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Clo 1
FUNDAMENTALS
Of
Propeller

propeller is the :
- component that must absorb the power output of the engine

most propellers are two-bladed, great increases in power output have resulted in the development of four-, five-, and six-bladed propellers of large diameters.

However, all propeller-driven aircraft are limited by the:
- revolutions per minute (rpm) at which propellers can be turned.

There are several forces acting on the propeller as it turns; a major one is:
- centrifugal force

This force at high rpm tends to :
- pull the blades out of the hub

blade weight and hub :
- strength are very important to the design of a propeller.

Excessive blade tip speed:
- (rotating the propeller too fast)

may result not only in poor blade efficiency:
- but also in flutter and vibration

Since the propeller speed is : limited

the forward speed of a propeller driven airplane is:
- also limited—to approximately 400 miles per hour (mph) or 650 km/h or 350 knots.

Propeller-driven aircraft have several advantages over pure jets and are:
- widely used for several applications
- lower cost and shortened takeoff
- landing distances for operation at smaller airports.

Successful propellers started as simple two-bladed wood propellers and have advanced to:
- the complex propulsion systems of turboprop aircraft that involve more than just the propeller blades

As an outgrowth of operating large, more complex propellers:
- a variable-pitch
- constant-speed feathering
- reversing propeller system

was developed

This system allows the engine rpm to:
- be varied only slightly during different flight conditions and, therefore, increases flying efficiency

basic constant-speed system consists of a :
- flyweight-equipped governor unit that controls the pitch angle of the blades

so;
- that the engine speed remains constant.

The governor can be regulated by:
- controls in the cockpit so that any desired blade angle setting and engine operating speed can be obtained

Figure 1-2. Parts of a Propeller.

The basic nomenclature of the parts of a propeller

FUNDAMENTALS

The aerodynamic cross-section of a propeller blade:

- terminology to describe relevant elements of a blade

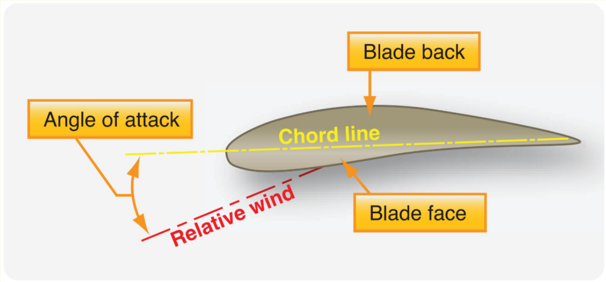

Figure 1-3. Cross Section of Propeller Airfoil.

BASIC PROPELLER PRINCIPLES

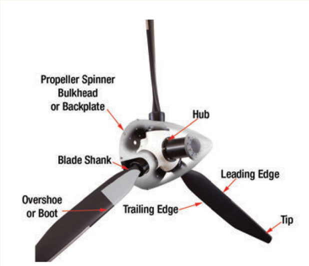

Figure 1-2. Parts of a Propeller.

The aircraft propeller consists of:

- two or more blades
- central hub to which the blades are attached

Each blade of an aircraft propeller is essentially a:

- rotating wing

As a result of their construction, the propeller blades produce :

- forces that create thrust to pull or push the airplane through the air.

The power needed to rotate the propeller blades is applied by :

- the engine

2 types of engines:

- high - horsepower
- Low - horsepower

The propeller is mounted for high and low :

Low : shaft that may be an extension of the crankshaft on low-horsepower engines. Low RPM

High : propeller shaft that is geared to the engine crankshaft with a reduction gear box to vary the rpm heigh RPM

the propeller transforms the rotary power of the engine into:

- thrust

Thrust

The thrust produced by the engine/propeller combination is the result of:

- how much air is pushed and the speed of the moving air mass.

The resulting action/reaction is in accordance with Newton's Third Law of Motion

In comparison to a jet engine, a propeller moves a :

- large mass of air at a relatively slow speed.

Thrust = Mass (V2 – V1)

F= Mxa

If I want to increase speed: F↑=↑M x a
Or
Increase the v2

efficiency

Efficiency is: the ratio of thrust horsepower to brake horsepower

$$\text{Efficiency} = \frac{\text{out put}}{\text{in put}} = \frac{\text{Thrust HP}}{\text{Break HP}}$$

Efficiency is not more than 1
Have to be 1 or less

50% to 87% is the power that can be transmitted

Brake horsepower

Brake horsepower is :

- the power delivered at the propeller shaft by the engine

or

- the horsepower that is transmitted to the output shaft from the engine

Pitch

The pitch is : the distance that a propeller moves forward in one rotation

The pitch determines the :

- amount of thrust produced by the propeller

The pitch is determined by the

- blade angle

Do to that :

- pitch and blade angle are directly proportional

there is 2 types of pitch;

1, fine pitch

2, coarse pitch

Fine pitch;

- the blade is slightly vertical
- More thrust
- Good for takeoff

Coarse pitch:

- good for high speed
- Good for high altitude

Slip

slip is the difference between the :

- geometric pitch of the propeller and its effective pitch

Geometric pitch is the :

- distance a propeller should advance in one revolution with no slippage

Effective pitch is the :

- distance it actually advances

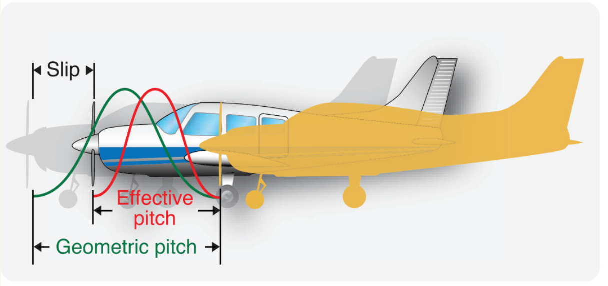

Figure 1-5. Effective Pitch versus Geometric Pitch.

Blade angle

Blade angle is the :

- angle between the face or chord of a blade section and the plane in which the propeller rotates.

chord line :

- Determined as determined in a airfoil

The typical propeller blade can be described as a :

- twisted airfoil of irregular planform

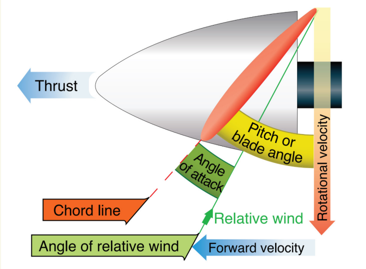

Figure 1-6. Propeller Aerodynamics.

blade shank and the blade butt.

blade shank is the :

- thick, rounded portion of the propeller blade near the hub and is designed to give strength to the blade

The blade butt, also called the :

- blade base
- root,

is the end of the blade that fits in the propeller hub.

The blade tip is that part of the:

- propeller blade farthest from the hub, generally defined as the last 6 inches of the blade.

In the blade element theory:

- the propeller blade is divided into small segments so that the performance of each segment may be critically analyzed

The reason why a propeller blade needs to be twisted:

- due to the difference in velocity between:

1, The blade hub

And

2, the blade at the tip

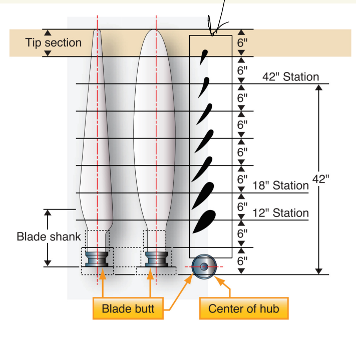

Figure 1-7. Propeller blade elements demonstrating twist.

The lower speeds at the hub region benefit from the :

- higher blade angle

The higher the speed at tip :

- requires less blade angle

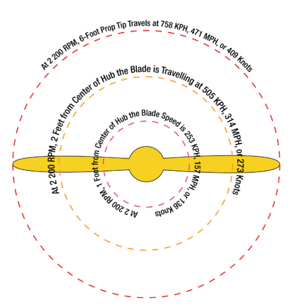

Figure 1-8. Velocities along blade span.

pitch of the blade:
- changes progressively from the root to the tip

to provide:
- the proper interaction with the air along the entire length of the blade.

Angle of attack

There is a distinction between
- blade angle

and
- angle of attack.

The blade angle for each segment of a fixed-pitch propeller is the angle formed by the:
- chord line of the blade segment and its plane of rotation

That relationship does not change

The same is true for controllable-pitch propellers

once the blade angle is established. By contrast,
- the angle of attack of a fixed-pitch propeller blade varies with forward speed of the aircraft.
- faster the airspeed of the airplane, the less the angle of attack
- When the aircraft is traveling at a low airspeed, the angle of attack encountered by the propeller blade is high.

The thrust for a given rpm will be high due to the high angle of

In terms of efficiency: the slow moving airplane will have
- poor propeller efficiency

At high airspeeds:
- the angle of attack of the propeller is relatively low

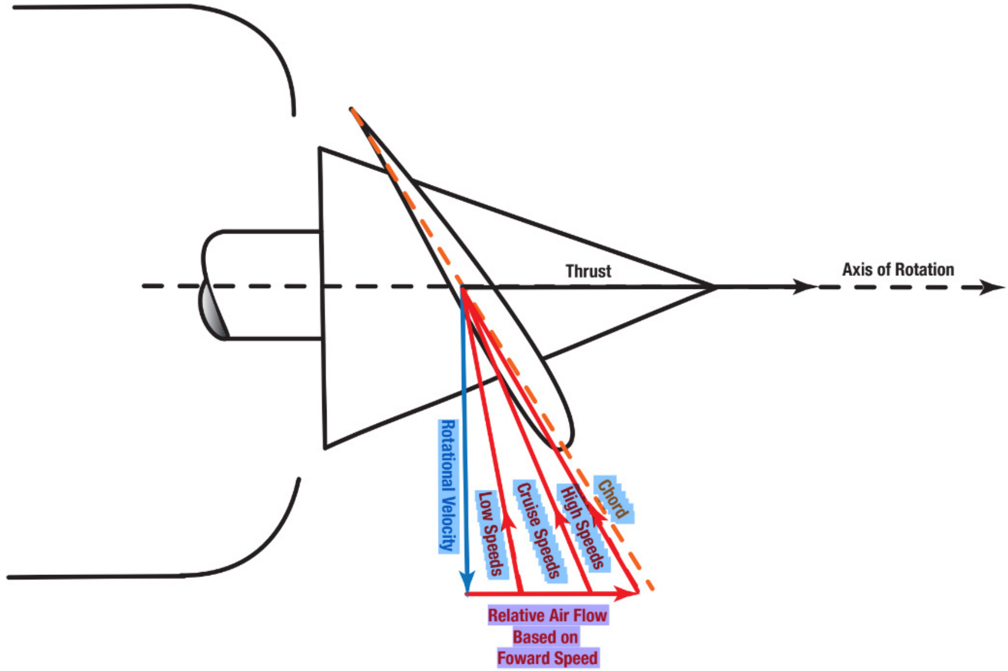

Figure 1-10. Relative air flow based on forward speed.

Fixed pitch / variable pitch

large number of small airplanes use

- fixed-pitch ; the pitch does not change at all

majority of higher performance aircraft are equipped with propellers that are:

- variable pitch

This allows the operator to :

- vary the pitch of the propeller during flight to increase the efficiency of the propeller
- in order to yield the desired performance in terms of speed and fuel economy.

These propellers often include a constant-speed mechanism that keeps the engine at the same rpm during cruise flight

When the aircraft changes flight attitude:

- the propeller changes pitch to keep the engine at the same rpm reverse thrust

Some propellers are able to produce:

- reverse thrust

Reverse thrust is accomplished by :

- reducing the pitch angle to achieve a negative angle of attack.

This produces reverse thrust that serves as a :

- means of aerodynamic braking to reduce aircraft speed following landing

The ability to reverse the thrust of the propeller is useful for:

- slowing the aircraft after touching down,

Some aircraft are able to back-up on the ground using reverse thrust

Reverse thrust may prove useful when maneuvering a :

- seaplane especially during docking.

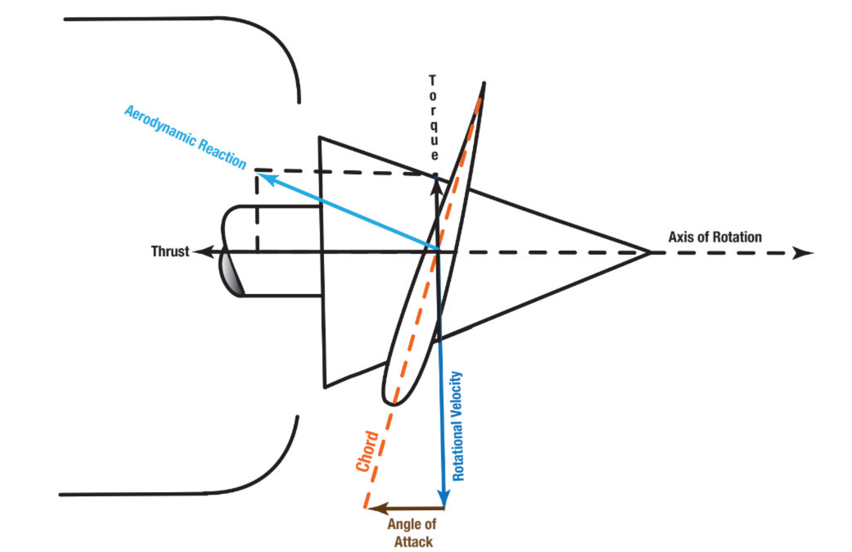

Figure 1-11. Reverse Thrust.

feathered

This feature is useful for when the aircraft experiences a:
- dead engine

or
- an engine incapable of producing proper thrust during flight

Without the ability to feather the propeller. Blade will produce:
- parasites drag, making it more difficult for the aircraft to sustain altitude (can’t glide properly)

When the propeller is feathered the blade angle is close to :
- 90°

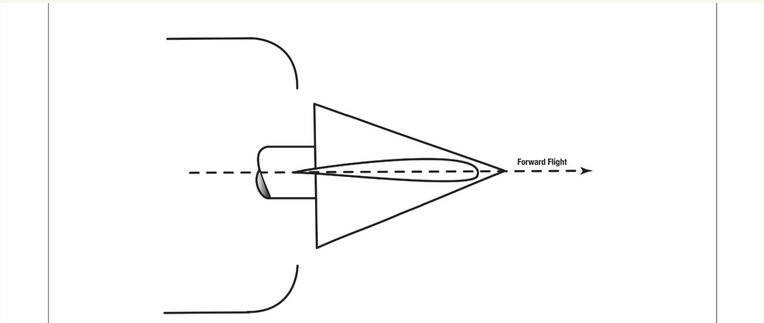

Figure 1-12. Feathered propeller blade.

RANGE OF PROPELLER PITCH
- This provides the aircraft with sufficient propeller capabilities to meet operational requirements

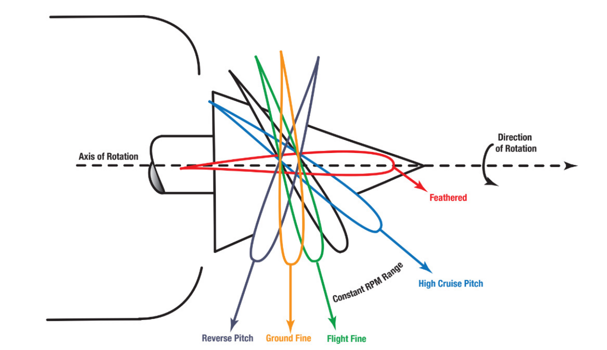

Figure 1-13. Range of propeller pitch for a variety of flight parameters.

FORCES ACTING ON A PROPELLER

1, Centrifugal force

Centrifugal force is a:

- physical action that tends to pull the rotating propeller blades out of the hub
- the most dominant force on the propeller

The centrifugal load exerted by the blades at high rpm is measured in :

- tons

Damage to the propeller near the:

- root

or

- damage to the hub may result in blade separation

2, Torque bending force : in the form of air resistance

Torque bending force tends to :

- bend the propeller blades in the direction opposite than of rotation.

The resistance generated by:

- the rotating blades is basically drag

Under varying flight configurations,

- the pilot has to use the flight controls to compensate for the torque generated by the engine/ propeller combination.

3, Thrust bending force

Thrust bending force is the:

- thrust load that bends propeller blades forward as the aircraft is pulled through the air.

The relative thinness of the propeller blade in the tip area :

- allows that section to bend forward in response to the generation of thrust

4, Aerodynamic twisting force (ATF)

also known as: aerodynamic twisting moment ATM

ATF tends to ;
- rotate the propeller blades to a high blade angle
- From low to high

This force is generated as the propeller produces:
- thrust

5, Centrifugal twisting force (CTF), also known as centrifugal twisting moment (CTM)

is generated as:
- the propeller rotates

Because the:
- axis of blade pitch rotation is basically the midpoint of the chord

the mass of the propeller blade on each side of the axis of rotation works to
- reduce propeller pitch due to the centrifugal force generated.
- Height to low

As with the other forces acting on the propeller blades, the:
- higher the rpm = the greater the CTM.

When compared to the aerodynamic twisting moment:
- the centrifugal twisting moment is more powerful and tends to force the propeller blades toward a low blade angle.

(CTM) is sometimes used to ;
- move the blades to the low pitch position

(ATM) is sometimes used to:
- move the blades into high pitch

These forces can be the: primary or secondary forces that move the blades to the new pitch position.

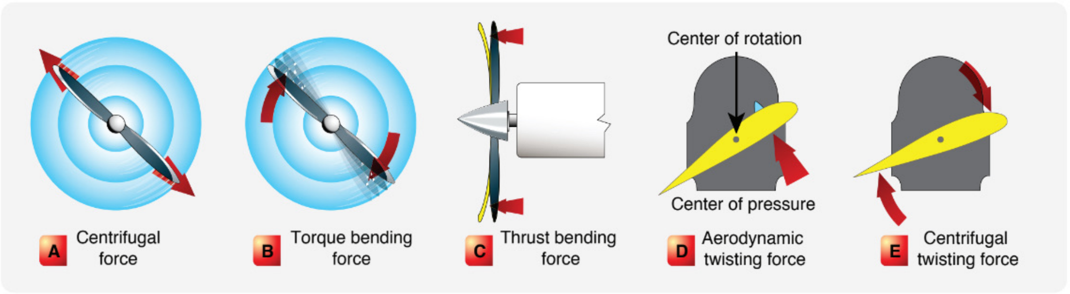

Figure 1-14. Forces acting on a propeller.

Stresses

In terms of construction, a propeller must be capable of:

- withstanding severe stresses, which are greater near the hub, caused by centrifugal force and thrust

The stresses increase in proportion to the :

- rpm

The blade face is also subjected to:

- tension from the centrifugal force

and

- additional tension from the thrust bending force

For these reasons :

- nicks or scratches on the blade may cause very serious consequences.

These could lead to :

- cracks and failure of the blade

rigid enough to prevent:

- fluttering

Fluttering:

- type of vibration in which the ends of the blade twist back and forth at high frequency around an axis perpendicular to the engine crankshaft

Fluttering is accompanied by :

- a distinctive noise, often mistaken for exhaust noise.

The constant vibration and resonance tends to :

- weaken the blade and eventually causes failure

P-FACTOR

When an airplane is flying in a level attitude, the thrust developed by the propeller is :
- fairly uniform between the descending blade and the ascending blade

Raising the nose of the aircraft produces:
- asymmetrical thrust between the ascending and descending propeller blades

This is often referred to as:
- "P-Factor

P-Factor is generated during :
- climbs ;
- because the descending blade has a greater angle of attack than the ascending blade.

The difference in thrust between the right and left regions of the propeller disc generates:
- yawing moment

For right-hand rotating propellers:
- left yawing moment is formed.

Pilots compensate for P-Factor by applying the;
- necessary rudder input

SLIPSTREAM EFFECT

- Another occurrence generated by the flowing air mass of the propeller is the slipstream effect

As the air acted upon by the propeller flows it :

- flows around the surface of the aircraft at an accelerated speed when compared to air flowing over the surface outside the propeller disc.

Control surfaces within the path of the slipstream:

- benefit from the accelerated flow and become more effective.

Slipstream:

- experience a yawing action due to the striking of the air against the vertical fin.
- For right-hand rotating propellers: the aircraft develops a yawing moment to the left.

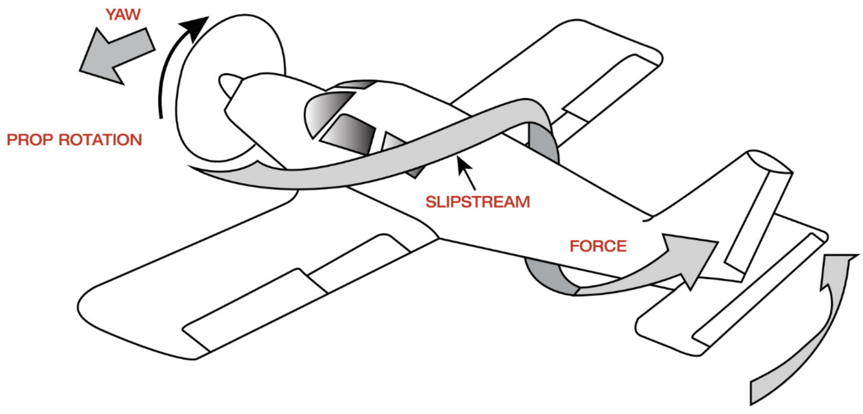

Figure 1-16. Slipstream Effect.

TORQUE: use ailerons to over come this type of stress

Torque is a natural resistance to a rotating mass

As the propeller revolves in one direction:

- torque works to rotate the airplane in the opposite direction

On a right-hand rotating propeller

- torque works to drop the left wing.
- lower the left Aileron to get aircraft in position
-

Pilots experience the effect of torque, P-Factor, and slipstream effect when :

- they perform power-on stalls

VIBRATION AND RESONANCE

During operation, the propeller is subjected to :

- vibrations

The mechanical and aerodynamic forces acting on the propeller generate:

- vibrations

Such vibrations are:

- harmful

when they result in:

- extreme blade flexing

Figure 1-17. Red arc from 1 800 to 2 000 rpm.

Pilots are allowed to:

- accelerate and decelerate through and beyond the red arc, or critical rmp range,

but must avoid continuous operations within the range of

- the red arc.