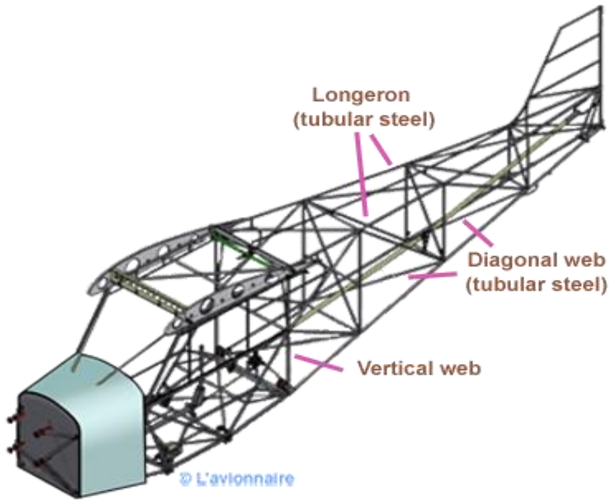
UNIT 4

AEROSPACE STRUCTURES

Types of aircraft fuselage construction

Truss Construction

When it comes to the fuselage construction, the oldest form of construction is the open truss type. A truss is a rigid framework made up of sub members, long beams called the longerons, struts, and bars which are welded in such a fashion that the entire assembly behaves as a single object. A fuselage with truss construction consists of longerons with periodical vertical and horizontal struts welded to the fuselage and gives a square or rectangular shape when viewed from the side. The struts are added to mainly overcome the loads coming from any direction. Initially, the entire structure was made from wood. However, to increase the load bearing capacity, the sub members were later made from steel tubes which were welded together to act as one unit. Trust type of construction is very good in resisting compression and tensile loads. They evenly distribute the loads without bending or shearing. Further, to reduce the weight of the aircraft, the steel tubes were slowly replaced by aluminium tubes which were either riveted or bolted into one piece and cross branching was achieved using solid rods or tubes.



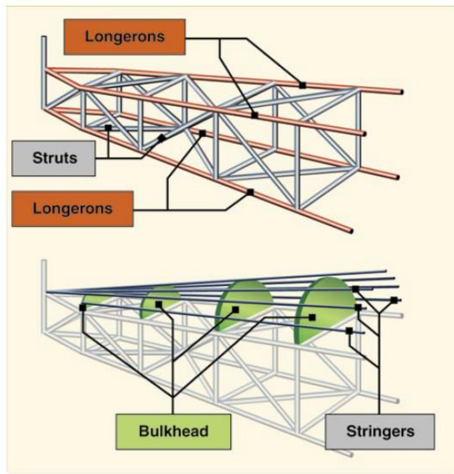
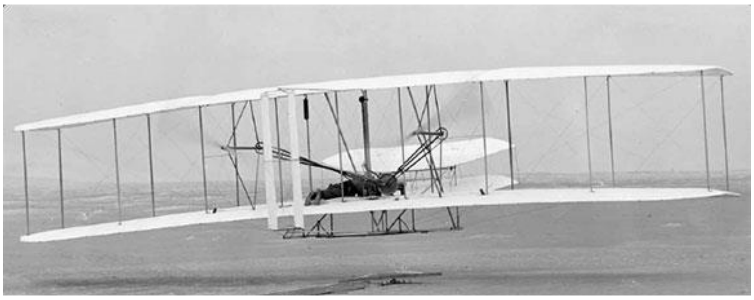


Figure 2-5. *Truss-type fuselage structure.*

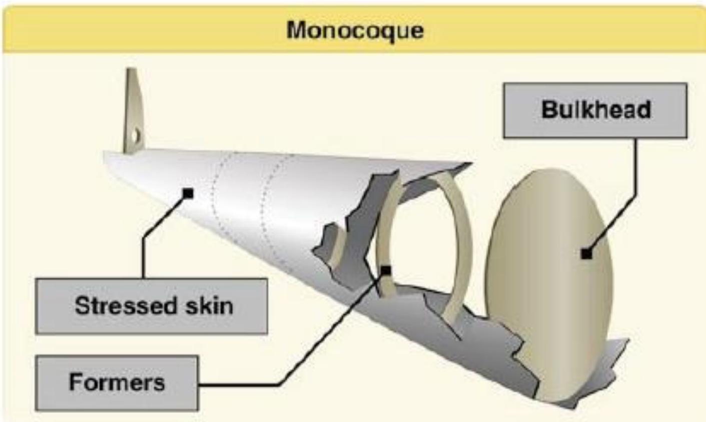
Most of the early aircraft used the truss type of construction and the members were typically made of wood and wires. The first successful aircraft, the Wright flyer was typically of biplane configuration wherein the wings contained the forward and the rear spars made entirely of wood. These two members were held together with struts which acted like the cross member. Here, the struts were also made of wood. The entire wings were covered in plain fabric and interconnected with the upper and lower wings using wires.



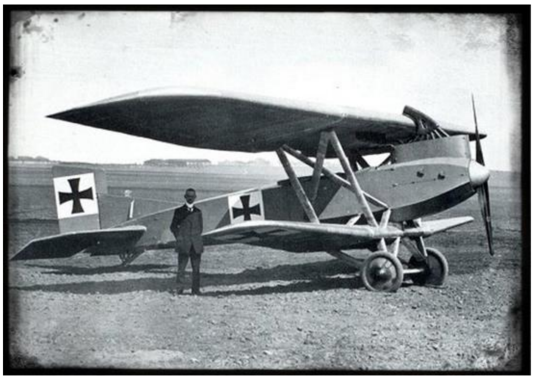
Monocooque construction

As time progressed, the power plants had also become more powerful enough which pushed the speeds of the aircraft. The main drawback of truss construction is that they do not render a streamlined shape to the aircraft. This was mainly due to the open framework of exposed wires, struts and braces which added a lot of drag to the vehicle. But as technology and requirements progressed, aircraft designers began to enclose the truss members with cloth or fabric and some even tried with canvas.

For aircrafts with great speeds, the truss construction with cloth and fabric was still unable to support the loads and hence eventually, it was replaced by lightweight aluminum skins. By doing this, the entire aircraft was completely covered with metal and the outer metallic skin was supporting most of the loads acting on the aircraft. This gave way for a newer construction technology called the monocooque construction. This is a type of aircraft construction wherein the outside skin carries most of the primary loads experienced by the aircraft during flight. The fuselage though it consists of sub members like the formers, frames, and bulkheads, they were mostly for providing the aerodynamic shape to the aircraft. Since no other bracing members are present, the major loads or the primary loads (shearing, bending, and twisting loads) were carried and supported by the skin alone. Hence, in monocoque (single shell) fuselage construction relies largely on the strength of the skin or covering to carry the primary loads. Since the skin is the most stressed part of the aircraft, this type of construction is also referred to as stressed skin structure.

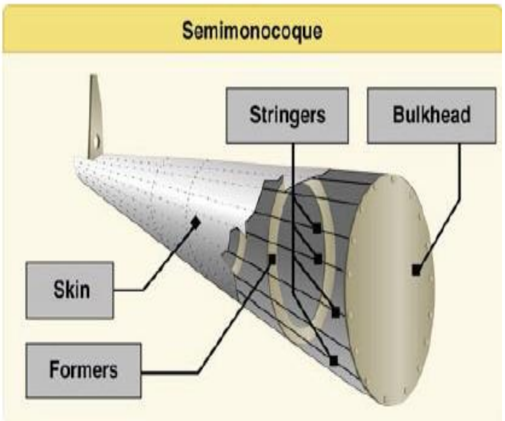


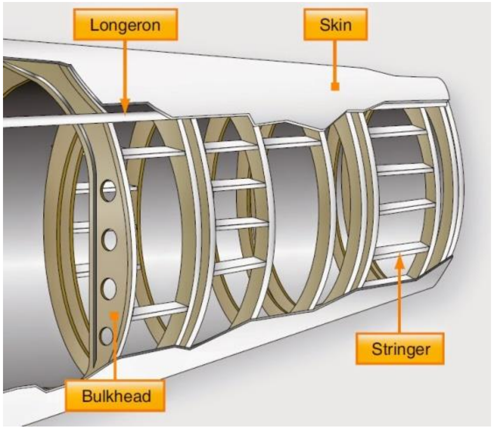
As metal was used for construction, there was no need for external bracing using wires and hence, wires were completely removed from the monocoque construction. German Hugo Junkers was the first aircraft to eliminate wood and external bracing using wires. It was the first all metal aircraft and unique in its time. Also it had shed the biplane configuration, which was the most common type of wing used during the world wars. This type of aircraft construction was utilized up to World War II.

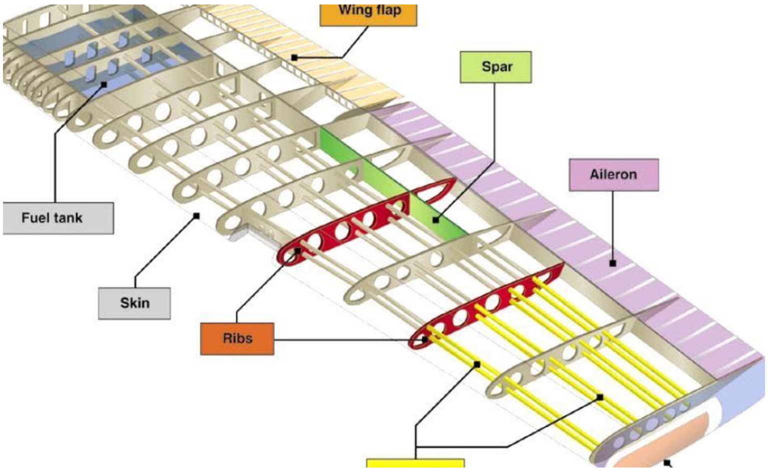


Semi Monocoque Construction

Later, the development of lighter and higher capacity engines pushed the operating envelope of the aircraft due to which cabin pressurization became a very important safety concern especially for commercial airplanes. As the aircrafts flew at higher altitudes, due to high pressure differences, the skin which was the formidable load bearing member had to be made thicker to withstand most of the loads. Increasing the thickness of the metal skin tremendously increased the weight of the aircraft and was found to be highly unsuitable in most of the cases. Thus, the biggest problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits. Besides, the major drawback of monocoque construction is that the thin-skinned construction means that compression and shear buckling become the most likely forms of failure.







To overcome this problem, and also increase the critical buckling loads the skins were stiffened by stringers and broken up into smaller sections by spars and ribs. The vertical structural members are referred to as bulkheads, frames, and formers. The heavier vertical members are located at intervals to allow for concentrated loads. This is very much similar to the monocoque construction, but the semi monocoque type get additional structural member called the longerons that extend across the fuselage length. Longerons with the skin usually help in resisting the bending loads. They are typically made of aluminum alloy either of a single piece or a built-up construction. The longerons are supplemented by other longitudinal members known as stringers. The stringers are usually the smaller and lighter ones as compared to the longerons but huge in numbers. They are chiefly used for giving shape and for attachment of skin. Stringers and longerons together prevent tension and compression from bending the fuselage. The strong, heavy longerons hold the bulkheads and formers. The bulkheads and formers hold the stringers. These members join together to form a rigid fuselage framework. The main advantage of the semimonocoque construction is that it depends on many structural members for strength and rigidity. A semimonocoque fuselage can withstand damage and still be strong enough to hold together as compared to the monocoque design.

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.

Stringers

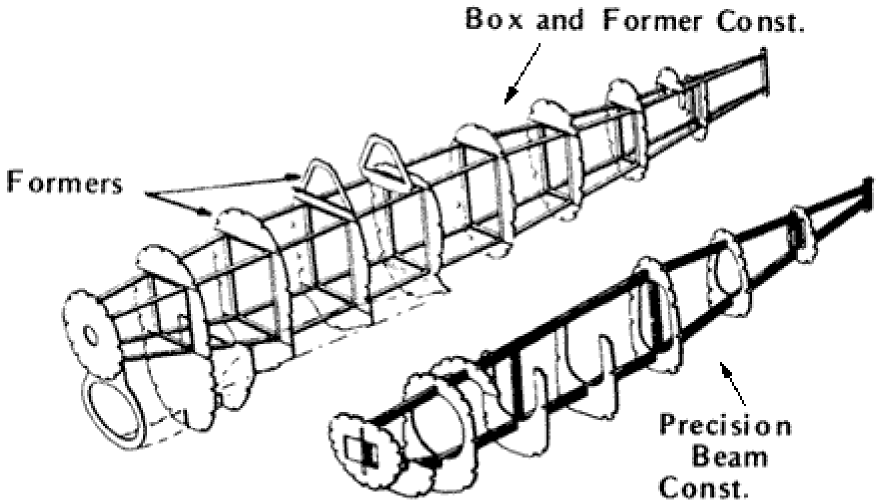
Stringer is a stiffening member which supports a section of the load carrying skin, to prevent buckling under compression or shear loads. Stringers keep the skin from bending. Longitudinal members are sometimes referred to as longitudinal, stringers, or stiffeners.

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.

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. 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.

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.

Since the success of Wright Brothers, many different types of aircrafts have been developed. It might be fighter, civil, cargo, reconnaissance, bomber etc. Although different types of airplanes are designed for a variety of purposes, from a structural perspective most of them have the same major components in common and major structural systems of any airplane are

1. Fuselage
2. Wings

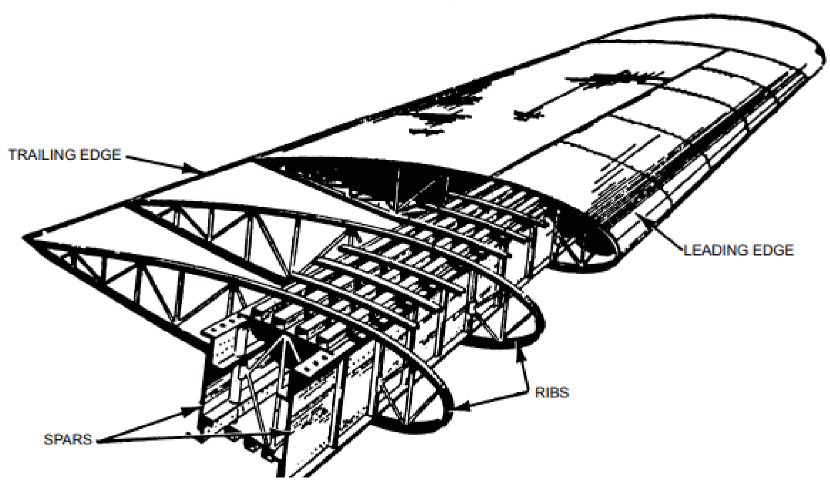
3. Empennage
4. Flight Control Surfaces
5. Landing gear

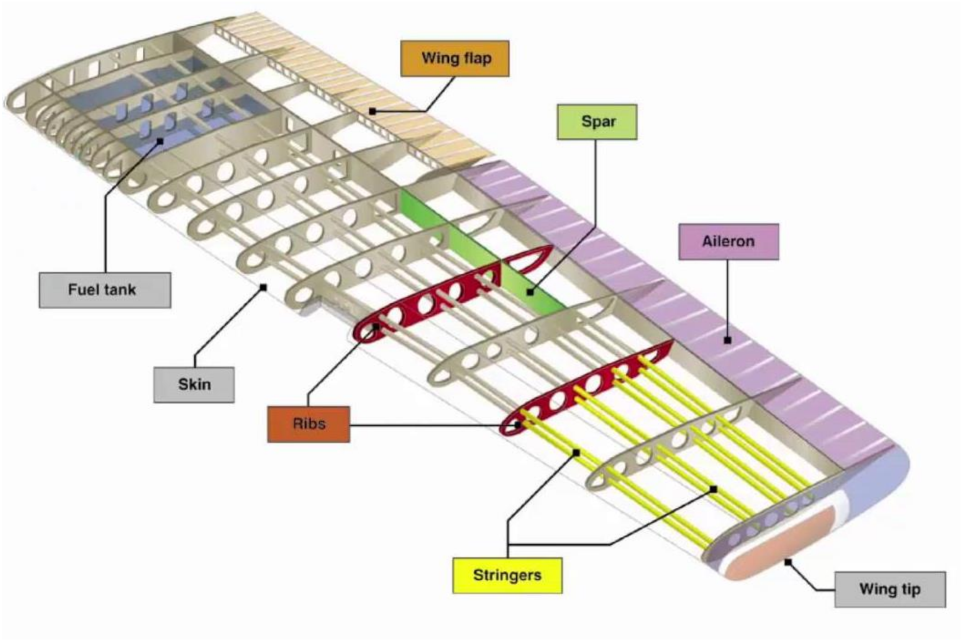
FUSELAGE

1. Fuselage forms the central body of any airplane and the major function of the airplane fuselage is to accommodate and protect the crew, passengers, cargo or payloads, controls and other subsystems like the landing gear, navigations equipments etc.
2. Besides, another important task of a fuselage is to provide the required structural connections for the wings and the tails assembly which supports large concentrated loads such as wing reactions, tail plane reactions, undercarriage reactions and it carries payloads of varying size and weight, which may cause large inertia forces.
3. Furthermore, aircraft designed for high altitude flight must withstand high pressure differences due to the external de compression.
4. The most efficient sectional shape for a pressurized fuselage is circular or a combination of circular elements. Irrespective of shape, the basic fuselage structure is essentially a single cell thin-walled tube comprising skin, transverse frames and stringers. Transverse frames which extend completely across the fuselage are known as bulkheads.

WINGS

1. Wings are the primary aerodynamic member that aid in the generation of required lift for the aircraft.
2. The maximum portion of the loads is generated by the wings alone.
3. The particular design of a wing depends on many factors, such as the size, weight, speed, rate of climb, and use of the aircraft.
4. Based on the configuration, a wing might be low, mod or high wing. Further, the number of wings can also vary. Airplanes with a single set of wings are referred to as monoplanes, while those with two sets are called biplanes and planes with three set are called as triplanes.
5. Apart from this, in most of the cases wing will be referred as wet wing that carries fuel cell within the wing. Storing and supplying large quantities of fuel is an additional function of a wing which is mainly done to counteract the large aerodynamic bending forces experienced by the wing in flight.
6. Since wing is the main lift generating member, the wing must be constructed so that it holds its aerodynamics shape under the extreme stresses of combat manoeuvres or wing loading
7. To make the aircraft wing string enough to support all the aerodynamic loads, in its simplest form, the wing is a framework made up of spars, stringers and ribs and covered with metal skin.





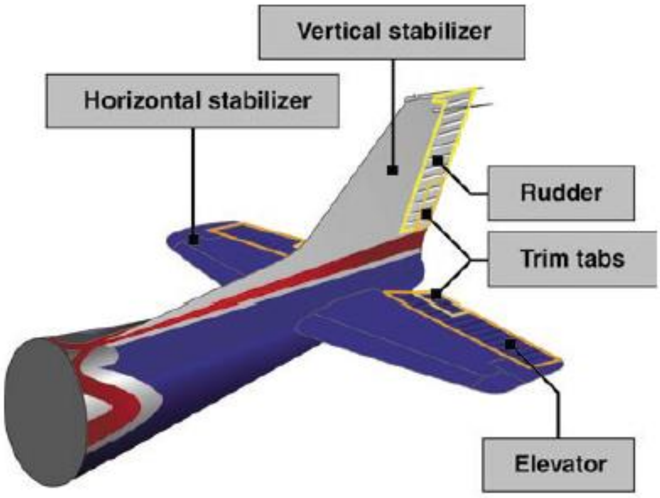
Internal members of a wing

1. Spars are the main structural members of the wing and they extend from the fuselage to the tip of the wing. The entire load carried by the wing is taken up by the spars. The spars are designed to have great bending strength.
2. The wing ribs determine the shape and thickness of the wing (airfoil) and they transmit the air load from the wing covering to the spars. Ribs extend from the leading edge to the trailing edge of the wing. Besides, ribs provide aerodynamic shape to the wing
    a. They also act with the skin in resisting the distributed aerodynamic pressure loads and concentrated load (undercarriage and additional wing store loads) into the structure.
    b. They increase the buckling strength of the skin panels.
    c. They support hinge reactions from ailerons, flaps and other control surfaces
3. Functions of Skin are

   a. The primary function of the wing skin is to form an impermeable surface for supporting the aerodynamic pressure distribution from which the lifting capability of the wing is derived.
   b. These aerodynamic forces are transmitted in turn to the ribs and stringers by the skin through plate and membrane action.
   c. Skin in conjunction with spar webs, they resist shear and torsional loads.
   d. Skin in combination with stringers resists axial and bending loads.
4. Functions of Stringers are
   a. Although the thin skin is efficient for resisting shear and tensile loads, it buckles under comparatively low compressive loads. Rather than increase the skin thickness and suffer a consequent weight penalty, stringers are attached to the skin and ribs, thereby dividing the skin into small panels and increasing the buckling and failing stresses.
   b. Combination of stringer with skin resists axial and bending loads.
5. Functions of Spar Webs
   a. They develop shear stresses to resist shear and torsional loads
   b. They stabilize the skin similar to the stringer
   c. Spar flanges or caps support large compressive loads from axial and bending loads.

EMPENNAGE

1. Combination of vertical stabilizer (Fin) and the horizontal stabilizer are called as empennage.
2. For inspection and maintenance purposes, the entire tail section is considered a single fixed unit called the empennage.
3. The main purpose of stabilizers is to keep the aircraft in straight-and-level flight.
4. To do this, the empennage unit is housed with elevator, rudder and one or more trim tabs.
5. Vertical stabilizer holds the rudder and the horizontal stabilizer houses the elevators.
6. During flight, rudder is used to move the airplane’s nose left and right.
7. The elevator, which is attached to the back of the horizontal stabilizer, is used to move the nose of the airplane up and down during flight.
8. The main purpose of stabilizers is to keep the aircraft in straight-and-level flight.
9. To do this, the empennage unit is housed with elevator, rudder and one or more trim tabs.
10. The vertical stabilizer maintains the stability of the aircraft about its vertical axis. This is known as directional stability.
11. The horizontal stabilizer provides stability of the aircraft about its lateral axis. This is known as longitudinal stability.



LANDING GEAR

1. The landing gear is the principal support of the airplane when parked, taxiing, taking off, or landing. The most common type of landing gear consists of wheels, but airplanes can also be equipped with floats for water operations, or skis for landing on snow.
2. The landing gear consists of three wheels—two main wheels and a third wheel positioned either at the front or rear of the airplane.
3. Landing gear with a rear mounted wheel is called conventional landing gear. Airplanes with conventional landing gear are sometimes referred to as tailwheel airplanes.
4. When the third wheel is located on the nose, it is called a nosewheel, and the design is referred to as a tricycle gear.
5. A steerable nosewheel or tailwheel permits the airplane to be controlled throughout all operations while on the ground.
6. Most aircraft are steered by moving the rudder pedals, whether nosewheel or tailwheel.
7. Additionally, some aircraft are steered by differential braking.

AIRCRAFT MATERIALS

METALLIC MATERIALS

The most common metals used in aircraft construction are aluminum, magnesium, titanium, steel, and their alloys.

1. ***Aluminium Alloys***
   - ***a.*** Aluminum alloys are widely used in modern aircraft construction. Aluminum alloys are valuable because they have a high strength-to-weight ratio. Aluminum alloys are

corrosion resistant and comparatively easy to fabricate. The outstanding characteristic of aluminum is its lightweight.

- Temperature range is around 260 degree.
- Posses low density, high strength to weigh ratio.
- They are mainly used to manufacture centrifugal compressors, wheels, and housing, air inlet sections, accessories sections.
- Combination of aluminium and lithium are 10% lighter and stiffer than the conventional aluminium alloys.
- They have superior fatigue properties and last 2 to 3 times longer than aluminium alloys.
- Combination of aluminium and iron and cerium increases the working temperature to around 650degrees.
- The only disadvantage is that they are expensive than conventional alloys.

2. ***Titanium Alloys***
    - They posses very high strength and low density and is suitable for operations upto 538 degrees.
    - Titanium aluminide alloy can be used at a working temperature of around 800 degrees Celsius.
    - Titanium is alloyed with vanadium, aluminium, chromium, tin, zirconium and molybdenum to improve its machineability.
    - They are used to manufacture centrifugal flow rotors, axial flow compressors wheels, blades, and other forged components in many large high performance engines.

3. ***Steel Alloys***
    - They are mainly alloyed with high chromium, high nickel iron based alloys and low alloy steels.
    - Alloying with low alloy steels may have properties like low cost, easy fabrication, and good mechanical properties.
    - They are commonly used in manufacturing of both rotating and static components, compressor blades, wheels, spacers, stator vanes and other structural members.
    - Heat treatment of steel alloys improves the working temperature.
    - Example Low alloy steels can be used upto 550degrees Celsius.
    - High nickel chromium iron base alloys upto 700 degrees Celsius**.**

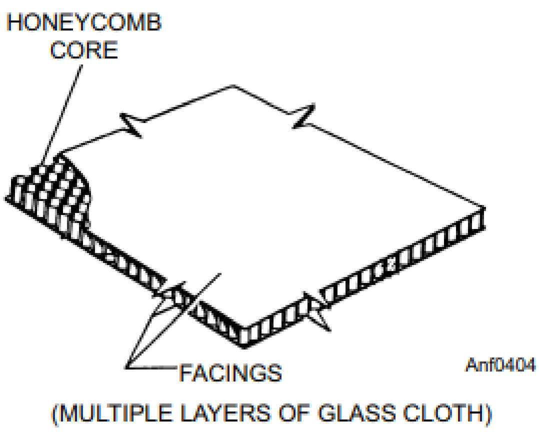
4. ***Nickel Base Alloys***
    - Addition of nickel increases the working temperature due to age hardening phenomenon.
    - Also the age hardening process increases the creep rupture strength, ultimate strength and yield strength and also add good ductility.

- addition of nickel increases the working temperature between 650 and 980 degrees Celsius.
- They are used for turbine buckets, turbine wheels, shafts, spacers and other parts.

5. ***Cobalt Based Alloys***
    - They posses high temperature strength and high corrosion resistance properties.
    - They are mainly used in the manufacture of afterburners, turbine vanes and other parts which are exposed to very high temperatures.
    - The only limitation is that they are very expensive.

NONMETALLIC MATERIALS

In addition to metals, various types of plastic materials are found in aircraft construction. Some of these plastics include transparent plastic, reinforced plastic, composite, and carbon-fiber materials. Transparent Plastic Transparent plastic is used in canopies, windshields, and other transparent enclosures. You need to handle transparent plastic surfaces carefully because they are relatively soft and scratch easily. At approximately 225°F, transparent plastic becomes soft and pliable. Reinforced Plastic Reinforced plastic is used in the construction of radomes, wingtips, stabilizer tips, antenna covers, and flight controls. Reinforced plastic has a high strength-to-weight ratio and is resistant to mildew and rot. Because it is easy to fabricate, it is equally suitable for other parts of the aircraft. Reinforced plastic is a sandwich-type material (fig. 4-4). 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.



Composite and Carbon Fiber Materials High-performance aircraft require an extra high strength-to-weight ratio material. Fabrication of composite materials satisfies this special requirement. Composite materials are constructed by using 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. Carbon fiber is extremely strong, thin fiber made by heating synthetic fibers, such as rayon, until charred, and then layering in cross sections