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Design and Aero Dynamical Analysis on LERX-Wing Combination

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ABSTRACT

LERX Wing aerodynamics is increasing interest now a days and have been subject of interest theoretical and experimental studies in both subsonic and supersonic speed ranges due to the mutual benefits derived from the combination. The work on it is kept limited to company or organisation because of possible use on military fighter aircrafts.

The effect can even be seen on a fighter aircraft with LERX provides usable airflow over the wing at high angles of attack, so delaying the stall and consequent loss of lift. The high pressure air from the lower surface of the LERX rolls around the edge to the lower pressure region on the upper surface of the LERX creates vortices. The vortices created have minimal interference at or below the cruise angle of attack; In particular, at cruise it is possible that the small impact of the strake may only be attainable by the use of camber or dihedral.

Beyond 15 degrees angle of attack there is evident upper-surface boundary-layer control which continues from moderate to high angle due to turbulence caused by vortices. Presence of LERX causes severe changes in pressure and velocity distribution which reduced area required for manoeuvre loads.LERX vortex is strengthened by up-wash from the main wing and the need for only a small area - hence, wetted area and comparatively lightweight structure - to generate its significant contribution to the total lift because the strake provides large amounts of vortex lift.

INTRODUCTION

Leading edge root extension (LERX) is an aerodynamic surface generally mounted on the fuselage of an aircraft to improve the flight characteristics by controlling the airflow.

On a modern fighter aircraft LERX provide usable airflow over the wing at high angles of attack, so delaying the stall and consequent loss of lift. In cruising flight the effect of the LERX is minimal. However at high angles of attack, as often encountered in a dog fight or during take-off and landing, the LERX generates a high speed vortex that attaches to the top of the wing. The vortex action maintains a smooth airflow over the wing surface well past the normal stall point at which the airflow would otherwise break up, thus sustaining lift at very high angles. LERX were first used on the Northrop F-5 which flew in 1959 and have since become commonon many high performance combat aircraft. The F/A-18 Hornet has especially large examples such as Sukhoi Su-27, its LERX help to make some advanced manoeuvres such as the Pugachev's Cobra, the Cobra Turn possible even at high speeds of flight and in dog fights.

A long narrow sideways extension to the fuselage, attached in this position, is an example of a LERX

Figure 1 Aircraft with LERX

Figure 2 Formation of vertices due to condensation of water vapour

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AERODYNAMICS OF LERX

The high pressure air from the lower surface of the LEX rolls around the edge to the lower pressure region on the upper surface of the LEX. This motion induces a rotation on the air flow causing it to roll up into a strong vortex. The strength of the vortex grows as angle of attack increases, and the high-speed vortex helps keep the air flow attached to the surface of the wing beyond the normal stall angle. The effect can be calculated and visualized using computational fluid dynamics (CFD) software as exemplified in the following images.

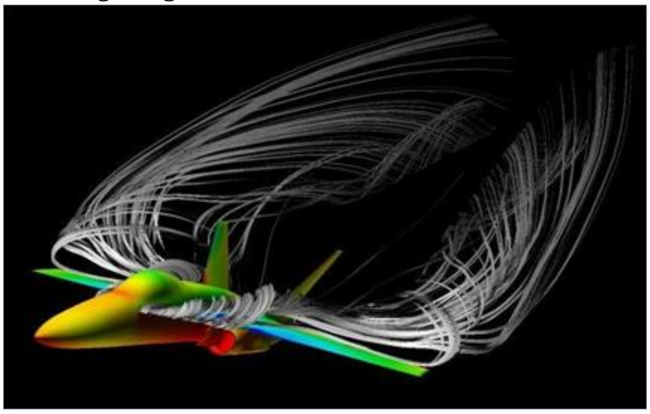

Figure 6Stream lines around wing and LERX in CFD simulation

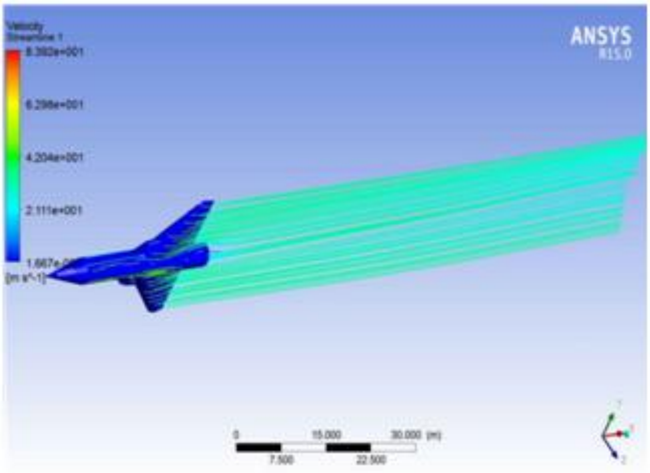

Figure 7Streamlines overthe3Dmodel

Wind-tunnel studies of sharp-leading-edge delta wings have shown that even at relatively low angles of attack the flow separates from the leading edges and rolls up into two vortex sheets or cone-shaped cores of rotating fluid attachment lines have been observed inboard of the vortex sheets and indicate that air is drawn over the vortex sheets and accelerated downward increase in lift at a given angle of attack results. The vortex flow not only increases the lift but changes the distribution of lift rather drastically, where typical measured spanwise pressure distributions at one longitudinal station are compared with distributions.

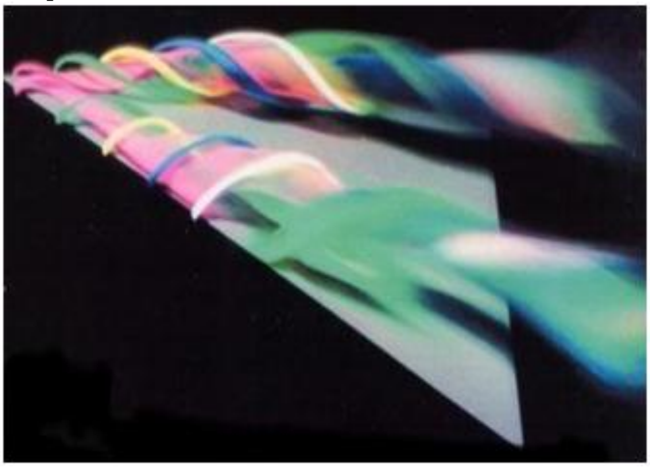

Figure 8visualisation of vortices around a delta wing

Application of suction analogy to flow field

Potential-flow theory is usually presented in a form applicable only for wings at low angles of attack, the development of the theory in a form more applicable for the high angles of attack of interest in the present study will be used.

Suction analogy

The method employing the leading-edge-suction analogy for predicting the vortex lift of sharp-edge delta wings is substantiated by experiment, that over the normal angle-of attack range, the flow external to the vortex passes around the vortex and reattaches to the wing upper surface. It is then assumed that the total lift is comprised of two parts:

(1)A lift associated with the reattached flow which can be estimated by an appropriate application of potential-flow lifting- surface theory, and

(2)A vortex lift which is equal to the force required to maintain the equilibrium of the potential-type flow around the spiral vortex.

Potential flow lift term

The potential-flow lift term is to be given by

$$CLp=Kp\sin\alpha*\cos^2\alpha$$

(1)Where surface theory, sinα accounts for the true boundary condition, and cos2α arises from the

assumption of a Kutta-type flow condition at the leading edge.
(2)Kp is the lift-curve slope given by small-angle-of -attack potential-flow lifting

Vortex lift term

To determine the vortex lift, an analogy between the force required to maintain the flow about the spiral vortex and that required to maintain potential flow about the leading edge as illustrated in flow, the force is the well-known leading-edge suction which has been shown to be relatively independent of leading- edge radius, the lower angle of attackinduced velocities associated with the larger radius acting over a larger area to provide the same suction force as for the smaller radius. With leading-edge vortex flow,A Kutta-type condition exists at the leading edge and the leading-edge suction is lost. However, the flow around the vortex is somewhat analogous to the potential flow around the large leading-edge radius. the wing upper surface rather than by the leading edge and therefore, the leading-edge suction is converted to a normal force, The vortex lift term, based on this approach, is

$$C_{l},v=K_{v}\sin^{2}\alpha\cos\alpha$$

The equation gives the potential-flow leading-edge suction and therefore the vortex normal force, and Cosα gives the component in the lift direction.

Total lift coefficient

By combining equations (1) and (2), the total lift coefficient is given by

$$C_{l}=K_{p}\sin\alpha\cos^{2}\alpha+K_{v}\cos\alpha\sin\alpha^{2}$$

Drag due to lift.-

For the thin flat sharp-edge wings having fully developed vortex flow, it is reasonable to assume that a Kutta-type flow exists along the leading edge and that the resultant force associated with angle of attack is therefore directed normal to the wing-chord plane. With this assumption and the assumption that the effects of angle of attack on skin friction are small, the drag coefficient due to lift can be given by

$$CD = Kp\sin\alpha^{2}\cos\alpha+K\nu\sin\alpha$$

RESULTS

The results clearly showing that the LERX-Wing combination is performing effectively even at high angle of attacks in the values of 300 without much flow separation and much increase in pressure gradient and temperature.

At an angle of attack of 100the velocity of the flow is nearly 21m/s and pressure gradient is 787 Pa. Flow separation is not much observed in the analysis, the flow directly stagnation at the LERX and root of wing joining, so pressure gradient is more at that particular location and on the upper surface of the wing the pressure gradient is going to negative due to low pressure zone forming by the flow velocity.

At an angle of attack of 200the velocity of the flow is nearly 28m/s and pressure gradient observed is -130.6 Pa. due to vortex generation, generally NACA0012 airfoil stalls at that high angle of attacksbut with the use of LERX Flow separation is not much observed in the analysis, but flow is increasing velocity due to vortex formation in the flow because of the LERX arrangement and angle of attack.

At an angle of attack of 300 the velocity of the flow is nearly 83.9m/s and pressure gradient observed is -4421 Pa. due to high angle of attack vortex generated, but flow separation is not much observed in the analysis even at 300 angle of attack and flow separation is not observed due to controlled and effective vortex generation with in turn increasing effectiveness of wing even at high angle of attacks. But pressure gradient is very high which in turn increase flow induced vibration in the structure of the aircraft with the disturbed low have to cross, so it requires to take care of the structural strength at that particular locations.

CONCLUSION

A study computational model has indicated that by using LERX there has been increase in lift and also the coefficient of lift in the model the effectiveness of the wing is enhanced. The flow visualization have confirmed the vortices created by the LERX minimal effect on the contribution to the total lift but as the angle of attack is increased to the angle greater than the 15 degree the effect of vortex lift become very evident and plays a very dominant role in the total lift of the aircraft. The upwash from the main wing enhances the effectiveness of the LERX, which clearly indicates that the effectiveness of LERX is dependent on the wing on which it is attached.

The computational study suggest that there is delay in stall of the model with LERX hinting the vortices generated from LERX prevent the attainment of stall by make the flow over main wing more turbulent in comparison with a model without LERX and analysis clearly shows that there is not only change in the pressure but also change in the pressure distribution on the entire wing hence there exist different loading condition when compared with model with LERX and without LERX

One of the limitations that is found in the analysis is that there is also increase in drag and coefficient of drag, predicting the drag penalty because of the LERX used on the model. The another disadvantage that flow vortex formed due to LERX not only interacts with the main wing but may also interact with vertical tail of the configuration suggesting greater fatigue in the model.

LERX have efficiently increased the total lift of the model with drag penalty, use of LERX completely changes the pressure distribution of entire main wings drastically. Thus the changes in pressure distribution due to LERX hints the potential usage as control surface.

Movement of LERX in the same direction changes the longitudinal distribution of pressure and velocity over the model. Hence variable pitching movement can be achieved thus usage of the LERX to enhance the longitudinal stability of the aircraft. The working of LERX is very different from the aft tail and the canard because the said components are separate from the main wing. The working of canard and aft tail is completely independent from the working of main wing, which is not so in the working of LERX

The differential movement of LERX changes the lateral distribution of pressure and velocity over the model. Hence it creates the variable rolling moment over the model due the differential movement. The conventionally used rolling moment generator i.e aileron changes the pressure distribution over the small part of the wing, where usage of LERX changes the pressure distribution over the larger part of wing .hence the usage can enhance the lateral stability of the entire configuration. It's a known fact that the lateral and normal stability of any aircraft are interlinked hence differential movement enhances the lateral and normal stability of the configuration.

FUTURE SCOPE

1. CFD analysis for the model can be done for higher speed slow rates
2. Different flow parameters can be analysed in CFD
3. CFD analysis for LERX-Wing combination for high g turns and pressure gradients, velocity gradients, temperature gradients, flow separations can be studied using flow simulation software.
4. CFD data can be transferred to structural analysis module and structural analysis, frequency analysis, model analysis, buckling analysis, harmonic analysis and flutter analysis can be dime for the LERX-Wing combination.
5. A prototype model can be fabricated and wind tunnel test can be done for various flow parameters and results can be evaluated with CFD results.

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