Aircraft Components Fuselage Structure Wing Structure Aerodynamics

Introduction to Aeronautics and Airframe

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General Overview

Main Components

Fuselage Wings Empenage Power Plant Landing Gear

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General Overview

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Aircraft parts and their Functions

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General Overview

Airframe Material Properties

High Strength to Weight ratio Light weight Corrosion Resistant Should be non flammable High quality

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General Overview

Airframe Material Properties

Selection Criteria for materials Materials selection is quite frequently a compromise involving various considerations and the more important considerations have historically been those associated with mechanical properties.

Static strength efficiency Fatigue Fracture toughness and crack growth Corrosion and embrittlement Environmental stability

Selection Criteria for producing materials

Other criteria equally important are the criteria associted with producing the basic material in the forms requred and fabricating the end product at the resonable cost.

Availability and producibility Materials cost Fabrication characteristics

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Material use in Airframe Construction

WOOD (Spruce) STEEL & ITS ALLOYS (Strong ) ALUMINIUM & ITS ALLOY (Commonly use) TITANIUM ALLOYS (Heat Barriers) MAGNESIUM ALLOYS (3 times lighter than AL) PLASTICS & COMPOSITE MATERIAL

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Material use in Airframe Construction

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Comparison of current material properties and efficiencies

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Truss Types

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

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Pratt Truss

Early days Wooden or metal structure Great weight Difficult to streamline Box with tubular longerons + vertical members

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Warren Truss

Longerons + only Diagonal Members Force transfer to every others structure Capable to carry tension + compression Reduce amount of webs work More space , strength , rigidity Better streamline

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Warren Truss Structure of an airplane

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Monocoque

The exterior surface of the fuselage is also the primary structure Early form of this was built using molded plywood. A later form of this structure uses fiberglass cloth impregnated with polyester or epoxy resin, instead of plywood, as the skin.

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Monocoque

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, powerplants, and stabilizers. Since no other bracing members are present, the skin must carry the primary stresses and keep the fuselage rigid. The skin must be fairly thick to take all loading encountered in flight and on the ground. Thus, the biggest problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits.

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Semi-Monocoque

This is the preferred method of constructing an all-aluminum fuselage. First, a series of frames in the shape of the fuselage cross sections are held in position on a rigid fixture, or jig. These frames are then joined with lightweight longitudinal elements called stringers. These are in turn covered with a skin of sheet aluminum, attached by riveting or by bonding with special adhesives. Most modern large aircraft are built using this technique, but use several large sections constructed in this fashion which are then joined with fasteners to form the complete fuselage.

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Semi-Monocoque

To overcome the strength/weight problem of monocoque construction, a modification called semimonocoque 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, the longitudinal members are typically more numerous and lighter in weight than the longerons. 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.Kamal Darlami Basic Aircraft Structures

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Semi-Monocoque

To summarize, in semimonocoque fuselages, the strong, heavy longerons hold the bulkheads and formers, and these, in turn, hold the stringers, braces, web members, etc. The fuselage skin thickness can vary with the load carried and the stresses sustained at a particular location. 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 semimonocoque fuselage, because of its stressed-skin construction, may withstand considerable damage and still be strong enough to hold together.

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Aircraft Loads

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Detailed loads on an aircraft

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Fuselage Loads

Forebody Loads

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Vertical airloads are generally neglected in forebody loads calculations except for wide body fuselage or their affect on local structure. Side loads (in the y direction) are caused by side and yawing accelerations and airloads incurred during unsymmetrical maneuvers Here the airloads make up a large part of the net loads and therefore cannot be neglected. Critical forebody loadings may also be experienced from application of nose landing gear loads

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Fuselage Loads

Aftbody Loads

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Aftbody vertical flight loads are a critical combination of inertia loads and horizontal tail balancing loads. Airloads on the fuselage aftbody are generally neglected, both in the vertical and side directions.

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Fuselage Structure

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Major Fuselage Components: Skin, Frames, Bulkheads, Stringers and Longerons.

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Fuselage Cross-section

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A typical double lobe fuselage cross-section

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Fuselage Cross-section

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Fuselage Loads

Ultimate design Conditions

Flight loads (acting alone) Flight loads + cabin pressure (p = maximum differential pressure loads) Cabin pressure only (1.33 x p) Landing and ground loads

Fail-safe design conditions

Fail-safe flight loads (acting alone) Fail-safe flight loads + cabin pressure Cabin pressure onlyKamal Darlami Basic Aircraft Structures

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Fuselage Loads

FatigueFatigue loads based on flight profiles developed by manufacturer

to encompass anticipated airplane usage Fatigue Objective design flight hours of service life without modification of primary structure

Special area conditions

Depressurization of one compartment Bird strike Hail strike Cargo and passenger loads on floors Crash loads (emergency landing)

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Wing Structure

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Ideal and real fluids

Mechanics of fluids become easier by studying ideal fluids instead of real fluids.

Ideal Fluids

Incompressible It has zero viscosity No resistance is encountered as the fluid moves.

Real Fluids

Compressible Viscous in nature Certain amount of resistance is always offered by these fluids as they move.

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Ideal and real fluids

Real Fluid is further classified into two types.

Newtonian fluid The fluids which obey Newtons law of viscosity are called as Newtonian fluids such fluids exhibit linear relationship between shear stress and rate of angular deformation. Eg. - water , air etc.

Non-Newtonian Fluid Fluids which do not follow the linear relation between shear stress and rate of angular deformation are termed as Non Newtonian fluids. Eg. - silly putty, ketchup etc.

https://www.youtube.com/watch?v=G1Op\_1yG6lQ

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Air flow around a body

Streamline: Streamline represents an imaginary flow line which is always tangent to the velocity vectors of an elementary fluid particles (for every point and every time instant).

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For the presence of the body, the streamlines are forced to deviate from their path → the body presence influences the trend of the streamlines up to a certain distance (beyond this distance the undisturbed free-flw condition exists).

Streamlines have aspects and trends that depends on the shape of the body (with same frontal area).

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Air flow around a body

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Inside the fluid flow, other elements can be detected.

Upwash: upwards flow Downwash: downwards flow impact point: point of flow seperation Stagnation point: a small area near the impact point where the fluid particles have no speed (compared to the body) and where an area a high pressure is created.

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Air flow around a body

Relative wind: It is the direction of movement of the atmosphere relative to an aircraft or an airfoil.

Stationary state: When the density, pressure and velocity of the fluid ata given pint remains constant over time, the particles follow line of current flow or streamline.

Free flow: Free from obstacles, streamlines are straight parallel and equidistant to one another.

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Leminar and Turbulant flow

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Laminar Flow: the flow of a fluid when each particle of the fluid follows a smooth path, paths which never interfere with one another. One result of laminar flow is that the velocity of the fluid is constant at any point in the fluid. Turbulent Flow: irregular flow that is characterized by tiny whirlpool regions. The velocity of this fluid is definitely not constant at every point

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Reynold Number

https://www.youtube.com/ watch?v=AfAM6mfuN3c https://www.youtube.com/ watch?v=GHOoZYhF6r4

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The Reynolds number is the ratio of iner- tial forces to viscous forces and is a con- venient parameter for predicting if a flow condition will be laminar or turbulent.

Re = ρULμ = Inertial

Viscous (1)

Where, ρ is density (kg/m3), U is fluid velocity (m/s), L is characteristic length (m) and μ is dynamic viscosity(Ns/m2). It can also be expressed as:

Re = ULν (2)

Where ν = μ/ρ is kinematic viscosity (m2/s).

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Reynold Number

The Reynolds Number can be used to determine if flow is laminar, transient or turbulent.

Laminar flow (Re < 2300)

Viscous force keep streamlines constant so they flow steadily over eachother in predictable path.

Transient flow (2300 < Re < 4000)

The flow of a fluid is transient or unsteady if its flow parameters (i.e. velocity and pressure) are dependent not only on the position in the coordinate system used to describe the field of flow, but also on time.

Turbulent flow(Re > 4000)

Inertial forces cause circular eddies to form in the flow creating turbulence. It induces mixing of fluid with random fluctuating parameters.

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Boundary Layer

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Airflow (or any fluid flow) will be zero at the surface of the object it’s passing over. Imagine the airflow as layers (or ”streamlines”), and remember the surface layer velocity is zero. As you move away from the surface, each layer will be going a little faster than the one beneath it until you finally reach ”free stream” velocity. All of these low-energy (lower velocity) layers of air between the aircraft surface and the free-stream air make up the boundary layer.

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Boundary Layer

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The surface of the body has a surface roughness (at microscopic level). When the air passes over a body, molecules nearest the surface remain attached to the surface → craetion of the boundary layer. Friction slows the air particles → increase of the boundary layer thickness. A decrease of the kinetic energy → increase in pressure The increase in pressure disturb the smooth flow of the fluid → turbulent regime.

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Boundary Layer

Laminar Boundary Layer:

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In a laminar boundary layer any exchange of mass or momentum takes place only between adjacent layers on a microscopic scale Consequently molecular viscosity μ is able predict the shear stress associated. Laminar boundary layers are found only when the Reynolds numbers are small. Turbulent Boundary Layer:

A turbulent boundary layer is marked by mixing across several layers of it. The mixing is now on a macroscopic scale. Packets of fluid may be seen moving across. Thus there is an exchange of mass, momentum and energy on a much bigger scale compared to a laminar boundary layer. A turbulent boundary layer forms only at larger Reynolds numbers.

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Wing profile

Cutting Concave-convex across a profile:

wing it gets its airfoil setion → wing profile They are used for gliders or for low-speed flight. The upper camber is convex, while the lower camber is concave. It generates lift when the angle of attack is 0◦. Plane-convex profile:

The upper camber is convex, while the lover camber is flat It generates many lift when the angle of attack is 0◦. It is very diffuse in hobby modeling due to its simplicity.

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Wing profile

Cutting Biconvex-asymmetric across a wing profile:

it gets its airfoil setion → wing profile The upper camber has a higher curvature than the lower one. It generates little lift when the angle of attack is 0◦. Biconvex-symmetric profile:

They are used for acrobatic aircraft and for the tail plane of most aircraft(rudder and tailplane of airliners). The upper camber and the lower camber are symmetrical in relation to the chord. It generates lift when the angle of attace is greater than 0◦.

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Airfoil terminology

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Leading edge: the thicker frontal edge of the profile. Trailing edge: the thin and tapered rear edge. Upper camber: the upper surface of the airfoil. Lower camber: the lower surface of the airfoil. Chord line: a straight line joining the leading edge and the trailing edge. Mean camber line (median line): a line drawn halfway between the upper and lower surface of the airfoil. Maximum camber: the maximum distance between the mean line and the chord line, measured perpendicular to the last one. Maximum thickness: The maximum distance between the upper and the lower surface, taken perpendicularly to the chord line. Generally it is about 1/3 from the leading edge.

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