Introduction to Aircraft Design
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Lecture – 35
Tail Plane Layout

Let us now move on to the tail plane layout. Now, when we come to the tail plane layout, we have many letters of the English alphabet appearing as the possible candidates. But before we can go ahead, let us look at what are the key requirements from a tail plane.

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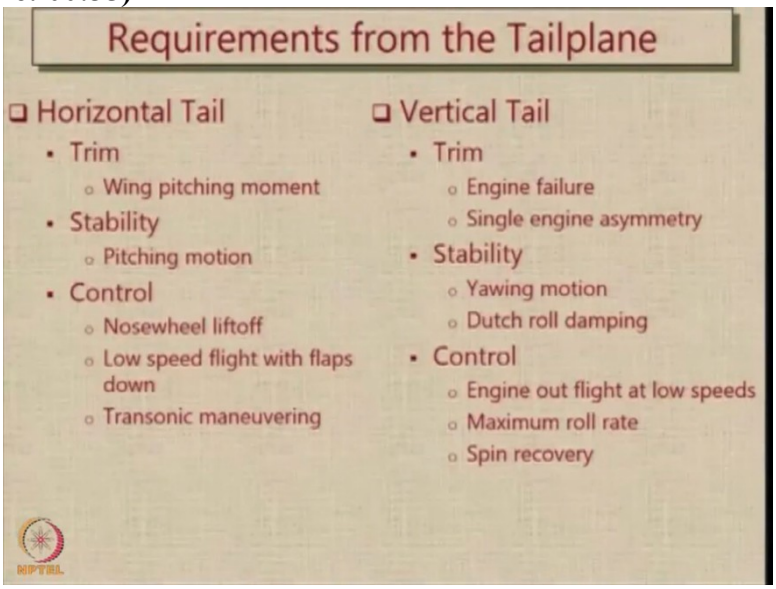

The horizontal tail is provided to serve 2 main missions one is to provide trim of the aircraft. So, it there is going to be a wing pitching moment and that wing pitching moment has to be cancelled out by providing the adequate trim. Then you require it for stability and stability in the pitching motion. And finally, we want it for control or to do certain tasks. For example, during take-off, we would like the nosewheel to lift off from the ground when the pilot makes the aircraft travel beyond a particular speed called as the take-off rotation speed.

When you have low speed flight with flaps down, there is a huge amount of pitching moment which is created generally nose down and this pitching moment has to then be counted by the deflection of the horizontal tail. And also we need the presence of a tail horizontal tail for additional moments created during transonic manoeuvring. As far as the vertical tail is concerned, a vertical tail is provided again from the same 3 considerations of trim, stability and control.

But as far the trimming is concerned in case one engine fails in a multiple engine aircraft, the vertical tail is required to give the correcting yawing moment. So that the aircraft can be flown safely also, whenever we have a single engine aircraft nose mounted, then there is going to be a swirl of air in one particular direction depending on the direction or rotation of the propeller.

So, that is going to give some kind of a sideward moment and to cancel that moment, the vertical tail is mounted at a slight offset angle to ensure that the single engine symmetry is taken care. The vertical tail is also needed for stability in the yawing machine and to provide adequate damping for the aircraft to overcome the Dutch roll, Dutch roll is a classical behaviour of the aircraft.

Which is because of the coupling between the yawing and the rolling motions of the aircraft when an aircraft typically has a very good directional stability, but poor lateral stability, then we end up with a phenomenon called Dutch roll in which the wing oscillates between roll pitch and little bit of yaw. We also need a vertical tail to provide the required moments to control the aircraft we need to control the aircraft if you have an engine of flight at low speeds.

At that time, we need covered control the aircraft there is a specified requirement for some roll rate which the aircraft should have and also we need to recover from the spin the vertical tail plays a very important role in spin recovery of the aircraft. So, the horizontal and the vertical tail together call another tail plane are the empennages are required to meet the 3 basic requirements of trim stability and control.

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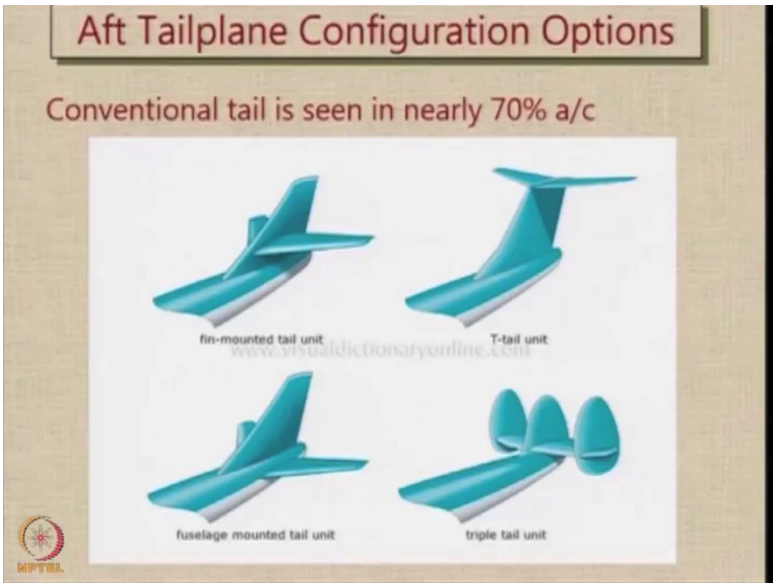

Now, let us see what kind of options do we have the most common configuration that you see is called as the conventional configuration. And in this configuration, you have dedicated single vertical tail of adequate size and there are 2 horizontal tails which are all 3 of them are attached to the rear of the fuselage. So, this one is the conventional tail and nearly you know 3 out of 4 aircraft that you will see nearly would have this kind of tail configuration.

But then there are some variations those variations normally come when this part of the fuselage is not available for mounting the tail or it is being used for mounting something else more important.

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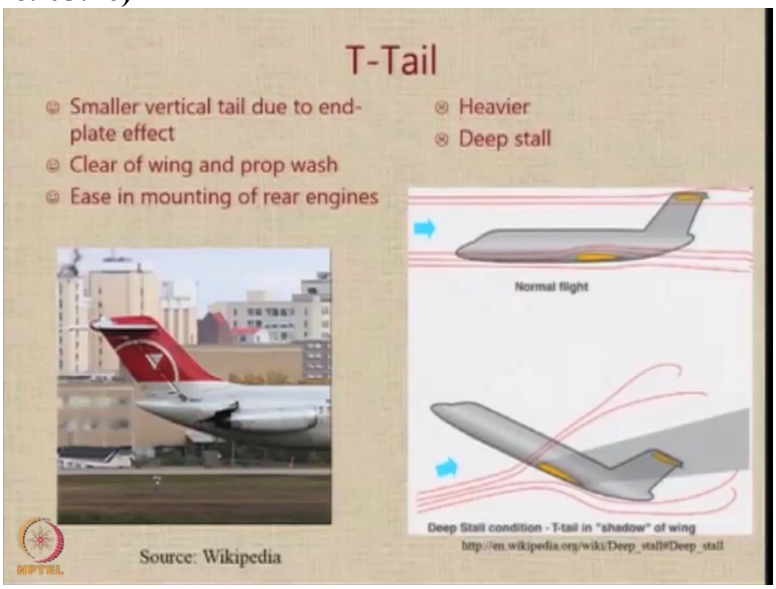

So, we will now have a look at some of the unconventional or not so common tail configurations and as I mentioned, there are going to be many alphabets of the English the first alphabet is a T-tail. So, in that T-tail, you essentially move the horizontal tail vertically

upwards. So, the horizontal tail is mounted at the top of the vertical tail that is the T-tail. So, because you have something at the end of the vertical tail, it creates an endplate effect.

And that endplate effect essentially gives you better vertical tail more effective vertical tail. So maybe you can reduce its length. Secondly, the horizontal tail has now moved away from the center of the fuselage. Therefore, it is away from the prop wash and the wing wash wing downwash during normal flights at reasonably low angle of attack. And such a configuration is normally provided only because you want to mount engines on the tail.

And if you mount the engine on the tail, then you know t tail is a configuration which allows you to mount the engines on the tail without necessarily creating hot spots on the horizontal tail. But there are problems. The T-tail is heavier, structurally it is not as efficient as the conventional tail and at higher angle of attacks when the wing wake is actually much larger and it is actually subjecting.

So, in the normal configuration, as you can see here in the figure, the tail is completely away from the wash of the wing. So, that is a good thing. But when you come to a situation where you have a very high angle of attack flight and the wake of the wing is quite large. Unfortunately, the surface which is helpful in overcoming from this situation, which is the tail is completely submerged and this phenomena is called as the deep stall condition. T-tails suffer from the deep stall problem.

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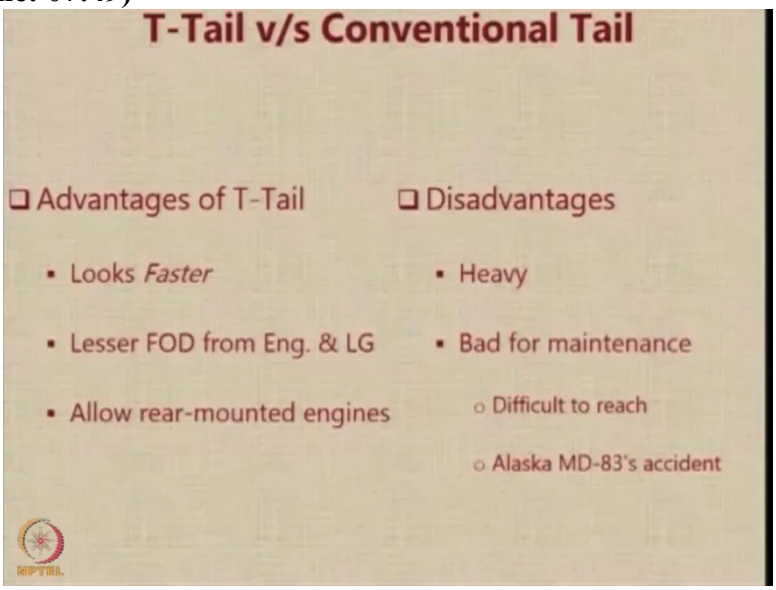

Let is compare a T-tail versus a conventional tail the detail looks faster, because it is far away, it will be less prone to foreign object damage from the engine and the landing gear and

as i said, it allows rear mounted engines, but there are problems heavy and also it is bad for maintenance, the T tail is actually far away. So therefore it is difficult to reach and hence it is not a very preferred option from the maintenance crew.

In fact, that is one accident that took place with Alaska MD 83 is in which a jackscrew of the horizontal tail got jammed. And one of the reasons why that particular accident took place is that it had a T-tail configuration. And the maintenance crew did not actually reach out to that particular part for lubrication, because it was a very cold wintry night. And you know, in such situations, there is always a lapse, people would like to cut corners. So there was a maintenance problem because of which the aircraft crashed and there was heavy damage.

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Here are some aircraft, popular aircraft, which have a kind of a T tail configuration. It is a very popular configuration amongst gliders. One of the most efficient riders available today's the ETA glider. You can see how much the wing is flexing in the flight. And that configuration has a T-tail. Piper Tomahawk is another famous aircraft which has a T-tail. And there are other 2 aircraft, the military F-101 voodoo and the Canadair CRJ, they all have a T-tail configuration.

In most cases, this particular requirement is driven by the need to have for example, you can see there is an engine here, there is an engine here on the rear. There is an engine here on the fuselage. And because of this, there is a requirement for a T tail.

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Let us look at a cruciform tail; it is a compromise between a conventional tail and the T-tail. So it is the horizontal tail which is not as high as a T-tail. But it is also not exactly at the junction of the fuselage and the vertical tail. So it is a little bit up, you can see it is a little bit up a little bit above. And you can see here it is right in the center. So, these, this configuration generally is arrived, keeping in mind the angle at which the aircraft would be normally flying in the trimmed flight.

During that condition, we keep the tail away from the horizontal tail junction; the horizontal tail is kept away and at very high angles of attacks. Again, the wing would be out of the tail would be out of the wake of the wing.

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Twin tail is very common in military aircraft. Generally a twin tail is given if you would like to reduce the height of the tail. So instead of one big tail you can put 2 tails and also it helps

in spin resistance, but it gives you higher structural weight. So many many military aircraft, especially fighters, you can see especially those which have very high requirements on their you know performance especially in turning flight; they go for a twin tail configuration.

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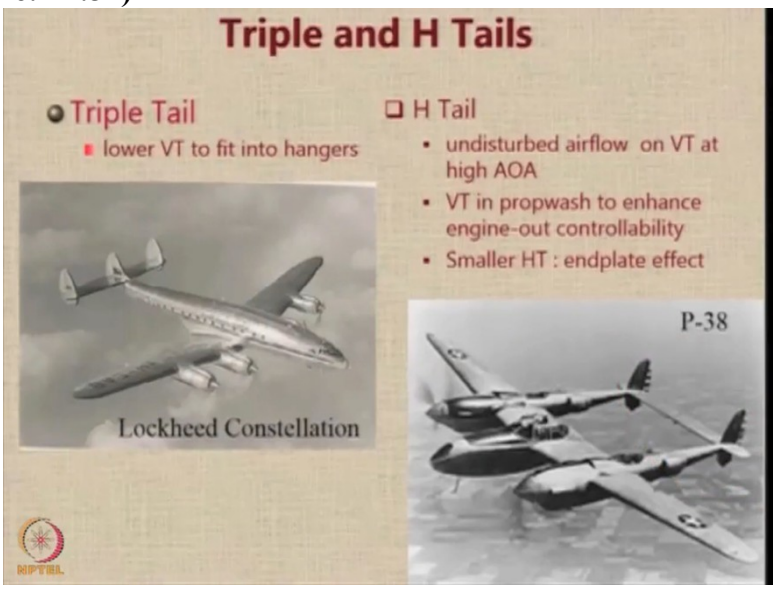

Then we also have triple tail and H tails. Lockheed constellation is an example of a triple tail configuration and this is a need driven by the requirement to fit the aircraft vertically into the hangar which are available. The horizontal the H tail has undisturbed flow on the vertical tail at high angle of attack, this is the H tail configuration in the P-38. So, what you do literally is you move away the vertical tail from the wake of the engine and also you provide double tail configuration.

So that the size of the tail can be smaller and when you have the tail at the ends of the horizontal tail, then you start creating an end plate if it has a horizontal tail, so, the horizontal tail becomes more efficient and can be made smaller.

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There is also configuration for the butterfly tail or a V-tail. The most prominent example of this is F-117 A, in a butterfly tail, rather than having 3 surfaces, 1 vertical tail, 2 horizontal tails, we get rid of them and have only 2 surfaces. So we lead to reduction of 1 tail surface. This gives you lower interference drive, it gives you lower weight, but there is a problem about complexity because now, both the tails are going to be deflected or used partly as a vertical tail and partly as the horizontal tail.

So you require a very complicated mixing unit to provide the required deflections. So Beechcraft Bonanza which is a very popular aircraft general aviation it began its design life with a butterfly tail configuration. But then there were many accidents and many people lost their lives. And hence, you know, the Beechcraft company decided to modify their design and go back to the typical conventional tail configuration.

So, the spate of accidents that took place in a Beechcraft Bonanza forced the company to convert the design from a V tail or a butterfly tail to a conventional tail.

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Here are a few other aircraft which have butterfly tail, the most prominent among them is the Global Hawk. And also there are a few other aircraft which are not so popular, not so well known, but yes, they have gone for this particular tail configuration. Cirrus vision SF 50 and Eclipse 400 you can see they want to Nacelle 1 engine on the top of the fuselage and because of that, by providing a butterfly tail you are clearing the engine clearing the tails from the hot exhaust of the jet engine.

So, in short, we have many configurational possibilities and layout options available for a designer you have to take a choice based on your own requirements and your own vision of what is most suitable. Thank you very much.