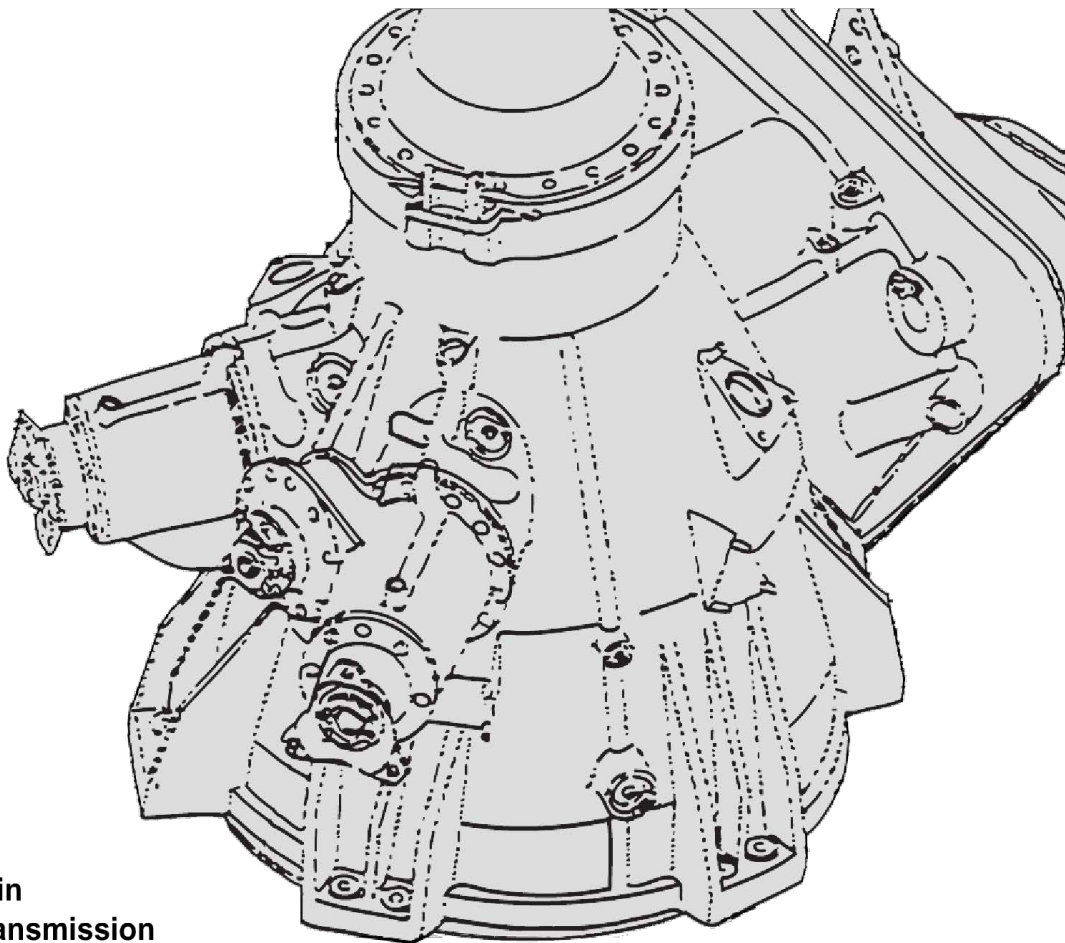
Movement of the power control lever to the OFF position moves a cable to shut off the fuel. Movement of the lever between IDLE and FLY sets the available gas generator turbine speed (Ng). Move the lever to the FLY position for flight rotor speeds. If demanded, this setting gives the highest available power. When moved to the LOCKOUT position momentarily, the power control lever manually controls Ng and Np. In this mode, the Digital Electrical Control Unit (DECU) is disabled. The only automatic function NOT de-energized is the Np overspeed protection. To return to automatic engine control, move the power lever to the IDLE position, and then back to the FLY position.

Transmission System

The transmission system takes combined power from two engines, reduces the revolutions per minute (rpm), and transfers the power to the main and tail rotors. The secondary transmission provides a drive for electrical and hydraulic power generation. The transmission system of a typical helicopter consists of the Main Gearbox Transmission, an Intermediate Gearbox Transmission, a Tail Gearbox Transmission, and drive shafts. Most systems also include an oil cooler, blower, and rotor brake system. *Figure 7-10 frames 1 and 2* shows the MH-53 transmission/rotor system, and *Figure 7-11* shows the SH-60 transmission system.

Main Transmission Gearbox

The purpose of the main transmission is to interconnect the two engines in order to drive and support the main rotor. The main transmission consists of five modules: two accessory module, two input modules, and a main module. The left-hand input and accessory modules are identical to the right-hand input and accessory modules and interchangeable.



**MH-53E Main
Gearbox Transmission**

Figure 7-10 — MH-53E rotor/transmission system (frames 1 and 2).

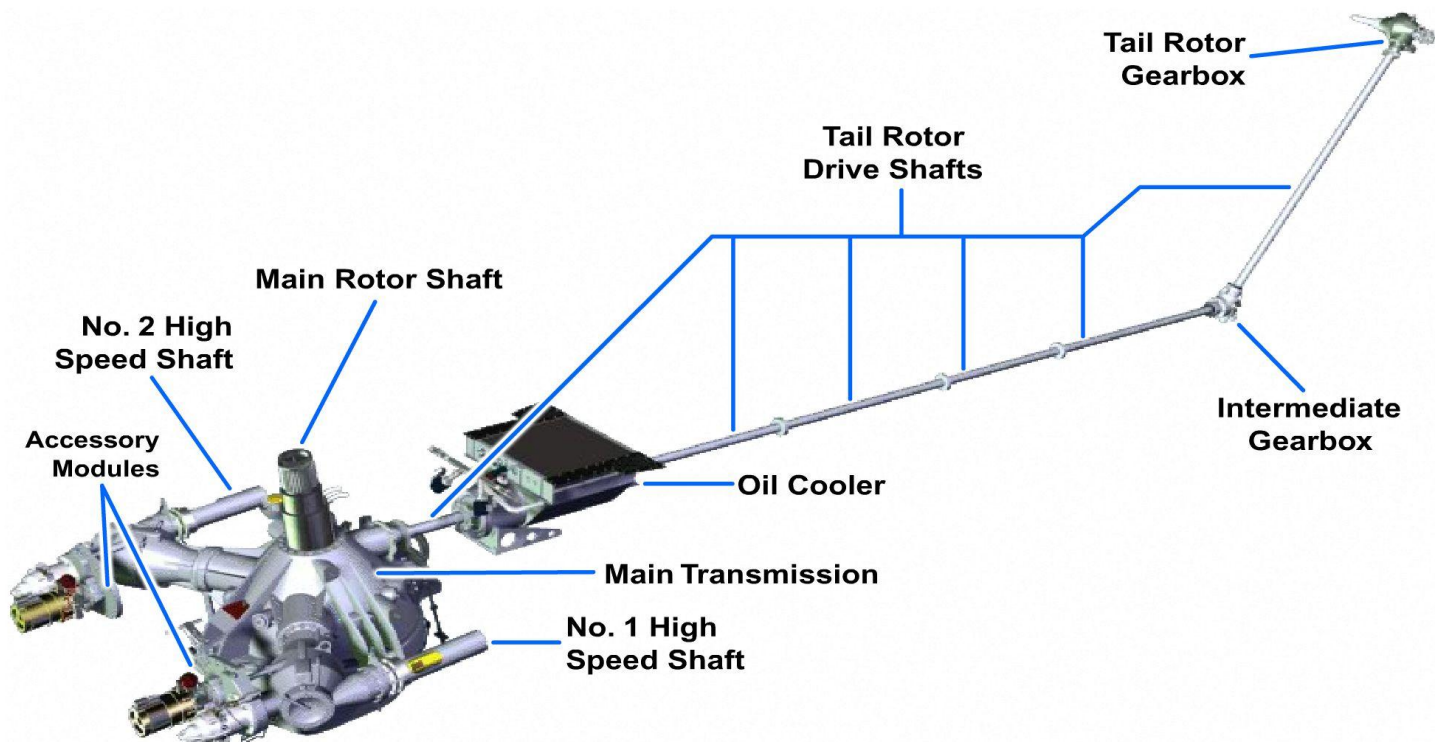


Figure 7-11 — SH-60 transmission system.

A freewheeling unit, at each engine input to the main gearbox, permits the rotary wing to auto-rotate without engine drag. The action occurs in case of engine (or engines) failure or when engine rpm decreases below the equivalent of rotor rpm. The freewheeling unit also provides a means of disengaging the rotary wing head while providing power to operate accessories (*Figure 7-12*).

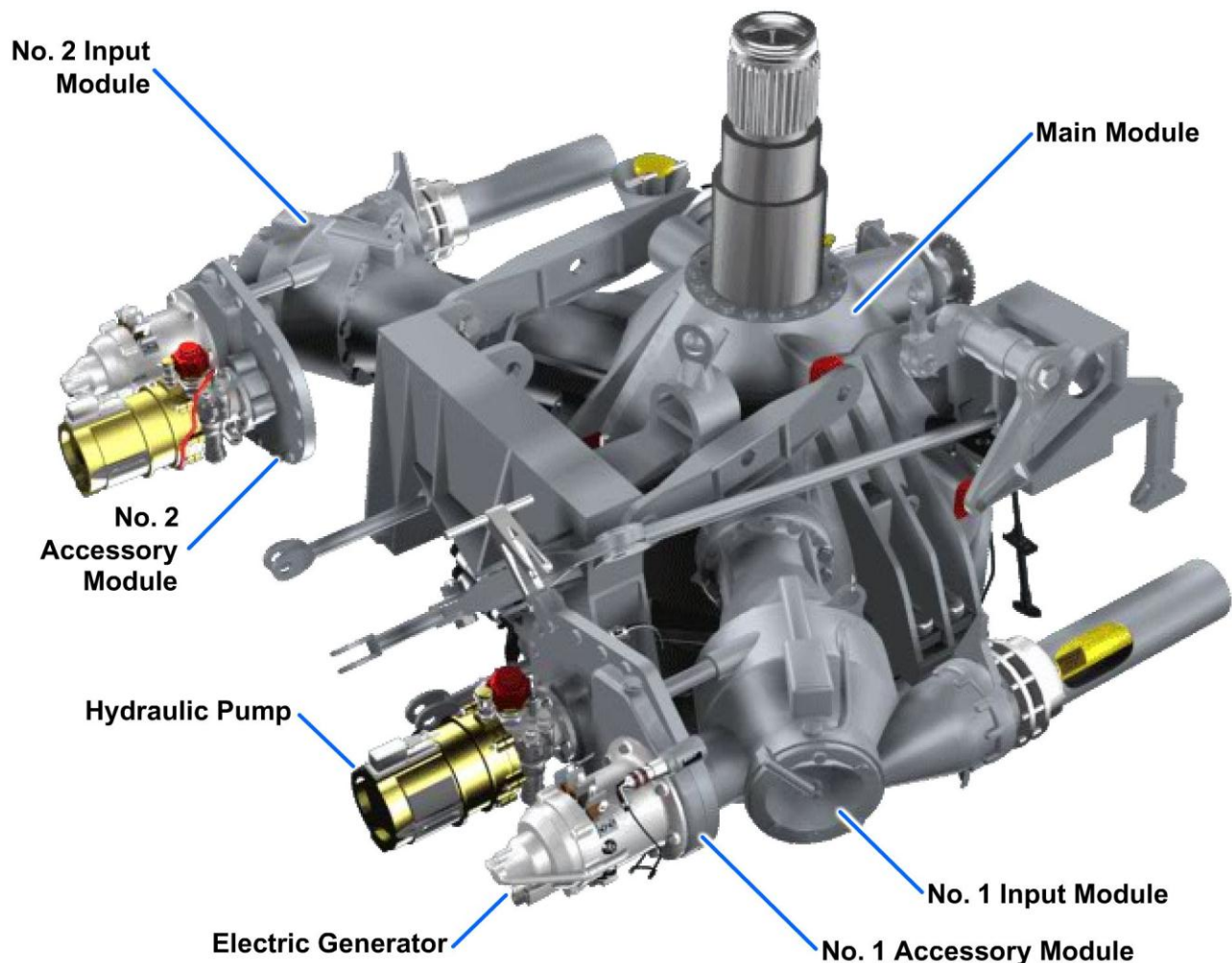


Figure 7-12 — SH60 main transmission gearbox and accessories.

Main Module

The main module provides mounting for the two input and accessory units. It has sensors that monitor, oil temperature, low oil pressure, high temperature warning, and chip detector systems.

A rotor brake mounted on the tail takeoff provides the capability to stop the rotor system. The rotor brake disc also provides the means to position the main rotor blades for folding. The module is driven by an output gear in the input module. This is linked to a bevel pinion by a quill shaft. The main bevel gear, which is driven by the main bevel pinions, and a sun gear are part of a single unit. As the bevel gears turn, the sun gears rotate which also turns the planetary gears linked to the main rotor shaft. A tail take off pinion rotates with the main bevel gear. The pinion provides drive to the radiator fan, tail driveshaft, and intermediate and tail gearboxes.

Input Module

The input modules mount on the right and left front of the main module and support the front of the engines. They each contain an input bevel pinion and gear and a freewheeling unit. The freewheeling unit allows engine disengagement during autorotation. If an engine fails, the freewheeling unit allows

the main transmission to continue to drive the accessory unit. The input module provides the first gear reduction between the engine and the main module.

Accessory Module

Each accessory module provides mounting and drive for an ac generator and a hydraulic pump package. Accessory modules mount on the forward section of each input module. Identical and interchangeable sensors are mounted on them. A rotor speed sensor mounts on the right module. The left module provides a mount for a low oil pressure sensor.

Intermediate Transmission Gearbox

The intermediate gearbox transmits torque and changes the angle of drive from the main transmission gearbox to the tail gearbox. The intermediate gearbox has an input housing and gear, a spring-loaded disconnect jaw, center housing, and an output housing and gear. The disconnect jaw permits folding and unfolding of the pylon without manually disconnecting the transmission. A transmission lock prevents the rotary rudder from wind milling when the pylon is folded. The lock is automatically unlocked when the pylon is unfolded (flight position). The input and output housings contain similar bevel gears to change the angle of drive up along the pylon. The center housing has an oil level sight gauge. It has a chip detector/drain plug on the bottom and the filler plug at the top (*Figure 7-13*). The electromagnetic chip detector, in addition to normal chip detector function, also detects overheating of the intermediate gearbox. The gearbox is splash-lubricated and air cooled.

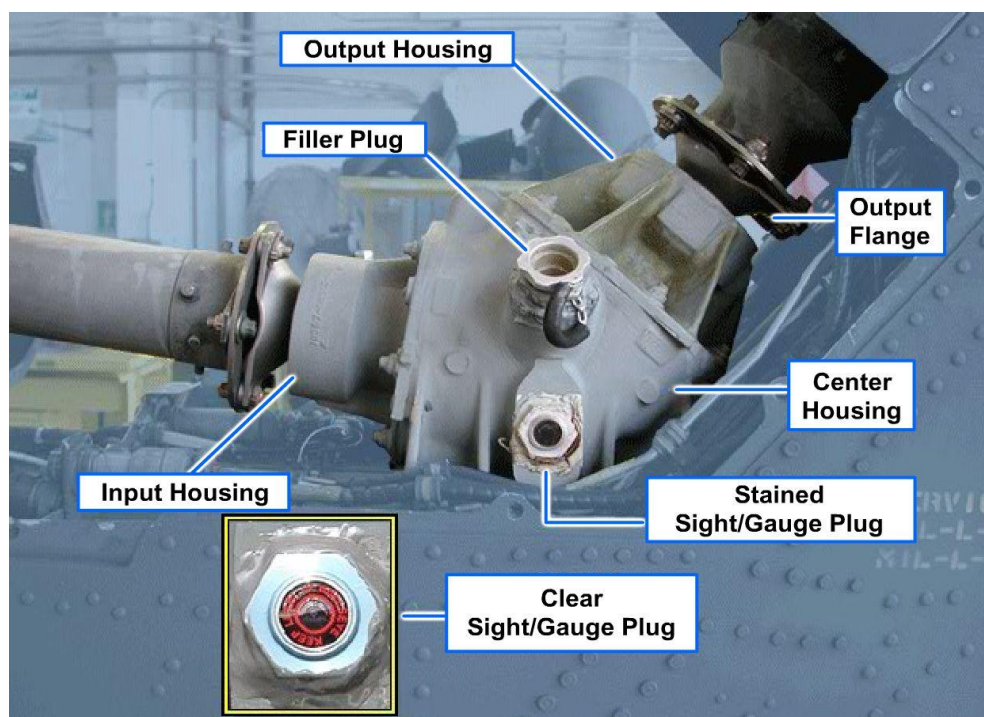


Figure 7-13 — Intermediate transmission gearbox.

Tail Transmission Gearbox

The tail gearbox, mounted at the top of the tail pylon, supports and drives the rotary rudder. It reduces shaft speed and changes the direction of drive by 105 degrees. It also enables pitch changes of the tail rotor blades through the flight control system. Lubrication is by means of a splash/mist method and is monitored by a chip detector. The tail gearbox chip detector is installed into the lower right side. In addition to normal chip detector function, it detects overheating of the tail gearbox. The gearbox is splash-lubricated and air cooled (*Figure 7-14*). It also has an oil level sight gauge and a filler plug. Access to the tail gearbox is through the tail gearbox access fairing at the top of the pylon.

High Speed Shaft

The high speed shaft is a dynamically balanced shaft that transmits torque from the turboshaft engine to the accessory module and then to the main gearbox. The SH-60 drive shaft assembly consists of a high-speed shaft, a flexible steel coupling called a Thomas coupling, and match-marked nuts for

engine attachment. The shaft assembly has match-marked bolts and nuts for attachment to the main gearbox coupling. It is flanged at both ends for connection to the Thomas coupling, adapter, and turboshaft engine coupling flange. The drive shaft is within and protected by the aft engine support. The direction of shaft rotation is clockwise (when viewed from the aft end of the engine).

Tail Drive Shaft

The tail drive shaft runs from the rear cover of the main gearbox to the disconnect coupling at the intermediate gearbox (*Figure 7-14*). The shaft between the intermediate gearbox and the tail gearbox is known as the pylon drive shaft.

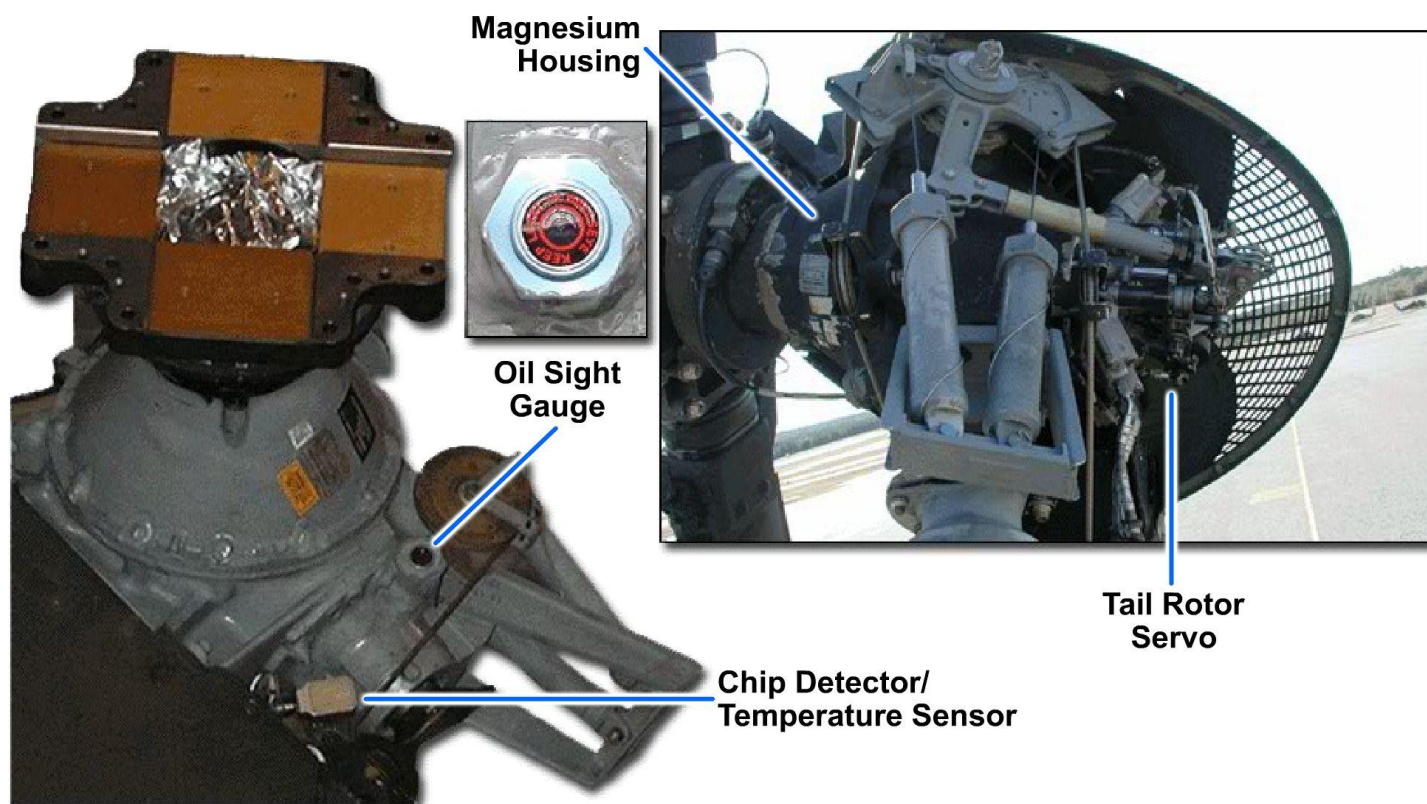


Figure 7-14 — Tail transmission gearbox.

The primary purpose of the tail drive shaft is to send engine power to drive the rotary rudder. On some installations it also provides a means to drive the main transmission gearbox oil cooler and blower fan. On the SH-60, there are five sections of drive shafts from the main transmission to the intermediate transmission gearbox and one section of tail drive shaft between the intermediate and tail transmission gearbox, making a total of six sections. Each section connects by a Thomas coupling, eliminating the need for universal joints. Each coupling has flexible stainless steel discs stacked together. Flats assure that the stack is in correct alignment. The grain in one disc runs parallel to the flats, and the grain in the other disc runs perpendicular to the flats. The shaft sections are supported by viscous-damped bearings. Each viscous-damped bearing support is a ball bearing enclosed by a thick rubber-type bag. Heavy silicone oil in the bag dampens vibrations in the tail drive shaft assembly. The pulley and belts that drive the oil cooler fan are attached to the oil cooler drive shaft. These are found between sections I and II of the tail drive shaft refer to (*Figure 7-11*). The section VI drive shaft is in the tail pylon. It sends power from the intermediate gearbox to the tail gearbox.

Oil Cooler and Blower

The main transmission gearbox oil cooler and blower unit of the SH-60 helicopter is directly aft of the main transmission gearbox, aft rotary wing fairing. It consists of a cooler (radiator), blower, and duct. The cooler is driven by the tail drive shaft. If the temperature of the oil is less than 130 degree Celsius (C), a thermostatic regulator bypasses the oil to the return line. Oil returning from the radiator or the bypass is forced through the lubricating jets located in the gearbox.

Rotor Brake

The rotor brake system permits applying the main rotor brake manually or automatically. It uses a master brake cylinder, pressure gauge, panel package, rotor brake, rotor brake accumulator, check valves, and pressure switches. Operation of the system is in conjunction with the operation of the automatic blade folding system. The rotor brake at the rear of the main gearbox is hydraulically actuated. Its purpose is to stop the rotation of the rotary wing head and rotary rudder. Actuation is manual by means of the rotor brake master cylinder in the cockpit. Operation is automatic during blade folding by the blade positioner control valve. The rotor brake consists of a rotor brake disc and housing.

Transmission Gearbox Component Maintenance

One of the most crucial types of maintenance on modern day helicopters will be maintaining, repairing, or inspecting transmission gearboxes. Apart from the turboshaft engines the transmission gearboxes give the helicopters the power of lift required for takeoffs and landings.

Main Transmission Inspection

Besides inspecting for corrosion and treating the main transmission outer surface for corrosion, there are some areas that require more attention. Visually inspect these areas for signs of overstress or over torqued conditions. The main areas are the barrel nuts, the forward bell crank support bridge mounting pad, and the main module mounting feet.

Barrel Nut Inspection

On the SH-60 helicopter there are three different part numbers for barrel nuts. The procedure for checking each one of them is the same for all. Install a mount bolt onto the barrel nut until there are two threads exposed beyond the nut. Using a torque wrench back out the bolt, if the breakaway torque is less than that specified in the MIM for that specific part number nut, discard the nut. Replace the nut with a new one, and repeat the procedure.

NOTE

When maintaining or performing inspections, removal, repairs, installation and all other maintenance functions on transmission gearboxes, always follow the appropriate procedures specified in the MIMs.

Bridge Support Mounting Pad

Following all safety procedures, clean all traces of paint and sealing compound from the mounting pad with dry-cleaning solvent. Repair minor nicks, gouges, scratches, and corrosion pitting on the surface of the mounting pad. Measure the depth of damage to make sure that blending out the damage does not go deeper than allowable repair limits. Remove corrosion by light sanding with aluminum oxide abrasive cloth. Inspect all blended areas using fluorescent penetrant. Crack indications or damage greater than specified requires replacement of the main module.

Main Module Mounting Feet

Visually inspect the main module mounts daily for cracks radiating outward from the center of the bushings. Check for cracks extending down from the sides of the mounting feet. If you do not find cracks in either the mounting feet or the sealing compound, no further inspection is required. Crack indications will require replacement of the main module. Repair minor damage as long as the repaired area stays within the specified repairable limits.

Main Transmission Removal

To make the main transmission accessible for removal, the removal of other items is necessary. First, remove rotor blades and head, swash-plate, and engine air inlets. Next, remove the left and right input modules with accessory modules attached. Remove all electrical connections and harnesses and all oil and hydraulic lines. Disconnect and support the tail rotor drive shaft. To prevent damage to the tail rotor and drive shafts while the tail drive is disconnected, make sure the tail rotor does not rotate. Remove bridge forward support and bridge aft support and arm. Remove main module mount bolts, and raise the main module clear of the helicopter. Lower the module onto an adapter and secure with the appropriate bolts, washers, and nuts.

NOTE

The main transmission weighs approximately 870 pounds.
Main transmission, with all equipment installed, weighs approximately 1200 pounds. Main transmission, with main rotor head installed, weighs approximately 2747 pounds.
Be sure to use a hoist with suitable capacity.

Main Transmission Installation

The main transmission installation procedures follow the removal procedures in reverse. There are some precautions to follow during the installation. To prevent damage, carefully guide the main module into place to clear all parts on the helicopter. Apply anti-seize compound to the mounting bolts.

To prevent corrosion damage to locator pins and supports on the main module, seal pins and supports from moisture accumulation. Lower the main module into position on the helicopter mounting surface. To ease installation, first, line up the front mounting holes and insert the mount bolts. Next, line up the rear mounting holes and insert the bolts. Follow the remainder of the installation procedures as specified in the MIMs.

Tail Drive Shaft Inspection

Inspect the shaft for scratches. Blend out scratches with crocus cloth. Replace the shaft section if the damaged or blended area exceeds specified limits. Inspect flexible couplings for nicks or dents. Blend out dents and nicks on the edges of individual discs, and replace the coupling if the damaged or blended area exceeds specified limits. Inspect each flexible coupling for disc separation. Each disc assembly may have disc separation or buckling, provided there are no kinks, sharp bends, or cracks. Replace the entire coupling if specified limits are exceeded. Inspect the plates in the coupling washer area for wear. Replace the entire coupling if you find any wear. Inspect the couplings for cracks in the disc. Check areas close to bolts and special washers. Replace the coupling if you find cracks.

Rotor Systems

The rotor system consists of the main rotor head, main rotor blades, tail rotor head, and tail rotor blades. This section on rotor systems discusses the general components and identifies some of the different features or materials being used.



WARNING



Anti-seize compound may contain lead. Do not smoke, drink, or eat when handling it. Wash thoroughly after use. If accidentally swallowed, do not induce vomiting. Seek medical attention. Sealing compounds and adhesives are toxic. Use rubber or polyethylene gloves and goggles. Wash hands thoroughly with soap and water before eating or smoking. Avoid breathing vapors during mixing, lay-up, or curing. Avoid breathing dust from sanding or grinding.

Main Rotor Head

The fully articulated rotary wing head is splined to the rotary wing shaft of the main gearbox. The head is supported by the rotary wing shaft. The head supports the rotary wing blades and is rotated by torque from the main gearbox. The head transmits movement of the flight controls to the blades. Its design permits automatic folding of the blades from a control panel in the cockpit.

There are two types of rotary wing heads in use. They are the grease-lubricated and self-lubricating heads (*Figure 7-15*).

The grease lubricated rotary wing head contains grease fittings for lubrication. The self-lubricated rotary wing head has fewer grease fittings, because oil reservoirs (tanks) are used on the hub plate at the vertical hinges. These reservoirs lubricate upper and lower hinge bearings and the stack bearings in sleeve spindles.

The fully articulated main rotor system consists of four subsystems: main rotor blades, hub, flight controls, and the bifilar vibration absorber. The four main rotor blades attach to hinged spindles and are retained by

elastomeric bearings contained in a one-piece titanium hub. The elastomeric bearings are laminated rubber and stainless steel and enable the blades to flap, lead, and lag, and also permit the blade to move about its axis for pitch changes. Two bearings are used per blade. The main rotor vibration absorber is mounted on top of the hub and consists of a four-arm plate with attached weights. Main rotor dampers are installed between each of the main rotor spindle modules and the hub to restrain

Grease Lubricated Head



Interaction Available

Figure 7-15 — Rotary wing head assemblies, (A) grease lubricated head, (B) self-lubricated head

lead and lag motions of the main rotor blades during rotation and to absorb rotor head starting loads. Each damper is supplied with pressurized hydraulic fluid from a reservoir mounted inside the main rotor shaft. The reservoir has indicators to monitor the fluid level and nitrogen pre-charge pressure. Rotor control is provided by flight control hydraulic servos tilting the swashplate assembly, which moves control rods attached to each spindle. When the rotor is not turning, the blades and spindles rest on hub-mounted droop stops. Upper restraints called antflap stops limit flapping motion at low rotor rpm. Both stops engage as the rotor slows down during engine shutdown. When the main rotor is rotating above 35 percent, centrifugal force pulls the antflap assemblies outward and holds them in that position to permit flapping and coning of the blades. When the main rotor head is rotating between 55 percent and 60 percent Nr, centrifugal force pulls the droop stops out and permits increased vertical movement of the blade. The main rotor head transmits the movements of the flight controls to the four main rotor blades. The main rotor head is supported by the main rotor shaft extension. The lower pressure plate, in conjunction with the main shaft nut, secures the shaft extension to the main shaft. The lower pressure plate also provides attachment for the scissors. The swashplate has stationary and rotating discs separated by a bearing. It transmits flight control movement to the main rotor head through the four pitch control rods. Four pitch control rods extend from the rotating swashplate to the blade pitch horn on each spindle. The pitch control rods transmit all movement of the flight controls from the swashplate to the main rotor blades. Each rod is ground adjustable for blade tracking. The Bifilar absorber absorbs vibrations and stresses. The bifilar vibration absorber is across-shaped aluminum forging. A tungsten weight pivots on two points at the end of each arm. The bifilar is bolted to the main rotor hub.

Main Rotor Blades

The rotary wing blades provide the lift necessary for flight. (Figure 7-16). The blades are of the nitrogen-pressurized spar type. Each blade has an air valve in the spar back wall near the root end and a cylindrical pressure plate. The root end plate is attached to the inboard end of the spar. A seal plate is found inside the spar tip end. Both are sealed for pressurization. Pressure loss in the spar shows impaired integrity of the spar or a seal leak. The cuff provides the means for attaching the blades to the rotary wing head sleeve spindles. Nickel-plated or titanium abrasion strips bonded to the spar leading edges prevent erosion.

Older blades consisted of a hollow extruded aluminum spar and aluminum pockets. They have a tip cap, a root cap, and a steel cuff. Newer blades consist of a pressurized titanium spar, honeycomb core, and fiberglass skin. The newer blades are often repairable at organizational-level instead of depot-level maintenance. They are repairable at the lower level of repair because of their honeycomb and fiberglass design. Both types of blades are

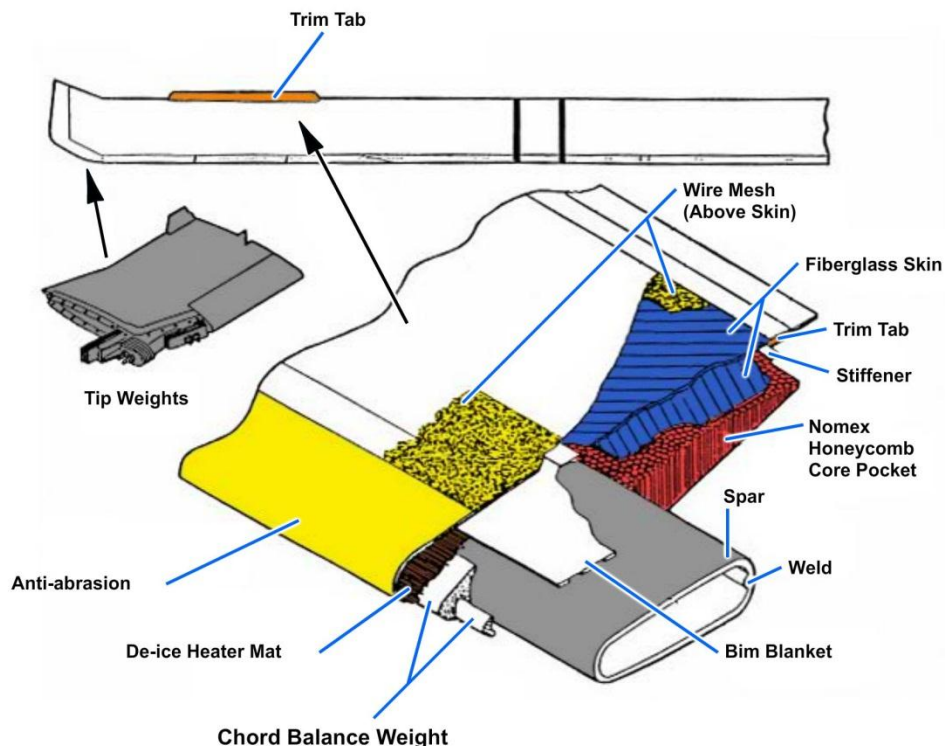


Figure 7-16 — Rotary wing blade.

statically and dynamically balanced to permit individual replacement and interchangeability of the blades. In addition to balancing, manufacturers and depot repair facilities stencil blades with a pre-track number to aid in blade tracking.

The pressure indicator, usually known as a blade inspection method (BIM), compares built-in reference pressure with blade spar pressure (*Figure 7-17*). When pressure in the spar is within the required service limits, three white stripes show in the indicator. If the pressure in the spar drops below the minimum permissible service pressure, the indicator will show three black stripes. When you see those black stripes, get the spar serviced immediately. The amount of black that shows depends on pressure in the spar. Remove from service any blade on which the pressure indicator shows any black color. The blade may be put back into service when the unsafe (black) indication is found and corrected. Replace a malfunctioning indicator, but only if the spar pressure is within permissible limits.

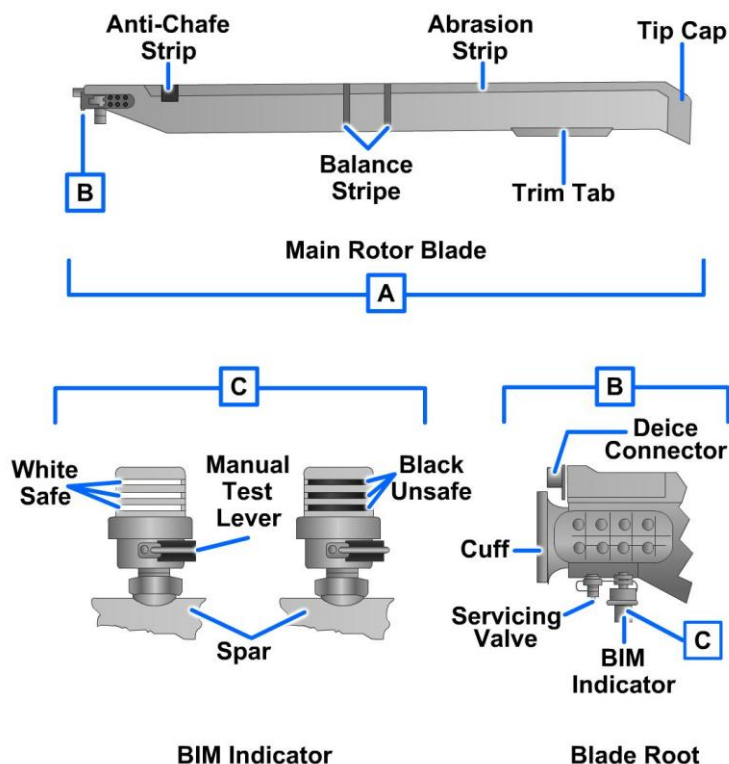


Figure 7-17 — BIM Indicator

Tail (Rotary) Rudder Head

The rotary rudder head provides for attachment of the rotary rudder blades and counteracts the torque of the main rotor head (*Figure 7-18*). It also serves as a rudder for directional control of the helicopter. The rotary rudder head is driven by the tail gearbox. Blade pitch changes by the action of the pitch change shaft. The pitch change shaft moves through the center of the output gear shaft of the tail gearbox. As the shaft moves outward from the gearbox, the pitch of the blades decreases. The pitch beam is connected by adjustable pitch change links to the forked brackets of the blade sleeves. The flapping spindles permit flapping of the blades in each direction.



WARNING

Both the rotary wing and rudder blades have areas that are joined by bonding adhesives. Never use solvents or cleaners not specifically authorized in the MIM. Never use lacquer thinner, naphtha, carbon tetrachloride, or other organic compounds for cleaning in these bonded areas. The solvent will weaken the bonding, and that weakening may result in blade failure.

Tail rotor blades are built around a spar that mounts on the tail rotor. The MH-53 has four composite blades built around titanium spars. The SH-60 blades are built around two graphite composite spars. Two honeycomb paddles are then bonded to the spars with fiberglass to form the blade.

Rotor System Maintenance

Organizational maintenance of the helicopter rotor system includes periodic inspection, lubrication, rigging, and adjustment. It also includes the cleaning of the rotary wing and rudder blades and the removal and replacement of malfunctioning components.

Vibration of the rotary mechanisms can result in work hardening of metals and later fatigue failure. Nondestructive testing of special parts of the rotary wing and the rotary rudder at specified intervals is necessary to prevent failures. The rotary wing head and rotary rudder assemblies are high-time removal items, as listed in the periodic maintenance information cards (PMIC).

Clean the rotary wing and rotary rudder as necessary, using approved cleaners mixed with water. The concentration of the mixture will vary depending on the surface condition.

An Aviation Machinist's Mate (AD) removes and replaces rotary wing parts; the airframes work center normally performs the rigging checks. Rigging checks and adjustment involve coordinating the cyclic pitch control stick, collective pitch control stick, and pedal positions with the correct rotary wing and rotary rudder blade angles. Rigging checks are necessary to ensure that the flight controls are operating under normal friction loads. At the completion of rigging, a qualified pilot performs a flight test. This test includes a check of blade tracking.

ATABS (Automated Track and Balance Set)

The unit is built around an International Business Machines (IBM) compatible computer with a 133 MHz 80586 processor (*Figure 7-19*). ATABS takes the voltage signal from the accelerometers and converts that signal into a plot of vibration level versus rpm for the selected range. ATABS uses the following equipment to track vibrations: ATABS unit, accelerometers, cable assemblies that resist electromagnetic interference, optical tachometers (photocell) used for track and balance of the main rotor blades or high speed shafts (magnetic pickup can be used in place of the optical tachometers for main rotor tracking and balance), aircraft specific ATABS unit software, and the camera for main rotor smoothing and balancing and finding blade track and blade lead/lag situations.

Rotor Blade Tracking

Perform blade tracking whenever the helicopter has been re-rigged. Blade tracking is necessary when the blades, the main gearbox, or the main rotor head assembly have been replaced. Unless the blades are in proper track, vibrations will occur in the helicopter with every revolution of the main rotor. At high rpm settings, those vibrations could cause serious structural damage.

Tracking the blades is necessary to be sure that all of the blades rotate in the same horizontal plane (track). This is accomplished by pre-track rigging of the rotary wing head and by the use of pre-tracked blades.

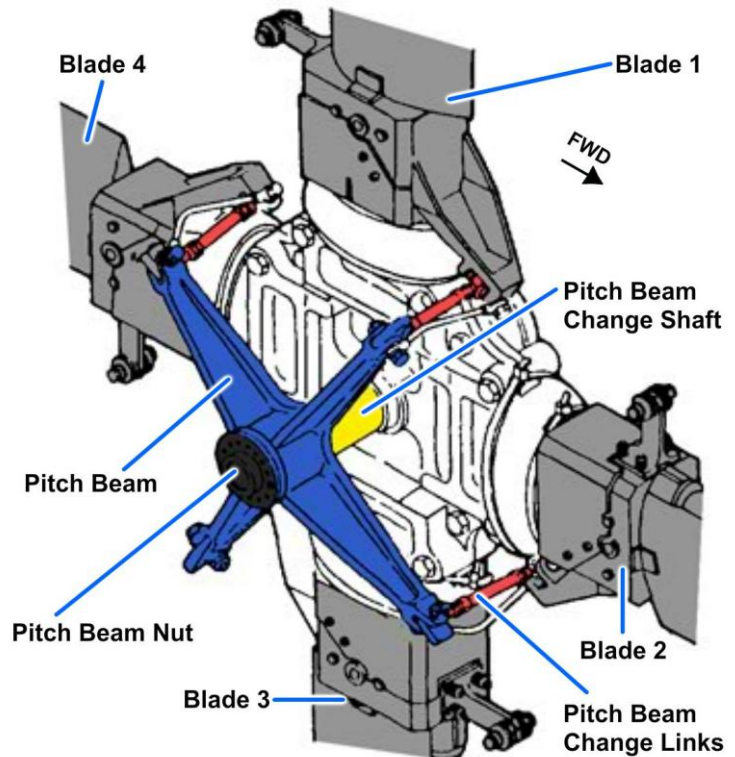


Figure 7-18 — Rotary rudder head.

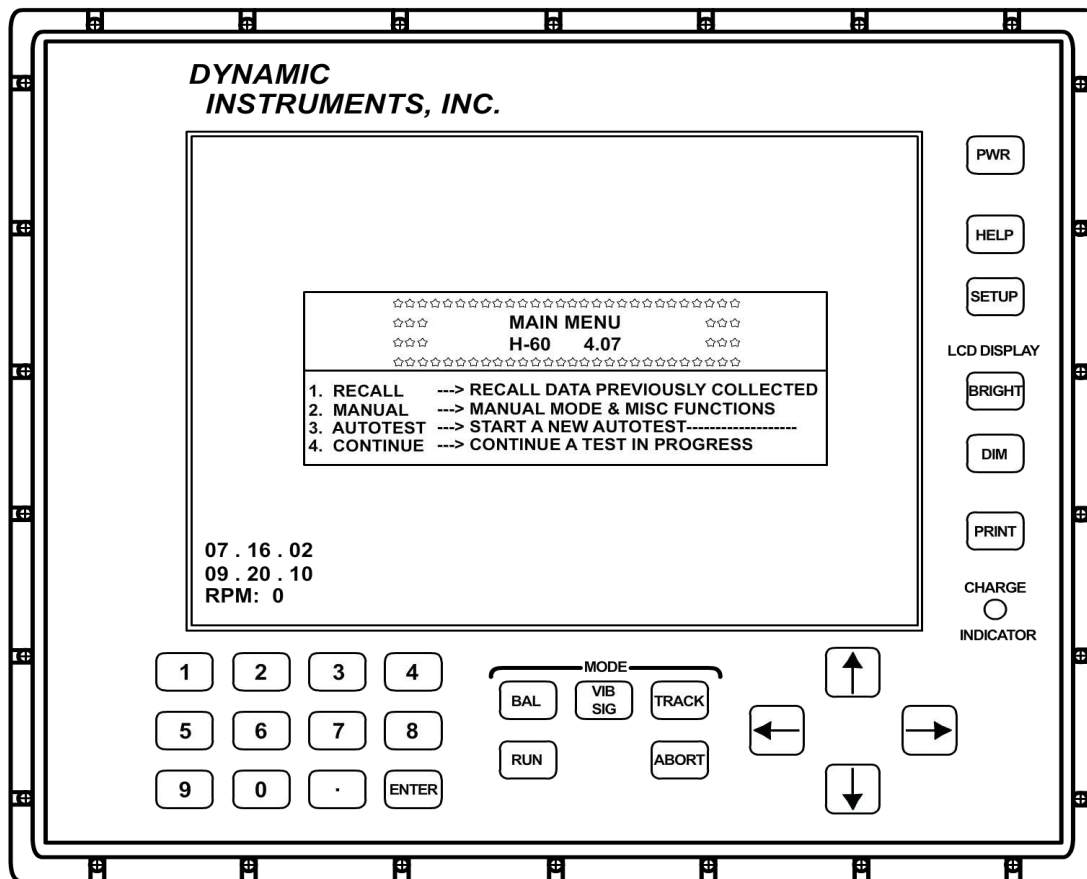


Figure 7-19 — ATABS unit and associated equipment.

Pretrack rigging of the main rotor head involves adjusting pitch control rods. First, compare pretrack number of removed blade with number of main rotor blade now installed. Pretrack numbers are stenciled on bottom of main rotor blades. Adjustment is not necessary if numbers are identical. Subtract pretrack number of installed (new) main rotor blade from number of removed (old) main rotor blade. If difference between old and new blade is a plus(+) number, loosen locknuts on pitch control rods and turn in -2 MINUTES/NOTCH direction. Each notch is equals to 2 minutes. If difference between installed main rotor blade and removed main rotor blade is a minus (-) number, loosen locknuts on pitch control rod and turn in +2 MINUTES/NOTCH direction. Tighten and torque locknuts as specified in the MIM. The blade tracking is then checked with Automated Track and Balance Set (ATABS).

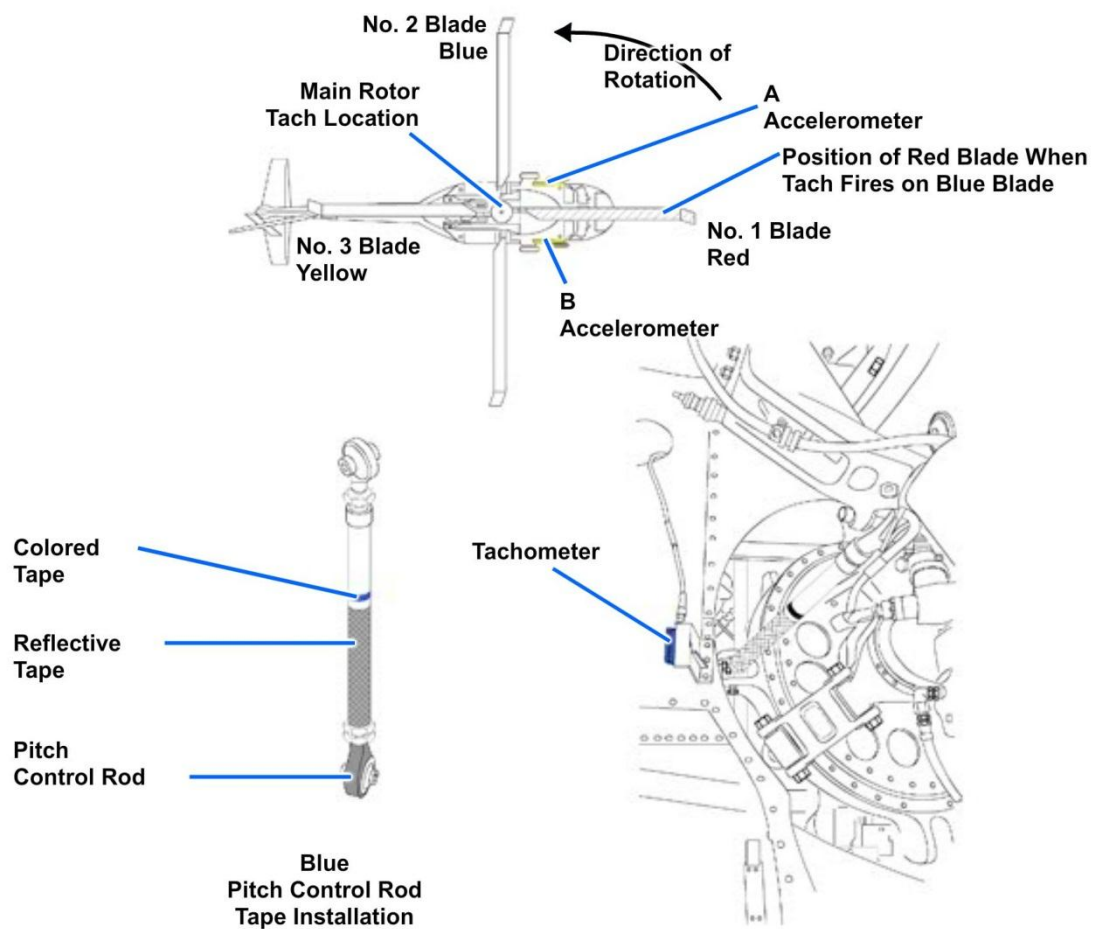


Figure 7-20 — Track and balance, pitch control rod adjusting.

End of Chapter 7

Helicopters and Turboshaft Powerplants

Review Questions

- 7-1. What determines the flight characteristics of a helicopter?
- A. Rotational speed and pitch variations of the rotor blades
 - B. Rotational pitch speed and air speed of the rotor blades
 - C. Rotational pitch hover and speed variations of the rotor blades
 - D. Rotational hover and air speed variations of the rotor blades
- 7-2. According to the theory of lift, lift results from what?
- A. accelerating a mass of air aft
 - B. accelerating a mass of air downward
 - C. accelerating a mass of air forward
 - D. accelerating a mass of air equal in both directions
- 7-3. Which of the following is a main factor affecting helicopter flight?
- A. air
 - B. blade
 - C. torque
 - D. rotor
- 7-4. Which factor is caused by a combination of lift and centrifugal force?
- A. acceleration
 - B. coning
 - C. speed
 - D. torque
- 7-5. What are the two basic types of helicopter rotors?
- A. triple/multi
 - B. single/multi
 - C. single/triple
 - D. multi/triple
- 7-6. How many factors affect rotor blade lift?
- A. 2
 - B. 4
 - C. 6
 - D. 8

7-7. Which component is mounted on the accessory module of an SH-60 helicopter?

- A. hydraulic pump
- B. fuel pump
- C. intake pump
- D. Oil pump

7-8. How many rotary wing heads are in use today?

- A. 1
- B. 2
- C. 3
- D. 4

7-9. What types of rotary wing heads are in use today?

- A. Grease lubricated/multi-lubricated
- B. Grease lubricated/single-lubricated
- C. Grease lubricated/double-lubricated
- D. Grease lubricated/self-lubricated

7-10. Which section is considered the major section of a T-700 turboshaft engine?

- A. Accumulator
- B. Accessory
- C. Compressor
- D. Diffuser

7-11. How many major sections are there on a T-700 turboshaft engine?

- A. 2
- B. 3
- C. 4
- D. 5

7-12. How many axial compressor stages are on the T64-GE-419?

- A. 5
- B. 11
- C. 14
- D. 16

7-13. When is blade tracking necessary?

- A. When the blades have been replaced
- B. When the engine has been replaced
- C. When the hydraulic unit has been replaced
- D. When the wheels has been replaced

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