CHAPTER 4

AIRCRAFT BASIC CONSTRUCTION

Naval aircraft are built to meet certain specified requirements. These requirements must be selected so they can be built into one aircraft. It is not possible for one aircraft to possess all characteristics. It is not possible, for example, for an aircraft to have the comfort of a passenger transport and the maneuverability of a fighter. The type and class of the aircraft determine how strong it must be built. A Navy fighter must be fast, maneuverable, and equipped for attack and defense. To meet these requirements, the aircraft is highly powered and has a very strong structure.

LEARNING OBJECTIVES

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

1. Identify the principal structural units of fixed-wing and rotary-wing aircraft.
2. State the five basic stresses acting on an aircraft.
3. Describe the various types of metallic and nonmetallic materials used in aircraft construction.

AIRCRAFT CONSTRUCTION

The airframe of a fixed-wing aircraft consists of five principal units. These units include the fuselage, wings, stabilizers, flight control surfaces, and landing gear. A rotary-wing aircraft airframe consists of four units: the fuselage, landing gear, main rotor assembly, and tail rotor. The following text describes the purpose, location, and construction features of each unit.

FIXED-WING AIRCRAFT

There are nine principal structural units of a fixed-wing (conventional) aircraft: the fuselage, engine mount, nacelle, wings, stabilizers, flight control surfaces, landing gear, arresting gear, and catapult equipment.

Fuselage

The fuselage is the body of the aircraft, the main structure to which all other units attach. It provides space for the crew, passengers, cargo, most of the accessories, and other equipment. Fuselages of naval aircraft have much in common from the standpoint of construction and design. They vary mainly in size and arrangement of the different compartments. Designs vary with the manufacturers and the requirements for the types of service the aircraft must perform.

The fuselages of most naval aircraft are of all-metal construction assembled in a modification of the monocoque design. The monocoque design relies largely on the strength of the skin or shell (covering) to carry the various loads. This design may be divided into three classes: monocoque, semimonocoque, and reinforced shell, and different portions of the same fuselage may belong to any of these classes. The monocoque has only vertical reinforcement rings, station webs, and bulkheads. In the semimonocoque design—in addition to these components—the skin is reinforced by longitudinal members known as stringers and longerons, but has no diagonal web members. The reinforced shell is strengthened by a complete framework of structural members. The cross-sectional shape is derived from bulkheads, station webs, and rings. The longitudinal contour is developed with longerons, formers, and stringers. The skin, which is fastened to all these members, primarily carries the shear load and, together with the longitudinal members, the loads of tension and bending.
stresses. Station webs are built-up assemblies located at intervals to carry concentrated loads and at points where fittings are used to attach external parts such as wings, alighting gear, and engine mounts. Formers and stringers may be single pieces of built-up sections.

The semimonocoque fuselage is constructed primarily of aluminum alloy; however, on newer aircraft, graphite epoxy composite material is often used. Steel and titanium are found in areas subject to high temperatures. Primary bending loads are absorbed by the “longerons,” which usually extend across several points of support. The longerons are supplemented by other longitudinal members called “stringers.” Stringers are lighter in weight and are used more extensively than longerons. The vertical structural members are referred to as “bulkheads, frames, and formers.” These vertical members are grouped at intervals to carry concentrated loads and at points where fittings are used to attach other units, such as the wings, engines, and stabilizers. Figure 4-1 shows a modified form of the monocoque design used in combat aircraft. The skin is attached to the longerons, bulkheads, and other structural members and carries part of the load. Skin thickness varies with the loads carried and the stresses supported.

There are many advantages in the use of the semimonocoque fuselage. The bulkheads, frames, stringers, and longerons aid in the construction of a streamlined fuselage. They also add to the strength and rigidity of the structure. The main advantage of this design is that all structural members aid in the strength of the fuselage for strength and rigidity—not just a few. This means that a semimonocoque fuselage may withstand considerable damage and still remain strong enough to hold together.

Fuselages are usually constructed in two or more sections on fighters and other small aircraft. Larger aircraft may be constructed in as many as six sections. Various points on the fuselage are located by station number. A station on an aircraft may be described as a rib or frame number. Aircraft drawings use various systems of station markings. For example, the centerline of the aircraft on one drawing may be taken as station zero. Objects to the right or left of center along a wing or stabilizer are found by giving the number of inches between them and the centerline station zero. Figure 4-2 shows station numbers for a typical aircraft.
Station 0 (zero) is usually located at or near the nose of the aircraft. The other fuselage stations (FS) are located at distances measured in inches aft of station 0. On this particular aircraft, stations are indicated by the letters X, Y, and Z as coordinates. Lines used to indicate vertical planes dividing the aircraft from wingtip to wingtip are called X coordinates. Lines used to indicate longitudinal planes dividing the aircraft from nose to tail are called Y coordinates. Y000.00, for example, is 60.50 inches in front of the radome nose. Lines used to indicate horizontal planes dividing the aircraft parallel to an arbitrary reference plane to ground level and to tail tip are called Z coordinates.

Quick access to the accessories and other equipment carried in the fuselage is achieved through numerous doors, inspection panels, wheel wells, and other openings. Servicing diagrams showing the arrangement of equipment and the location of access doors are supplied by the manufacturer in the maintenance instruction manuals and maintenance requirement cards for each model or type of aircraft.
**Engine Mounts**

Engine mounts are designed to meet particular conditions of installations, such as their location on the aircraft; methods of attachment; and size, type, and characteristics of the engine they are intended to support. Although engine mounts vary widely in their appearance and in the arrangement of their members, the basic features of their construction are similar. They are usually constructed as a single unit that may be detached quickly and easily from the remaining structure. In many cases, they are removed as a complete assembly or power plant with the engine and its accessories. Vibrations originating in the engine are transmitted to the aircraft structure through the engine mount.

**Nacelles**

In single-engine aircraft, the power plant is mounted in the center of the fuselage. On multiengine aircraft, the power plants are usually mounted in nacelles. The nacelle is primarily a unit that houses the engine. Nacelles are similar in shape and design for the same size aircraft. They vary with the size of the aircraft. Larger aircraft require less fairing, and therefore smaller nacelles. The structural design of a nacelle is similar to that of the fuselage. In certain cases the nacelle is designed to transmit engine loads and stresses to the wings through the engine mounts.

**Wings**

The wings of an aircraft are designed to develop lift when they are moved through the air. The particular wing design depends upon many factors: for example, size, weight, use of the aircraft, desired landing speed, and desired rate of climb. In some aircraft, the larger compartments of the wings are used as fuel tanks. The wings are designated as right and left, corresponding to the right- and left-hand sides of a pilot seated in the aircraft.

The wing structures of most naval aircraft are of all-metal construction, usually of the cantilever design; that is, no external bracing is required. Usually wings are of the stress-skin type. This means that the skin is part of the basic wing structure and carries part of the loads and stresses. The internal structure is made of "spars and stringers" running spanwise, and "ribs and formers" running chordwise (leading edge to trailing edge). The spars are the main structural members of the wing, and are often referred to as "beams."

One method of wing construction is shown in Figure 4-3. In this illustration, two main spars are used with ribs placed at frequent intervals between the spars to develop the wing contour. This is called
“two-spar” construction. Other variations of wing construction include “monospar” (open spar), “multispar” (three or more spars), and “box beam.” In the box beam construction, the stringers and sparlike sections are joined together in a box-shaped beam. Then, the remainder of the wing is constructed around the box.

The skin is attached to all the structural members and carries part of the wing loads and stresses. During flight, the loads imposed on the wing structure act primarily on the skin. From the skin, the loads are transmitted to the ribs and then to the spars. The spars support all distributed loads as well as concentrated weights, such as a fuselage, landing gear, and nacelle. Corrugated sheet aluminum alloy is often used as a subcovering for wing structures, as, for example, in the Lockheed P-3 Orion wing.

Inspection and access panels are usually provided on the lower surface of a wing. Drain holes are also placed in the lower surfaces. Walkways are provided on the areas of the wing where personnel should walk or step. The substructure is stiffened or reinforced in the vicinity of the walkways to take such loads. Walkways are usually covered with a nonskid surface. Some aircraft have no built-in walkways. In these cases removable mats or covers are used to protect the wing surface. On some aircraft, jacking points are provided on the underside of each wing. The jacking points may also be used as tiedown fittings for securing the aircraft.

Various points on the wing are located by station number. Wing station 0 (zero) is located at the centerline of the fuselage. All wing stations are measured in inches outboard from that point, as shown in Figure 4-2.

Stabilizers

The stabilizing surfaces of an aircraft consist of vertical and horizontal airfoils. These are known as the vertical stabilizer (or fin) and the horizontal stabilizer. These two airfoils, together with the rudder and elevators, form the tail section. For inspection and maintenance purposes, the entire tail section is considered a single unit of the airframe, and is referred to as the “empennage.”

The primary purpose of the stabilizers is to stabilize the aircraft, that is, to keep the aircraft in straight and level flight. The vertical stabilizer maintains the stability of the aircraft about its vertical axis. This is known as “directional stability.” The vertical stabilizer usually serves as the base to which the rudder is attached. The horizontal stabilizer provides stability of the aircraft about the lateral axis. This is “longitudinal stability.” It usually serves as the base to which the elevators are attached.

At high speeds, forces acting upon the flight controls increase, and control of the aircraft becomes difficult. This problem can be solved through the use of power-operated or power-boosted flight control systems. These power systems make it possible for the pilot to apply more pressure to the control surface against the air loads. By changing the angle of attack of the stabilizer, the pilot maintains adequate longitudinal control by rotating the entire horizontal stabilizer surface.

Construction features of the stabilizers are in many respects identical to those of the wings. They are usually of all-metal construction and cantilever design. Monospar and two-spar construction are both commonly used. Ribs develop the cross-sectional shape. A “fairing” is used to round out the angles formed between these surfaces and the fuselage.

The construction of control surfaces is similar to that of the wing and stabilizers. They are usually built around a single spar or torque tube. Ribs are fitted to the spar near the leading edge. At the trailing edge, they are joined together with a suitable metal strip or extrusion. For greater strength, especially in thinner airfoil sections typical of trailing edges, a composite construction material is used.

On most modern day fighters like the F/A-18 there is also a stabilator incorporated as part of the flight controls. The stabilator is a control surface located on either side of the tail. In flight, the stabilator deflects symmetrically to produce pitch motion and asymmetrically to produce roll motion. The
maximum surface deflection of each stabilator is 10.5 degrees trailing edge down to 24 degrees trailing edge up.

**FLIGHT CONTROL SURFACES**

The flight control surfaces are hinged or movable airfoils designed to change the attitude of the aircraft during flight. Flight control surfaces are grouped as systems and are classified as being either primary or secondary. Primary controls are those that provide control over the yaw, pitch, and roll of the aircraft. Secondary controls include the speed brake and flap systems. All systems consist of the control surfaces, cockpit controls, connecting linkage, and other necessary operating mechanisms.

The systems discussed in this chapter are representative of those with which you will be working. However, you should bear in mind that changes in these systems are sometimes necessitated as a result of later experience and data gathered from fleet use. Therefore, prior to performing the maintenance procedures discussed in this chapter, you should consult the current applicable technical publications for the latest information and procedures to be used.

**PRIMARY FLIGHT CONTROL SYSTEMS**

The primary flight controls are the ailerons, elevators, and rudder. The ailerons and elevators are operated from the cockpit, by a control stick on fighter aircraft, and a wheel and yoke assembly on large aircraft such as transports and patrol planes. The rudder is operated by rudder pedals on all types of aircraft.

The ailerons are operated by a lateral (side-to-side) movement of the control stick or a turning motion of the wheel on the yoke. The ailerons are interconnected in the control system and work simultaneously, but in opposite directions to one another. As one aileron moves downward to increase lift on its side of the fuselage, the aileron on the opposite side of the fuselage moves upward to decrease lift. This opposing action allows more lift to be produced by the wing on one side of the fuselage than on the other side; this results in a controlled movement or roll because of unequal forces on the wings. The aileron system can be improved with the use of either powered controls or alternate control systems.

The elevators are operated by a fore-and-aft movement of the control stick or yoke. Raising the elevators causes the aircraft to climb. Lowering the elevators causes it to dive or descend. The pilot raises the elevators by pulling back on the stick or yoke and lowers them by pushing the stick or yoke forward.

The rudder is connected to the rudder pedals and is used to move the aircraft about the vertical axis. If the pilot moves the rudder to the right, the aircraft turns to the right; if the rudder is moved to the left, the aircraft turns to the left. The pilot moves the rudder to the right by pushing the right rudder pedal and to the left by pushing the left rudder pedal.

Power control systems are used on high-speed jet aircraft. Aircraft traveling at or near supersonic speeds have such high air loads imposed upon the primary control surfaces that the pilot cannot control the aircraft without power-operated or power-boosted flight control systems. In the power-boost system, a hydraulically operated booster cylinder is incorporated within the control linkage to assist the pilot in moving the control surface. The power-boost cylinder is still used in the rudder control system of some high-performance aircraft; however, the other primary control surfaces use the full power-operated system. In the full power-operated system, all force necessary for operating the control surface is supplied by hydraulic pressure. Each movable surface is operated by a hydraulic actuator (or power control cylinder) incorporated into the control linkage.

In addition to the current Navy specification requiring two separate hydraulic systems for operating the primary flight control surfaces, specifications also call for an independent hydraulic power source.
for emergency operation of the primary flight control surfaces. Some manufacturers provide an emergency system powered by a motor-driven hydraulic pump; others use a ram-air-driven turbine for operating the emergency system pump.

**Lateral Control Systems**

Lateral control systems control roll about the longitudinal axis of the aircraft. On many aircraft the aileron is the primary source of lateral control. On other aircraft flaperons and spoilers are used to control roll.

**AILERONS** – Some aircraft are equipped with a power mechanism that provides hydraulic power to operate the ailerons. When the control stick is moved, the control cables move the power mechanism sector. Through linkage, the sector actuates the control valves, which, in turn, direct hydraulic fluid to the power cylinder. The cylinder-actuating shaft, which is connected to the power crank through a latch mechanism, operates the power crank. The crank moves the push-pull tubes, which actuate the ailerons. In the event of complete hydraulic power failure, the pilot may pull a handle in the cockpit to disconnect the latch mechanisms from the cylinder and load-feel bungee. This places the aileron system in a manual mode of operation. In manual operation, the cable sector actuates the power crank.

This lateral control system incorporates a load-feel bungee, which serves a dual purpose. First, it provides an artificial feeling and centering device for the aileron system. Also, it acts as an interconnection between the aileron system and the aileron trim system. When the aileron trim actuator is energized, the bungee moves in a corresponding direction and actuates the power mechanism. The power mechanism repositions the aileron control system to a new neutral position.

**FLAPERON** – As aircraft speeds increased, other lateral control systems came into use. Some aircraft use a flaperon system. The flaperon, shown in *Figure 4-4*, is a device designed to reduce lift on the wing whenever it is extended into the airstream. With this system, control stick movement will cause the left or right flaperon to rise into the airstream and the opposite flaperon to remain flush with the wing surface. This causes a decrease of lift on the wing with the flaperon extended and results in a roll.
Figure 4-4 — Flaperon control system.
SPOILER/DEFLECTOR — Many aircraft use a combination aileron and spoiler/deflector system for longitudinal control. The ailerons are located on the trailing edge of the outer wing panel and, unlike most aircraft, can be fully cycled with the wings folded. The spoiler/deflector on each wing operates in conjunction with the upward throw of the aileron on that wing. They are located in the left- and right-hand wing center sections, forward of the flaps. The spoiler extends upward into the airstream, disrupts the airflow, and causes decreased lift on that wing. The deflector extends down into the airstream and scoops airflow over the wing surface aft of the spoiler, thus preventing airflow separation in that area.

A stop bolt on the spoiler bell crank limits movement of the spoiler to 60 degrees deflection. The deflector is mechanically slaved to the spoiler, and can be deflected a maximum of 30 degrees when the spoiler is at 60 degrees. The spoilers open only with the upward movement of the ailerons.

Longitudinal Control Systems

Longitudinal control systems control pitch about the lateral axis of the aircraft. Many aircraft use a conventional elevator control system for this purpose. However, aircraft that operate in the higher speed ranges usually have a movable horizontal stabilizer. Both types of systems are discussed in the following text.

ELEVATOR CONTROL SYSTEM — A typical conventional elevator control system is operated by the control stick in the cockpit, and is hydraulically powered by the elevator power mechanism. The operation of the elevator control system is initiated when the control stick is moved fore or aft. When the stick is moved, it actuates the control cables that move the elevator control bell crank. The bell crank transmits the movement to the power mechanism through the control linkage. In turn, the power mechanism actuates a push-pull tube, which deflects the elevators up or down. If the hydraulic system fails, the cylinder can be disconnected. In this condition, the controls work manually through the linkage of the mechanism to actuate the elevators.

HORIZONTAL STABILIZER CONTROL SYSTEM — Horizontal stabilizer control systems are given a variety of names by the various aircraft manufacturers. Some aircraft systems are termed a unit horizontal tail (UHT) control system, while others are labeled the stabilator control system. Regardless of the name, these systems function to control the aircraft pitch about its lateral axis.

The horizontal stabilizer control system of the aircraft shown in Figure 4-5 is representative of the systems used in many aircraft. The slab-type stabilizer responds to fore-and-aft manual inputs at the control stick and to automatic flight control system inputs introduced at the stabilizer actuator. The actuator can operate in three modes: manual, series, or parallel.

MANUAL MODE — In this mode, pilot input alone controls the power valve.

SERIES MODE — In this mode, input signals from the automatic flight control system (AFCS) may be used independently or combined with manual inputs to control stabilizer movement.

PARALLEL MODE — In this mode, input signals from the AFCS alone control stabilizer movement.
Directional Control Systems

Directional control systems provide a means of controlling and stabilizing the aircraft about its vertical axis. Most aircraft use conventional rudder control systems for this purpose. The rudder control system is operated by the rudder pedals in the cockpit, and is powered hydraulically through the power mechanism. In the event of hydraulic power failure, the hydraulic portion of the system is bypassed, and the system is powered mechanically through control cables and linkage. When the pilot depresses the rudder pedals, the control cables move a cable sector assembly. The cable sector, through a push-pull tube and linkage, actuates the power mechanism and causes deflection of the rudder to the left or right.

Secondary Flight Controls

Secondary flight controls include those controls not designated as primary controls. The secondary controls supplement the primary controls by aiding the pilot in controlling the aircraft. Various types are used on naval aircraft, but only the most common are discussed here.

TRIM TABS — Trim tabs are small airfoils recessed in the trailing edge of a primary control surface. Their purpose is to enable the pilot to neutralize any unbalanced condition that might exist during flight, without exerting any pressure on the control stick or rudder pedals. Each trim tab is hinged to its parent control surface, but is operated independently by a separate control.

The pilot moves the trim tab by using cockpit controls. The tab on the control surface moves in a direction opposite that of the desired control surface movement. The airflow striking the trim tab causes the larger surface to move to a position that will correct the unbalanced condition of the aircraft. For example, to trim a nose-heavy condition, the pilot sets the elevator trim tab in the “down” position. This causes the elevator to be moved and held in the “up” position, which, in turn, causes the tail of the aircraft to be lowered. Without the use of the trim tab, the pilot would have to hold the elevator in the up position by exerting constant pressure on the control stick or wheel.
Construction of trim tabs is similar to that of the other control surfaces, although greater use is being made of plastic materials to fill the tab completely, which improves stiffness. Tabs may also be honeycomb-filled. Tabs are covered with either metal or reinforced plastic. Trim tabs are actuated either electrically or manually.

**WING FLAPS** — Wing flaps are used to give the aircraft extra lift. Their purpose is to reduce the landing speed, thereby shortening the length of the landing rollout. They are also used to assist in landing in small or obstructed areas by permitting the gliding angle to be increased without greatly increasing the approach speed. In addition, the use of flaps during takeoff serves to reduce the length of the takeoff run.

Most flaps are hinged to the lower trailing edges of the wings inboard of the ailerons; however, leading edge flaps are in use on some Navy aircraft. Four types of flaps are shown in Figure 4-6. The **PLAIN** flap forms the trailing edge of the airfoil when the flap is in the up position. In the **SPLIT** flap, the trailing edge of the airfoil is split, and the bottom half is so hinged that it can be lowered to form the flap. The **FOWLER** flap operates on rollers and tracks. This causes the lower surface of the wing to roll out and then extend downward. The **LEADING EDGE** flap operates similarly to the plain flap. It is hinged on the bottom side and, when actuated, the leading edge of the wing actually extends in a downward direction to increase the camber of the wing. Leading edge flaps are used in conjunction with other types of flaps.

**SPOILERS** — Spoilers are used for decreasing wing lift; however, their specific design, function, and use vary with different aircraft.

The spoilers on some aircraft are long, narrow surfaces hinged at their leading edge to the upper wing skin. In the retracted position, the spoiler is flush with the wing skin. In the extended position, the spoiler is pivoted up and forward approximately 60 degrees above the hinge point. The spoilers disturb the smooth flow of air over the wing so that burbling takes place. The lift is consequently reduced, and considerable drag is added to the wing.

Another type of spoiler in common use is a long, slender, curved, and perforated baffle that is raised edgewise through the upper surface of the wing forward of the aileron. It also disrupts the flow of air over the airfoil and destroys lift. These spoilers are actuated through the same linkage that actuates the ailerons. This arrangement makes movement of the spoiler dependent upon movement of the aileron. The linkage to the aileron is devised so that the spoiler is extended only when the aileron is raised. In other words, when the aileron moves downward, no deflection of the spoiler takes place.

**SPEED BRAKES** — Speed brakes are hinged, movable control surfaces used for reducing the speed of aircraft. Some manufacturers refer to them as *dive brakes* or *dive flaps*. They are hinged to the top or bottom of the fuselage. Regardless of their location, speed brakes serve the same purpose on all aircraft. Their primary purpose is to keep aircraft from building up excessive speed during dives. They are also used to reduce the speed of the aircraft prior to landing. Speed brakes are operated hydraulically or electrically.

**SLATS** — Slats are movable control surfaces attached to the leading edge of the wing. When the slat is retracted, it forms the leading edge of the wing. At low airspeed, the slat improves the lateral...
control-handling characteristics and allows the aircraft to be controlled at airspeeds below the normal landing speed. When the slat is opened (extended forward), a slot is created between the slat and the leading edge of the wing. The slot allows high-energy air to be introduced into the air layer moving over the top of the wing. This is known as boundary layer control. Boundary layer control is primarily used during operations from carriers; that is, for catapult takeoffs and arrested landings. Boundary layer control can also be accomplished by a method of directing high-pressure engine bleed air through a series of narrow orifices located just forward of the wing flap leading edge.

AILERON DROOP — The ailerons are also sometimes used to supplement the flaps. This is called an aileron droop feature. When the flaps are lowered, both ailerons can be partially deflected downward into the airstream. The partial deflection allows them to act as flaps as well as to serve the function of ailerons.

Landing Gear

The landing gear of the earliest aircraft consisted merely of protective skids attached to the lower surfaces of the wings and fuselage. As aircraft developed, skids became impractical and were replaced by a pair of wheels placed side by side ahead of the center of gravity with a tail skid supporting the aft section of the aircraft. The tail skid was later replaced by a swiveling tail wheel. This arrangement was standard on all land-based aircraft for so many years that it became known as the conventional landing gear. As the speed of aircraft increased, however, the elimination of drag became increasingly important. This led to the development of retractable landing gear.

Just before World War II, aircraft were designed with the main landing gear located behind the center of gravity and an auxiliary gear under the nose of the fuselage. This became known as the tricycle landing gear. It was a big improvement over the conventional type. The tricycle gear is more stable during ground operations and makes landing easier, especially in crosswinds. It also maintains the fuselage in a level position that increases the pilot's visibility. Nearly all Navy aircraft are equipped with tricycle landing gear. See Figure 4-7 for a typical landing gear system.

Main Landing Gear

A main landing gear assembly is shown in Figure 4-8. The major components of the assembly are the shock strut, tire, tube, wheel, brake assembly, retracting and extending mechanism, side brace, downlock actuator, and drag braces. Tires, tubes, and wheels are discussed in another chapter of this nonresident training course.

The shock strut absorbs the shock that would otherwise be sustained by the airframe structure during takeoff, taxiing, and landing. The air-oil shock strut is used on all Navy aircraft. This type of strut is composed essentially of two telescoping cylinders filled with hydraulic fluid and compressed air or nitrogen. Figure 4-9 shows the internal construction of a shock strut.
The telescoping cylinders, known as *cylinder and piston*, form an upper and lower chamber for the movement of the fluid. The upper chamber (cylinder) contains the compressed air or nitrogen, while the lower chamber (piston) is always filled with fluid. An orifice is placed between the two chambers through which the fluid passes into the upper chamber during compression and returns during extension of the strut. The size of the orifice is controlled by the up-and-down movement of the tapered metering pin.

Whenever a load is placed on the strut because of the landing or taxiing of the aircraft, compression of the two strut halves begins. The piston (to which the wheel and axle are attached) forces fluid through the orifice into the cylinder and compresses the air or nitrogen above it. When the strut has made a stroke to absorb the energy of the impact, the air or nitrogen at the top expands and forces the fluid back into the lower chamber. The slow metering of the fluid acts as a *snubber* to prevent rebounds. Instructions for the servicing of shock struts with hydraulic fluid and compressed air or nitrogen are contained on an instruction plate attached to the strut, as well as in the maintenance instruction manual (MIM) for the type of aircraft involved. The shock absorbing qualities of a shock strut depend on the proper servicing of the shock strut with compressed nitrogen and the proper amount of fluid.

**RETRACTING MECHANISMS** — Some aircraft have electrically actuated landing gear, but most are hydraulically actuated. *Figure 4-8* shows a retracting mechanism that is hydraulically actuated. The landing gear control handle in the cockpit allows the landing gear to be retracted or extended by directing hydraulic fluid under pressure to the actuating cylinder. The locks hold the gear in the desired position, and the safety switch prevents accidental retracting of the gear when the aircraft is resting on its wheels.
A position indicator on the instrument panel indicates the position of the landing gear to the pilot. The position indicator is operated by the position-indicating switches mounted on the UP and DOWN locks of each landing gear.

**EMERGENCY EXTENSION**  
Methods of extending the landing gear in the event of normal system failure vary with different models of aircraft. Most aircraft use an emergency hydraulic system. Some aircraft use pneumatic (compressed air or nitrogen), mechanical, or gravity systems, or a combination of these systems.

**Nose Gear**  
A typical nose gear assembly is shown in Figure 4-10. Major components of the assembly include a shock strut, drag struts, a retracting mechanism, wheels, and a shimmy damper.

The nose gear shock strut, drag struts, and retracting mechanism are similar to those described for the main landing gear. The shimmy damper is a self-contained hydraulic unit that resists sudden twisting loads applied to the nosewheel during ground operation, but permits slow turning of the wheel. The primary purpose of the shimmy damper is to prevent the nosewheel from shimmying (extremely fast left-right oscillations) during takeoff and landing. This is accomplished by the metering of hydraulic fluid through a small orifice between two cylinders or chambers.

Most aircraft are equipped with steerable nosewheels and do not require a separate self-contained shimmy damper. In such cases, the steering mechanism is hydraulically controlled and incorporates two spring-loaded hydraulic steering cylinders that, in addition to serving as a steering mechanism, automatically subdue shimmy and center the nosewheel.

**Arresting Gear**  
A carrier aircraft is equipped with an arresting hook for stopping the aircraft when it lands on the carrier. (See Figure 4-11.) The arresting gear is composed of an extendible hook and the mechanical, hydraulic, and pneumatic equipment necessary for hook operation. The arresting hook on most aircraft is mechanically released, pneumatically lowered, and hydraulically raised.

The hook is hinged from the structure under the rear of the aircraft. A snubber, which meters hydraulic fluid and works in conjunction with nitrogen pressure, is used to hold the hook down to prevent it from bouncing when it strikes the carrier deck.
Catapult Equipment

Carrier aircraft are equipped with facilities for catapulting themselves off the aircraft carrier. This equipment consists of nose-toe launch equipment. Older aircraft have hooks that are designed to accommodate the cable bridle, which is used to hook the aircraft to the ship’s catapult. The holdback assembly allows the aircraft to be secured to the carrier deck for full-power turnup of the engine prior to takeoff. The holdback tension bar separates when the catapult is fired and allows the aircraft to be launched with the engine at full power.

For nose gear equipment, a track is attached to the deck to guide the nosewheel into position. (See Figure 4-12.) The track also has provisions for attaching the nose gear to the catapult shuttle and for holdback. In comparison with the bridle and holdback pendant method of catapult hookup for launching, the nose gear launch equipment requires fewer personnel, the hookup is accomplished more safely, and time is saved in positioning an aircraft for launch.

ROTARY-WING AIRCRAFT

The history of rotary-wing development embraces 500-year-old efforts to produce a workable direct-lift-type flying machine. Aircraft designers’ early experiments in the helicopter field were fruitless.
Today, helicopters are found throughout the world. They perform countless tasks especially suited to their unique capabilities. Helicopters are the modern-day version of the dream envisioned centuries ago by Leonardo da Vinci.

Early in the development of rotary-wing aircraft, a need arose for a new word to designate this direct-lift flying device. A resourceful Frenchman chose the two words—heliko, which means screw or spiral, and pteron, which means wing. The word “helicopter” is the combination of these two words.

A helicopter employs one or more power-driven horizontal airscrews, or rotors, from which it derives lift and propulsion. If a single rotor is used, it is necessary to employ a means to counteract torque. If more than one rotor is used, torque is eliminated by turning the rotors in opposite directions.

The fundamental advantage the helicopter has over conventional aircraft is that lift and control are independent of forward speed. A helicopter can fly forward, backward, or sideways, or it can remain in stationary flight (hover) above the ground. No runway is required for a helicopter to take off or land. The roof of an office building provides an adequate landing area. The helicopter is considered a safe aircraft because the takeoff and landing speed is zero.

The construction of helicopters is similar to the construction of fixed-wing aircraft.

**Fuselage**

Like the fuselage in fixed-wing aircraft, helicopter fuselages may be welded truss or some form of monocoque construction. Many Navy helicopters are of the monocoque design. A typical Navy helicopter, the H-60, is shown in Figure 4-13. The fuselage consists of the entire airframe, sometimes known as the body group. The body group is of all-metal semimonocoque construction, consisting of an aluminum and titanium skin over a reinforced aluminum frame.

**Landing Gear Group**

The landing gear group includes all the equipment necessary to support the helicopter when it is not in flight. Conventional landing gear consists of main landing gear and a tail landing gear. Most helicopters have nonretractable landing gear. See Figure 4-13.

**Main Landing Gear**

The main landing gear system consists of left and right single-wheel landing gear assemblies and the weight-on-wheels system. Each main landing gear assembly is composed of a shock strut, drag beam, axle, wheel, tire, and wheel brake. The left main landing gear assembly also includes a weight-on-wheels sensing switch.

The main landing gear supports the helicopter when on the ground and cushions the helicopter from shock while landing. The weight-on-wheels switch provides helicopter ground/flight status indications for various helicopter systems.

**Tail Landing Gear**

The tail landing gear system consists of a dual-wheel landing gear, tail wheel lock system, and tail bumper. The tail landing gear is a
cantilever-type with an integral shock strut. The gear is capable of swiveling 360 degrees. It can be locked in trail position by the tail wheel locking system. A tail recovery assist, secure, and traverse (RAST) probe is mounted on the tail gear.

**Main Rotor Assembly**

The main rotor (rotary wing) and the rotor head are discussed in the following section. Their functions are closely related and neither functions without the other.

**Rotor Wing**

The H-60 has four main rotor blades that provide lift for the helicopter. (See Figure 4-14.) They receive power from the main rotor head to which they are attached. The root (inboard end of the main rotor blade) allows bolting of the main rotor blade to the main rotor head. A heater mat in the main rotor blade leading edge provides blade deicing, and it is connected to the blade deicing system.

Each main rotor blade has a titanium spar that is pressurized with nitrogen (to detect cracks), and contains a honeycomb core, fiberglass skin, and nickel and titanium abrasion strips. A removable sweptback tip cap is attached by screws onto the end of each main rotor blade. Pressure loss in the spar is indicated through the use of a blade inspection method (BIM®) indicator. This indicator is located at each main rotor blade root, and continuously monitors spar pressure. See Figure 4-15.
**Rotor Head**

The H-60 main rotor head transmits the movement of the flight controls to the four main rotor blades. The components of the main rotor head are as follows: hub, droop stops, bifilar absorber, pitch control rods, dampers, damper accumulator, anti-flap assemblies, swashplate, swashplate guide shaft extension, pressure plates, and rotor blade fold system. See Figure 4-16.

**Main Rotor Pylon**

The main rotor pylon is attached to the upper cabin and transition section. The forward section is made up of a sliding control/accessories fairing, removable platform, air inlet fairings, and engine air inlets. The midsection includes the No. 1 and No. 2 work platform/engine access, left and right oil cooler access, environmental control system (ECS) access, auxiliary power unit APU inlet, APU access, and exhaust module. The aft section contains the fire bottle access and aft fairing.

**Tail Rotor Assembly**

The H-60 tail rotor is a bearingless, controllable-pitch, cross-beam-type system. The tail rotor blades are built around two interchangeable graphite composite spars that cross each other in the center. The two tail rotor blades are retained on the tail rotor hub by a set of retention plates. These plates bolt the tail rotor blades together to form four blades 90 degrees apart. Counterweights are bolted to each tail rotor blade for balancing. See Figure 4-17.
Tail Rotor Blades
The tail rotor blades are built around two graphite composite spars. The spar is the main structural member of the tail rotor blade and is continuous from tip cap to tip cap. Two paddle assemblies, made up of honeycomb, are bonded to the spar. Several layers of fiberglass are bonded over the honeycomb and spar. These form the tail rotor blade skin and aerodynamic shape of the tail rotor blade. A deice heater mat is bonded into the tail rotor blade leading edge. The heater mat connects to an electrical connector mounted close to each counterweight. Power to heat the tail rotor blades is supplied through a slipring on the tail gearbox from the deice system.

Tail Pylon
The tail rotor pylon is a foldable section at the aft end of the helicopter. The pylon is supported by and hinged to the tail cone section. It supports the horizontal stabilator, intermediate gearbox, tail gearbox, connecting tail rotor drive shaft, tail rotor assembly, and part of the flight controls. See Figure 4-18.

STRUCTURAL STRESS
Primary factors in aircraft structure design are strength, weight, and reliability. These three factors determine the requirements to be met by any material used in airframe construction and repair. Airframes must be strong and light in weight. An aircraft built so heavy that it could not support more than a few hundred pounds of additional weight would be useless. In addition to having a good strength-to-weight ratio, all materials must be thoroughly reliable. This reliability minimizes the possibility of dangerous and unexpected failures.

TYPES OF STRESS
Numerous forces and structural stresses act on an aircraft when it is static and when it is flying. When it is static, gravity force alone produces weight, which is supported by the landing gear. The landing gear also absorbs the forces imposed during takeoffs and landings.

During flight, any maneuver that causes acceleration or deceleration increases the forces and stresses on the wings and fuselage. These loads are tension, compression, shear, bending, and torsion stresses. These stresses are absorbed by each component of the wing structure and transmitted to the fuselage structure. The empennage, or tail section, absorbs the same stresses and also transmits them to the fuselage structure. The study of such loads is called a “stress analysis.” The stresses must be analyzed and considered when an aircraft is designed. These stresses are shown in Figure 4-19.
Tension may be defined as “pull.” Tension is the resistance to pulling apart or stretching, produced by two forces pulling in opposite directions along the same straight line. An elevator control cable is in additional tension when the pilot moves the control column.

Compression
If forces acting on an aircraft move toward each other to squeeze the material, the stress is called compression. Compression is the opposite of tension. Tension is a “pull,” and compression is a “push.” Compression is the resistance to crushing, produced by two forces pushing toward each other in the same straight line. While an airplane is on the ground, the landing gear struts are under a constant compression stress.

Shear
Cutting a piece of paper with a pair of scissors is an example of shearing action. Shear in an aircraft structure is a stress exerted when two pieces of fastened material tend to separate. Shear stress is the outcome of sliding one part over the other in opposite directions. The rivets and bolts in an aircraft experience both shear and tension stresses.

Bending
Bending is a combination of tension and compression. Consider the bending of an object such as a piece of tubing. The upper portion stretches (tension) and the lower portion crushes together (compression). The wing spars of an aircraft in flight undergo bending stresses.

Figure 4-19 — Five stresses acting on an aircraft.
Torsion

Torsional stresses are the result of a twisting force. When you wring out a chamois skin, you are putting it under torsion. Torsion is produced in an engine crankshaft while the engine is running. Forces that cause torsional stresses produce torque.

VARYING STRESS

All materials are somewhat elastic. A rubber band is extremely elastic, whereas a piece of metal is not very elastic. All the structural members of an aircraft experience one or more stresses. Sometimes a structural member has alternate stresses. It is under compression one moment and under tensions the next. The strength of aircraft materials must be great enough to withstand maximum force of varying stresses.

SPECIFIC ACTION OF STRESSES

You should understand the stresses encountered on the main parts of an aircraft. A knowledge of the basic stresses on aircraft structures helps you understand why aircraft are built the way they are. The fuselage of the aircraft encounters the five types of stress—torsion, bending, tension, shear, and compression.

Torsional stress in a fuselage is created in several ways. An example of this stress is encountered in engine torque on turboprop aircraft. Engine torque tends to rotate the aircraft in the opposite direction that the propeller is turning. This force creates a torsional stress in the fuselage. Figure 4-20 shows the effect of the rotating propellers. Another example of torsional stress is the twisting force in the fuselage due to the action of the ailerons when the aircraft is maneuvered.

Figure 4-20 – Engine torque creates torsional stress in aircraft fuselages.
When an aircraft is on the ground, there is a bending force on the fuselage. This force occurs because of the weight of the aircraft itself. Bending greatly increases when the aircraft makes a carrier landing. This bending action creates a tension stress on the lower skin of the fuselage and a compression stress on the top skin. This bending action is shown in Figure 4-21. These stresses are also transmitted to the fuselage when the aircraft is in flight. Bending occurs due to the reaction of the airflow against the wings and empennage. When the aircraft is in flight, lift forces act upward against the wings, tending to bend them upward. The wings are prevented from folding over the fuselage by the resisting strength of the wing structure. This bending action creates a tension stress on the bottom of the wings and a compression stress on the top of the wings.

**MATERIALS OF CONSTRUCTION**

An aircraft requires materials that must be both light and strong. Early aircraft were made of wood. Lightweight metal alloys with strength greater than wood were developed and used on later aircraft. Materials currently used in aircraft construction may be classified as either metallic or nonmetallic.

**METALLIC MATERIALS**

The most common metals in aircraft construction are aluminum, magnesium, titanium, steel, and their alloys. Aluminum alloy is widely used in modern aircraft construction. It is vital to the aviation industry because the alloy has a high strength-to-weight ratio. Aluminum alloys are corrosion-resistant and comparatively easy to fabricate. The outstanding characteristic of aluminum is its light weight.

Magnesium—the world's lightest structural metal—is a silvery-white material weighing only two-thirds as much as aluminum. Magnesium is used in the manufacture of helicopters. Magnesium's low resistance to corrosion has limited its use in conventional aircraft.

Titanium is a lightweight, strong, corrosion-resistant metal. It was discovered years ago, but has only recently been made suitable for use in aircraft. Recent developments make titanium ideal for applications where aluminum alloys are too weak and stainless steel is too heavy. In addition, titanium is unaffected by long exposure to seawater and marine atmosphere.

An alloy is composed of two or more metals. The metal present in the alloy in the largest portion is called the base metal. All other metals added to the alloy are called alloying elements. Alloying elements—in either small or large amounts—may result in a marked change in the properties of the base metal. For example, pure aluminum is relatively soft and weak. When small amounts of other elements such as copper, manganese, and magnesium are added, aluminum's strength is increased many times. An increase or a decrease in an alloy's strength and hardness may be achieved through heat treatment of the alloy. Alloys are of great importance to the aircraft industry, because they provide materials with properties not possessed by a pure metal alone.

Alloy steels that are of much greater strength than those found in other fields of engineering have been developed. These steels contain small percentages of carbon, nickel, chromium, vanadium, and
Molybdenum. High-tensile steels will stand stresses of 50 to 150 tons per square inch without failing. Such steels are made into tubes, rods, and wires. Another type of steel that is used extensively is stainless steel. This alloy resists corrosion and is particularly valuable for use in or near salt water.

NONMETALLIC MATERIALS

In addition to metals, various types of plastic materials are found in aircraft construction. Transparent plastic is found in canopies, windshields, and other transparent enclosures. Transparent plastic surfaces must be handled with care because this material is relatively soft and scratches easily. At approximately 225 °F, transparent plastic becomes soft and very pliable.

Reinforced plastic is made for use in the construction of radomes, wing tips, stabilizer tips, antenna covers, and flight controls. Reinforced plastic has a high strength-to-weight ratio and is resistant to mildew and rot. Its ease of fabrication makes it equally suitable for other parts of the aircraft.

Reinforced plastic is a sandwich-type material. (See Figure 4-22.) It is made up of two outer facings and a center layer. The facings are made up of several layers of glass cloth, bonded together with a liquid resin. The core material (center layer) consists of a honeycomb structure made of glass cloth. Reinforced plastic is fabricated into a variety of cell sizes.

High-performance aircraft require an extra high strength-to-weight ratio material. Fabrication of composite materials satisfies this special requirement. This construction method uses several layers of bonding materials (graphite epoxy or boron epoxy). These materials are mechanically fastened to conventional substructures. Another type of composite construction consists of thin graphite epoxy skins bonded to an aluminum honeycomb core.

METALLIC MATERIALS

Metallurgists have been working for many years to improve metals for aircraft construction. Each metal has certain properties and characteristics that make it desirable for a particular application, but it may have other qualities that are undesirable. For example, some metals are hard, others comparatively soft; some are brittle, some tough; some can be formed and shaped without fracture; and some are so heavy that weight alone makes them unsuitable for aircraft use. The metallurgist's objectives are to improve the desirable qualities and tone down or eliminate the undesirable ones. This is done by alloying (combining) metals and by various heat-treating processes.

You do not have to be a metallurgist to be a good AN, but you should possess a knowledge and understanding of the uses, strengths, limitations, and other characteristics of aircraft structural metals. Such knowledge and understanding is vital to properly construct and maintain any equipment—especially airframes. In aircraft maintenance and repair, even a slight deviation from design specifications or the substitution of inferior materials may result in the loss of both lives and equipment. The use of unsuitable materials can readily erase the finest craftsmanship. The selection of the specific material for a specific repair job demands familiarity with the most common properties of various metals.
Review Questions

4-1. How many principal structural units are there in a fixed-wing aircraft?

A. Two  
B. Four  
C. Six  
D. Nine

4-2. On a semimonocoque fuselage, what component absorbs the primary bending loads?

A. Engine mounts  
B. Fuselage  
C. Landing gear  
D. Longerons

4-3. What aircraft structure is designed to transmit engine loads, stresses, and vibrations to the aircraft structure?

A. Fuselage  
B. Landing gear  
C. Nacelle  
D. Tires

4-4. What type of stress is produced by two forces pulling in opposite directions along the same straight line?

A. Compression  
B. Shear  
C. Tension  
D. Torsional

4-5. What force is the opposite of tension?

A. Bending  
B. Compression  
C. Shear  
D. Torsional

4-6. What type of stress is a combination of tension and compression?

A. Bending  
B. Shear  
C. Stretching  
D. Torsional
4-7. What is the most widely used metal in modern aircraft construction?

A. Aluminum alloy  
B. Composite  
C. Steel  
D. Titanium

4-8. What is the world's lightest structural metal?

A. Aluminum  
B. Copper  
C. Magnesium  
D. Steel

4-9. What were early aircraft made of?

A. Copper  
B. Magnesium  
C. Steel  
D. Wood
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