Aircraft Structures - I
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Module – 1
Lecture – 4
Load Encountered by a Typical Aircraft

Welcome back to structures 1 course. Myself Anup Ghosh from Aerospace Engineering Department, IIT Kharagpur. We are in the lecture series of the first week. This is the fourth part of the week. So we will be covering today the load encountered by a typical aircraft. So what we have covered so far?

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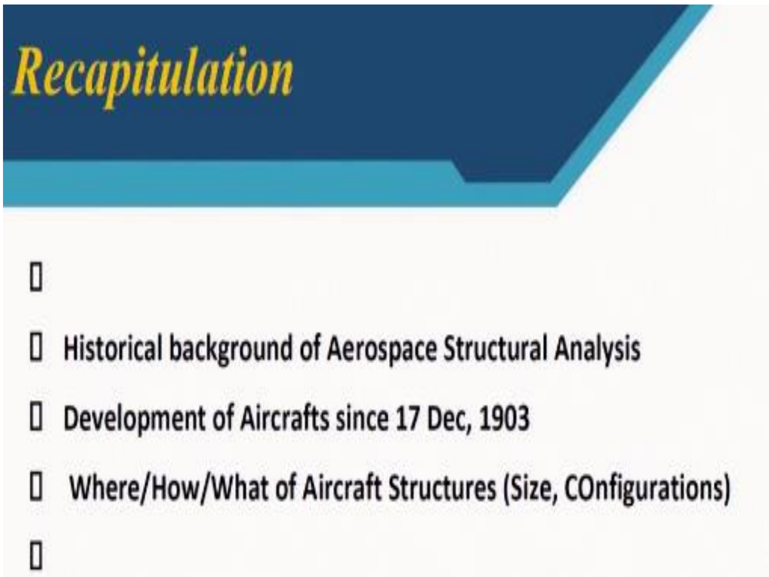

We have covered so far is important to keep a track on it. We have already done a historical background of aerospace structural analysis. We have seen the contribution of a physicist, scientist starting from Leonardo da Vinci to maybe Koiter, Sanders and in between Leibniz, Euler, Kirchhoff, Mindlin, Hooke; there are many, it is an endless list. With their contribution, we are able to fly today. Definitely, we should not forget the contribution of Wright brothers on the day of 17th December 1903 the first controlled aircraft flight at Kitty Hawk.

Then from there in the second lecture, we have covered the development of aircraft. In this lecture, we have seen how the aircraft development has taken place from the first one and then we have got a fair idea of how big an aircraft can be or whether how small it can be and what is the basic structural difference between the aircrafts. It is almost same. We have seen aircrafts in size range of a football field to the size range of like a car and configuration.

There are many configurations high wing, mid wing, low wing, tail configuration different, landing gear configuration different and depending on that how the structures changes. So let us move to today's lecture.

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Today's lecture is mainly two things we will be covering, and most of the lecture is on various types of external loads encountered by an aircraft and concepts of stressed skin structure. This we will you just introduce, we will cover in the next lecture in more detail, but our main stress will be on these various types of external loads.

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So if we see an aircraft structure is designed from thin, load bearing skins, frames and stiffeners. So this is the most important difference between the other structures and aircraft structures. It is thin and there are frames, stiffeners, it bears loads definitely, skins also bear a small amount of load. These are fabricated from lightweight, high strength materials. The lightweight, high strength materials, the most popular material was the different alloys of aluminium.

Presently there are different laminated composites are available, those are being used. Forming of metal sheets as I told you is the basic process, for aluminium alloys generally forming process is used to fabricate different shapes and then using those shapes the aircraft is generally built. High specific stiffness of a material is desirable. Specific stiffness is a quantity by which we generally define with respect to its weight how stiff it is.

Then different aluminium alloy and laminated composite materials are most widely used in this type of structures, for example. So details of this will come later, let us move to the different types of loads encountered by structure.

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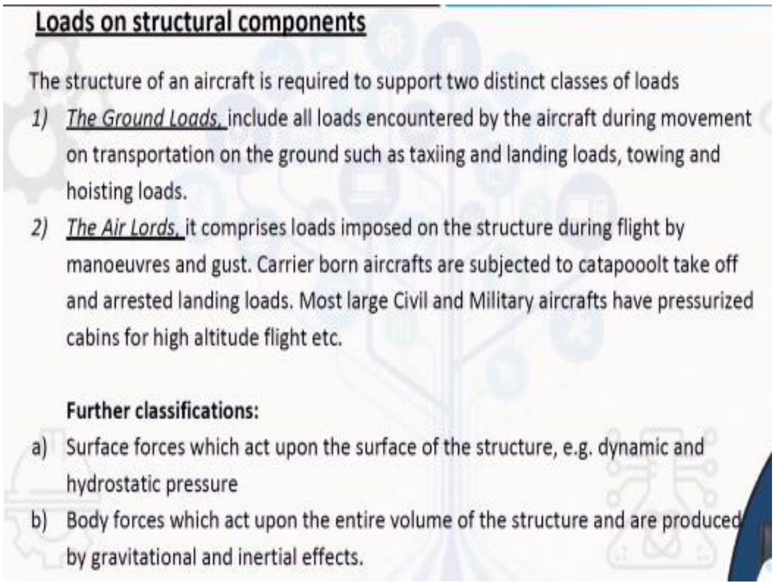

So loads on structural components mainly or the total overall aircraft is mainly divided into two groups. First is the ground loads and the next is the air loads. There are some other subdivisions from an engineering point of view, but these are from the source from where it is coming on that at the ground while it is airborne or it is flying. From ground load, if you talk about ground loads include all loads encountered by the aircraft during movement on transportation on the ground such as taxi, landing loads, towing and hoisting.

We need to taxi in the airport to come to the takeoff point and during that, an aircraft is hugely loaded by the fuel. Fuel is generally stored in the wing in all civil aircrafts and during that any small bump in taxiing generally creates a lot of disturbances, a lot of loads in the wing fuselage junction that becomes very important. So landing load is definitely coming through the landing gear to the fuselage, it bears the impact.

Towing we need too, while it is at the airport we need to tow it from one place to the other, we need to move it back to steer. For steering requirement also we need to tow it. Hoisting, for maintenance purposes we need to hoist it, where to hoist and how to hoist that is very important. There are specific positions for hoisting to prevent damage and if we look at the air loads, air loads come in the form of it comprises loads imposed on the structure during flight by manoeuvres and gust.

Carrier borne aircrafts are subjected to catapult takeoff and arrested landing loads. This is another important specific type of requirement, aircraft carriers usually use catapult takeoff system and arrested landing system. So during that, it has to bear the loads on the fuselage through that catapult. So those loads also have to be carried by the fuselage. Most large civil and military aircrafts have the pressurized cabin for high altitude flight.

This is another important thing. We generally have a huge pressure difference at the altitude we fly and altitude at sea level, so to compensate that pressure difference. Generally, the cabins are pressurized and that introduces a load on the fuselage. So we need to take care of that. Not only these where from the loads are coming, but it is also dependent on other engineering aspects, further classification we may do.

Surface forces which act upon the surface of the structure, in general the dynamics and hydrostatic pressure, it comes on the wing. Body forces which act upon the entire volume of the structure and are produced by gravitational and inertial effects. So during flight, this inertial effect is very important and these effects create extra load on the structure and gravitational force is always there to act. So combining all these things, these are the basic classifications of aircraft loads.

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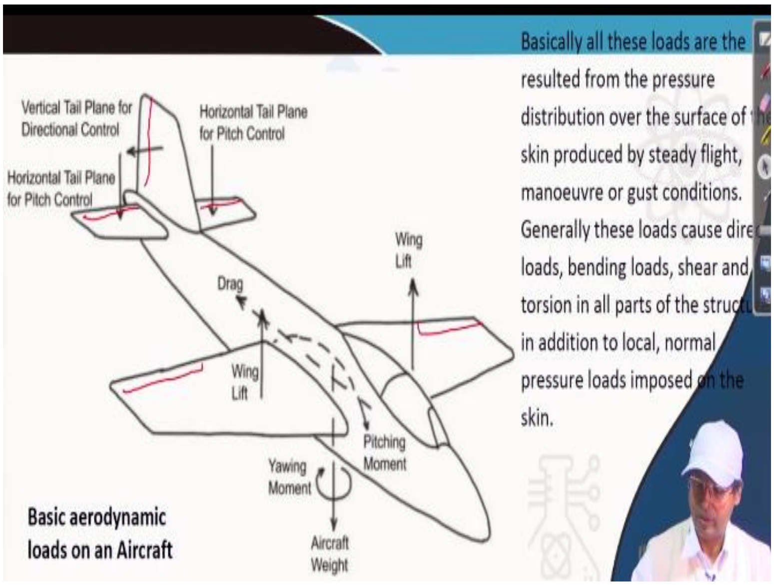

So basically, all these loads are the result of the pressure distribution over the surface of the skin produced by steady flight, manoeuvre or gust conditions. Generally, these loads cause direct loads, bending loads, shear loads, shear and torsion in all parts of the structure in addition to local normal pressure loads imposed on the skin. So this is some of the loads what is generally encountered by an aircraft while from the flight condition that is why it is said as basic aerodynamic loads on an aircraft.

So if we see for different manoeuvre as well as for flying, we have different types of loads to fly. We generally need the lift that acts on the wing and that carries the total fuselage structure, inside that the cargo or other payloads are there, but during flight for control purpose to take off and to land the main control surfaces that is horizontal tail plane, these two horizontal tail planes. These two also experiences aerodynamic loads for pitching stability and this is for the lateral stability.

The vertical tail plane, directional control and lateral stability. For yaw movement control, this the forces coming on that, this is generally used and the other forces generally created by the rudder or the elevator portion and rolling moment if we took at is generally acted by the aileron portion. So all these the rolling moments create the partial difference between the lift of these two wings and due to that rolling moment it rolls and we need to do the drag is also acting on the aircraft that has to be encountered.

As I told a few minutes back, the pitching moment is very important. Characteristics aircraft weight acts through the CG or center of gravity point of it. So as a combined manner, it experiences in general these loads, but we will see further specifications for the differences between these loads, okay.

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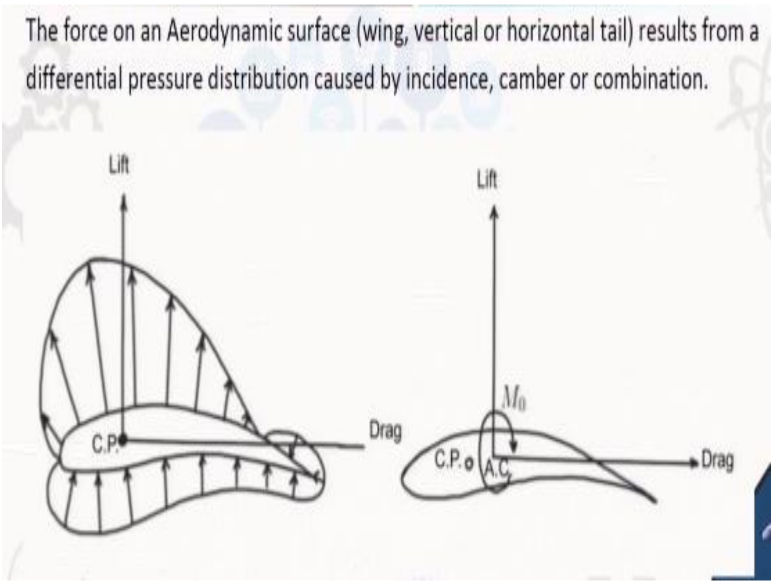

So the force on an aerodynamic surface wing, vertical or horizontal tail results from a differential pressure distribution caused by incidence, camber or combination. So we will not go into detail of how these pressure profiles is created, why camber or other things assist in increasing lift and in flying the aircraft easily, but as a result, we have lift, we have drag, we have a pitching moment. So these things have to be encountered by a wing that we need to see.

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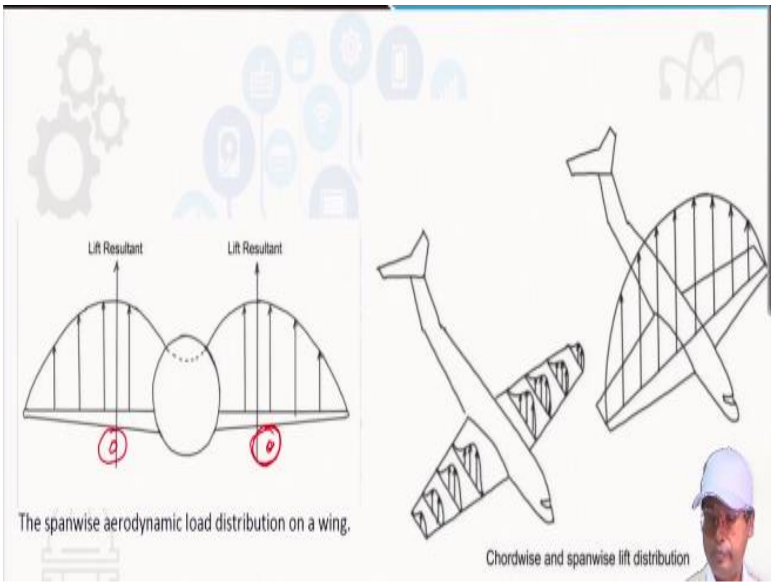

So another important thing is the distribution of the load. The distribution of the load is important. The lift is distributed not uniformly on the wing, if we look at along the span, along the span it is followed it has a distribution similar to this and along the cord, if you look at that also has a different type of distribution. So as a whole region are sometimes simplify the total effect in this form, chordwise and spanwise lift distribution.

Sometimes wherever possible we consider the spanwise distribution in this form and we need to find out this load along with the other loads like if we have an engine here that engine load has to be considered, loads coming from that engine. So that will come later in our discussion.

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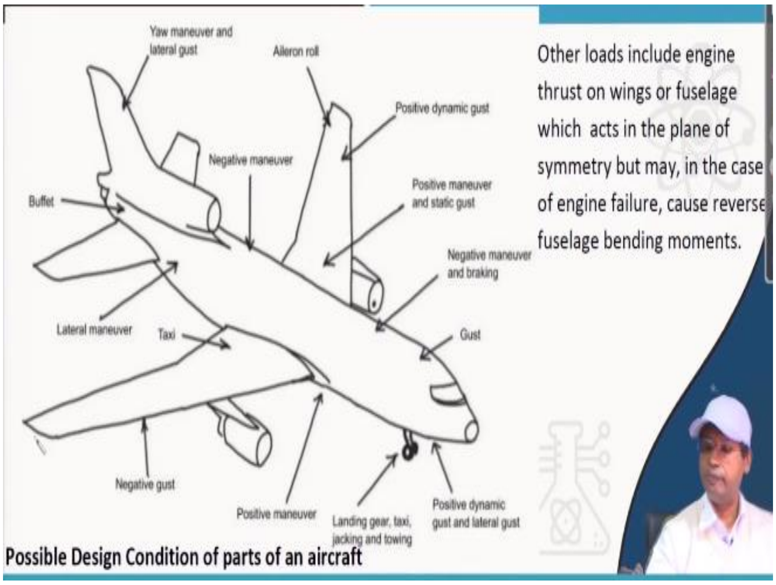

So if we look at the possible design conditions of parts of an aircraft from the aerodynamic loads, if we look at, there are many positions and which are governed by different types of loads. Let us try to see which part is governed by which type of load. So as we have seen, so the design of this portion of the wing is generally governed by the positive dynamic gust. This portion of the wing we need to fix the aileron with the ribs or with the wing structure.

Aileron comes this way so that has to be fixed with the wing and we need to design that portion that aileron load has to be transferred here. If we look at the root section, that is positive manoeuvre and static gust. If we look at the front portion of the fuselage that is negative manoeuvre and breaking. This is also designed for the gust governs this portions design, positive dynamic gust and lateral gust governs the design of this portion.

Landing gear, taxiing, jacking and towing from the front landing gear all these operations are generally done. So those things the design of landing gear is governed by those loads. This portion of the fuselage is governed by the loads coming from the positive manoeuvre. This portion the lower portion is from the negative gust. This for taxiing, as I told you this is very important in general. The fuel tanks are located as the box in this portion, and different boxes are there.

So if we look at the different boxes on this and while it is taxiing this, this wing is completely full of fuel and this portion while taxiing is very important because the fuel weight affects the design of this root junction portion. During flight during landing, most of the fuels get burned, so that problem is not encountered. So if we look at the aft portion of the fuselage that is the lateral manoeuvre is the governing load, lateral load due to the lateral manoeuvre.

This portion is due to the Buffett or the force induced by the Buffett or the trailing wind vibration whatever comes on the horizontal tailplane that governs the design of this portion. As a whole, though the structure of the fuselage remains almost the same from the tip to the tail, but different portions are designed for different loads. Like that wing construction basically is similar from the root to the tail, but there are different requirements which govern the design of that particular portion.

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So if we see what the reference we have considered for this is, the references are Wang, a book of Wang, Donaldson, Bruhn, Rivello, Megson, and Peery and Azar.

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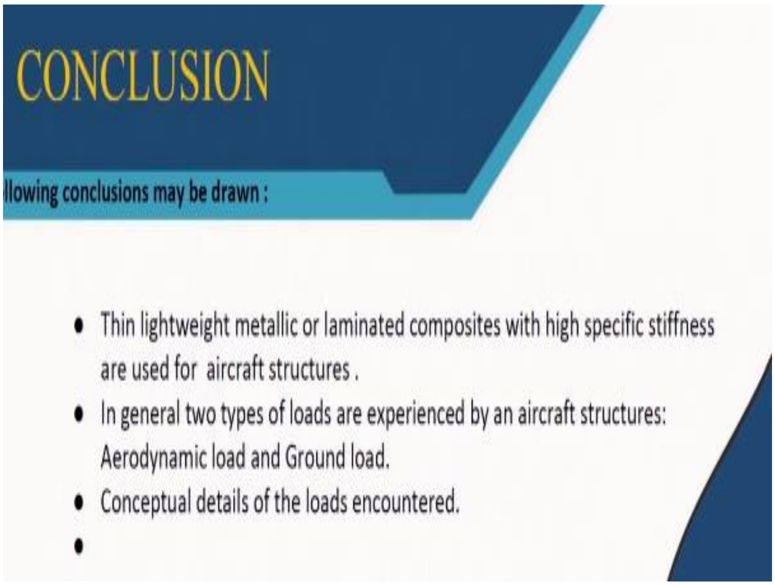

So if we come to a conclusion, this conclusion slide consists of a few bullets which are thin lightweight metallic or laminated composites with high specific stiffness are used for aircraft structures. In general, two types of loads are experienced by aircraft structures, aerodynamic load and ground load. Conceptual details of the loads as encountered by an aircraft has been discussed. So with this, we will conclude this load portion and we will move forward for more detail or conceptual detail of structures of an aircraft.