PROPELLER OPERATION AND MALFUNCTIONS BASIC FAMILIARIZATION FOR FLIGHT CREWS

INTRODUCTION

The following is basic material to help pilots understand how the propellers on turbine engines work, and how they sometimes fail. Some of these failures and malfunctions cannot be duplicated well in the simulator, which can cause recognition difficulties when they happen in actual operation.

This text is not meant to replace other instructional texts. However, completion of the material can provide pilots with additional understanding of turbopropeller operation and the handling of malfunctions.

GENERAL PROPELLER PRINCIPLES

Propeller and engine system designs vary widely. They range from wood propellers on reciprocating engines to fully reversing and feathering constant-speed propellers on turbine engines. Each of these propulsion systems has the similar basic function of producing thrust to propel the airplane, but with different control and operational requirements. Since the full range of combinations is too broad to cover fully in this summary, it will focus on a typical system for transport category airplanes - the constant speed, feathering and reversing propellers on turbine engines.

Major propeller components

The propeller consists of several blades held in place by a central hub. The propeller hub holds the blades in place and is connected to the engine through a propeller drive shaft and a gearbox. There is also a control system for the propeller, which will be discussed later. Modern propellers on large turboprop airplanes typically have 4 to 6 blades. Other components typically include:

- The spinner, which creates aerodynamic streamlining over the propeller hub.
- The bulkhead, which allows the spinner to be attached to the rest of the propeller. The bulkhead typically has a slip ring arrangement that allows electrical power to be transmitted to the blade de-icing boots.
- The pitch change actuator, to transmit hydraulic energy to rotate the blades in the hub.
- A source of high pressure oil to supply that hydraulic energy to the propeller actuator.

- The primary control, also called the governor, for controlling propeller speed and blade pitch.
- The overspeed governor, which serves as a backup if the primary control malfunctions.

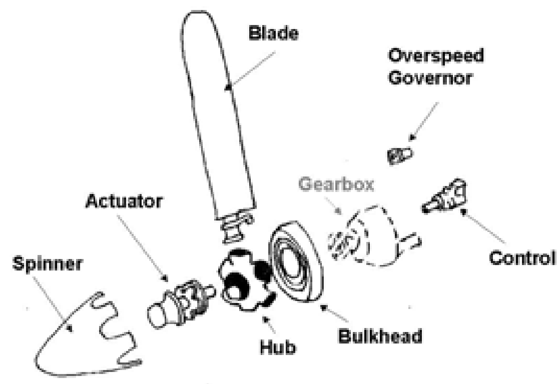

Figure 1
Major Propeller Components

Blade pitch

The propeller blade pitch, also more simply called the propeller pitch, is the angle that the blade presents to the plane of rotation of the propeller. The blade pitch known as "feather" describes the pitch that results in no or slow rotation of the propeller at a specific flight condition (typically, cruise) with the engine shut down. Due to the twist of the blade, this angle is typically slightly less than 90 degrees. Basically, feather leaves the propeller blades edge-on to the direction of travel. "Flat pitch" refers to the pitch that results in minimum torque with the engine operating while on the ground. Typically, flat pitch is about 0 degrees. The blades present an essentially flat face to the direction of travel. Angles below flat pitch are considered reverse pitch.

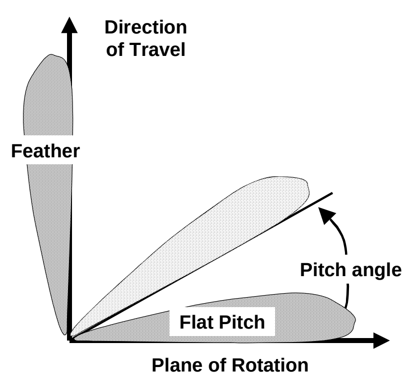

Figure 2
Blade Pitch

Blade twist

Propeller blades need to be twisted to optimize the aerodynamic performance of the specific blade design with the angle of attack to the air as they rotate. The angle of the air approaching a blade is a combination of the airplane's forward speed and the propeller's rotational speed. The airplane forward speed is constant along the blade, but the rotational speed increases from the blade root to the blade tip (the tip has to travel farther for each rotation). This means that the propeller blade needs to be twisted to get the optimum amount of lift along the full length of the blade.

Thrust

Propellers produce thrust using the same principle as airplane wings do to produce lift. If you look at a section of a propeller blade, you will notice that it looks like a wing. The air approaches the blade section (airfoil) at an angle of attack that causes a pressure change over the airfoil, producing lift. This lift produces a force to propel the airplane in the direction of flight.

The propeller produces the majority of the thrust for the airplane, but the engine also provides a small amount. The propeller accelerates the air into the engine inlet, and the engine itself further accelerates the air out the exhaust. This force of the exhaust air out the back of the engine results in an equal and opposite force that pushes the engine (and thus, the airplane) forward, adding to the thrust.

Constant speed propeller

A constant speed propeller is a propeller with a control system that maintains a constant propeller rotational speed (RPM) setting at any flight condition. To maintain constant propeller RPM, you must adjust the pitch of the propeller blades as you change airspeed and/or engine power. The pitch is adjusted by rotating the whole blade on a bearing in the hub using an actuator that is linked to the control system. When you change the pitch, you change the "bite" that the blades make with the wind. This, in turn, increases or decreases the aerodynamic load on the propeller.

The advantages of a modern turboprop constant speed propeller are: better performance over a wider range of flight conditions, the ability to produce reverse thrust during landing rollout and ground handling, and the ability to minimize drag on the aircraft by feathering the propeller in the event of an engine shutdown.

Efficiency and speed control. Since all turbine engines are most efficient within specific RPM ranges, it is desirable to have a propeller with the ability to change thrust while maintaining the most efficient engine RPM possible. In a propeller, this is done by changing the propeller blade pitch, which increases or decreases the load as needed to maintain a constant RPM. The ability of the propeller to change pitch allows both the engine and the propeller to spend most of their time operating in their most efficient range.

Reverse thrust. Pitch angle can be changed to actually produce reverse thrust. Reverse thrust helps to stop the airplane, and even allows it to back up on the ground.

Feathering. When an engine is shutdown in flight, an unfeathered propeller presents a large, flat surface face-on into the airstream. This can result in high drag on the airplane. Since the propeller is free to turn, it acts as a windmill, with the force of the air turning the propeller. The force extracted from the air causes drag on the airplane. Additionally, the windmilling of the propeller causes the engine to rotate. When the propeller drives the engine (rather than the intended situation of the engine driving the propeller), the situation is called negative torque. In single-shaft turbine engines, high levels of negative torque can result from the windmilling load of the propeller on the engine, resulting in very high drag and potential engine damage by driving the engine. Because of this, single-shaft engines incorporate a negative torque system to prevent these high levels of drag from occurring and the propeller from driving the engine should the propeller not feather following an engine shutdown. The NTS adjusts the blade angle towards feather to minimize windmilling.

The windmilling load is less on a free-turbine engine, but drag can still be high if the propeller is not feathered.

On a variable pitch propeller, the drag can be minimized by rotating the blades until they are edgewise to the flight direction. This is called feathering the propeller. At this angle, the propeller does not rotate or rotates slowly; thus, its drag on the airplane is greatly reduced. Engine failure or malfunction may or may not require feathering the propeller, depending on the type of problem. Additionally, certain problems require prompt feathering to avoid serious drag issues. Knowing when or if it is necessary to feather the propeller is critical. (Some of these situations are covered below.) The Airplane Flight Manual (AFM) data for single engine performance and V_{MC} typically assumes that the propeller is feathered, unless special instructions are provided.

In general, for malfunctions where the engine is still operating, the propeller should be feathered and the engine should be shut down. A number of accidents have occurred when the flight crew kept the engine running as a contingency or for the use of ancillary services, and neglected to feather the propeller. Later in the flight, during approach at low speed, or during go-around, the excessive drag from the windmilling propeller resulted in loss of control and loss of the airplane. For this reason, do not keep a malfunctioning powerplant running for contingency purposes. Modern airplanes certificated to FAR/JAR 25 regulations are safe to fly on one engine; they can meet all performance and airframe system integrity requirements. Should the AFM provide for continued operation of the engine, the pilots should be given specific operational guidance regarding the decision not to shutdown the affected engine.

In a single-shaft engine, feathering the propeller while the engine is running could result in an overtorque. However, in modern airplanes, there are interlocks to prevent this occurrence, so flight procedures typically call for feathering the propeller and then shutting down the engine.

Propeller speed-sensing operation

Propellers have a speed-sensing governor that controls oil pressure on a piston attached to the blades by a mechanical linkage. If the pilot commands a change in propeller RPM, or if flight conditions (engine power or airspeed) change, the propeller speed-sensing governor adjusts the oil pressure, changing the pitch of the blades. It does this to maintain the speed of the propeller as set by the pilot. If the propeller is turning too quickly, the blade pitch is automatically changed to take a bigger bite out of the air, creating more torque and slowing the propeller RPM. If the prop is turning too slowly, the blade angle is decreased to take smaller bites, producing less torque and allowing propeller RPM to speed up. The speed-sensing governor continually adjusts the oil pressure to keep the propeller at the commanded RPM at constant speed.

Propeller control systems

There are several different systems that are used to control propellers. These are:

- Single-acting systems, with a spring and blade counterweights.
- Double-acting systems, with either blade counterweights or a pitch lock mechanism.

The one common feature of these propeller control systems is that they all use hydraulic pressure acting on a piston to change the pitch angle of the blades.

Single-acting systems. A single-acting propeller has counterweighted blades and a feather spring that constantly push the blades toward high pitch (feather). Since the blades are always being driven to high pitch, the propeller only needs a piston with pressure on one side to push back against the counterweights and spring. When the piston pressure is increased, the blades go toward low (flat) pitch. When the piston pressure is decreased, the counterweights and springs drive the propeller back toward high pitch. The counterweights do most of the work to drive the blades to high pitch. The springs help feather when the propeller RPM is low and the centrifugal loads acting on the counterweights do not have enough force to drive the blades completely to feather.

Double-acting systems. A double-acting propeller uses a piston that provides force in both directions to control the propeller RPM. The governor controls the pressure on both sides of the piston to increase or decrease the pitch as required. A double-acting propeller typically uses oil pressure, either from the normal high-pressure pump or from an auxiliary pump, to completely feather the blades, although it may also use counterweights to increase pitch in the event of oil system failure.

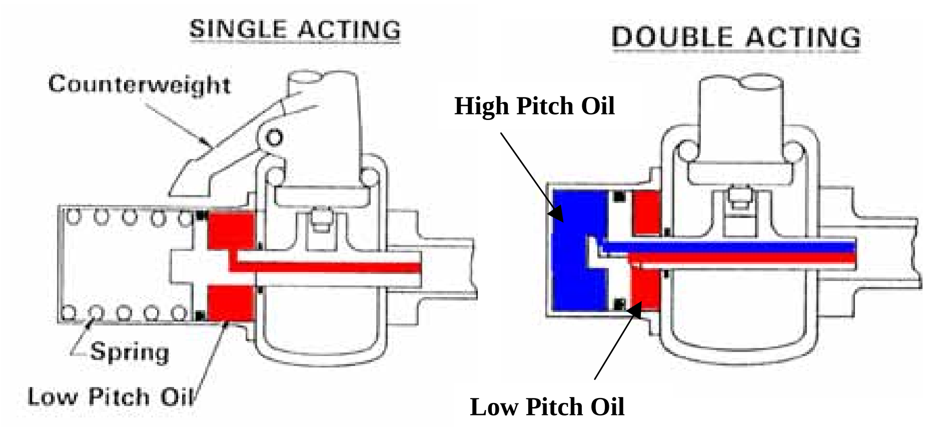

Figure 3
Single- and double-acting systems

Pitch-limiting systems. The natural forces on a propeller blade want to drive the propeller blades to low pitch. In flight, this is an unsafe failure condition. At low pitch in flight, a propeller can windmill, overspeed, and produce high drag. Without a safety device to prevent this from happening, a loss of hydraulic pressure could result in a propeller pitch angle that could create so much drag that the airplane could become uncontrollable. Variable pitch propellers have either counterweights or a lock to limit unwanted blade angle movement to low pitch after failures.

Counterweights are attached to the blade at a position that will cause the centrifugal loads on the counterweights to drive the blades towards higher pitch (towards feather). In this way, a loss of hydraulic pressure will cause the pitch to increase to a safe setting.

A pitch lock is a device that locks the blade pitch when hydraulic pressure is lost. Pitch locks are typically used on non-counterweighted, dual-acting propellers. The pitch lock mechanism will lock the blade pitch at a setting slightly less than the pitch of the propeller at the time the oil pressure was lost. The propeller is now operating at a safe pitch setting as a fixed-pitch propeller, allowing the powerplant to continue to provide thrust for the aircraft.

Feathering the propeller

In cases of engine shutdown, it will almost always be possible to feather the propeller. The propeller control system is designed to continue to function when an engine is shut down, and will allow for feathering except in the unlikely event that the system has been assembled incorrectly, or the actuator jams. If oil pressure is lost on a counterweighted propeller, the propeller will automatically increase pitch towards feather (in single-acting propellers, it will increase all the way to feather). If the oil pressure is lost on a propeller with a pitch lock, there are several options available to feather the propeller. If the pressure is lost due to a main pump failure, there is a backup pump that can be used to create pressure and feather the propeller. If the oil pressure is lost because the engine oil has drained out, the propeller has a backup supply of oil sufficient to feather the propeller through the backup pump. Because of these redundancies, it is rare that the propeller cannot be feathered. Even if that rare event does occur, the blade pitch is still limited either by the counterweights to a pitch angle near feather, or by the pitch lock to a safe setting.

Operation below flight idle

Unless it is specifically permitted by the Airplane Flight Manual, any operation of the power lever below flight idle while in flight must be avoided due to high drag (potentially, dangerously high drag) and the overspeed it causes. In flight, the forward speed of the airplane may cause the propeller to windmill at a very high speed as the propeller transitions to reverse pitch angle. Thus, operation below flight idle is typically restricted to ground operations.

Other turboprop functions

***De-ice*.** Airplanes are often flown in conditions that can cause ice to form on various airplane surfaces. In these conditions, ice can also form on the blades of the propeller. The buildup of ice on the blades can degrade their aerodynamic performance just as ice can reduce the lift of the airplane's wings. Ice on the blades can also cause an imbalance that will result in vibration in the aircraft.

The most common approach to prevent the buildup of ice on the propeller blades is to de-ice the leading edge of each blade with a heater. Ice is allowed to build up slightly before the heater is turned on. Once the heater is on, the ice is slung off, and the heater is turned off again. The on-off cycle is controlled either by a de-icing timer or by the aircraft computer. This permits minimal use of electric power, as the requirement is for only enough heat to melt the thin layer of ice holding the mass of ice to the blade. Once the ice is loosened from the inside, centrifugal force removes the ice.

***Synchronizing/synchrophasing*.** A synchronizing or synchrophasing function provides automatic control of the relative RPMs of all the propellers on an airplane and the rotational positions of their respective sets of blades. Maintaining the same RPM and a constant blade phase relationship within close limits reduces vibration ("beat") and noise in the cabin.

Summary of safety features

Feather. Feather is employed if an engine must be shut down. In feathering, the blades are turned so that the leading edges are pointed essentially in the direction of flight. In this position, the aerodynamic forces on the propeller result in a low drag condition.

Pitch lock. Pitch lock is used with dual-acting systems. Pitch lock functions whenever there is a loss of oil pressure to the propeller, locking the blade pitch at a slightly lower pitch angle than when the pitch was under the control of the governor. This feature prevents the blade pitch from decreasing while still allowing the blades to increase pitch up to feather if so commanded.

Counterweight. When there is a loss of oil pressure, the counterweight increases the blade pitch to a safe setting. This system is always used in single-acting systems, and can be used for dual-acting systems.

Overspeed governor. The overspeed governor is a backup governor that controls propeller speed if the main governor or control is not functioning. Typically, it protects against overspeed of the propeller by governing at about 102-104% RPM.

Auxiliary oil pump and oil sump. In the event of an oil system failure or loss of oil pressure due to engine failure, these auxiliary components provide backup oil pressure to feather the propeller in dual-acting systems.

PROPELLER INSTRUMENTATION AND CONTROLS

Airplanes in service today are equipped with devices available to the flight crew that provide feedback information about the turboprop to set power and monitor the condition of the propulsion system. In older airplanes, these devices were gages on a panel. In newer airplanes, these gages have been largely replaced with electronic screens, which produce computer-generated displays that may resemble gages. In either case, similar information is provided to the flight crew.

The following is a brief description of the gages and indicators and what information they provide:

Propeller RPM (NP) – rotational speed of the propeller, typically in %.

Propeller Torque – torque provided to the propeller by the engine, typically in %.

Beta Light – indicates that the propeller blades are at their reverse thrust blade angle.

The flight crew also has a series of controls to provide direct input to the turboprop system. The following is a brief description of these controls and their functions:

Power Lever – allows selection of engine power settings at any time and also the propeller settings when the engine is below flight idle and the governor is inactive. In this latter case, the power lever either sets the blade angle directly for ground handling, or allows the engine control to govern the propeller by controlling of torque during ground operations.

Condition Lever – sets the propeller governing speed and also allows feather/unfeather of the propeller blades.

Feather Switch/E-handle/C-handle – Allows manual feathering of propeller.

Synchrophaser/Synchronizer Selector Switch – Engages the system to match the RPMs and blade positions of multiple propellers to minimize cabin noise.

De-ice Switch – Used to activate the propeller de-ice system

Ammeter – Used to display the level of electrical power usage for monitoring of the de-icing system.

TURBOPROP MALFUNCTIONS

The following information describes some turbopropeller malfunctions, their consequences, and the appropriate pilot responses in a manner that is applicable to most modern turboprop-powered airplanes. The engine and propeller systems operate together as one system, and it can be difficult to isolate the cause of a malfunction by the symptoms observed. However, the actions for a particular symptom, whether caused by an engine or a propeller condition, are often the same.

Note that the following information is meant to be general, and does not supersede or replace the specific instructions that are provided in your Airplane Flight Manual and appropriate checklists.

PROPELLER REACTIONS TO ENGINE MALFUNCTIONS

The following material explains how the propeller will react to certain engine malfunctions. (Information on the engine effects is contained elsewhere in this training package.)

Flameout or severe engine damage

For propeller systems with an auto-feather, auto-coarsen or Negative Torque Sensing (NTS) feature, the propeller will automatically react in the event of loss of engine power as long as the system is armed. For systems without autofeather, the propeller system will attempt to continue to govern the propeller operation. This will result in windmilling, and the propeller will begin driving the engine section to which it is connected. This in turn causes an increase in drag, causing the airplane to yaw in the direction of the dead engine.

For a free-turbine engine, the windmilling propeller will drive only the power turbine section of the engine, and negative torque will not be a factor. For a single-shaft (fixed-turbine) engine, the windmilling propeller will drive both the turbine and compressor sections of the engine, resulting in increasing levels of negative torque as blade angle decreases as the governor attempts to continue to control RPM. In this situation, the NTS system (if installed) will limit the amount of negative torque and, thus, the subsequent drag.

The pilot’s response to a flameout is to first stabilize the airplane and then follow the procedures for engine failure. Typically, this will call for feathering the propeller to minimize drag.

Compressor surge

Depending on the severity of the surge, there may be insufficient time for the propeller system to react to the event. If the event is prolonged, a drop in propeller torque might be observed. If the engine does not recover, the propeller will react as in the flameout case, and may require similar action.

Birdstrike or Foreign Object Damage (FOD)

If a bird or other foreign object strikes the propeller with sufficient force, blade damage can occur. This damage may, in turn, cause unbalance in the propeller’s rotation, resulting in vibrations in the aircraft. Follow the recommended procedures for excessive vibration, after first ensuring that the airplane is in stable flight at a safe altitude. The procedures may include feathering the propeller and shutting down the engine to reduce vibration.

The foreign material may reach the engine without damaging the propeller. In this case, the engine may surge, flameout, or suffer damage. See the applicable information for surges and engine flameout/damage.

Oil system problems

Many propeller systems rely on oil from the engine to provide the hydraulic pressure needed to change the pitch of the propeller. When the engine oil pressure is low or lost altogether, the propeller backup systems come into play. In propellers with a pitch lock, the pitch lock engages and the propeller acts as a fixed pitch propeller. A pitchlock can be detected by the fact that propeller RPM will increase as power is added or airspeed increases, or decrease as power or airspeed is reduced. For counterweighted propellers, the blades will increase pitch towards feather with a corresponding decrease in propeller RPM. Unless the propeller is protected by a torque-limiting feature in the engine control, the loss of oil pressure in a counterweighted propeller could result in a high-torque condition. For either type of propeller system (pitch lock or counterweight), it will still be possible to feather the propeller. Activation of the feather switch will engage the electric auxiliary pump, and oil will be pumped from the dedicated oil sump to provide pressure to feather the propeller. Follow the instructions provided in the AFM for the proper procedures following loss of oil pressure to the propeller.

PROPELLER SYSTEM MALFUNCTIONS

The following material provides brief summaries of malfunctions of the propeller itself.

Loss of reverse function

This condition can be difficult to detect prior to landing. One indicator during normal flight is when a propeller is found to be pitchlocked. In this case, reverse will not be available and should not be attempted on landing. Refer to the AFM for the procedures for landing with a pitchlocked propeller.

If a pitchlock is not evident and the powerplant is functioning normally, the pilot should check that both (or all, on a 4-engine plane) beta lights illuminate during landing when the power lever is pulled to flight idle, prior to selection of reverse. If one light does not illuminate, the pilot should assume that its associated propeller will not reverse due to being pitchlocked or having a malfunctioning control system. The lack of beta light may be the only indication available to the pilot.

Selecting reverse on both propellers when one is incapable of reverse operation will result in asymmetric thrust, since one propeller will reverse and the other propeller will remain in positive or neutral thrust. Follow the AFM procedures for landing with one propeller at the low-pitch stop (no reverse).

Overspeed governor activation

Failure of the main propeller governor will result in the activation of the propeller overspeed governor. The NP gage will typically be steady at 103 to 105%. The noise in the cabin will be increased because the RPM is higher than normal and the synchronizer/syncrophaser will not be functioning (because the other propeller is turning at a normal RPM). The RPM will not decrease or increase when commanded by the condition lever or a speed-selection device. Operating on the overspeed governor typically means that reverse thrust operation is not available, although flat-pitch operation on the ground may be available. Each installation is different, and the AFM instructions should be used.

Overspeed above the overspeed governor setting

One of the concerns many flight crews have when an overspeed is encountered is that the blades will be released from the hub. However, propeller blade retention systems are designed not only to withstand the centrifugal loads from overspeed rotation, but also to withstand the loads caused by the effect of airflow on the blades. Blade and retention system capability is demonstrated during certification by testing at twice the maximum centrifugal load. Twice centrifugal load occurs at 141% speed. No turboprop propeller blades have ever been broken or released due to an overspeed event.

There are a number of different situations that could cause overspeed above the overspeed governor's ability to control the propeller. Appropriate responses will be different for each system. A general recommendation is to avoid being distracted by the noise of the overspeeding propeller. Continue to fly the airplane and follow AFM recommendations for aircraft operation and/or engine shutdown.

Overtorque

Overtorque malfunctions may occur for a number of reasons. Overtorquing will occur whenever the propeller blade pitch increases faster than the engine control can accommodate the rate of increase. This can be due to an autofeather malfunction of the autofeather control system, or a malfunction of the propeller control system that results in uncommanded increase in pitch. For these malfunctions, the airplane may experience a temporary yaw, followed by a low NP and high torque indications. The high torque indication may be a transient condition, and the propeller RPM will remain low. Follow the approved AFM procedures for feathering the propeller and shutdown of the engine.

Uncommanded feather

Uncommanded feather is very similar to the overtorque condition noted above. The propeller pitch will abruptly increase, causing a rapid rise in torque with a rapid drop in RPM because the engine is still providing power to the propeller. While the pitch is changing, the thrust may increase and then decrease rapidly. The airplane will have asymmetric thrust. The pilot will need to control the airplane and then shut down the engine. The high torque may cause engine and propeller damage, but it will not, if properly handled, cause loss of control of the airplane.

There are a number of different reasons why an uncommanded feather may occur. Most of these reasons involve an unprompted command to the feather solenoid. Stabilize the aircraft and follow the AFM recommended procedure. Typically, this will call for feathering the propeller to minimize drag and shutting down the engine.

Inability to change pitch

A malfunction resulting in the inability to change pitch will effectively leave the flight crew with a fixed-pitch propeller. As power is increased, the propeller RPM will increase, and as power is reduced, the propeller RPM will decrease. In flight, a change in the condition lever without a corresponding change in propeller RPM (NP) is also an indication that the propeller has lost the ability to change pitch.

Various malfunctions may result in an inability to change pitch. These include oil pressure failure or a jam within the actuator or blade retention bearing. If the fixed pitch is due to oil pressure failure leading to pitchlock, it will nearly always be possible to feather the propeller. Refer to the AFM for the appropriate procedures with a pitchlocked propeller.

Even though the pitch cannot be changed, the propeller is still controllable and capable of producing thrust. The procedures for operating an airplane with a free-turbine engine and a fixed-pitch propeller may be significantly different than those for operating an airplane with a single-shaft engine and a fixed-pitch propeller. The pilot needs to assess the situation carefully. If the propeller cannot be feathered, shutting down the engine may cause a situation where, at slow speed, the extra drag of the windmilling propeller may affect the pilot's ability to control the airplane. On the other hand, if the engine is not shutdown but is kept running, the added thrust at low aircraft speeds from a high blade angle may make it difficult to control the airplane. Additionally, reverse thrust will not be available on the fixed-pitch propeller.

Follow the AFM recommendations for continued propeller operation or engine shutdown. Review the characteristics of operation with a fixed-pitch propeller, both with the engine operating and with the engine shutdown, and how those characteristics will affect the thrust and drag of the airplane during various flight regimes. If the propeller can be feathered, follow the AFM procedures for feathering.

Vibration

If excessive vibration is present, the propeller that is creating vibration may be identified by adjusting power or RPM settings. Ensure that the airplane is in stable and controlled flight before undertaking any troubleshooting. Follow the AFM procedures for propeller feather and engine shut down if the vibration is beyond limits or is otherwise unacceptable, and if the source of the vibration has been clearly identified as coming from a specific propeller.

Sudden high vibration

Sudden high vibration is typically caused by the loss of a portion of a blade, a large crack in a blade, the release of a counterweight, or the failure of a blade pitch change pin. These events are sudden and can be startling. The pilot needs to react promptly and deliberately. After ensuring stable and controlled flight, identify the propeller that is causing the vibration and follow the AFM feather and shutdown procedures. Identification may be difficult; be sure to verify by crosschecking instrumentation.

RPM and torque fluctuation

Propeller speed and torque fluctuations occur due to changes in engine power, changes in propeller pitch, or a combination of the two. Generally, if RPM and torque increase or decrease together, the situation is usually caused by a change in the power delivered to the propeller. If either RPM or torque increases while the other decreases, the situation is usually caused by a blade angle change. If the frequency or rate of the fluctuation is low, it may be possible to determine its source through cockpit instrumentation. High-frequency fluctuations may not lend themselves to in-flight diagnosis; on-ground troubleshooting will likely be required. Refer to the airframe manufacturer's recommendations for specific procedures during RPM/Torque fluctuation.

Loss of de-icing

Loss of de-icing capability may be indicated by reduction of the indicated amps drawn by the system, or by slowly increasing vibration (due to ice buildup). Severe icing can cause loss of performance of the propeller and significant vibration. The propellers will continue to shed ice even without blade de-icing due to centrifugal loads. Increasing the propeller RPM will cause the centrifugal loads to increase, and, thus, the ice will shed more readily. Follow the AFM procedures for aircraft operation in icing conditions.

Electronic propeller control failure indication

Electronic propeller controls typically have cockpit indicators that annunciate the health of the propeller system. These indicators may include individual channel fail indicators, dual channel fail indicators, and/or maintenance indicators. Specific flight crew procedures based on these different indicators vary widely across the various fleets equipped with electronically-controlled propellers. Refer to the AFM and manufacturer recommendations for specific configuration and procedural information. Loss of the operation of a single channel in these systems typically does not limit the operation of the propeller system during flight, landing or ground handling.

Loss of synchronizing/synchrophasing

The loss of the synchronizer will result in an increase in cabin noise and the "beat" of the propellers. Synchronizing systems have very limited authority to affect the control of the slave to master propellers, and, in itself, failure of the synchronizing or synchrophasing system will not cause the loss of control of the propeller. Follow AFM recommendations for loss of synchronization/ synchrophasing.

Lightning strike

Following a lightning strike to the propeller, the flight crew may not know that a strike has occurred, as there may be no change in the propeller's operation. If vibration is detected, the response should be as described in the vibration section, above. Stabilize the airplane and follow the recommended procedures. If vibration is excessive, these procedures will typically call for feathering the propeller and shutting down the engine.

Blade/propeller separation

Separation of the propeller or one of its blades is an extremely rare event. The situation is similar to severe engine damage or separation. Stabilize the airplane and follow the AFM recommended procedures for separation or severe damage. Typically, these will require feathering the propeller and shutting down the engine.

PROPELLER PITCH DURING A TYPICAL FLIGHT

On the ground, an airplane with free-turbine engines is usually parked with the propellers feathered. For single-shaft engines, the propellers are typically in flat pitch.

Prior to the startup of single-shaft engines, the propeller blades are set to the blade angle that produces minimum torque. Typically, this will be at a pitch close to 0 degrees. This is also near the blade angle that produces minimum thrust for a non-moving airplane.

For free-turbine engines, the engine is started with the propeller in feather. After the engine has warmed up, the propeller is unfeathered to the ground-idle blade position. Typically, this is near flat pitch.

When the power lever is increased, the blade angle increases along a prescribed path known as the beta schedule, and thrust is produced so that the airplane can taxi. For taxi, the power lever needs only to be a few degrees above the angle for ground idle.

For a non-rolling takeoff, the power is increased, which increases the blade pitch along the beta schedule until the propeller begins to govern. This occurs with the airplane braked until takeoff power and RPM are reached. Blade angle is typically about 25 degrees.

When the brakes are released, the airplane rolls down the runway. To maintain constant power and RPM, the propeller pitch will increase as airspeed increases. When a reduction in the RPM is commanded after initial climb, the propeller blade angle will increase to allow governing at the selected RPM. The propeller pitch continues to increase with increasing airspeed, and also increases whenever a command to reduce RPM is made. The propeller reaches its maximum angle at cruise airspeed, power and altitude. This angle is typically about 40 to 45 degrees, depending on the operating conditions and selected governing speed.

When the airplane descends, power is reduced and the blade pitch decreases to maintain RPM. The pitch will decrease as the airspeed is reduced to maintain a constant RPM.

During approach, a propeller RPM of 100% is selected. This will decrease the blade pitch. During final approach, the airspeed and power are low, and the propeller RPM may fall below the selected governing speed. This occurs because the blade angle is limited to a minimum inflight angle to protect against high drag at very low airspeeds and power. This angle limitation is commonly referred to as the low-pitch stop. The low-pitch stop is the lowest blade angle that the propeller can achieve in-flight. This angle is set by the airplane manufacturer, and is dependent on the specific installation.

After touchdown, the power lever is pulled back to below flight idle. The propeller transitions to operation on the prescribed beta schedule. The actual blade angle is typically a function of power lever position and engine operating conditions; the angle may be as high as full reverse pitch with the power lever at full reverse.

As the airplane slows, the blade pitch is controlled by the power lever, which is typically positioned near ground idle. After taxi, the engine is shutdown with the propeller in flat pitch for a single-shaft engine, and feathered for a free turbine engine.