

SCHOOL OF AERONAUTICS (NEEMRANA)

UNIT-1 NOTES

FACULTY NAME: D.SUKUMAR

CLASS: B.Tech AERONAUTICAL

SUBJECT CODE: 7AN6.3

SEMESTER: VII

SUBJECT NAME: MAINTENANCE OF AIRFRAME AND SYSTEMS DESIGN

AIRFRAME CONSTRUCTION:

Various types of structures in airframe construction, tubular, braced monocoque, semimonocoque, etc.

longerons, stringers, formers, bulkhead, spars and ribs, honeycomb construction.

Introduction:

An aircraft is a device that is used for, or is intended to be used for, flight in the air. Major categories of aircraft are airplane, rotorcraft, glider, and lighter-than-air vehicles. Each of these may be divided further by major distinguishing features of the aircraft, such as airships and balloons. Both are lighter-than-air aircraft but have differentiating features and are operated differently. The concentration of this handbook is on the airframe of aircraft; specifically, the fuselage, booms, nacelles, cowlings, fairings, airfoil surfaces, and landing gear. Also included are the various accessories and controls that accompany these structures. Note that the rotors of a helicopter are considered part of the airframe since they are actually rotating wings. By contrast, propellers and rotating airfoils of an engine on an airplane are not considered part of the airframe. The most common aircraft is the fixed-wing aircraft. As the name implies, the wings on this type of flying machine are attached to the fuselage and are not intended to move independently in a fashion that results in the creation of lift. One, two, or three sets of wings have all been successfully utilized. Rotary-wing aircraft such as helicopters are also widespread. This handbook discusses features and maintenance aspects common to both fixed wing and rotary-wing categories of aircraft. Also, in certain cases, explanations focus on information specific to only one or the other. Glider airframes are very similar to fixed wing aircraft. Unless otherwise noted, maintenance practices described for fixed-wing aircraft also apply to gliders. The same is true for lighter-than-air aircraft, although thorough coverage of the unique airframe structures and maintenance practices for lighter-than-air flying machines is not included in this handbook. The airframe of a fixed-wing aircraft consists of five principal units: the fuselage, wings, stabilizers, flight control surfaces, and landing gear. Helicopter airframes consist of the fuselage, main rotor and related gearbox, tail rotor (on helicopters with a single main rotor), and the landing gear. Airframe structural components are constructed from a wide variety of materials. The earliest aircraft were constructed primarily of wood. Steel tubing and the most common material, aluminum, followed. Many newly certified aircraft are built from molded composite

materials, such as carbon fiber. Structural members of an aircraft's fuselage include stringers, longerons, ribs, bulkheads, and more. The main structural member in a wing is called the wing spar.

The skin of aircraft can also be made from a variety of materials, ranging from impregnated fabric to plywood, aluminum, or composites. Under the skin and attached to the structural fuselage are the many components that support airframe function. The entire airframe and its components are joined by rivets, bolts, screws, and other fasteners. Welding, adhesives, and special bonding techniques are also used.

Major Structural Stresses

Aircraft structural members are designed to carry a load or to resist stress. In designing an aircraft, every square inch of wing and fuselage, every rib, spar, and even each metal fitting must be considered in relation to the physical characteristics of the material of which it is made. Every part of the aircraft must be planned to carry the load to be imposed upon it.

The determination of such loads is called stress analysis. Although planning the design is not the function of the aircraft technician, it is, nevertheless, important that the technician understand and appreciate the stresses involved in order to avoid changes in the original design through improper repairs.

The term "stress" is often used interchangeably with the word "strain." While related, they are not the same thing. External loads or forces cause stress. Stress is a material's internal resistance, or counterforce, that opposes deformation. The degree of deformation of a material is strain. When a material is subjected to a load or force, that material is deformed, regardless of how strong the material is or how light the load is.

There are five major stresses to which all aircraft are subjected:

- Tension
- Compression
- Torsion
- Shear
- Bending

Tension is the stress that resists a force that tends to pull something apart. *[Figure 1-14A]* The engine pulls the aircraft forward, but air resistance tries to hold it back. The result is tension, which stretches the aircraft. The tensile strength of a material is measured in pounds per square inch (psi) and is calculated by dividing the load (in pounds) required to pull the material apart by its cross-sectional area (in square inches).

Compression is the stress that resists a crushing force. [Figure 1-14B] The compressive strength of a material is also measured in psi. Compression is the stress that tends to shorten or squeeze aircraft parts.

Torsion is the stress that produces twisting. [Figure 1-14C] While moving the aircraft forward, the engine also tends to twist it to one side, but other aircraft components hold it on course. Thus, torsion is created. The torsion strength of a material is its resistance to twisting or torque.

Shear is the stress that resists the force tending to cause one layer of a material to slide over an adjacent layer. [Figure 1-14D] Two riveted plates in tension subject the rivets to a shearing force. Usually, the shearing strength of a material is either equal to or less than its tensile or compressive strength. Aircraft parts, especially screws, bolts, and rivets, are often subject to a shearing force.

Bending stress is a combination of compression and tension. The rod in has been shortened (compressed) on the inside of the bend and stretched on the outside of the bend.

A single member of the structure may be subjected to a combination of stresses. In most cases, the structural members are designed to carry end loads rather than side loads. They are designed to be subjected to tension or compression rather than bending. Strength or resistance to the external loads imposed during operation may be the principal requirement in certain structures. However, there are numerous other characteristics in addition to designing to control the five major stresses that engineers must consider. For example, cowling, fairings, and similar parts may not be subject to significant loads requiring a high degree of strength. However, these parts must have streamlined shapes to meet aerodynamic requirements, such as reducing drag or directing airflow.

Fixed-Wing Aircraft

Fuselage

The fuselage is the main structure or body of the fixed-wing aircraft. It provides space for cargo, controls, accessories, passengers, and other equipment. In single-engine aircraft, the fuselage houses the power plant. In multiengine aircraft, the engines may be either in the fuselage, attached to the fuselage, or suspended from the wing structure. There are two general types of fuselage construction: truss and monocoque.

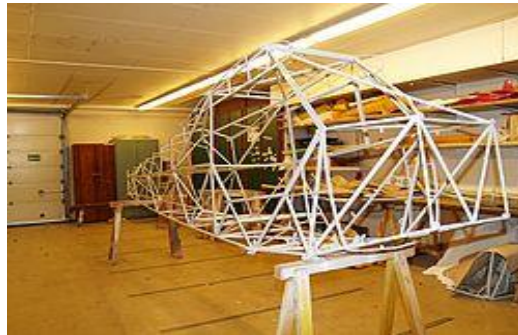
Truss Type

A truss is a rigid framework made up of members, such as beams, struts, and bars to resist deformation by applied loads.

The truss-framed fuselage is generally covered with fabric. The truss-type fuselage frame is usually constructed of steel tubing welded together in such a manner that all members of the truss can carry both tension and compression loads. In some aircraft, principally the light,

single engine models, truss fuselage frames may be constructed of aluminum alloy and may be riveted or bolted into one piece, with cross-bracing achieved by using solid rods or tubes.

Most early aircraft used this technique with wood and wire trusses and this type of structure is still in use in many lightweight aircraft using welded steel tube trusses. The truss type fuselage frame is assembled with members forming a rigid frame e.g. beams, bar, tube etc... Primary members of the truss are 4 longerons.



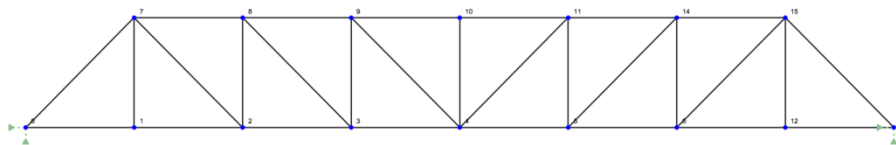
There are two types of truss structure.

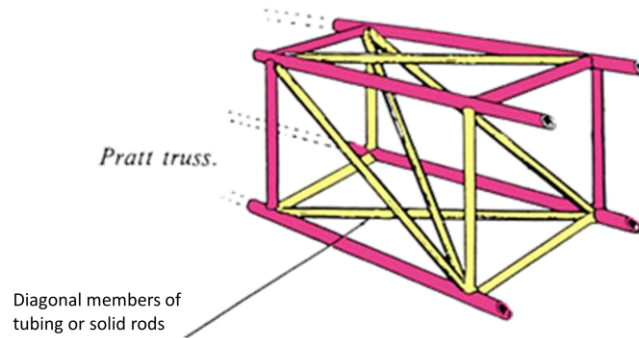
- PRATT TRUSS
- WARREN TRUSS

PRATT TRUSS

A Pratt Truss has been used over the past two centuries as an effective truss method. The vertical members are in compression, whilst the diagonal members are in tension. This simplifies and produces a more efficient design since the steel in the diagonal members (in tension) can be reduced. This has a few effects - it reduces the cost of the structure due to more efficient members, reduces the self weight and eases the constructability of the structure. This type of truss is most appropriate for horizontal spans, where the force is predominantly in the vertical direction.

Below is an example of a Pratt Truss,





A truss-type fuselage with pratt truss.

Advantages

- Aware of member's behaviour - diagonal members are in tension, vertical members in compression
- The above can be used to design a cost effective structure
- Simple design
- Well accepted and used design

Disadvantages

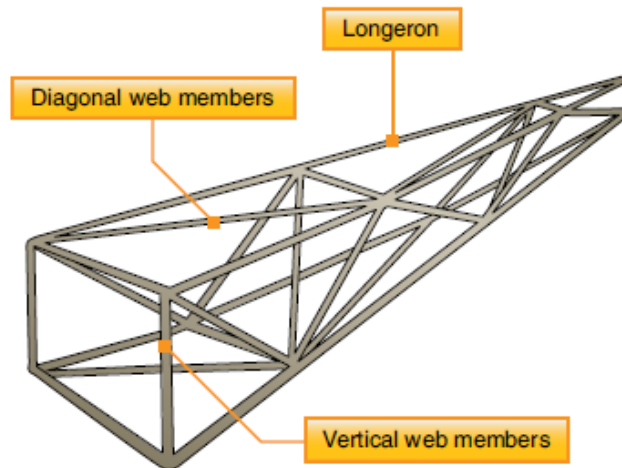
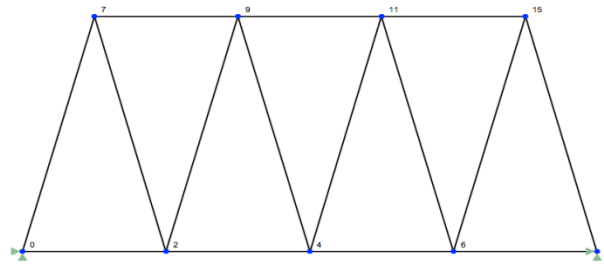
- Not as advantageous if the load is not vertical

Best Used For:

- Where a cost effective design is required
- Where a mix of loads are applied
- Where a simple structure is required

WARREN TRUSS

The Warren Truss is another very popular truss structure system and is easily identified by its construction from equilateral triangles. One of the main advantages of a Warren Truss is its ability to spread the load evenly across a number of different members; this is however generally for cases when the structure is undergoing a spanned load (a distributed load). Its main advantage is also the cause of its disadvantage - the truss structure will undergo concentrated force under a point load. Under these concentrated load scenarios, the structure is not as good at distributing the load evenly across its members. Therefore the Warren truss type is more advantageous for spanned loads, but not suitable where the load is concentrated at a single point or node. An example of a Warren Truss and its axial forces under a distributed load is shown below.



A truss-type fuselage. A Warren truss uses mostly diagonal bracing.

Advantages

- Spreads load fairly evenly between members
- Fairly simple design

Disadvantages

- Poorer performance under concentrated loads
- Increased constructibility due to additional members

Best Used For:

- Long span structures
- Where an evenly distributed load is to be supported
- Where a simple structure is required

Monocoque Type

The monocoque (single shell) fuselage relies largely on the strength of the skin or covering to carry the primary loads.

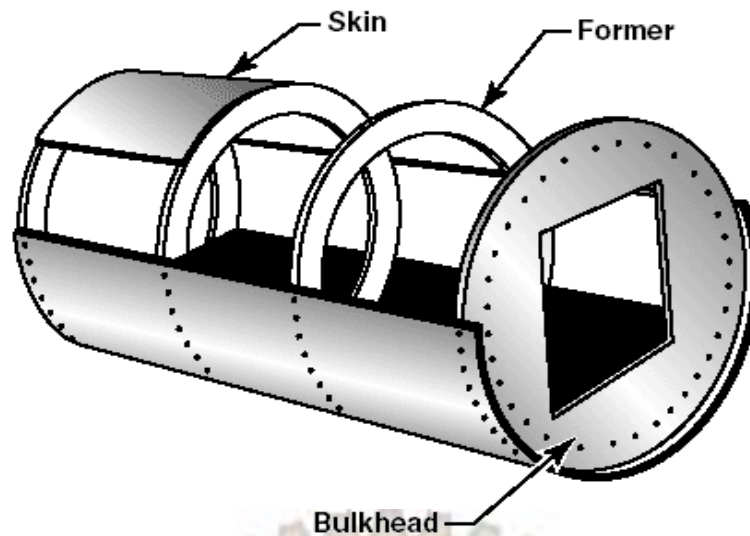
The design may be divided into two classes:

1. Monocoque
2. Semimonocoque

Different portions of the same fuselage may belong to either of the two classes, but most modern aircraft are considered to be of semi-monocoque type construction.

The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage. The heaviest of these structural members are located at intervals to carry concentrated loads and at points where fittings are used to attach other units such as wings, power plants, and stabilizers. Since no other bracing members are present, the skin must carry the primary stresses and keep the fuselage rigid. Thus, the biggest problem

involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits.



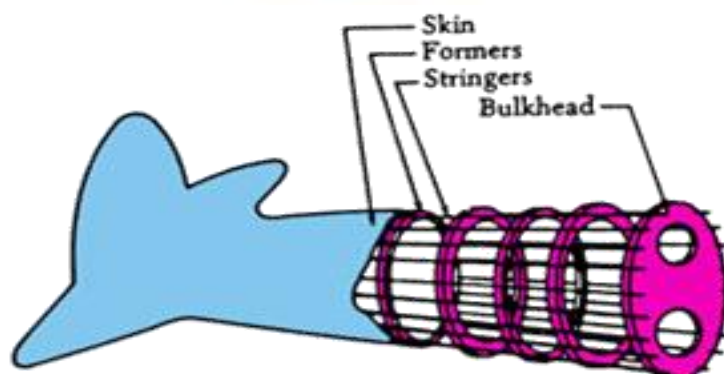
An airframe using monocoque construction.

Semi-monocoque Type

To overcome the strength/weight problem of monocoque construction, a modification called semi-monocoque construction was developed.

It also consists of frame assemblies, bulkheads, and formers as used in the monocoque design but, additionally, the skin is reinforced by longitudinal members called longerons. Longerons usually extend across several frame members and help the skin support primary bending loads. They are typically made of aluminum alloy either of a single piece or a built-up construction.

Stringers are also used in the semimonocoque fuselage. These longitudinal members are typically more numerous and lighter in weight than the longerons. They come in a variety of shapes and are usually made from single piece aluminum alloy extrusions or formed aluminum. Stringers have some rigidity but are chiefly used for giving shape and for attachment of the skin. Stringers and longerons together prevent tension and compression from bending the fuselage.



Semi-monocoque Structure of an airplane

Other bracing between the longerons and stringers can also be used. Often referred to as web members, these additional support pieces may be installed vertically or diagonally. It must be

noted that manufacturers use different nomenclature to describe structural members. For example, there is often little difference between some rings, frames, and formers. One manufacturer may call the same type of brace a ring or a frame. Manufacturer instructions and specifications for a specific aircraft are the best guides.

The semi-monocoque fuselage is constructed primarily of alloys of aluminum and magnesium, although steel and titanium are sometimes found in areas of high temperatures. Individually, no one of the aforementioned components is strong enough to carry the loads imposed during flight and landing. But, when combined, those components form a strong, rigid framework. This is accomplished with gussets, rivets, nuts and bolts, screws, and even friction stir welding.

A gusset is a type of connection bracket that adds strength.



Gussets are used to increase strength.

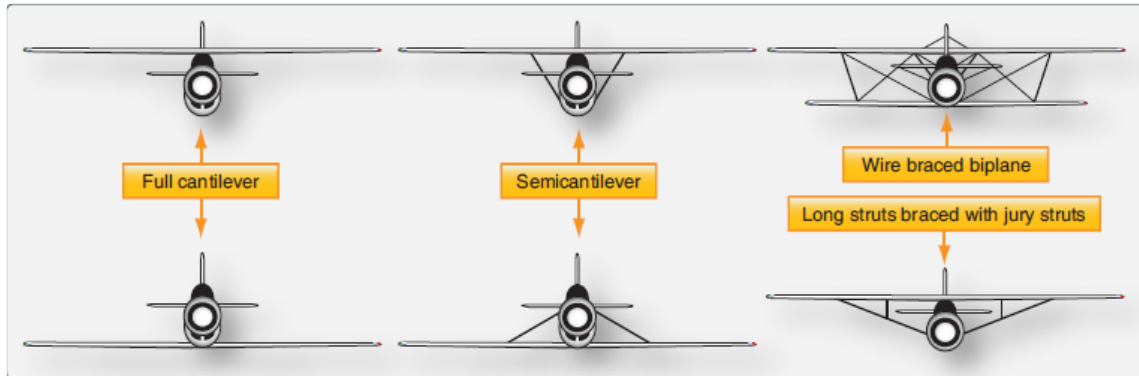
To summarize, in semi-monocoque fuselages, the strong, heavy longerons hold the bulkheads and formers, and these, in turn, hold the stringers, braces, web members, etc. All are designed to be attached together and to the skin to achieve the full strength benefits of semi-monocoque design. It is important to recognize that the metal skin or covering carries part of the load. The fuselage skin thickness can vary with the load carried and the stresses sustained at a particular location.

The advantages of the semi-monocoque fuselage are many. The bulkheads, frames, stringers, and longerons facilitate the design and construction of a streamlined fuselage that is both rigid and strong. Spreading loads among these structures and the skin means no single piece is failure critical. This means that a semi-monocoque fuselage, because of its stressed-skin construction, may withstand considerable damage and still be strong enough to hold together. Fuselages are generally constructed in two or more sections. On small aircraft, they are generally made in two or three sections, while larger aircraft may be made up of as many as six sections or more before being assembled.

Wing Structure

The wings of an aircraft are designed to lift it into the air. Their particular design for any given aircraft depends on a number of factors, such as size, weight, use of the aircraft, desired speed in flight and at landing, and desired rate of climb. The wings of aircraft are designated left and right, corresponding to the left and right sides of the operator when seated in the cockpit. Often wings are of full cantilever design. This means they are built so that no external bracing is needed. They are supported internally by structural members assisted by the skin of the aircraft. Other aircraft wings use external struts or wires to assist in supporting the wing and carrying the aerodynamic and landing loads. Wing support cables and struts are

generally made from steel. Many struts and their attach fittings have fairings to reduce drag. Short, nearly vertical supports called jury struts are found on struts that attach to the wings a great distance from the fuselage. This serves to subdue strut movement and oscillation caused by the air flowing around the strut in flight. Figure shows samples of wings using external bracing, also known as semicantilever wings. Cantilever wings built with no external bracing are also shown.

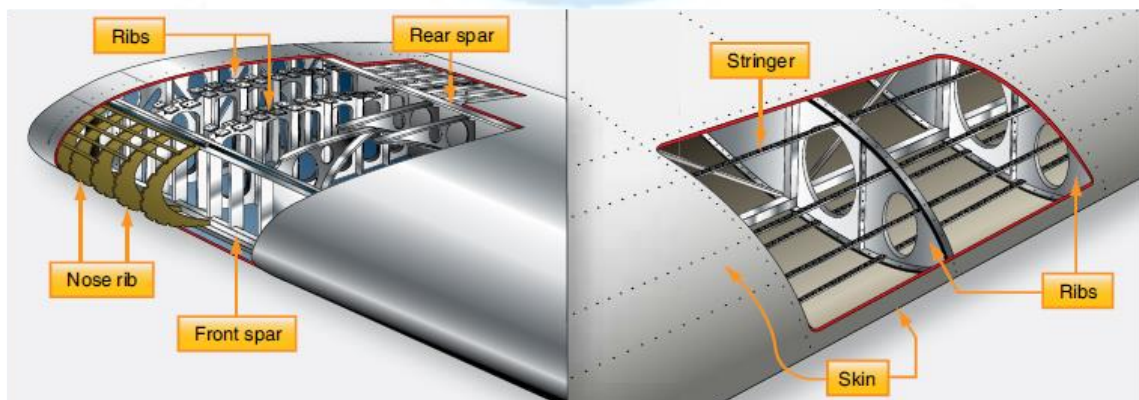


Externally braced wings, also called semicantilever wings, have wires or struts to support the wing. Full cantilever wings have no external bracing and are supported internally.

Aluminum is the most common material from which to construct wings, but they can be wood covered with fabric, and occasionally a magnesium alloy has been used. Moreover, modern aircraft are tending toward lighter and stronger materials throughout the airframe and in wing construction. Wings made entirely of carbon fiber or other composite materials exist, as well as wings made of a combination of materials for maximum strength to weight performance.

The internal structures of most wings are made up of spars and stringers running spanwise and ribs and formers or bulkheads running chordwise (leading edge to trailing edge).

The spars are the principle structural members of a wing. They support all distributed loads, as well as concentrated weights such as the fuselage, landing gear, and engines. The skin, which is attached to the wing structure, carries part of the loads imposed during flight. It also transfers the stresses to the wing ribs. The ribs, in turn, transfer the loads to the wing spars.



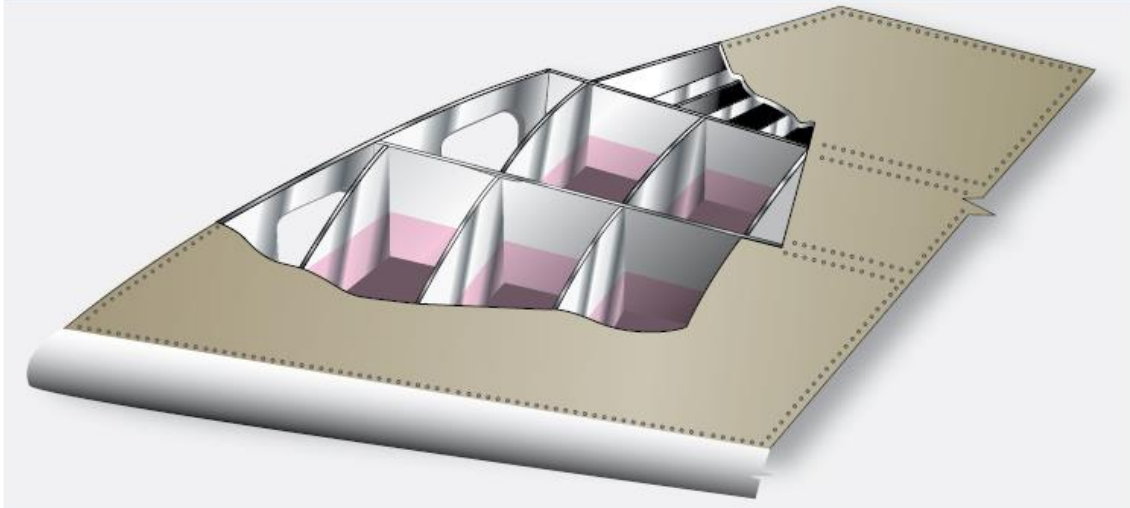
Wing structure nomenclature

In general, wing construction is based on one of three fundamental designs:

1. Monospar
2. Multispar

3. Box beam

Modification of these basic designs may be adopted by various manufacturers. The monospar wing incorporates only one main spanwise or longitudinal member in its construction. Ribs or bulkheads supply the necessary contour or shape to the airfoil. Although the strict monospar wing is not common, this type of design modified by the addition of false spars or light shear webs along the trailing edge for support of control surfaces is sometimes used. The multispar wing incorporates more than one main longitudinal member in its construction. To give the wing contour, ribs or bulkheads are often included.



Box beam construction.

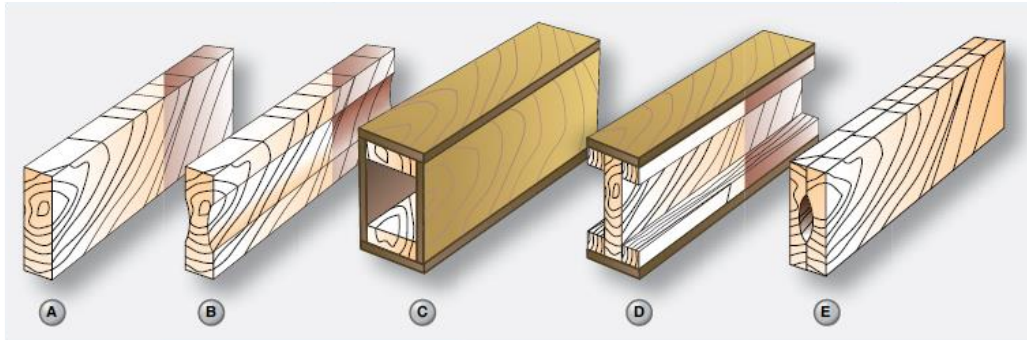
The box beam type of wing construction uses two main longitudinal members with connecting bulkheads to furnish additional strength and to give contour to the wing. A corrugated sheet may be placed between the bulkheads and the smooth outer skin so that the wing can better carry tension and compression loads. In some cases, heavy longitudinal stiffeners are substituted for the corrugated sheets. A combination of corrugated sheets on the upper surface of the wing and stiffeners on the lower surface is sometimes used. Air transport category aircraft often utilize box beam wing construction.

Wing Spars

Spars are the principal structural members of the wing. They correspond to the longerons of the fuselage. They run parallel to the lateral axis of the aircraft, from the fuselage toward the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or a truss. Spars may be made of metal, wood, or composite materials depending on the design criteria of a specific aircraft.

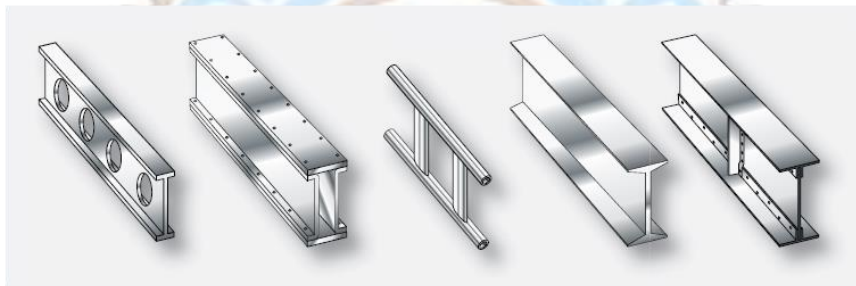
Wooden spars are usually made from spruce. They can be generally classified into four different types by their cross-sectional configuration.

As shown in figure,



They may be (A) solid, (B) box shaped, (C) partly hollow, or (D) in the form of an I-beam. Lamination of solid wood spars is often used to increase strength. Laminated wood can also be found in box shaped spars. The spar in *Figure 1-25E* has had material removed to reduce weight but retains the strength of a rectangular spar. As can be seen, most wing spars are basically rectangular in shape with the long dimension of the cross-section oriented up and down in the wing.

Currently, most manufactured aircraft have wing spars made of solid extruded aluminum or aluminum extrusions riveted together to form the spar. The increased use of composites and the combining of materials should make airmen vigilant for wings spars made from a variety of materials. Figure shows examples of metal wing spar cross-sections.

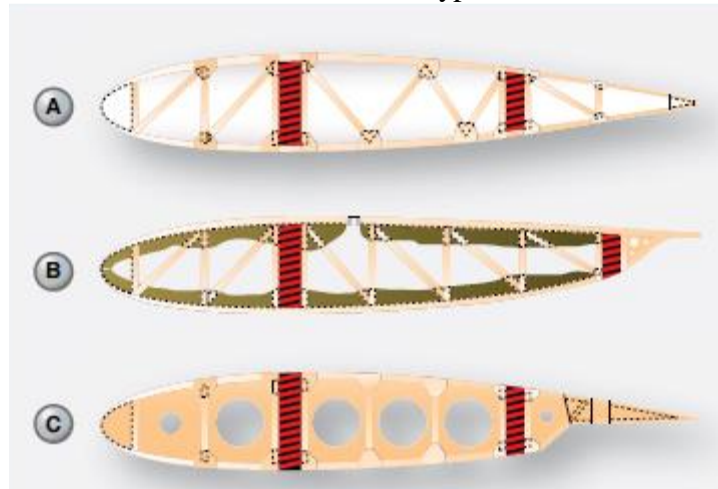


Wing Ribs

Ribs are the structural crosspieces that combine with spars and stringers to make up the framework of the wing. They usually extend from the wing leading edge to the rear spar or to the trailing edge of the wing. The ribs give the wing its cambered shape and transmit the load from the skin and stringers to the spars. Similar ribs are also used in ailerons, elevators, rudders, and stabilizers. Wing ribs are usually manufactured from either wood or metal. Aircraft with wood wing spars may have wood or metal ribs while most aircraft with metal spars have metal ribs. Wood ribs are usually manufactured from spruce. The three most common types of wooden ribs are the plywood web, the lightened plywood web, and the truss types. Of these three, the truss type is the most efficient because it is strong and lightweight, but it is also the most complex to construct.

Figure shows wood truss web ribs and a lightened plywood web rib. Wood ribs have a rib cap or cap strip fastened around the entire perimeter of the rib. It is usually made of the same material as the rib itself. The rib cap stiffens and strengthens the rib and provides an attaching surface for the wing covering. In *Figure A*, the cross-section of a wing rib with a truss-type web is illustrated. The dark rectangular sections are the front and rear wing spars. Note that to reinforce the truss, gussets are used. In *Figure B*, a truss web rib is shown with a continuous gusset. It provides greater support throughout the entire rib with very little additional weight. A continuous gusset stiffens the cap strip in the plane of the rib. This aid in preventing

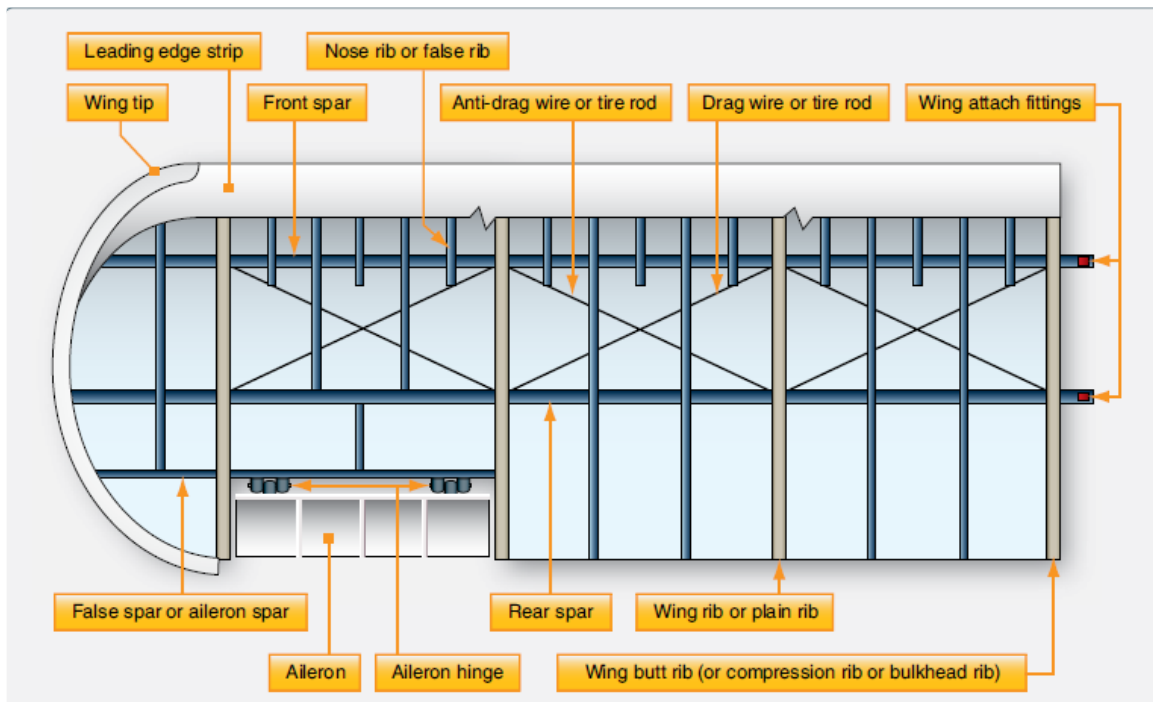
buckling and helps to obtain better rib/skin joints where nail-gluing is used. Such a rib can resist the driving force of nails better than the other types.



Continuous gussets are also more easily handled than the many small separate gussets otherwise required. *Figure C* shows a rib with a lightened plywood web. It also contains gussets to support the web/cap strip interface. The cap strip is usually laminated to the web, especially at the leading edge.

A wing rib may also be referred to as a plain rib or a main rib. Wing ribs with specialized locations or functions are given names that reflect their uniqueness. For example, ribs that are located entirely forward of the front spar that are used to shape and strengthen the wing leading edge are called nose ribs or false ribs. False ribs are ribs that do not span the entire wing chord, which is the distance from the leading edge to the trailing edge of the wing. Wing butt ribs may be found at the inboard edge of the wing where the wing attaches to the fuselage. Depending on its location and method of attachment, a butt rib may also be called a bulkhead rib or a compression rib if it is designed to receive compression loads that tend to force the wing spars together. Since the ribs are laterally weak, they are strengthened in some wings by tapes that are woven above and below rib sections to prevent sidewise bending of the ribs. Drag and anti-drag wires may also be found in a wing. In *Figure*, they are shown crisscrossed between the spars to form a truss to resist forces acting on the wing in the direction of the wing chord. These tension wires are also referred to as tie rods. The wire designed to resist the backward forces is called a drag wire; the anti-drag wire resists the forward forces in the chord direction. *Figure illustrates* the structural components of a basic wood wing.

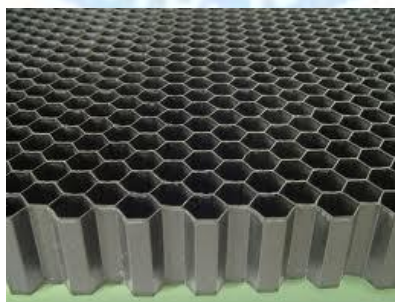
At the inboard end of the wing spars is some form of wing attach fitting as illustrated in *Figure*. These provide a strong and secure method for attaching the wing to the fuselage.



Basic wood wing structure and components.

Honeycomb construction

Honeycomb structures are natural or man-made structures that have the geometry of a honeycomb to allow the minimization of the amount of used material to reach minimal weight and minimal material cost. The geometry of honeycomb structures can vary widely but the common feature of all such structures is an array of hollow cells formed between thin vertical walls. The cells are often columnar and hexagonal in shape. A honeycomb shaped structure provides a material with minimal density and relative high out-of-plane compression properties and out-of-plane shear properties.



Honeycomb structure

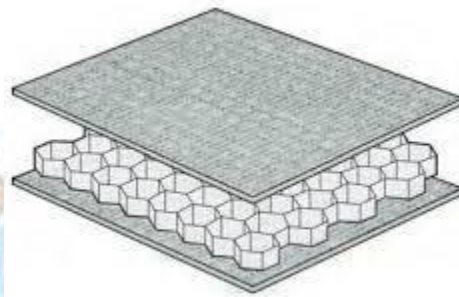
Man-made honeycomb structural materials are commonly made by layering a honeycomb material between two thin layers that provide strength in tension. This forms a plate-like assembly. Honeycomb materials are widely used where flat or slightly curved surfaces are needed and their high strength is valuable. They are widely used in the aerospace industry for this reason, and honeycomb materials in aluminium, fibreglass and advanced composite

materials have been featured in aircraft and rockets since the 1950s. They can also be found in many other fields, from packaging materials in the form of paper-based honeycomb cardboard, to sporting goods like skis and snowboards.

The main use of honeycomb is in structural applications. The standard hexagonal honeycomb is the basic and most common cellular honeycomb configuration.

Honeycomb composites

Natural honeycomb structures occur in many different environments, from beehives to honeycomb weathering in rocks. Based on these, man-made honeycomb structures have been built with similar geometry to allow the reduction of the quantity of material used, and thereby realizing minimal weight and material cost.



Honeycomb structure with panels

Man-made honeycomb structures have an array of hollow cells formed between thin vertical walls, so that the material has minimal density, strength in tension and high out-of-plane compression properties.

Geometric types of honeycomb structures

In geometry, a honeycomb is a space filling or close packing of polyhedral or higher-dimensional cells, so that there are no gaps. It is an example of the more general mathematical tiling or tessellation in any number of dimensions.

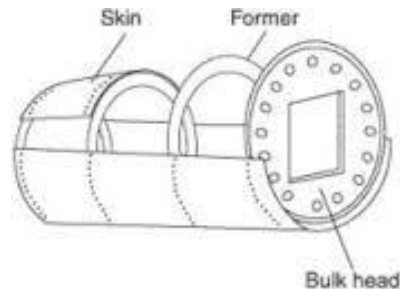
Honeycombs are usually constructed in ordinary Euclidean ("flat") space. They may also be constructed in non-Euclidean spaces, such as hyperbolic honeycombs. Any finite uniform polytope can be projected to its circumsphere to form a uniform honeycomb in spherical space.

Bulkheads

The bulkheads provide shape for the fuselage. The skin of the fuselage to bear the structural load with bulkheads at each end and forming rings at intervals to maintain the skin shape. A hybrid of truss and monocoque, in semi-monocoque construction panels of aerodynamically-curved skin are riveted on top of an internal structure consisting of bulkheads, stringers and followers to absorb the bending forces. The monocoque design uses stressed skin to support

almost all imposed loads. The true monocoque construction mainly consists of the skin, formers, and bulkheads. The formers and bulkheads provide shape for the fuselage.

The semi-monocoque system uses a substructure to which the airplane's skin is attached. The substructure, which consists of bulkheads and/or formers of various sizes and stringers, reinforces the stressed skin by taking some of the bending stress from the fuselage.



Bulkhead

Stringers

Stringer is a stiffening member which supports a section of the load carrying skin, to prevent buckling under compression or shear loads. Stringers keep the skin from bending. Longitudinal members are sometimes referred to as longitudinal, stringers, or stiffeners.

Role of Stringers in Aircraft Wings

In aircraft construction, a stringer is a thin strip of material to which the skin of the aircraft is fastened. In the fuselage, stringers are attached to formers (also called frames) and run in the longitudinal direction of the aircraft. They are primarily responsible for transferring the aerodynamic loads acting on the skin onto the frames and formers. In the wings or horizontal stabilizer, longerons run span wise and attach between the ribs. The primary function here also is to transfer the bending loads acting on the wings onto the ribs and spar.

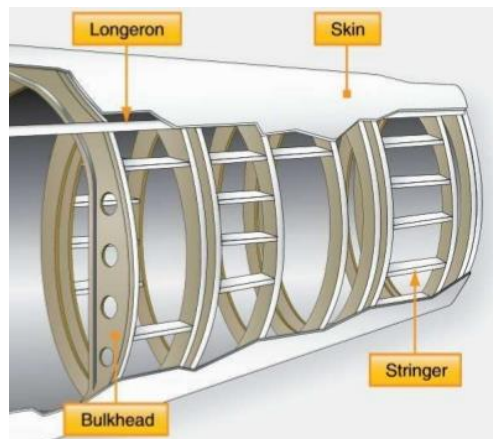
Different Shapes of Stringers

The stringers on an aluminum airplane are normally extruded or bent into shape, and can have a number of different cross sections.

Typically Shapes for stringers are

- i. HAT Stringer
- ii. I-Stringer
- iii. J-Stringer
- iv. Y-Stringer
- v. Z Stringer.

On wooden airplanes, they are usually spruce square or rectangular cross sections.

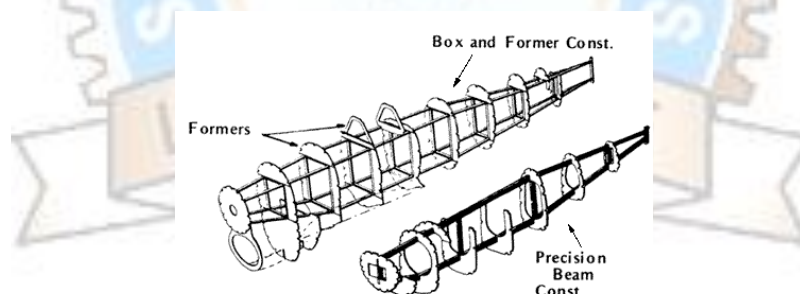


Stringers

Formers

A former is a structural member of an aircraft fuselage, of which a typical fuselage has a series from the nose to the empennage, typically perpendicular to the longitudinal axis of the aircraft. The primary purpose of formers is to establish the shape of the fuselage and reduce the column length of stringers to prevent instability. Formers are typically attached to longerons, which support the skin of the aircraft.

The Former-and-Longeron technique was adopted from boat construction (also called stations and stringers), and was typical of light aircraft built until the advent of structural skins, such as fibreglass and other composite materials.



Longerons

A longeron is part of the structure of an aircraft, designed to add rigidity and strength to the frame. It also creates a point of attachment for other structural supports, as well as the skin of the aircraft. They provide lengthwise support and the number of longerons present in an aircraft varies, depending on the size and how it is designed. Like other structural members, they need to be checked periodically for signs of damage that might compromise their function.

Materials like wood, carbon fiber, and metal can be used in longeron construction. Older aircraft were made almost entirely with wood, while it is a more rare construction material today because it does not provide as much strength and flexibility as other materials. The

materials are carefully tested before being installed to make sure there are no cracks or other flaws that might cause them to fail once in place or while the plane is in use.

Each longeron attaches directly to the frame of the aircraft using bolts. In some planes, shorter longitudinal supports called stiffeners or stringers are fastened to the longerons. Confusingly, these terms are also sometimes used as alternate names for the longeron. The skin, whether made from metal, leather, canvas, or other materials, can be attached to the aircraft once the longerons are in place. Insulating material and lining may be installed on the other side, depending on how the plane is going to be used.

Longerons functions

They resist bending and axial loads along with the skin.

They divide the skin into small panels and thereby increase its buckling and failure stresses.

They act with the skin in resisting axial loads caused by pressurization.

