Aircraft Structures - I
Prof. Anup Ghosh
Department of Aerospace Engineering
Indian Institute of Technology – Kharagpur

Module – 1
Lecture – 2
Introduction Continued

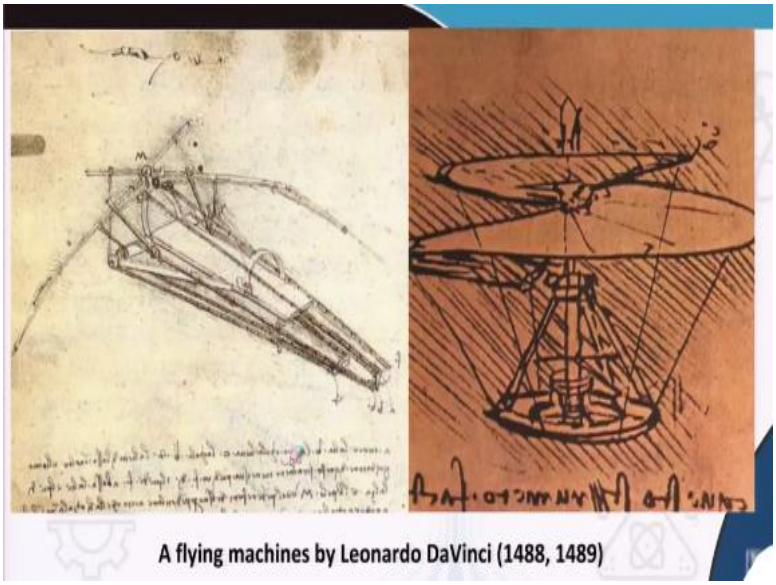
Welcome back to structures 1. We are in the process of introduction. We are already introduced with the history of solid mechanics. We have seen there are many contributors in that from different parts of the world in our last lecture and this lecture we will concentrate more on things like the development of aircraft. It is a kind of timeline view and we will see how industry considers the development and fabrication of aircraft. So with that part, let us proceed.

(Refer Slide Time: 01:24)

So as concepts covered slide if we look at in this the first controllable human flight, we will see the Wright Brother's flight, and it is a nice photograph, that time video was not there, we will see that and basic developments of aircraft structures. As we have said that this we will see in the two different way from the very lower end of the structural capability to the higher end of the structural capability as well as we will see the timeline view how it is progressing.

It has progressed till date. Importance of structural design and analysis. So let us see, let us proceed step by step.

(Refer Slide Time: 02:12)



So to bring back really, I always remember and always try to appreciate the work of Leonardo da Vinci. He is not only famous for his art related works, but he is also famous for his engineering contribution also. In the last lecture also we have seen, in this lecture also we see there are two photographs, first is for a fixed-wing we may say, probably it was a flapping wing, I do not have much information about it and the right hand side if we look at, this right hand side one this one is a kind of helicopter design if we look at.

So with that one, let us proceed further. It was proposed in the year 1488. This one was proposed in 1488, and this was proposed in 1489. So with this, let us proceed.

(Refer Slide Time: 03:31)

This is the most famous photograph in the aircraft industry or aircraft development engineering whatever way we say. In this, we will definitely cover the historical trend, we

will cover the historical trend here, but we will definitely also start with the concept first flight which is on December 17, 1903, at Kitty Hawk, North Carolina, Wright brothers or the Orville Wright, one of the Wright brothers Orville Wright was able to fly it for 20 seconds.

It was for 120 feet that is the initiation and after that probably the development is endless, it is going continuing till date, so we will see.

(Refer Slide Time: 04:40)

We will see in this page what we have noted down is development in terms of a few key parameters, as we have said that we will also again look back from the Wright brothers plane where we are at present. First, if we talk about range and endurance, that means how much it can fly and how long it can fly. So in that sense that that limit is 120 feet, it was the first flight and 20 second was the endurance.

From there we have aircraft which is solar-powered, developed by some commercial company Zephyr which also comes in the category of HALE or in the full form we say high altitude long endurance aircraft. This aircraft is able to probably fly endlessly. So one of the example the highest flight record is noted down here that is 336 hours 22 minutes and 8 seconds. So we can easily imagine a flight which is almost endless.

From the payload point of view if we see one of the Wright brothers was the first pilot for the first aircraft, so we say it is for one person and it is on 380, on passenger capacity if we look at airbus 380. Airbus 380 has a capability of 525 passengers that in terms of how many people an aircraft can fly, but if we look at in other sense it is very surprising to note the

capacity of Antonov or AN225 model which has a capacity of 250 tons or 1100 meter cube of space.

So either it has to fit, it can carry this much volume which may weigh less than 250 ton, or it may carry 250 ton, maybe having a volume less than this capacity. Now if you talk about the speed another key parameter, the first Wright Flyer was something about 10.98 kilometres per hour to now we have the highest record holder from Lockheed, Lockheed and Martin SR 71 Blackbird.

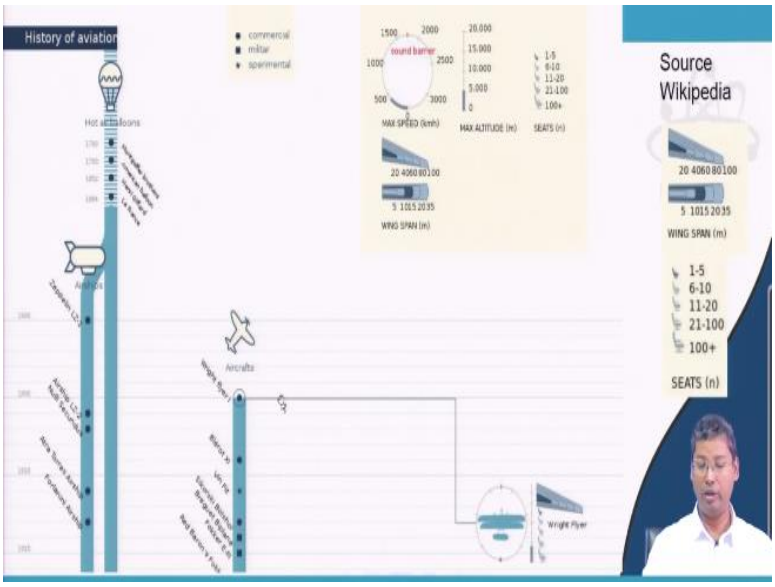
It is advisable that it is not possible for me to cover each and every content with detail from the internet or from other references, better you, please look at the open resource or on the internet and have a look that gives a different feeling. So Lockheed and Martin Blackbird is 3529.6 kilometre per hour is its speed, that is about aircraft, but if you look at the speed of any flying vehicle that comes about 28,000 kilometres per hour, the Space Shuttle Columbia.

So that is many jumps in may be in terms of hundreds and thousands. Now if you look at the wingspan, this is a very surprising point here wingspan. Wright brother's plane was about 12 meter in wingspan and at present, if you look at the longest wingspan civil aircraft that is 79.8 meter A380. There is what I say the known story about it that airbus has tried to keep it within 80 meters. Their first design, initial design, a preliminary design was much more than that.

Then they have improved their design with additional lifting devices and many other things. They have limited it to 79.8 well within 80 meters to which makes the A380 to be usable in many of the airports throughout the world, and if we look at the other one AN225 that is having 88.4 meters, it is slightly more and about 8.4 meters more than the allowed one, so it is not able to land everywhere, it needs some special attention.

About the weight, if we look at the super heavy one, the lift launch vehicle of Saturn V that is height is 110.6meter, diameter 10.1 metres, mass 2970000 kg. It is a problem of English and Indian system. Suppose we look at in different way 29 lakh 70,000 kg. So the other way also we may say about 2,970,000 kg. Anyway, this gives us a fair idea from where from120 feet to how long it has progressed. So let us have a look in a different way with a slow timeline view of this progress in a different frame.

(Refer Slide Time: 10:47)

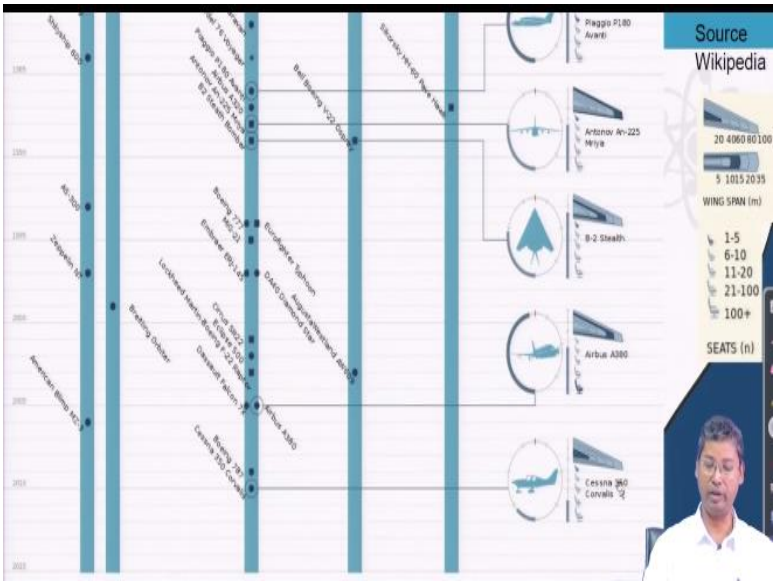


This is with courtesy to Wikipedia. So we have segmented development in different slides one after another. If you look at it in flying vehicle, history of aviation in that it is the balloon which starts it's maybe in 1783 and then it continues. It continues slowly and then it bifurcates again to Zeppelin. Zeppelin is a very popular tool in around the year 1900 to 1935 or 36 where it ended the journey with Lindbergh. Lindbergh journey is a famous disaster which took place.

After that nobody builds Zeppelin, but our aim is not to discuss Zeppelin in this particular context. Our aim is particularly to discuss about aircraft, but since aircraft cannot be considered as a separate one from the flying vehicles, please look at this notation here or nomenclature or annotations which we can use to understand our progress. This one is about 20 meter wingspan, 40 meter, 60 meter, 80 meter and 100 meter and similarly, whichever is darkened, it shows that group.

If we look at this one the Wright Flyer, Wright Flyer in the wingspan less than 20 or within the 20 and it has one seat. If it is that one seat shows that it is 1 to 5 passenger to carry or including pilot to carry, so that is the reason Wright Flyer has one seat and within this 20 meter wingspan. So slowly it is difficult to name each and every one, one after another if we look back after in 1905 it is mentioned. Actually, it was in 1903.

(Refer Slide Time: 12:59)



So after that, there is quite good progress and from there it goes to a notable point we come across about the Fokker, more popularly known as Fokker aircraft or Red Baron's Fokker. It has three lifting surfaces and it looks very good, but though now it is not being used because of many other technical disadvantages. It also comes within the 20 meter wingspan and also within the 1 to 5 seating capacity and then slowly after that the development of helicopter starts in the year around saying it is 1923.

The first successful rotorcraft was conceptualized, was built on laboratory and then if you look at this that a Spirit of St. Louis is the next fixed wing aircraft. So, in general, we categorize the aircraft in 2 groups. One we say fixed wing and the other we say the rotary wing and one more mixed thing is there, but there are not many aircraft. The last successful one we will come across about V-22 Osprey.

But there are difficulties in control management, controller design, so that is not much popular. So if we look at the progress, the notable point here it is mentioned as St. Louis as Spirit of St. Louis which is having a capacity of within 5 and wingspan of 20 meter. Then this Cierva C.30 is the first rotary-wing aircraft which was flown and it was a kind of autogyro consideration, was considered their design based on autogyro it was having.

Though it is not very wise to compare the blade span of a rotary-wing aircraft with the fixed wing aircraft wingspan, but just for comparison, it is noted here that it is about 15 meter span. Next notable point is about B-314. Before that, I think it is worth to mention this Boeing 247 also. Boeing 247 which is in the year if we look at about 1933 is the first aircraft where we

saw that it is all metal body, retractable landing gear fast aircraft and that was very successful.

Means it has been used in second world war in many ways many times, but again anyway if we look at if we go further, Boeing 314 which we have some data here which is about wingspan in the range of 60 meter and its capacity is I think within 100. This one is 21 to 100 and then if we go further, we have the Sikorsky series. Sikorsky series is famous for its helicopter mostly from the Russian side. So Sikorsky S-55 which is having a blade or rotorcraft span of about 15 meter.

Then if we move further, it is the notable point we come across is about piper. This is another piper or more popularly known as Cherokee. Piper is very famous for its mass production and popularity, and now still it is being used for the robotic purpose for different clubs by different clubs. So Piper pa PA-28 or Cherokee comes within the wingspan of 20 meter and it has a capacity of within 10, 10 passengers including the pilot. So next if we look at that is this Bristol 192.

Bristol 192 is having is a rotorcraft having two contra rotating, sorry I am not very sure about whether contra rotating or not, two rotary wing helicopter and it is from Boeing, this reference is for Boeing CH-47, CH-47 may be traced here, I am not able to trace it here at this point but more popularly known as a Chinook series which is still continuing. So with that, we move forward with the big jumbo jet that is Boeing 747.

It is most popular for its wide body design and it has a huge capacity, more than 500 passenger capacity and a wingspan of about 80 meter and it has a capacity as I mentioned already it is more than 100. Definitely, it is more than 100, and it is having a capacity of around 500. Then if we look at to the further development F-16. F-16is a fighter aircraft, definitely it does not have much seating capacity, but it is famous for its agile nature, most advanced control and its flexibility in maneuvering.

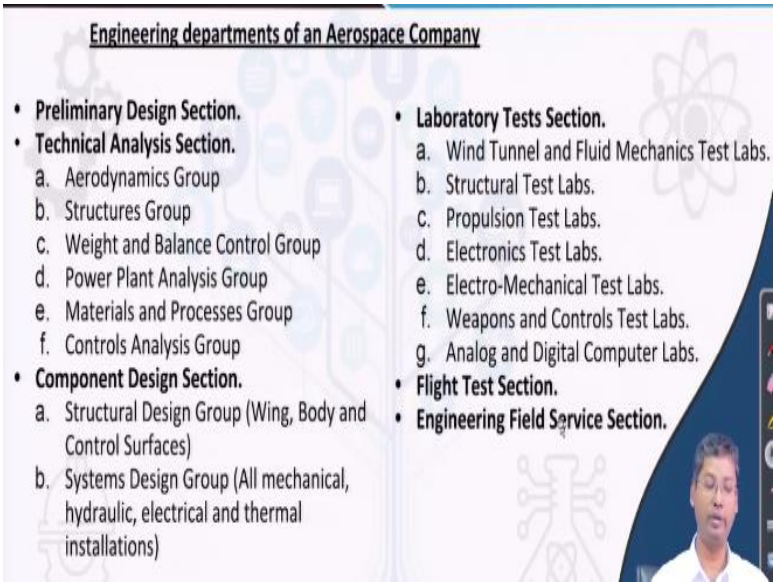
Then if we go for that Avanti Piaggio P.180 that is also within the 150, but these two are two different class if we look at, all the three if you look at, this is the biggest aircraft till some date and then this is the most agile aircraft at that time and this is in the group of business jet that is coming there and then if we go further business jet category is much popular in the

business community nowadays and if we go further, this is the most famous cargo aircraft.

We will see more photographs in our next lecture. An-225, then another Stealth aircraft that is B2 Stealth. This is having a wingspan of about 60 meter and definitely, it is fighter one, so it is within the 1 to 5 pilots or passengers or co-pilots including everyone and then another recent milestone we see is about A380 which is having about 525 passenger capacity and well within the airport requirement, we have already mentioned here.

Then this is a worth mention aircraft recent one developed in the year 2010 that is Cessna 350. Engine wise it is a different engine aircraft based on engine aircraft, but it has a very good utility or purpose in a small range and with a lower capacity of passenger, its 2 to 4 seater designs are available.

(Refer Slide Time: 20:48)



Now these are the huge range of aircraft available or have been developed in our industry we have seen, but if we look at this slide, this slide predominantly considers, this slides displays the engineering departments of an aerospace company. So the development can be divided in many ways, but the design process if we look at the first and foremost design process is the preliminary design section.

So each and every aircraft according to the requirement of the client, according to the requirement for which it is to be served. Preliminary design section designs it in a preliminary way what should be the configuration, what type of engine it should be or what should be the wing position but where the engine should be mounted, all those things are decided by

preliminary design section. Then it goes for the technical analysis group.

Technical analysis groups consist of aerodynamic groups, structures group, weight and balance control group, power plant analysis group, materials and process group, controls analysis group. Then one more big section is there that is known as component design section, laboratory test section, flight test section, engineering field service section. So it is a kind of chronology followed.

If we look at the preliminary design section gives it to the technical analysis section and which consists of as I said aerodynamic structures, weight balance, power plant, materials, controls. So these are the basic subcategories on which the design is carried out and then each and every detailed design phase, we say the component design section. That means this goes the overall design and then the component level design group like in structures design group.

They design each and every part of the wing, will see how much detail is required to design, body and control surfaces, system design group, all mechanical, hydraulic, electrical and thermal installations it designs and depending on all these detailed designs, things are get assembled and then it goes to the laboratory test section. So in the wind tunnel, these are tested. Wind tunnel and fluid mechanics test labs, they test each and every after assembly all these aircraft and parts.

In structural test group test for its structural strength, propulsion test lab test it for propulsion capability, electronic test lab test the part of electronics, electromechanical test groups also is involved in this process. Weapons and control groups test the weapons portion separately and then after all these tests carried out in the laboratory, it goes to the flight test section. In the flight test section, in flight, all these components are again tested, then again engineering field service section which looks at the service conditions required for an aircraft.

(Refer Slide Time: 24:27)

Now see those are the sections and parts which are involved in the development of aircraft in an industry, but we are in the structures course and we are supposed to look at the structure side how it takes care about the design. So before we go for any design, it is necessary to look at what load it encounters. So that is the first thing, the applied loads. Once the loads are determined, it goes to the stress analysis and then definitely it has to come across the dynamic analysis.

There is one more research group which always think of the new concepts. So let us try to see more in detail. The applied load calculation groups are the group which calculates loads from aerodynamics forces, power plants, aircraft inertia, control system actuator, launching and recovery gear and armaments. So if we go in very brief in this sense, the aerodynamic force is definitely the lift force on the wing and on other surfaces for stability.

The power plant, yes this power plant is important, this thrust only makes it fly. So that total thrust has to be transferred to the fuselage, there should not be any anomalies. The aircraft inertia, for any movement in any dynamic condition the inertia becomes much very important, so that has to be calculated inertial force. Control system actuator that means while any control surface is deflected say for banking ailerons are deflected that creates differential stress on the total aircraft, or if a rudder is applied, it also creates that.

So launching and recovery gear, this is some kind of special gears in navy versions we usually use it, instead of that, in general, the landing gear is used and the armament. Armament really is a thing we generally do not visualize, just think about the missile which is

getting detached from the wing of an aircraft. As soon as the missile is detached, it creates an asymmetry of load and that has to be encountered by the total aircraft.

Now all these things are how the loads are coming on the aircraft that has to be analyzed. So the stress analysis group or the stress analysis and strength group, they design each and individual part. They think of the material and its thickness, size and cross-section of every structural member, joints and connections of such members. So these are some of the important things they decide, they analyze, they fix it.

Dynamics analysis group takes care of the vibration and shock, flutter, probably you are not very introduced with it but scope in this course is also not much. Flutter is something say couple phenomena with aerodynamic load and the structure and inertia and we have to have a flutter clearance for each and every aircraft and the establishment of design requirements or change for its control or correction.

So dynamics group look at the establishment of design requirements and change for its control or correction. Special projects and research groups, these usually look for new material use like the advanced laminated composite materials. Advanced laminated composite material has become very popular because of its high specific strength, and it reduces weight but as well as it gives us the required strength to provide all requirements from a structural point of view.

Analysis of new concept that means how new materials or a new way of fabrication or design can be carried out the research group takes care of that, replacement of components with new technology, this is really going on now. Most of the aircraft components wherever possible are getting replaced from metal to plastic composite.

(Refer Slide Time: 29:25)

This today's lecture has been taken or prepared from materials from Wikipedia, materials from Megson, materials from Bruhn, Donaldson, Rivello or Wesley, Peery Azar.

(Refer Slide Time: 29:48)

So if we look at the conclusion slide, what we have learned in today's lecture that is the history of aircraft development and how does the development or fabrication of aircraft is taken care in the industry, history of a flying vehicle with the timeline we have seen in a very brief way, a payload from 1 passenger to 250 ton that is the notable point we should look at, range and endurance from 120 feet or 20 seconds to endless as we have mentioned in your first or second slide thus I feel, how an aircraft industry works.

With these things, I would like to conclude today's lecture. Thank you for attending today's lecture and wish to meet you again with our next phase of the lecture. Thank you.