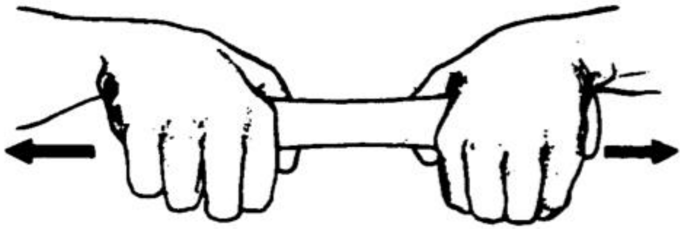
Structures

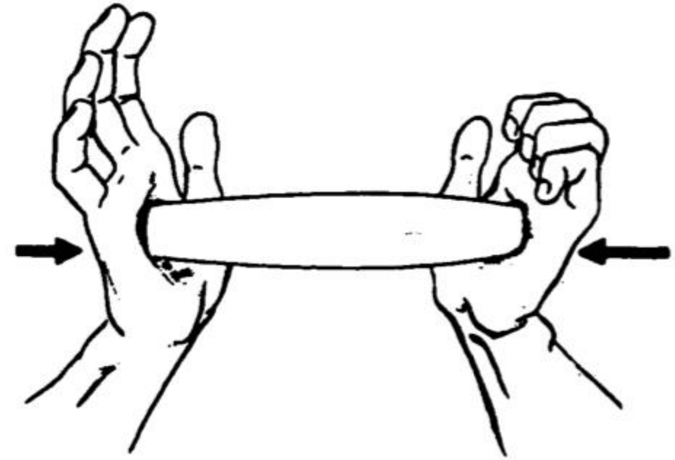
Major Structural stresses acting on an UAV

There are five major stresses:

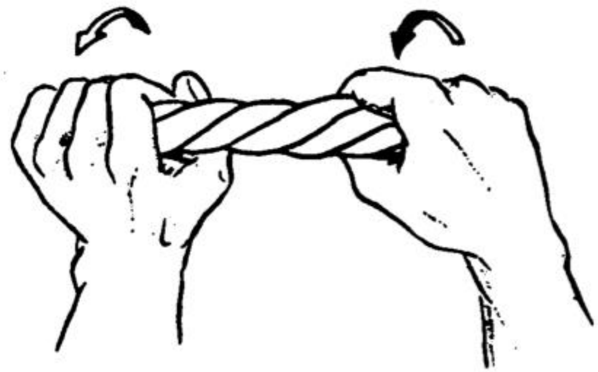
- (1) Tension.
- (2) Compression.
- (3) Torsion.
- (4) Shear.
- (5) Bending.



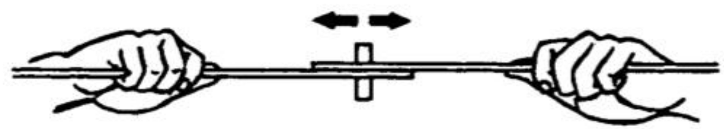
(a) Tension



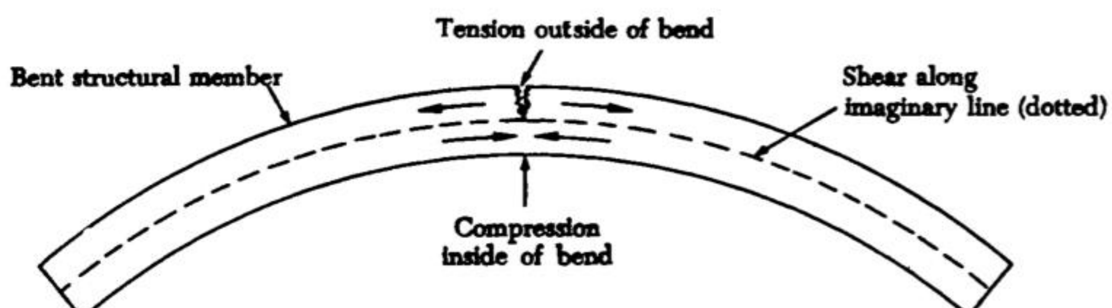
(b) Compression



(c) Torsional



(d) Shear



(e) Bending (the combination stress)

1)Tension:Tension is the resistance to pulling apart or stretching produced by two forces pulling in opposite directions along the same straight line

Example:The engine pulls the aircraft forward, but air resistance tries to hold it back. The result is tension, which tries to stretch the aircraft.

2)Compression:it is the stress that resists a crushing force.Compression is the resistance to crushing produced by two forces pushing toward each other in the same straight line

Example:When an airplane is on the ground, the landing gear struts are under a constant compression stress.

3)Torsion:it is the stress that produces twisting.The torsional strength of a material is a resistance to twisting or torque.

Example: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.

4)Shear:it is the stress that resists the force tending to cause one layer of a material to slide over an adjacent layer.

Example:Aircraft parts, especially screws, bolts, and rivets, are often subject to a shearing force.

5)Bending stress :it is a combination of compression and tension.when bending a piece of tubing, the upper portion stretches (tension) and the lower portion crushes together (compression).

Example:The wing spars of an aircraft in flight are subject to bending stresses.

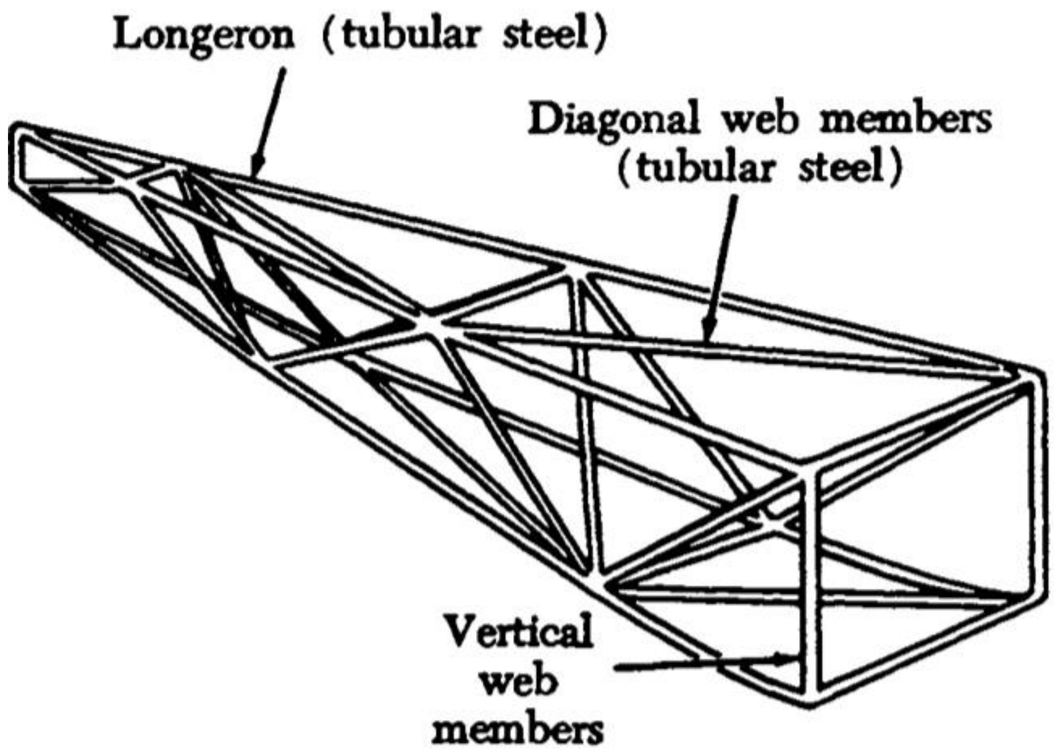
Note

- Stress is an internal force of a substance which opposes or resists deformation.
- Strain is the deformation of a material or substance. Stress, the internal force, can cause strain.

Major aircraft structural members

Fuselage structure

Truss structure:The truss type fuselage frame is usually constructed of tubing joined together in such a manner that all members of the truss can carry both tension and compression loads.



Monocoque structure :

The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage, but the skin carries the primary stresses.

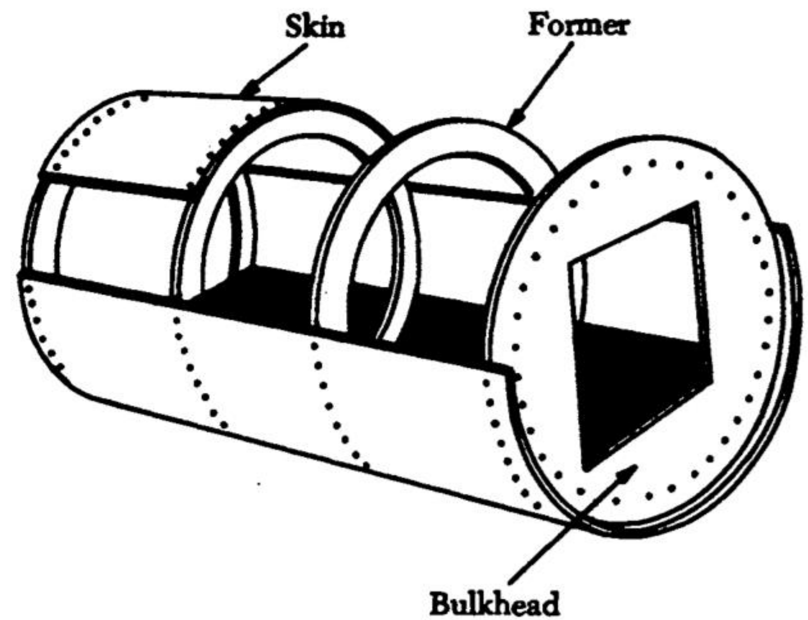


FIGURE 1–5. Monocoque construction.

Semi monocoque structure:

In addition to formers, frame assemblies, and bulkheads, the semimonocoque construction has the skin reinforced by longitudinal member called stringer. The reinforced shell has the skin reinforced by a complete framework of structural members

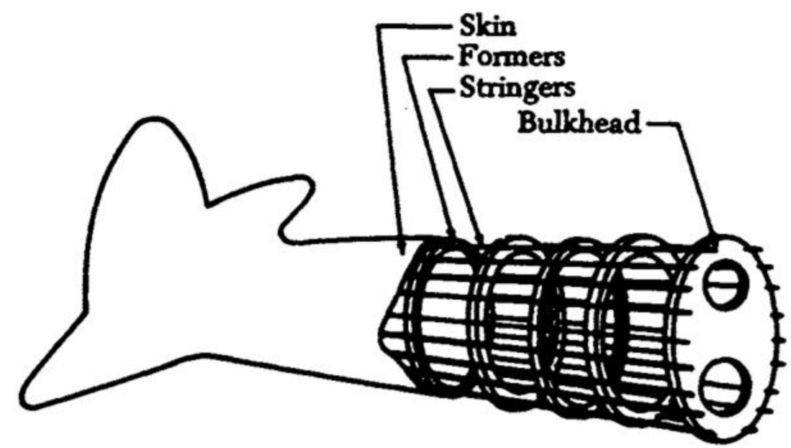
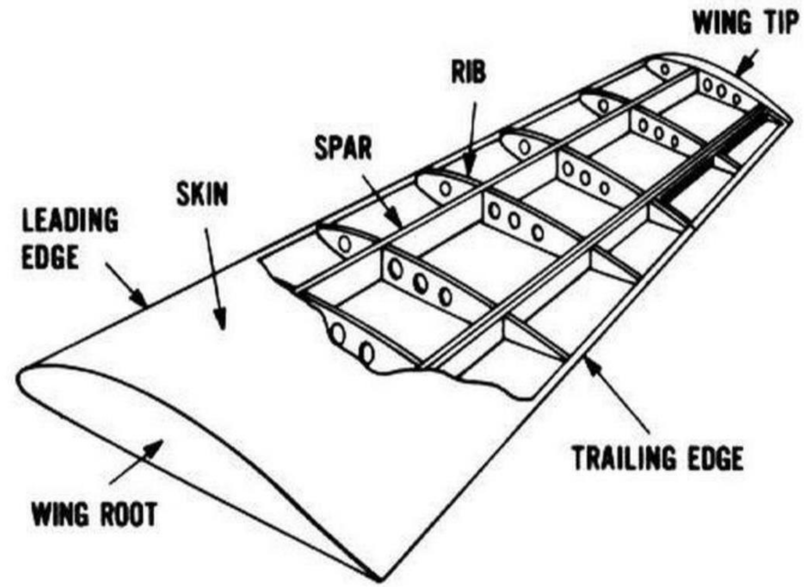


FIGURE 1–6. Semimonocoque construction.

WING STRUCTURE

- The main structural parts of a wing are the spars, the ribs or bulkheads, and the stringers or stiffeners.
- Spars are the principal structural members of the wing.They run parallel to the lateral axis, or toward the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or a truss system.
- Stringers act as a substitute for spars and help in improving the structural strength of skin
- Ribs are the structural crosspieces that 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.
- All the structural members are integrated and then covered under skin.Skin resists the shear loads.



Dynamic load on aircraft structure

- Aircraft's turns, pull-ups, and gusts influence the loads on the structure by upsetting or modifying the balance of forces, and must be accounted for.
- Maneuvering always involves acceleration and acceleration adds or magnifies forces.
- The acceleration is measured in multiples of the acceleration due to gravity (g) and a 3-g pull-up will magnify the vertical forces by a factor of three.
- If the spar was designed to carry only the loads in straight and level flight it will not only fail during a 3-g pull-up but also will fail in a 3-g turn
- to turn without losing altitude, the vertical component of the lift must always equal the weight and consequently the total lift must be increased to make up for the bank angle.
- The larger the bank angle, the greater the required total lift and, therefore, the force on the wing.

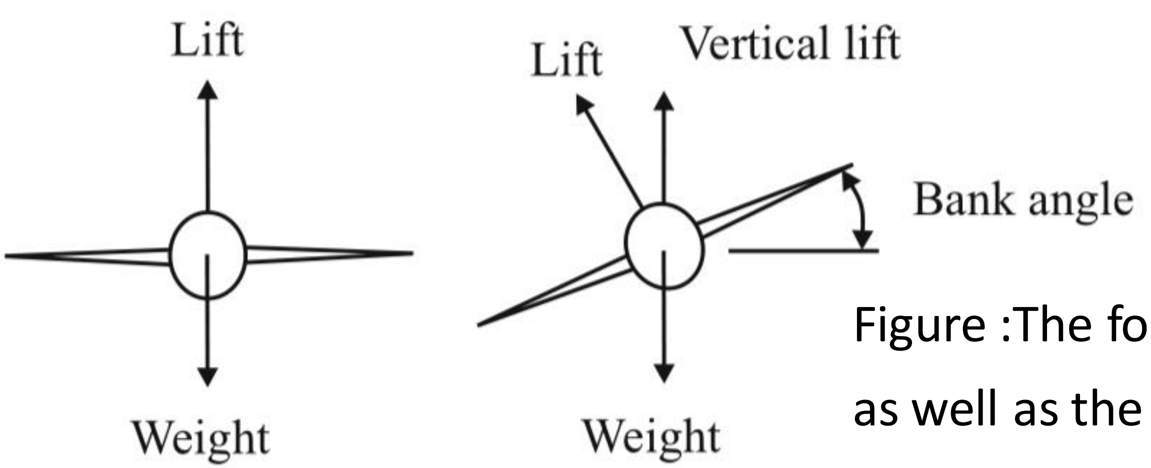


Figure :The forces in straight-and-level flight as well as the forces in a turn.

Load factor

The load factor is defined as the ratio of lift to weight.

In level, steady flight the load factor is 1, since the load equals the weight under those conditions.

The Relation with bank angle as following:

$$W = L\cos\phi \tag{7.4}$$

where ϕ is the bank angle.

The relationship is simply:

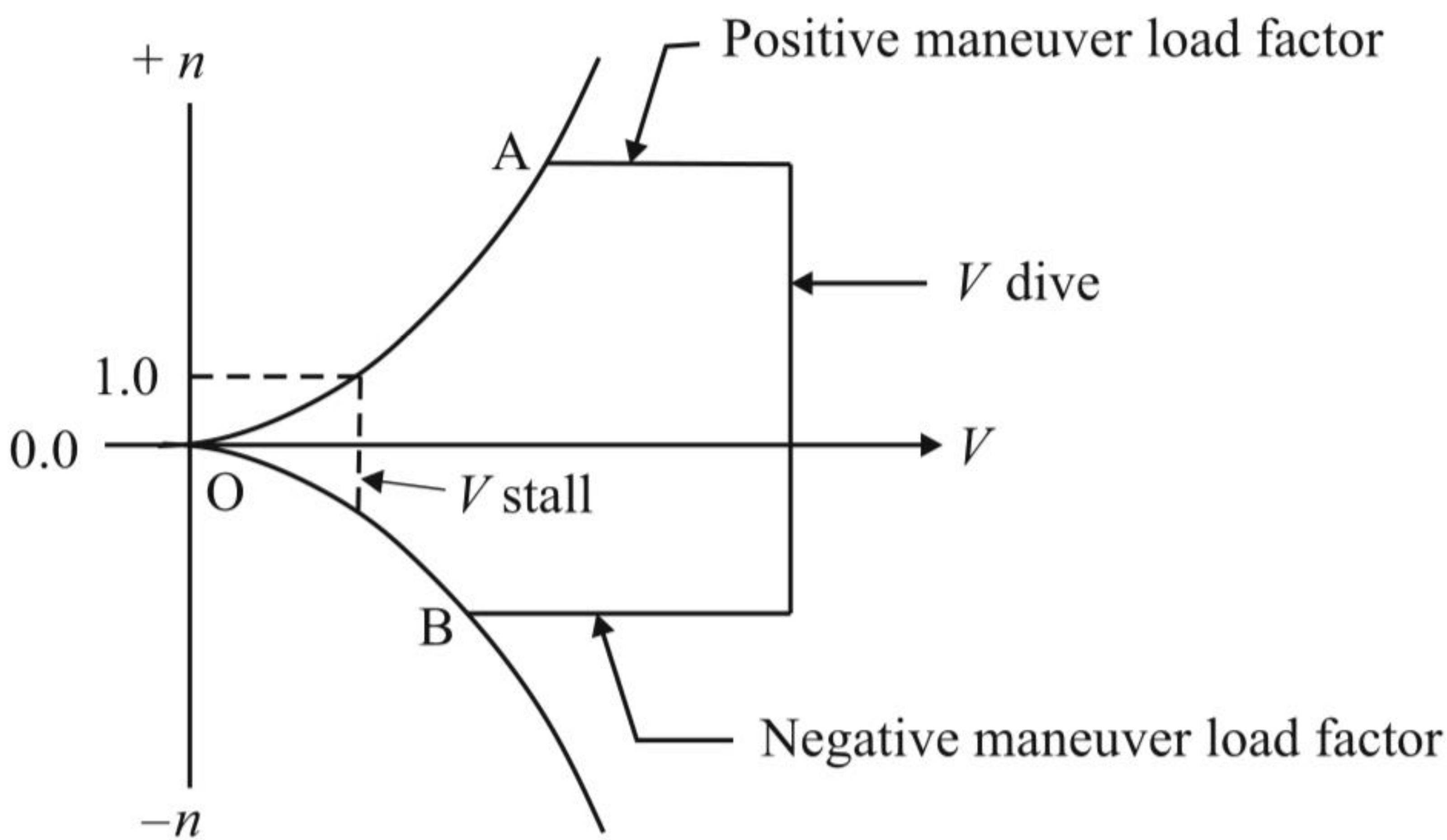
$$\frac{L}{W} = \frac{1}{\cos(\phi)} = n \tag{7.5}$$

where n is called the "load factor" and is equal to 1 when $L = W$.

The g's in a turn are given by $n = L/W$ so for a 30-degree bank, $n = 1.15$ and the structure is subjected to a 1.15-g load perpendicular to the wing, and all the loads on the span must be multiplied by 1.15.

V n diagram

- The operating flight strength of an air vehicle can be presented in the form of a V-g or V-n diagram, also called the maneuver f l ight envelope.
- The diagram has airspeed on the horizontal axis and structural load, n, in units of g, on the vertical axis.
- The diagram or envelope is applicable to a particular altitude and air-vehicle weight.
- Two of the lines in its construction are related to aerodynamics and are called stall lines.They show the load at a maximum rate of climb, just before stalling.
- The aircraft cannot fly at any larger rate of climb, so cannot experience any load larger than that shown along the stall lines, which is a function of the maximum lift coefficient and velocity squared.
- The load lines take the form of a parabolic curve with positive and negative branches that meet at zero airspeed and zero load. The two branches, lines O-A and O-B in Figure, represent regular flight and inverted flight, respectively.
- The horizontal lines starting at A and B are the limiting loads for positive and negative forces, respectively. In other words, any increase in speed at point A that was accompanied by an increase in attack angle to remain on the stall line would overstress the aircraft and risk structural failure.



Positive maneuver load factor
+ n
A
V dive
1.0
0.0
V
O
V stall
B
Negative maneuver load factor
−n

Materials

- Metallic materials

Aluminum

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.

Magnesium

Magnesium is the world's lightest structural metal. It is a silvery-white material that weighs two-thirds as much as aluminum. Magnesium is used to make helicopters. Magnesium's low resistance to corrosion has limited its use in conventional aircraft.

Titanium

Titanium is a lightweight, strong, corrosion-resistant metal. Recent developments make titanium ideal for applications where aluminum alloys are too weak and stainless steel is too heavy. Additionally, titanium is unaffected by long exposure to seawater and marine atmosphere.

Steel Alloys

Alloy steels used in aircraft construction have great strength, more so than other fields of engineering would require. These materials must withstand the forces that occur on today's modern aircraft. These steels contain small percentages of carbon, nickel, chromium, vanadium, and molybdenum. High-tensile steels will stand stress of 50 to 150 tons per square inch without failing. Such steels are made into tubes, rods, and wires.

Another type of steel used extensively is stainless steel. Stainless steel resists corrosion and is particularly valuable for use in or near water.

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.

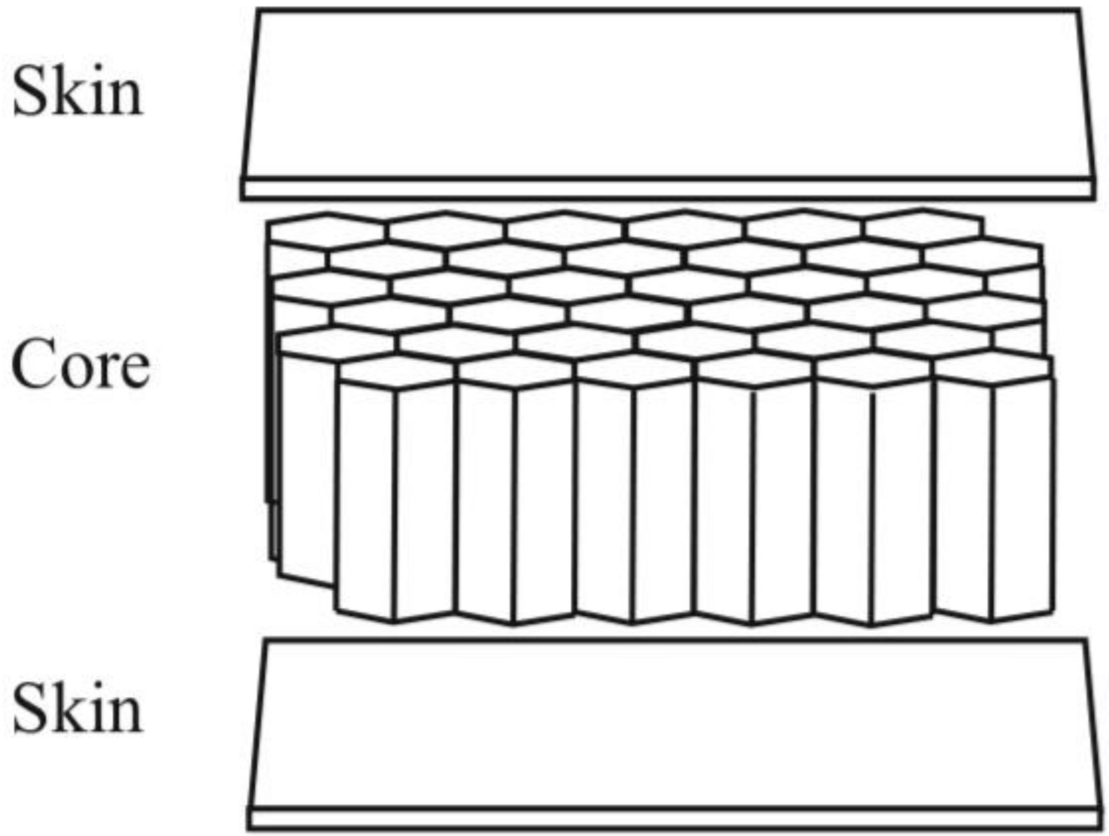
Reinforced Plastic

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.

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.

Sandwich Construction



7.4.2 *Skin or Reinforcing Materials*

The strength of a composite structure is almost entirely dependent on the amount, type, and application of the skin or reinforcing material. The skin fabrics come in two primary configurations or patterns: unidirectional (UD) and bidirectional (BD). A unidirectional fabric has almost all of its fibers running in one direction so the tensile strength would be greatest in that direction.

Bidirectional fabrics have some fibers woven at angles relative to others and therefore have strength in multiple directions. Of course, the UD fibers can be combined at various angles to also provide greater strength in all directions. In addition, multiple layers of material or fabric sheets can be applied to give greater strength where needed and lesser weight where less strength is needed. The skins are usually made of the following materials:

E Glass	Standard fiberglass, the workhorse of composites.
S Glass	Fiberglass similar in appearance to E but 30% stronger.
Kevlar	An aramid organic chemical material, very strong but also difficult to work with.
Graphite	Long-parallel chains of carbon atoms, very strong and expensive.

7.4.3 Resin Materials

The resin is used to bond or "glue" the skin to the core material and transfer the stresse throughout the skin. Resins irreversibly harden when cured and provide high strength and chemical resistance to the structure:

Polyester	A common resin that is used to make everything from boats to bathtubs.
Vinyl ester	A resin that is a polyester–epoxy hybrid.
Epoxy	A thermosetting resin used extensively with home-built aircraft and UAVs

7.4.4 Core Materials

Core materials used in UAV construction are usually foams, but balsa wood is also used:

Polystyrene	A white-colored foam that is easy to cut with a hot wire to produce airfoil shapes. It is easily dissolved by fuel and other solvents.
Polyurethane	A low-density foam that is easily carved but cannot be cut with a hot wire. Used for carving detailed shapes.
Urethane polyester	Foam used in surfboards that has good resistance to solvents.

Composite part construction

Mould preparation

Before starting with the lay-up process an adequate mold preparation must be done. Mainly, this preparation consists of cleaning the mold and applying a release agent in the surface of it to avoid the resin to stick. In this experiment the mold preparation is simply taping the plastic sheeting to the tabletop. Otherwise following steps are taken to clean the mold;

- Clean the mold with a clean cloth
- Apply and spread release agent in the surface of the mold
- Wait certain to set up the release agent
- Buff with clean cloth

Hand layup process

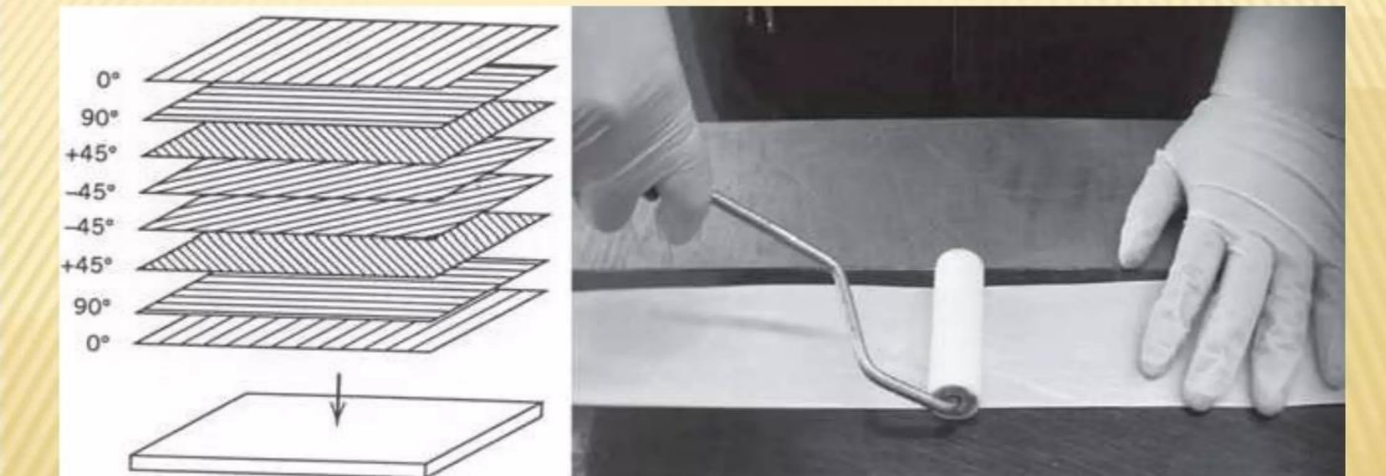
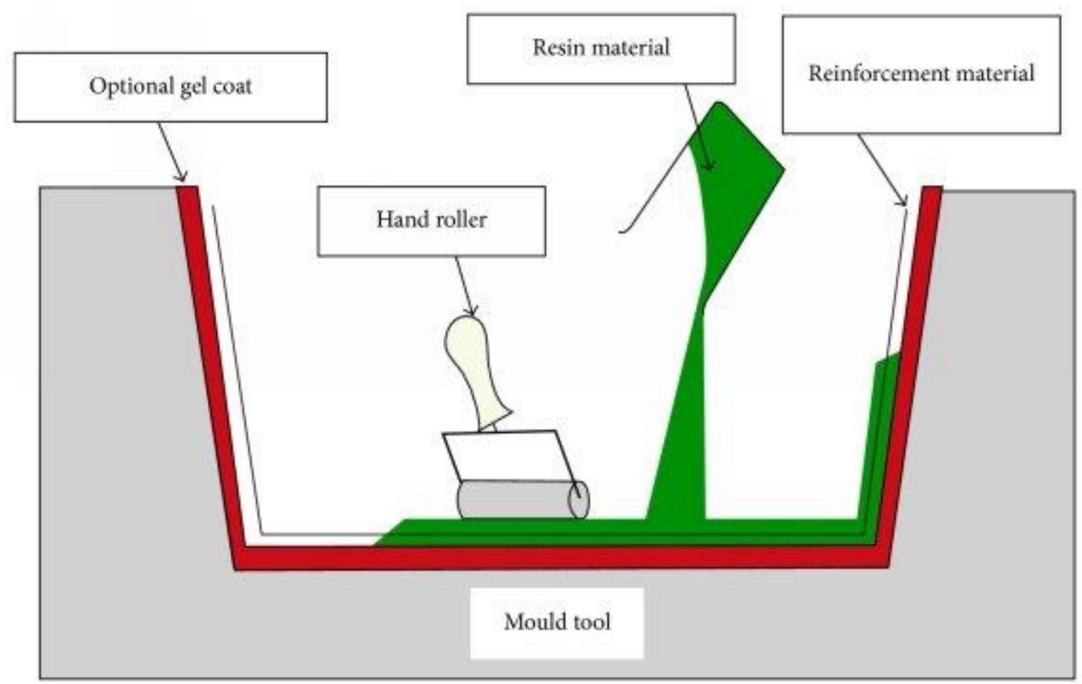


Figure : 2 hand-lay-up fabrication method and a representative lay-up sequence. Individual layers can be cut by hand or by a computerized machine cutter. The layers can be stacked one on top of the other by hand or by a robot.

- Aligning of fibers
- Single filaments
- Fabrics (mats, weaves, braids, knits)
- Bed consisting of many layers of fabrics
- Filling the interstices between filaments with liquid matrix •Wetting the fibers
- Curing the resin



Vaccum moulding

- The whole moulding system is covered with a flexible vacuum bag. The edge of the bag is sealed using vacuum sealing compounds.
- Layers of bleeder, perforated Teflon film, and nylon peel ply, in order.

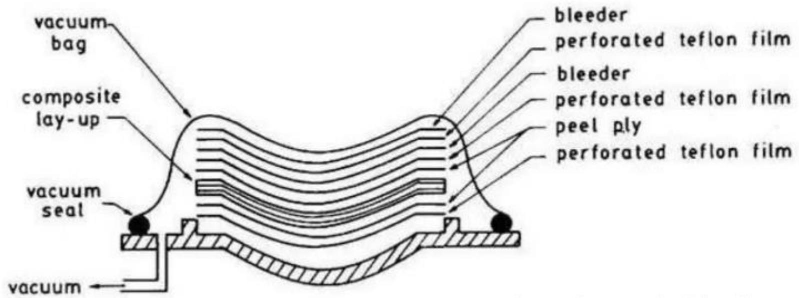
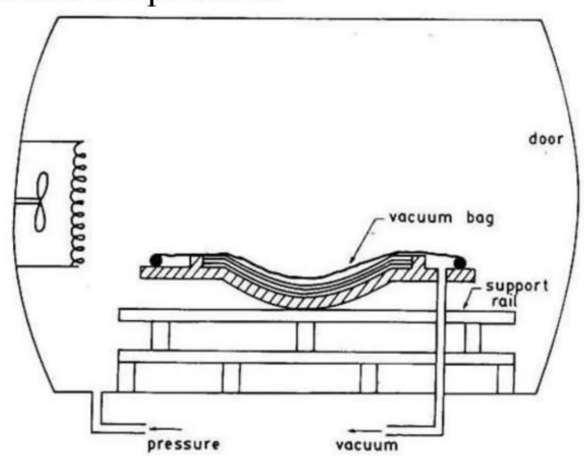


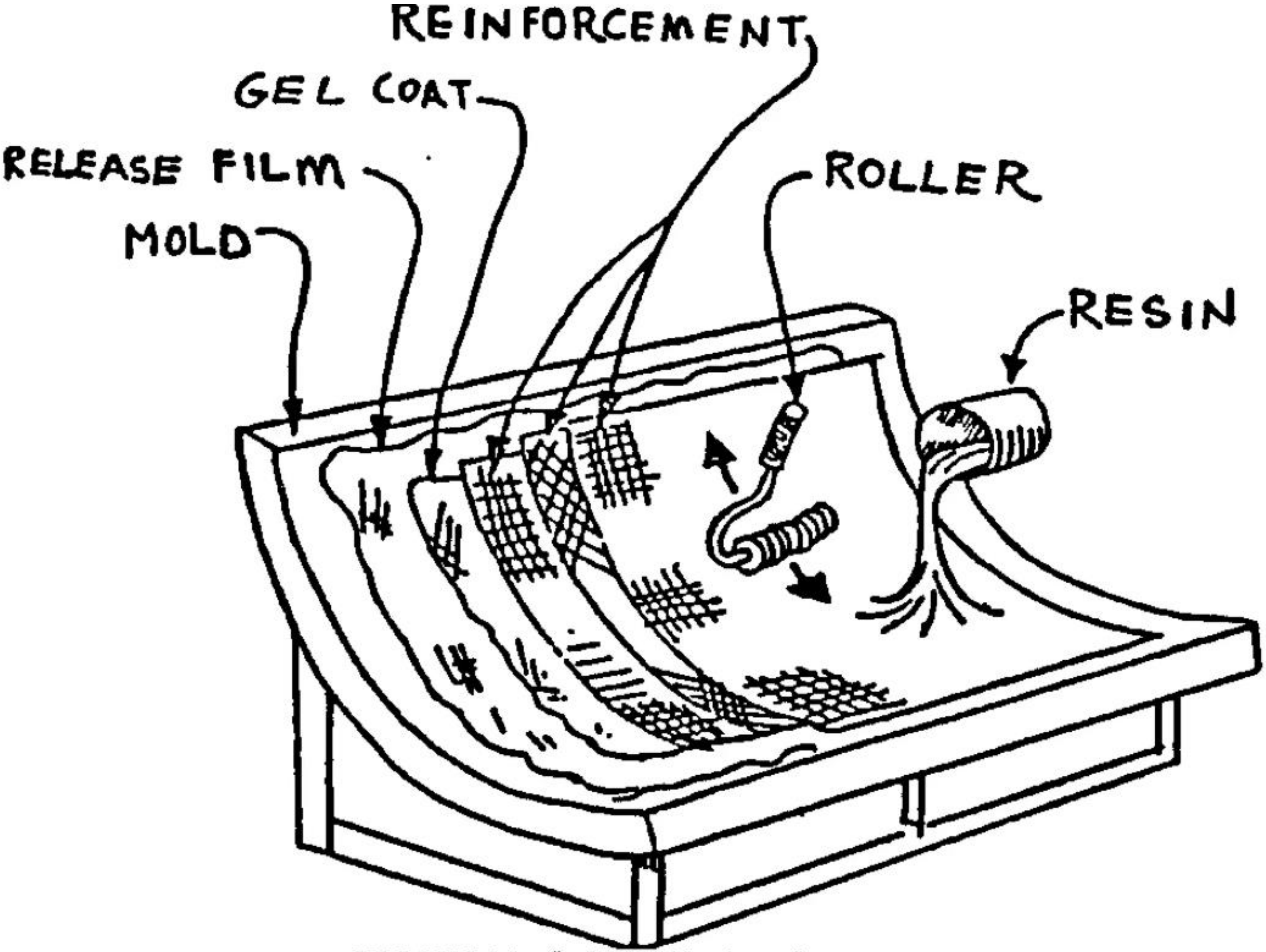
Fig. Vacuum bag moulding. (PMC, Defense Handbook (2002))

- When vacuum is applied, volatiles, trapped air and excess resin escapes out and further consolidates the laminate. The whole assembly can be put in an oven, if a high temperature curing is needed.

Autoclave curing

- It is a highly sophisticated process in which controlled temperature and pressure can be applied. In addition, vacuum is also applied to suck volatile matters and entrapped air or gases.
- The whole assembly is put inside an autoclave. Curing takes place in presence of simultaneous. pressure and temperature.
- After curing, the mould is taken out of the autoclave.
- It yields highly densified products and is therefore favoured in fabrication of major **aerospace components like aircraft wing parts, helicopter blades, etc.**





MANUAL LAY UP PROCESS