MODULE 17A

FOR B1 CERTIFICATION

PROPELLER

Aviation Maintenance Technician Certification Series

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REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2016 01	Module Creation and Release
002	2019 10	Minor Format Updates

PROPELLER

SUB-MODULE 01
FUNDAMENTALS

SUB-MODULE 02
PROPELLER CONSTRUCTION

SUB-MODULE 03
PROPELLER PITCH CONTROL

SUB-MODULE 04
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FUNDAMENTALS

SUB-MODULE 01

PART-66 SYLLABUS LEVELS

	CERTIFICATION CATEGORY → B1
Sub-Module 01 **FUNDAMENTALS** Knowledge Requirements	
17.1 - Fundamentals Blade element theory; High/low blade angle, reverse angle, angle of attack, rotational speed; Propeller slip; Aerodynamic, centrifugal, and thrust forces; Torque; Relative airflow on blade angle of attack; Vibration and resonance.	2

INTRODUCTION

During the invention era of the airplane, the propeller proved to be a very difficult challenge. Early aviation pioneers made crude propellers that were inefficient. This further complicated the invention process by requiring a larger propeller to provide the requisite thrust to propel the airplane at or above its minimum flying speed. Furthermore, the larger propeller required a more powerful engine and sturdier structure, which further compounded the problem by increasing weight, which meant more lift was needed to ascend from the surface.

The Wright Brothers are credited with developing and implementing effective theories regarding the design of propellers. Their early, hand-carved wooden propellers were remarkably efficient for their day. They considered the propeller to be a rotating airfoil. Upon reflecting on the designing aspect of their propellers, Orville Wright concluded, "*... on further consideration it is hard to find even a point from which to make a start; for nothing about a propeller, or the medium in which it acts, stands still for a moment. The thrust depends upon the speed and the angle at which the blade strikes the air; the angle at which the blade strikes the air depends upon the speed at which the propeller is turning, the speed the machine is travelling forward, and the speed at which the air is slipping backward; the slip of the air backwards depends upon the thrust exerted by the propeller, and the amount of air acted upon. When any one of these changes, it changes all the rest, as they are interdependent upon one another. But these are only a few of the many factors that must be considered and determined in calculating and designing propellers.*"

OVERVIEW

The propeller, the component that must absorb the power output of the engine, has passed through many stages of development. Although 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. Thus, 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. As aircraft speeds increased, turbine engines were used for higher speed aircraft. Propeller-driven aircraft have several advantages over pure jets and are thus widely used for several applications. Among those advantages are a generally lower cost and shortened takeoff and landing distances for operation at smaller airports. New blade materials and manufacturing techniques have increased the efficiency of propellers. Many smaller aircraft will continue to use propellers well into the future.

Many different types of propeller systems have been developed for specific aircraft installation, speed, and mission. Propeller development has encouraged many

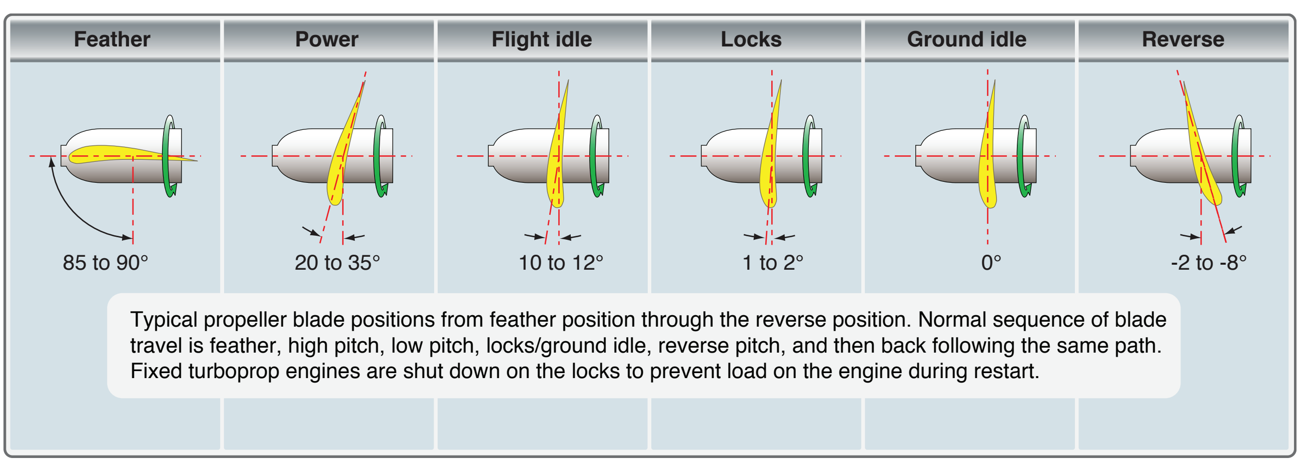

Figure 1-1. Ranges of Propeller Pitch.

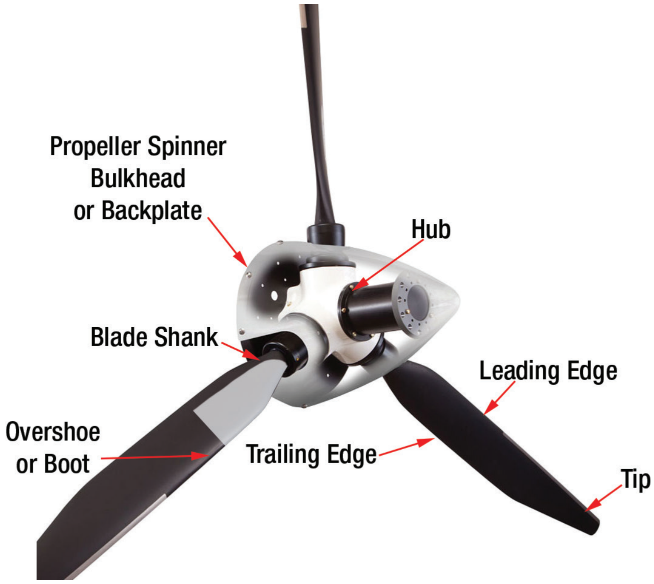

Figure 1-2. Parts of a Propeller.

changes as propulsion systems have evolved. Early experimental propellers, which proved unsuccessful, were sticks extended from the hub in which fabric was stretched across. They forced air in a rearward direction. 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 and 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. A 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. A low pitch, high rpm setting, for example, can be utilized for takeoff. Then, after the aircraft is airborne, a higher pitch and lower rpm setting can be used for cruise operations. ***Figure 1-1*** shows normal propeller movement with the positions of low pitch, high pitch, feather (used to reduce drag if the engine quits), and zero pitch into negative pitch, or reverse pitch.

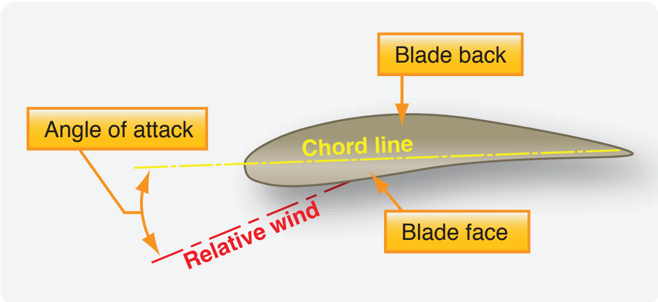

Figure 1-3. Cross Section of Propeller Airfoil.

FUNDAMENTALS

The basic nomenclature of the parts of a propeller is shown in ***Figure 1-2***. The aerodynamic cross-section of a propeller blade presented in ***Figure 1-3*** includes terminology to describe relevant elements of a blade.

BASIC PROPELLER PRINCIPLES

The aircraft propeller consists of two or more blades and a 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 furnished by the engine. The propeller is mounted on a shaft that may be an extension of the crankshaft on low-horsepower engines.

On high horsepower engines, it is mounted on a propeller shaft that is geared to the engine crankshaft. In either case, the engine rotates the airfoils of the blades through the air at high speeds, and the propeller transforms the rotary power of the engine into thrust.

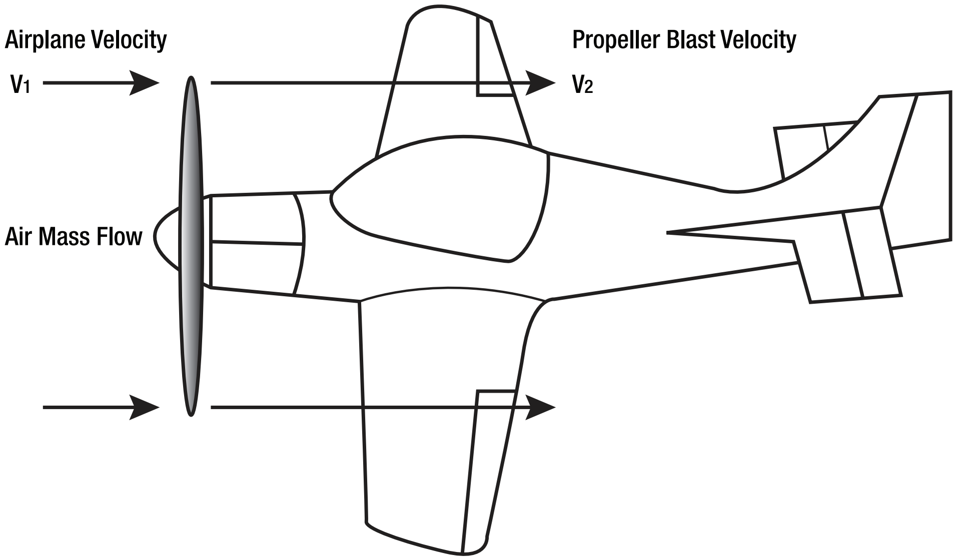

Figure 1-4. Thrust.

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.

$$\text{Thrust} = \text{Mass}\ (V_2 - V_1)$$

PROPELLER AERODYNAMIC PROCESS

An airplane moving through the air creates a drag force opposing its forward motion. If an airplane is to fly on a level path at a constant speed, there must be a force applied to it that is equal to the drag but acting forward. This force is called thrust. The work done by thrust is equal to the thrust times the distance it moves the airplane.

$$\text{Work} = \text{Thrust} \times \text{Distance}$$

The power expended by thrust is equal to the thrust times the velocity at which it moves the airplane.

$$\text{Power} = \text{Thrust} \times \text{Velocity}$$

If the power is measured in horsepower units, the power expended by the thrust is termed thrust horsepower. The engine supplies brake horsepower through a rotating shaft, and the propeller converts it into thrust horsepower. In this conversion, some power is wasted. For maximum efficiency, the propeller must be designed to keep this waste as small as possible. Since the efficiency of any machine is the ratio of the useful power output to the power input, propeller efficiency is the ratio of thrust horsepower to brake horsepower. The usual symbol for propeller efficiency is the Greek letter η (eta). Propeller efficiency varies from 50 percent to 87 percent, depending on how much the propeller slips.

Pitch is not the same as blade angle, but because pitch is largely determined by blade angle, the two terms are often used interchangeably. An increase or decrease in one is usually associated with an increase or decrease in the other. Propeller slip is the difference between the geometric pitch of the propeller and its effective pitch. ***(Figure 1-5)*** Geometric pitch is the distance a propeller should advance in one revolution with no slippage.

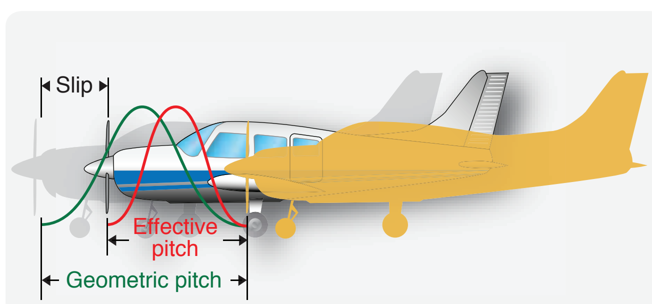

Figure 1-5. Effective Pitch versus Geometric Pitch.

Effective pitch is the distance it actually advances. Thus, geometric or theoretical pitch is based on no slippage.