Introduction to Aircraft Design
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Lecture - 24
Wing Sweep

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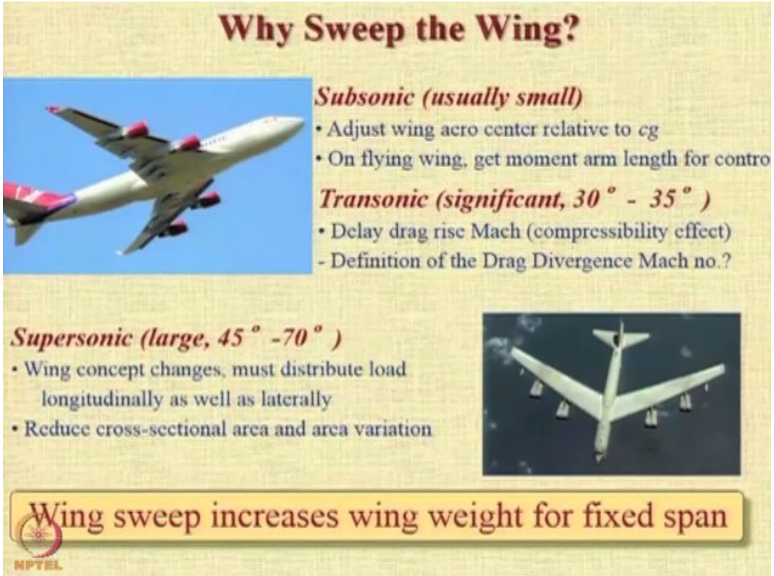

One question that many people ask is why sweep the wings, what is the benefit of providing sweep back on the wing? When it is a subsonic aircraft usually we provide a very small amount of sweep 1 reason for this could be to adjust the wing aerodynamic centre relative to the centre of gravity, because, you would like to have the distance between them the minimum.

And one way of doing it is to actually take the aerodynamic centre slightly behind them on a flying wing by providing sweep back you get required moment arm for control purposes otherwise the moment arm will be very small and then you will not have adequate control in the transonic aircraft we normally provide significant amount of sweep typically 30 to 35 degrees is what we see.

And the main reason for this is to delay the drag rise Mach number and to try to minimize or delay the compressibility effects. And for this one has to understand that there is something called as a drag divergence Mach number which is slightly beyond the critical Mach number and the critical Mach number is a Mach number at which the free stream Mach number at which the sonic conditions are first observed anywhere on the aircraft.

So, by sweeping the wing, you are going to delay the drag divergence Mach number due to which the aircraft can fly faster without entering this domain where the drag increases very large. In the case of supersonic aircraft, we go for a very large sweep 45 to 70 degrees or even a delta wing configuration. So, here because in supersonic flow there is a large movement of the centre of pressure therefore, you have to distribute the load both longitudinally as well as laterally and hence you have to go for a very large sweep.

Secondly, large sweep back in case of supersonic flight reduces the cross sectional area and also it gives you lesser variation of cross sectional area along the length. So, it is a kind of a compulsion to sweep. But please remember that wings sweep is not a desirable feature under any circumstances other than the need to go faster. So, there are many drawbacks of sweep, the principal drawback being that it makes the aircraft wing heavier.

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Now, we know many aircraft has sweep back, but we do see some aircraft having sweep forward. So the question that normally arises in the minds of people is what is the advantage of providing forward sweep? So, let us have a look at X 29 where the forward sweep technology was tested and studied.

The X 29 A forward swept wing program marked the return of the x planes to drive after a 9 year absence. The 2 phase program ran from 1984 and 1992. The first phase concentrated on the proof of concept at low angles of attack and high speed. The second phase of the X 29 A program, the high angle of attack test is covered in the 5th decade, 2 X 29 A air aircraft were built as technical demonstrator to test the forward swept wing with advanced composites variable camber.

And a thin super critical ailerons also tested was highly unstable and highly augmented multi surface controls that required an extremely high gain triple redundant digital control computer with analogue backup. The fiber strands of the composite narrow elastic tailored weighing on the X 29 A were specifically aligned to allow it to twist under load. The twisting relieves the loads at the tip, preventing structural divergence or breakage at a high speed.

The digital flight control computer system provided sufficient artificial stability and predictable handling qualities in a very unstable aircraft. Moreover, it is super critical wings contributed to good maneuvering and cruise characteristics in the transonic range. Despite these accomplishments, a predicted higher lift to drag ratio is not materialized made about equal to or slightly less than that then current fighter aircraft in contrast to the F 18 R, and X 31.

The X 29 A vehicle exhibiting good high angle of attack characteristics without the need for as much as 45 degrees angle of attack, the vehicle demonstrated much better than predictive control and maneuverability. At high angle of attack, the flow on the wingtips of a forward swept wing remains attached and the ailerons remain effective. Conversely, for conventional swept back wing the wingtip flow becomes separated before the rest of the wing and the ailerons quickly lose effect even at 67 degrees, the maximum angle of attack of X 29 A displayed.

So, as you noticed, the X 29 was a technology demonstrator aircraft. But the final conclusion of this particular trial was that the expected value of the lift over drag which are supposed to be very high, actually did not appear and the maximum L over D of this aircraft was either comparable or slightly less than that of the other conventional aircraft. The Russians also looked at forward sweep and here is a video showcasing their aircraft.
Another concept that people wonder is the variable sweep.

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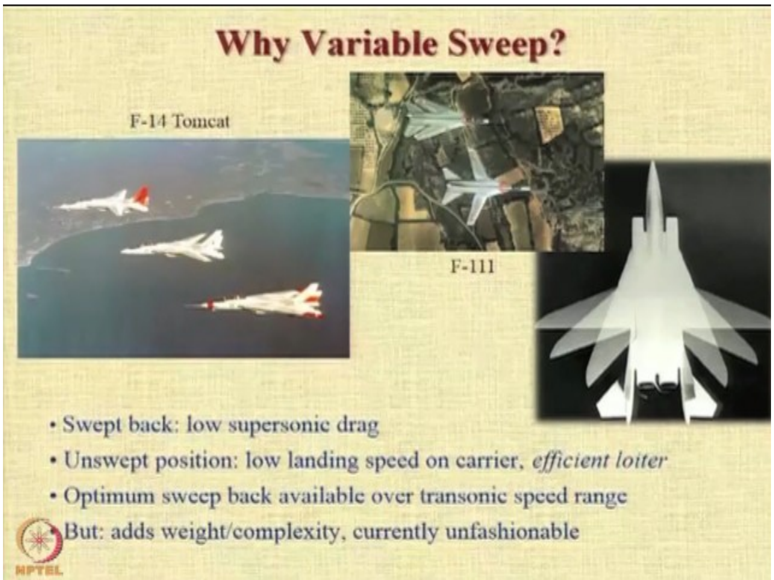

Now, variables sweep has been provided in some aircraft and the basic idea of variable sweep is to morph the shape of the wing to a configuration that is the most suited for the operating condition. So, when you have supersonic flight, you will have very low drag if you have an aircraft swept completely back. But when you want to fly at low speeds, for takeoff landing initial climb, or when you want to come in and land on an aircraft carrier, you would like to have low speed during lighter you would like to have higher aspect ratio.

So, during that time you would like to have little or no sweep. So, the unswept position corresponds to the low speed flight and during transonic speed you need to have an intermediate sweep not very large and not very low around 45 degrees or so. So, during transonic speed during maneuvers or during the segments of the mission at which you are flying transonic this particular aircraft can have the wings swept at that specific position.

The F 111 was the first aircraft to demonstrate sweep. And there we had a continuous variation possible such as, you can see in this photograph. But in most cases the decision was taken to fix the sweep at maybe 3 locations. Let us have a look at a small video on how this is achieved.

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So we saw that there is a lever in the cockpit which the pilot operates, and that lever decides the position of the sweep either a conventional unswept condition or a swept back condition. But let us remember that provision of variable sweep adds weight and complexity to the aircraft. And currently, it is not considered to be really fashionable. Very few aircraft you will see in modern times that are provided with variable sweep.

Because many a times it is felt that the cost complexity and the weight penalty of this particular feature, it might outweigh its benefits and aircraft will be 4% heavier in empty weight by providing a facility of sweepback thanks for your attention, we will now move to the next section.