Design, Analysis And Experimental Evaluation of Active Aeroelastic Wing (AAW) Technology

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Abstract – This paper summarizes the design, analysis and experimental evaluation of Active Aeroelastic Wing (AAW) technology and is need over conventional design process. The results provide control derivatives of control surface of an aircraft by using AAW design. Also the result indicates some different behaviour which was not expected while doing the conceptual design. It is multidisciplinary study in engineering technology. This is a new technology in the area of structural design approach. This is a intergradations of flight control, aerodynamic control, and structural performance.

Keywords: AAW, Aeroelasticiy, Conventional approach, Wind tunnel model

1. Introduction

Aircraft structures are very flexible and this can be destroyed under load. The load is depended on the geometry of the aircraft. When there is a combination effect due to aerodynamic force and elastic forces is known as *Aeroelasticity.*

A. Aeroelasticity

Aeroelasticity is a multi-disciplinary branch of study. As can be seen from fig. 1, aeroelasticity considers all kinds of forces acting on the body, providing a more effective approach in designing of a structure especially structures such as Aircraft.

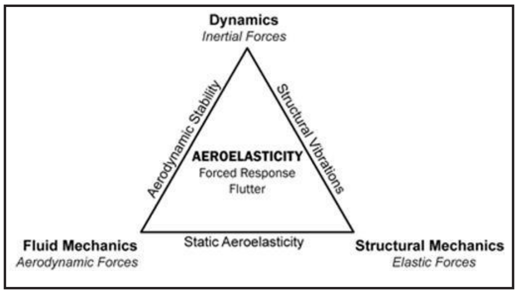

Fig. 1. Inter-relation between different forces

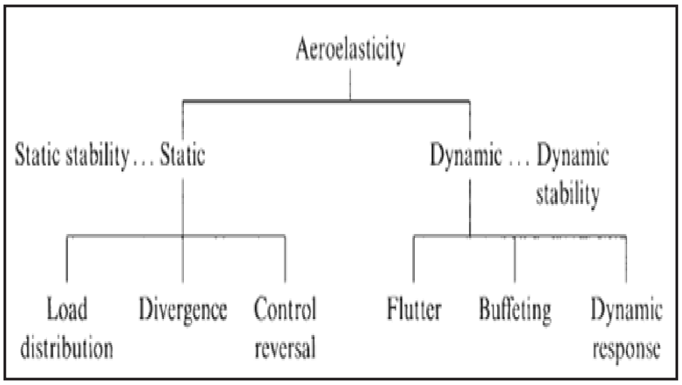

Fig. 2. Classification of aeroelasticiy

B. Conventional Design

The philosophy of conventional aircraft design philosophy views the deformation of Aeroelastic of an aircraft. Due to aileron deflection the wing can twist. This may so happen the angle of attack will reduce. This cause to decrease the lift. This phenomenon is called aileron reversal. The aileron is used to roll the aircraft. Due to this phenomenon there will not be any rolling moment.

AAW is a new conceptual design which is integrated with flight control design to enhance aerodynamic, control. This gives structural flexibility of the aircraft. Advantages of this were to utilizing both aero-elastically of leading and trailing edge control. In this case full wing will work like a aileron. And the trailing adge device will work like a trim tab.

Using AAW design approach the aeroelastic phenomenon can be remove.

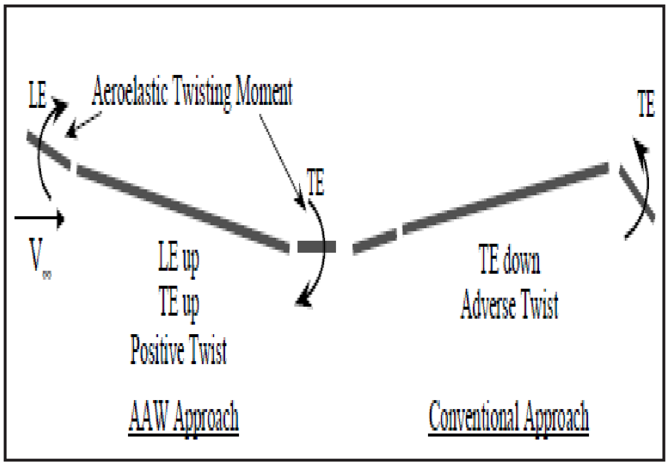

Fig. 3. AAW approach v/s conventional approach

C. Impact of AAW on Conceptual Design Decisions

Generally this technique can be used for an aircraft so that the specification of the new vehicle geometry design can meet all the specification requirements and mission of vehicle. Using this design thickness to chord ration, sweept back angle, tapered ratio, AR and wing surface area and other gemotric parameters. This approach can help a designer to take different aproch to finalize the configurations, which are not in the conventional design. By using AAW designe aeroelastic deformation is a net advantages.

II. Objective

Experiments are made for the validation of the Active Aeroelastic Wing (AAW) technology concepts, which includes FEM model and wind tunnel model.

III. Methodology

A. Using Experimental Set Up

NASA has taken a incentive with Boeing to do AAW program. This was a cooperative effort among NASA and Boeing Company. In July and august 2004 the testing eas don in NASA Langley Transonic Dynamics wind Tunnel. Doing the experiment in the wind tunnel following goal can be served.

- First- wind tunnel can be used primary approach to take the decision.
- Second- It can give detail aerodynamics parameter before freezing the gemotric parameter of the aircraft.
- Third- alos it can give result for scaling effect with respect to statically scaled aeroelastic models.

B. Model inside Wind Tunnel

a. Scaling

It is very difficult to match the Aeroelastic properties of a testing model with full scale model of aircraft. Aerodynamic loads and stiffness are main properties in model of static aeroelastic wind tunnel λ was used as a scale factors. Scale is the ratio between the model inside the wind tunnel and full scale of aircraft. This should have two similarity. One is geometric similarity and other one is dynamic similarity. Geometric similarity is one when both full scale and testing model are identical to each other. And dynamic similarity is one when the Reynolds no matches between the identical place of model and full scale aircraft.

b. Model Design

While doing the a model for wind tunnel test, many parameter need to be considered. Need to see the scaling effect inside the wind tunnel. Depending the size of the model the there may be blockage or even horizontal bouncy force can occurred inside the wind tunnel. Due to blockage of the wind tunnel the major parameters can be wrong. Due to horizontal bouncy there may be a horizontal force will add along the drag direction. So the result in measurements drag will have much more higher vale than actual value. Also dynamic similarity should be satisfied for model testing so that the inertia forces will be identical respective point in model. Fig. 3 shows the conceptual designee of AAW inside wind tunnel.

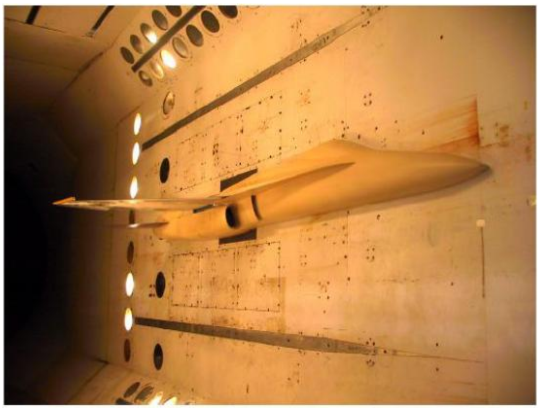

Fig. 4. Model for AAW mounted inside TDT test section

c. Characteristics of Model

The scale of the AAW model was 26. This was respect to full scale of F/A-18A. Fig. 4 provide the view of the model inside the test section. Here the main fuselage structure. An this was covered by thin balsa wood. The model was constructed with 4 control surfaces. Those are four highlift and control devices. This consist of a flap at leading edge outboard (LEO) and at inboard (LEI). This also have flap at trailing edge inboard (TEI) and outboard (TEO). All the high lift device and the control surfaces were fixed to main wing structure. Fig. 5 shows a schematic layout of the AAW model.

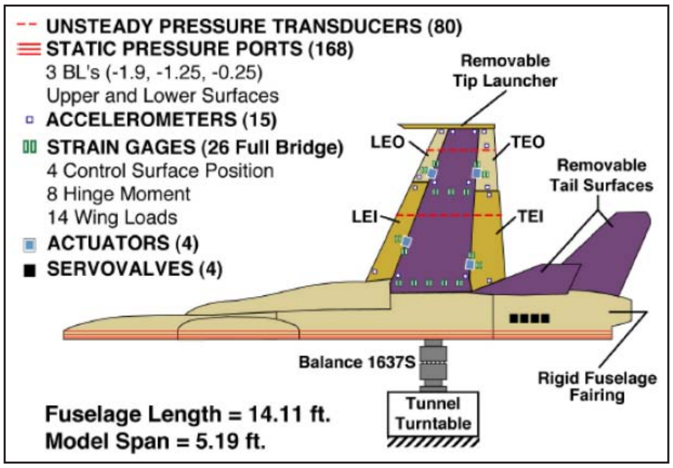

Fig. 5. Schematic layout of the model

d. Test Facility

The Transonic Dynamics Tunnel (TDT) was a closed-circuit wind tunnel. This was reduced-pressure tunnel located at sea level. Two different medium were taken to conduct the testing. This was done to test the model at different density. The working fluid was air and a heavy gas R134.

All the wind tunnel forces, moment and sign conventions were presented in table. Also stability parameters and derivatives for control surface presents in table.

e. Analysis of Forces and Moment

The Finite element methods (FEM) was used to analysis the force and aero elasticity on the model. The model was designe using CATIA and transfer to ANSYS platform for analysis.

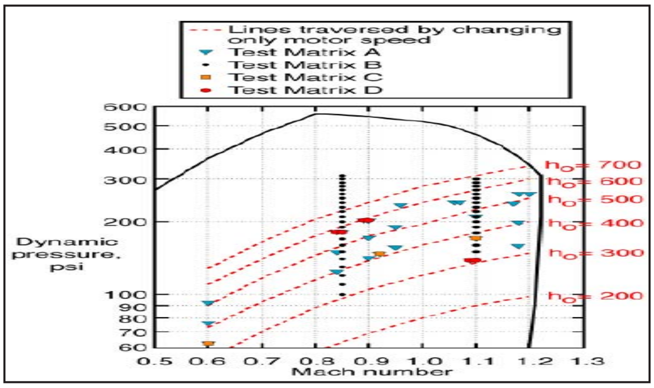

Fig. 6. Test matrices and TDT test envelope in R134a

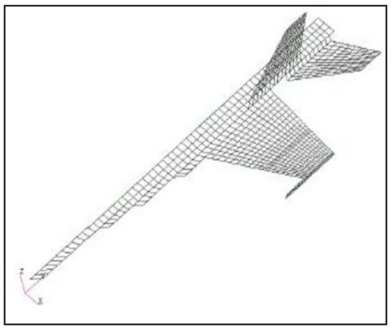

Fig. 7 Aerodynamic Box Layout of Wind Tunnel Model for Linear Analysis

TABLE 1
CONVENTIONS FOR FORCES AND MOMENTS

Quantity	Symbol	Nondimensionalization	Definition of Positive
Lift force	L	1/(qS)	UP
Pitching moment	m	1/(qSc)	Nose UP
Drag force	D	1/qS	Downstream
Rolling moment	l	1/(qSb)	Right wing UP
Yawing moment	n	1/(qSb)	Nose out of wall, or nose right
Side force	s	1/(qS)	Out of wall, or out the right wing

TABLE 2
CONVENTIONS FOR DEFLECTIONS

Quantity	Symbol, Subscript	Symmetric Deflection	Antisymmetric Deflection
Angle of attack	α	+nose up	
Leading edge inboard deflection	δ_{LEI}	+ free edge ↓	+ free edge ↓
Leading edge outboard deflection	δ_{LEO}	+ free edge ↓	+ free edge ↓
Trailing edge inboard deflection	δ_{TEI}	+ free edge ↓	+ free edge ↑
Trailing edge outboard deflection	δ_{TEO}	+ free edge ↓	+ free edge ↑

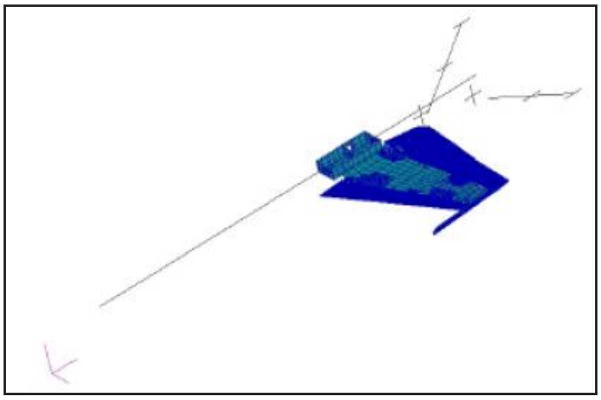

Fig. 8. FEM of wind tunnel model

IV. E-Results & Discussion

In this work 3 different result sets were presented. One result seat was related to the linear rigid aeroelastic analysis of the model. Second one was "aeroelastic linear analysis of the wind tunnel model". And third result set was related to the experimental result of the model.

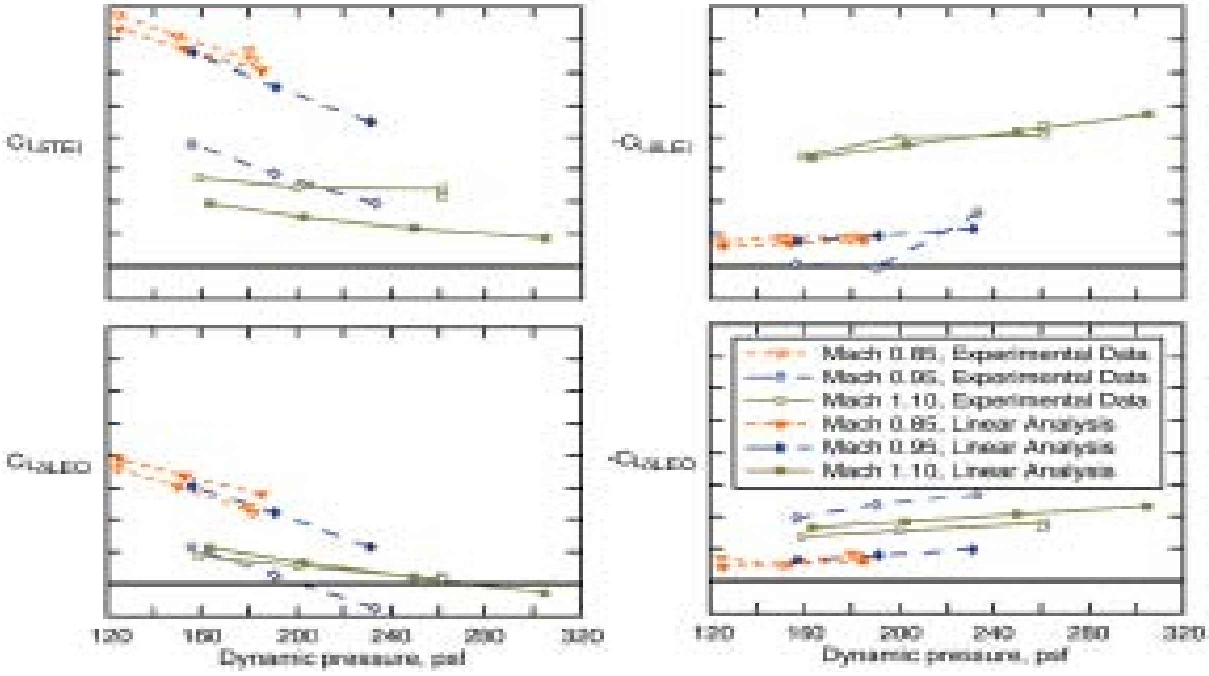

Fig. 9. Lift derivatives of wind tunnel model, experimental and analytical data as function of dynamic pressure, vertical scale identical

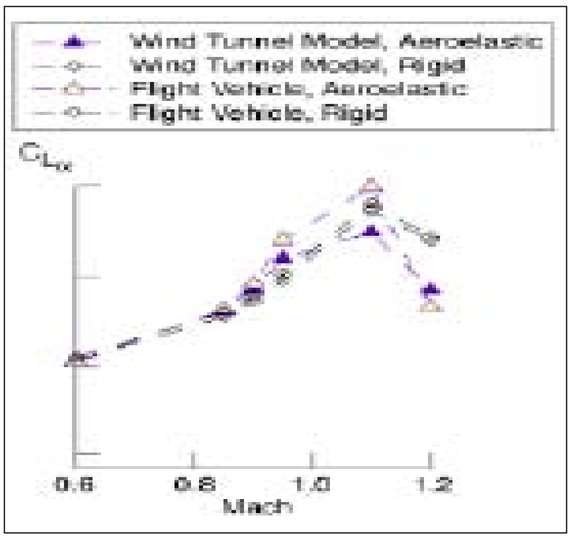

Fig. 10. Analytical results for lift curve slope, 10,000 ft

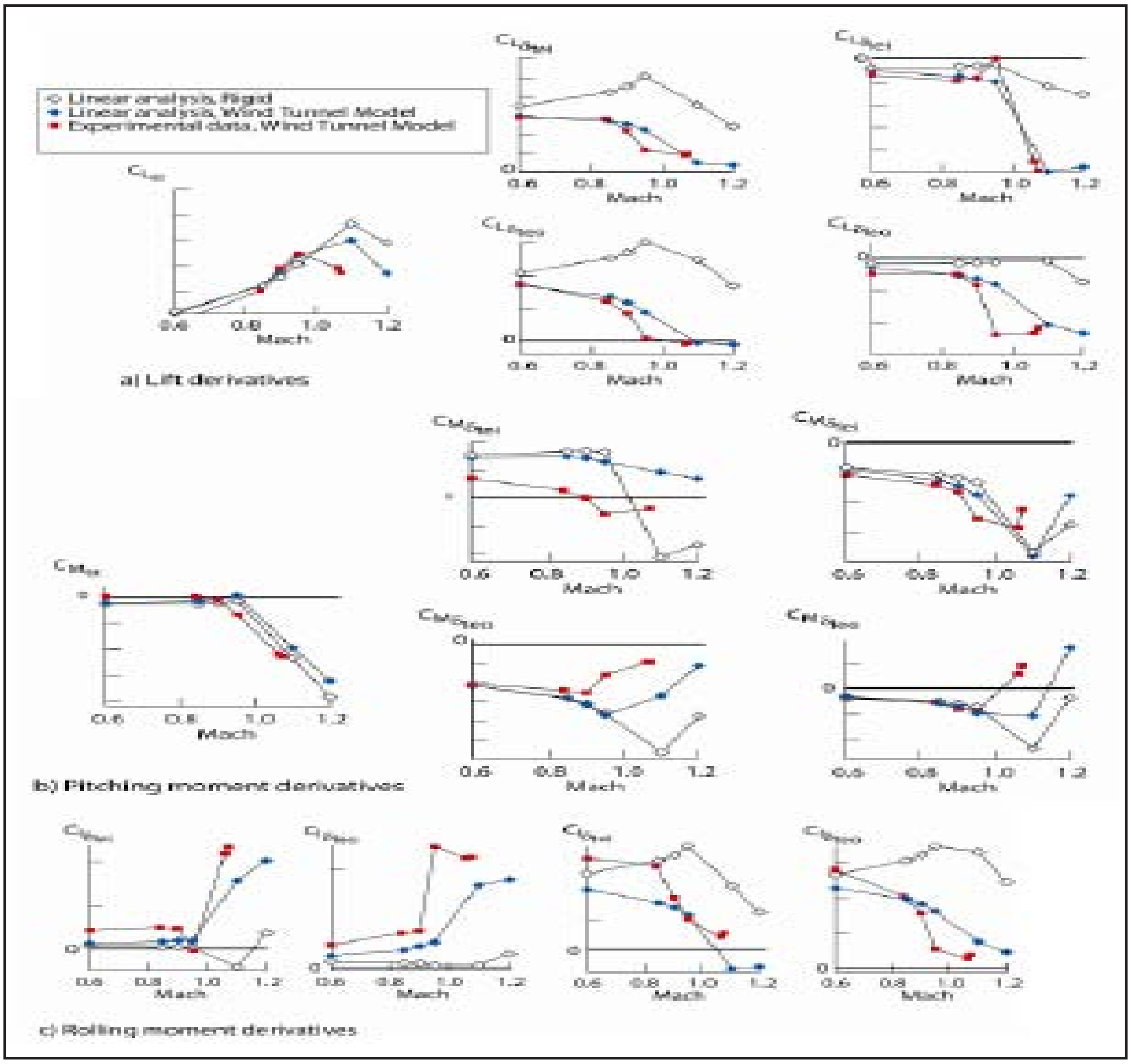

Fig. 11. Stability and control derivatives at 10,000 feet altitude

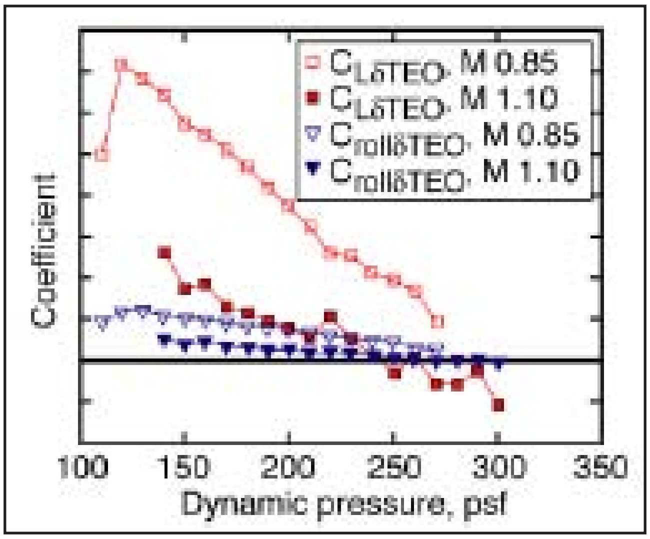

Fig. 12. Analytical results for lift curve slope, 10,000 ft

V. Conclusion

It was observed from the test data that this design proves the conceptual ideas for transonic behaviour of stability and also the control derivatives of control surface of an aircraft. Also the result indicates some different behaviour which was not expected while doing the conceptual design. As the wing was flexible, there was reversal in rolling moment due to deflection of the leading-edge control surface. This study was given lot more input for model designing in all the stages of development of aircraft. Also it helps to get proper experimental data in wind tunnel testing. By using AAW design, the aero elasticity phenomenon can be reduced.

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