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Flutter Prediction on Wing and Redesigning Of Wing

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Abstract: The wings of the aircraft reflect an aircraft's primary lift unit. The aerodynamic strain, weather, wind and vibration are the liability of the aircraft's wing throughout the ride. Aeronautical and structural stresses may often be handled by aircraft wings. Therefore, aircraft wings must be constructed to have good overall efficiency throughout each period of operation, both structurally and aerodynamically. Spar, ribs, thongs and skin are the main structural elements of a wing construction. It is a fluttering experiment regarding the wing and re-designing of zodiac aircraft. The method was identified in the literature survey to decide the current wing design parameters. Main objective of this project is to makes a stable aircraft wing which can overcome all flutter related problems in the design limit region. We always tried to keep the weight margin in same limit. To achieve weight in same limit we are trying with various cross section stringers and it is placing at various regions, instead of increasing thickness directly.

Keywords: Flutter prediction**,** Aero elastic, Aerodynamic, wing design, Re-designing.

I. INTRODUCTION

The aerodynamic, rafters, wind and vibration loads are the subject of the airplane, the aircraft wing. Aeronautical and structural stresses may often be handled by aircraft wings. Therefore, aircraft wings must be constructed to have good overall efficiency throughout each period of operation, both structurally and aerodynamically. The Zodiac is a Canadian all-metal two-seat family of aircraft that flew first in 1984 with fixed landing gear. Zenair in Canada and Zenith Aircraft Company in the USA assembled these planes as kits and finished aircraft. The basic CH 601 was specifically built for the Specialized Ultra-light (AULA) group, the Lightened variant of the ZODIAC CH 601 HD in Canada and other European countries. Where it is possible to use CH 601 as a simulator and personal aircraft. A group of extreme ultra-light is far more than ultralight; it can best be referred to as a main category of aviation.

This concept is somewhat close to the specifications of the CH 601 HD concept for its lower gross weight. A lighter gross weight ensures that lightweight components in chosen regions reach a lower empty weight. Listed as a state-of - the-art ultra-light, the CH 601 is a low cost coach and personal jet. Pre-assembled planes are accessible from the supplier directly as a licensed product.

II. AERO ELASTICITY

Aero elasticity is the branch of physics and engineering that studies the interactions between the inertial, elastic, and aerodynamic forces that occur when an elastic body is exposed to a fluid flow. An elastic force is the kind of force that arises from the deformation of a solid body, which depends on the body's instantaneous deformation and not on its obvious history. This type of force is also conservative. Aero elastic problems would not exist if airplane structures where perfectly rigid. Many important aero elastic phenomena involve inertia forces as well as aerodynamic and elastic forces. The study of aero elasticity may be broadly classified into two fields: static aero elasticity, which deals with the static or steady response of an elastic body to a fluid flow; and dynamic aero elasticity, which deals with the body's dynamic (typically vibration) response. Aero elasticity draws on the study of fluid mechanics, solid mechanics, structural dynamics and dynamical systems. The synthesis of aero elasticity with thermodynamics is known as aerothermoelasticity, and its synthesis with control theory is known as aeroservoelasticity

A. Collar Diagram

Your Describes the aero elastic phenomena by means of a triangle of forces

A – Aeroelastic force.
E – Elastic force.
I – Inertial force

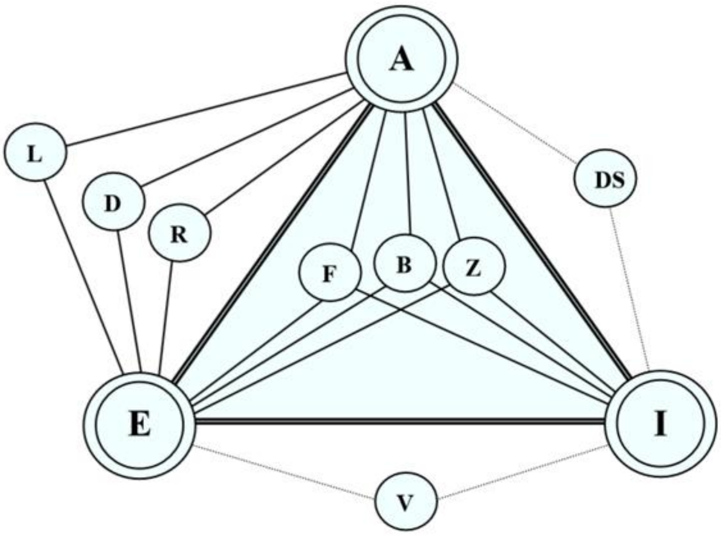

Fig.1 Collar diagram

III. DYNAMIC AEROELASTICITY

Phenomena involving all three type of forces:
F – Flutter: dynamic instability occurring for aircraft in flight at a speed called flutter speed.
B – Buffeting: transient vibrations of aircraft structural components due to aerodynamic impulses produced by wake behind wings, nacelles, fuselage pods, or other components of the airplane
Z – Dynamic response: transient response of aircraft structural components produced by rapidly applied loads due to gusts, landing, gun reactions, abrupt control motions, and moving shock waves.

IV. STATIC AEROELASTICITY

Science which studies the mutual interaction between aerodynamic forces and elastic forces, and the influence of this interaction on airplane design. Phenomena involving only elastic and aerodynamic forces
L – Load distribution: influence of elastic deformations of the structure on the distribution of aerodynamic pressures over the structure
D – Divergence: a static instability of a lifting surface of an aircraft in flight, at a speed called the divergence speed, where elasticity of the lifting surface plays an essential role in the instability.
R – Control system reversal: A condition occurring in flight, at a speed called the control reversal speed, at which the intended eff ect of displacing a given component of the control system are completely nullified by elastic deformations of the structure.

A. Flutter

Flutter is a self-feeding and potentially destructive vibration where aerodynamic forces on an object couple with a structure's natural mode of vibration to produce rapid periodic motion. Flutter can occur in any object within a strong fluid flow, under the conditions that a positive feedback occurs between the structure's natural vibration and the aerodynamic forces. That is, the vibration movement of the object increases an aerodynamic load, which in turn drives the object to move further. Even changing the mass distribution of an aircraft or the stiffness of one component can induce flutter in an apparently unrelated aerodynamic component. At its mildest this can appear as a "buzz" in the aircraft structure, but at its most violent it can develop uncontrollably with great speed and cause serious damage to or lead to the destruction of the aircraft, as in Banff.

B. Buffeting

Buffeting is high-frequency instability, caused by airflow separation or shock wave oscillations from one object striking another. It is caused by a sudden impulse of load increasing. It is a random forced vibration. Generally it affects the tail unit of the aircraft structure due to air flow downstream of the wing.

V. INTRODUCTION TO MODEL

Fig.2 Zodiac aircraft

The Zodiac is a family of Canadian all-metal, two-seat; fixed landing gear airplanes that first flew in 1984. The aircraft have been produced as kits and completed aircraft by Zenair in Canada and Zenith Aircraft Company in the USA. The ZODIAC is a sleek and docile aircraft, as shown in the fig which is ideal for both local and long cross-country flights. All Zodiac models offer comfortable two-place side-by-side seating in an ergonomically designed 44-inch wide cabin

A. Aircraft Specification and Performance

The specification of Zodiac CH 601 is given Table 1. The huge tinted bubble canopy, which provides outstanding 360 degree visibility, is hinged on both sides of the cabin, to allow access from either side of the aircraft. Access to the cabin is easy over the 20-inch wide reinforced wing walkway on both sides of the cockpit, and facilitated by a 'step' located below the trailing edge of the wing.

Table 1 Specification of Zodiac Aircraft

SPECIFICATIONS	ZODIAC CH 601 (UL)
WING SPAN	27 FT.
WING AREA	130 SQ.FT.
LENGTH	19 FT.
EMPTY WEIGHT	550 LB.
USEFUL LOAD	508 LB.
GROSS WEIGHT	1,058 LB.
WING LOADING	8.0 psf
POWER LOADING	13.2 LB./HP
DESIGN LOAD FACTOR	+/- 6 "G"
CABIN WIDTH	44 INCHES
FUEL CAPACITY (std)	16 Gallons (US)
with Optional Wing Tanks	30 Gallons (US)

The ZODIAC has been configured to take full advantage of its increased useful load. The fuel is located in dual welded-aluminum wing tanks. The standard dual wing tanks offer a fuel capacity of 24 US gallons. Long Range fuel tanks are optionally available, which increase the total capacity to 30 US gallons (2 x 15 gallons) to provide superior range and endurance which is given in Table 2.

Table 2 Performance of zodiac aircraft

PERFORMANCE	**SINGLE 800 LB.**	**DUAL 1,050 LB.**
TOP SPEED (mph)	135	135
CRUISE (mph)	120	120
VNE (mph)	150	150
STALL SPEED (mph)	39	44
RATE OF CLIMB (FPM)	1,400	1,200
TAKE-OFF ROLL (ft.)	360	430
LANDING DISTANCE (ft.)	450	550
SERVICE CEILING (ft.)	12,000+	12,000+
RANGE (std., SM)	480	480
RANGE (with wing tanks, SM)	820	820
LOAD FACTOR (G)	+/- 7.9	+/- 6.0

B. Aircraft Wing

ZODIAC CH 601 Wings are made up of a single cantilevered spar with near full-span non-hinged ailerons. The CH 601 and CH 601 HD models use a simple constant-chord airfoil, while the CH 601 HDS and the new ZODIAC XL feature tapered 'speed' wings. With reference to the schematic diagram given in Fig, the high-lift low-drag airfoils provide an efficient cruise speed, as well as desired slow flight and gentle stall characteristics. Flaps are not required with the high-lift wing designs of the ZODIAC. The outboard wing panels can easily be removed in 15 minutes each for tailoring and storage. With the wings removed, the fuselage fits through the door of a standard single-car garage and can be tailored.

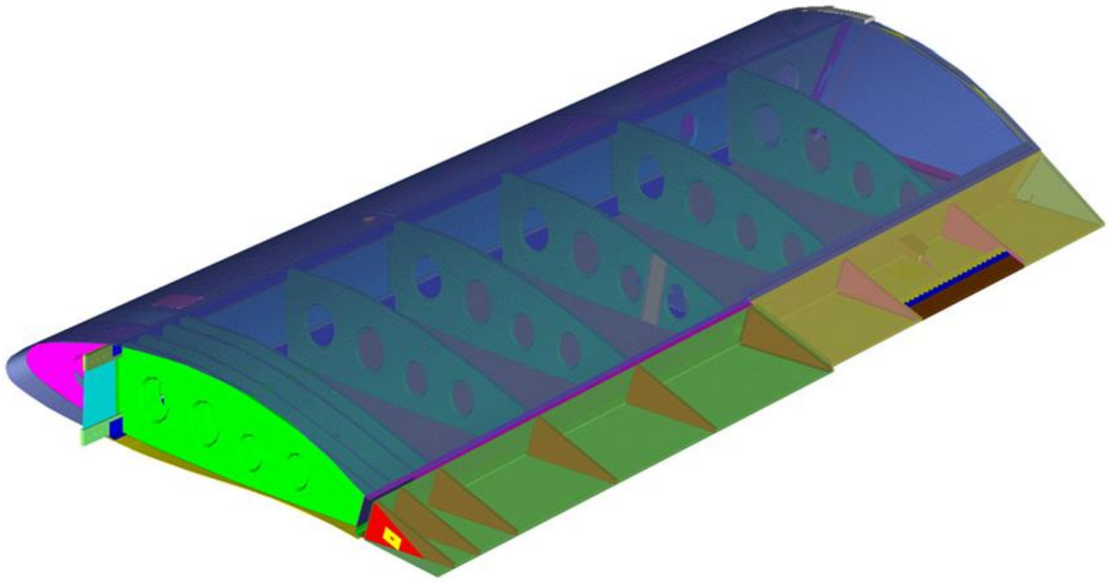

Fig.3 Schematic diagram of zodiac wing

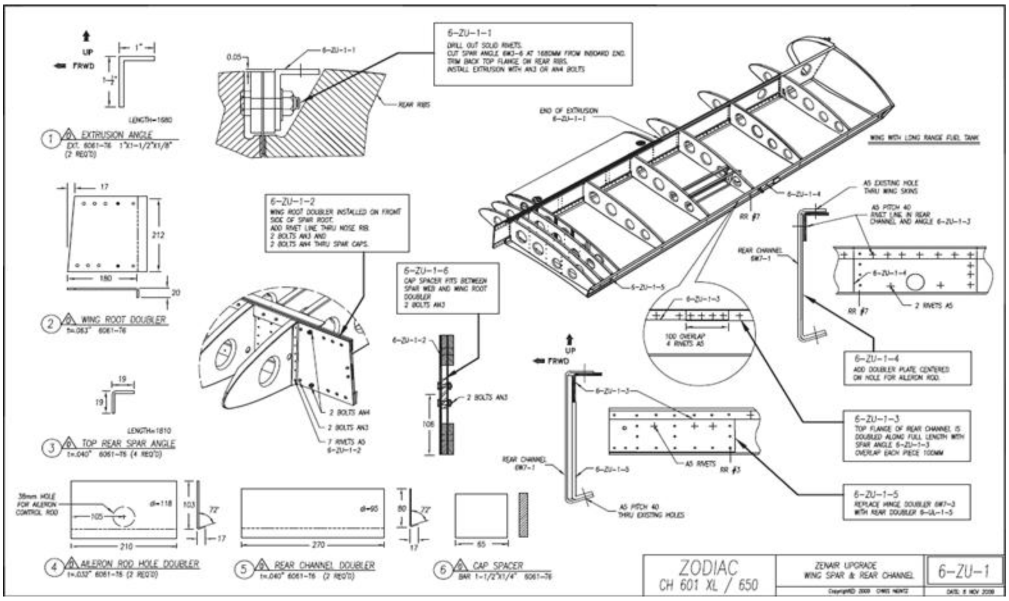

Fig.4 Detailed view of the wing structure

ZODIAC CH 601 Wings are made up of a single cantilevered spar with near full-span non-hinged ailerons. The CH 601 and CH 601 HD models use a simple constant-chord airfoil (NACA 2415 Airfoil M=2.0% P=40.0% T=15.0%) while the CH 601 HDS and the new ZODIAC XL feature tapered ‘speed’ wings.

The profile of the ZODIAC wing is 15% thick (Riblett GA 35-A-415 airfoil). Plan form of this wing is slightly tapered with a straight spar and leading edge. Ailerons and flaps are on the trailing edge as shown in the fig.3.4. The large ailerons provide precise and light roll control. The standard ailerons are attached to the wing with a unique "hinge less" system, flexing the aileron skin which is riveted to the top of the wing trailing edge. Wing dihedral is standard, starting at the fuselage.

Table 3 Wing Details

Component	**Material**	**Element Property**	**No: of element**
Lower Skin	Aluminum	Membrane	36
Upper Skin	Aluminum	Membrane	36
Rib	Aluminum	Shear Panel	39
Spar Flange	Aluminum	Shear Panel	48
Spar Web	Aluminum	Shear Panel	24
Total			183

VI. WING DESIGN

Wing design was carried out in MSC. Patran. Basic design parameters were taken from existing Zodiac aircraft model as shown. Main difficulty in design was the generation of airfoil geometry. In order to achieve the basic airfoil geometry we made the airfoil coordinates as GRID point ID card in *.bdf, and imported those grid points to MSC Patran using import option. From those grid points required curves was generated and followed by top and bottom surface

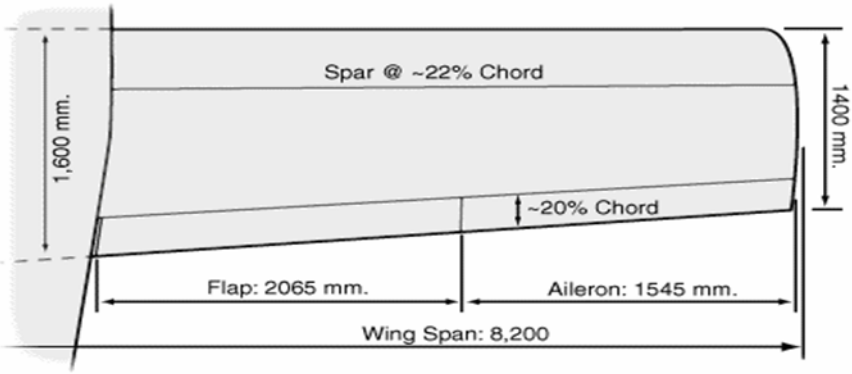

Fig.5 Wing dimensions

Generation of FEM is much important in Dynamic analysis, because of complicated computation procedure. We use Quad4 elements to generate wing model, because of its efficiency to capture the reality to maximum. Certain critical areas triangular elements have used to obtain the continuity. Wing model consist of 183 elements and 78 nodes. Detailed element details has already mentioned in Table 3. We constrained the element number as well as node number to the least because it has to reach the system requirement

VII. NORMAL MODE ANALYSIS

Understanding the basic and fundamentals of vibration analysis are very important in forming solid background to analyze problems on a flexible wing. All systems can be break down into two categories Mass and stiffness. The governing equation behind normal mode analysis is

$$fn = 1/2\pi\sqrt{K/m}.$$

So stiffness and mass will matter while a dynamic run happens. Wing is considered as cantilever beam. So it has to follow the basic dynamic behavior of cantilever beam. Normal model analysis will give proper mode shape as similar as cantilever beam in 7th mode onward in a free run condition. Up to 7th mode it will give the rigid modes of wing.

VIII. RIGID BODY ANALYSIS

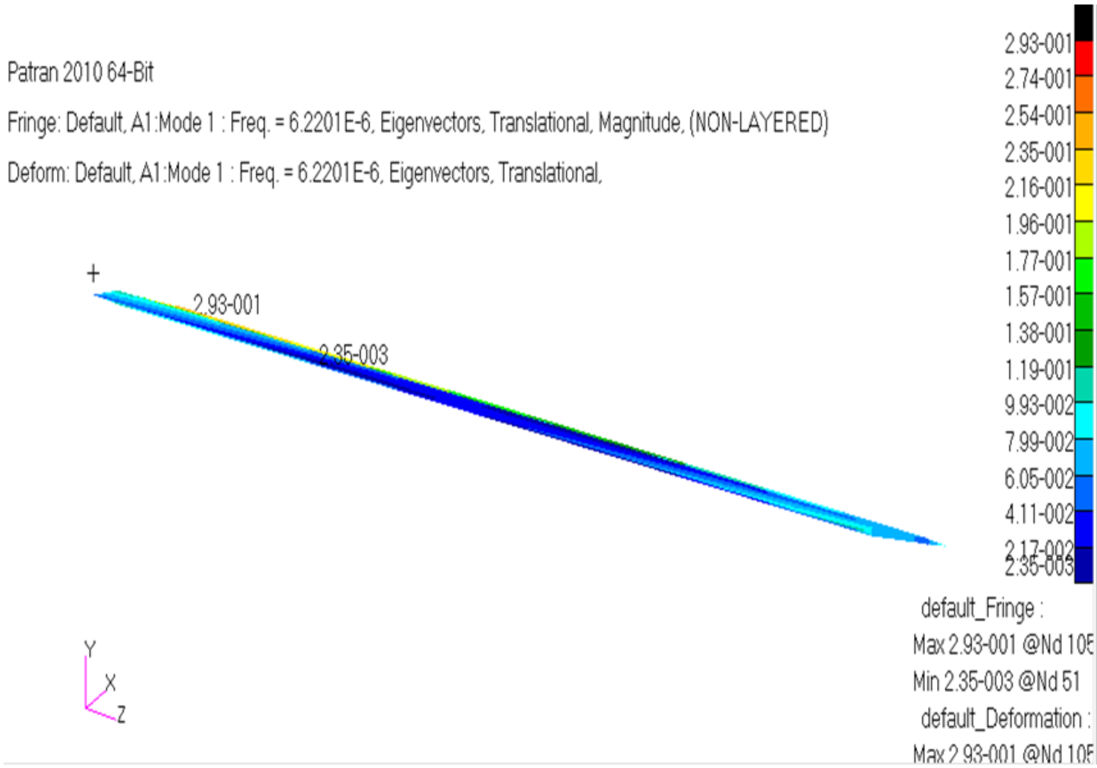

Fig.6 Rotation along Z axis

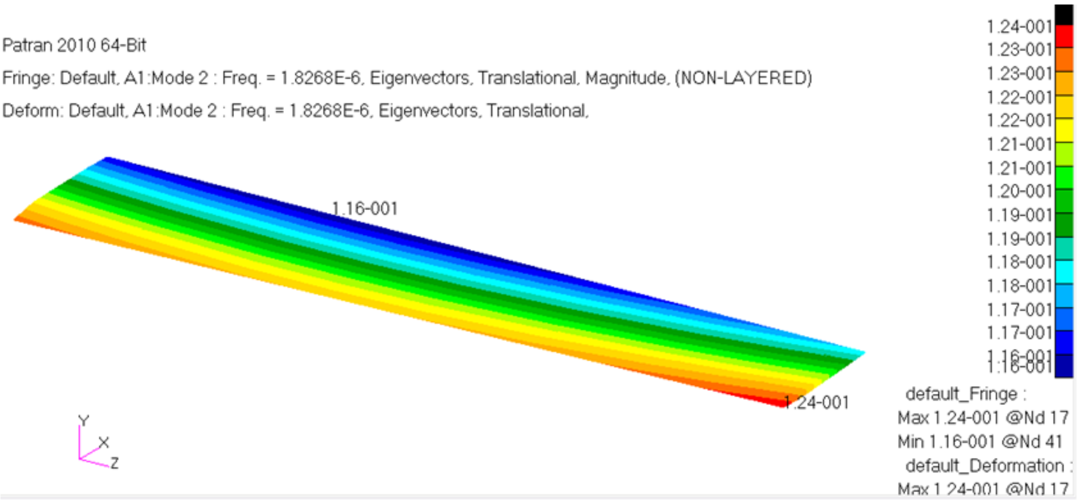

Fig.7 Translation along Z axis

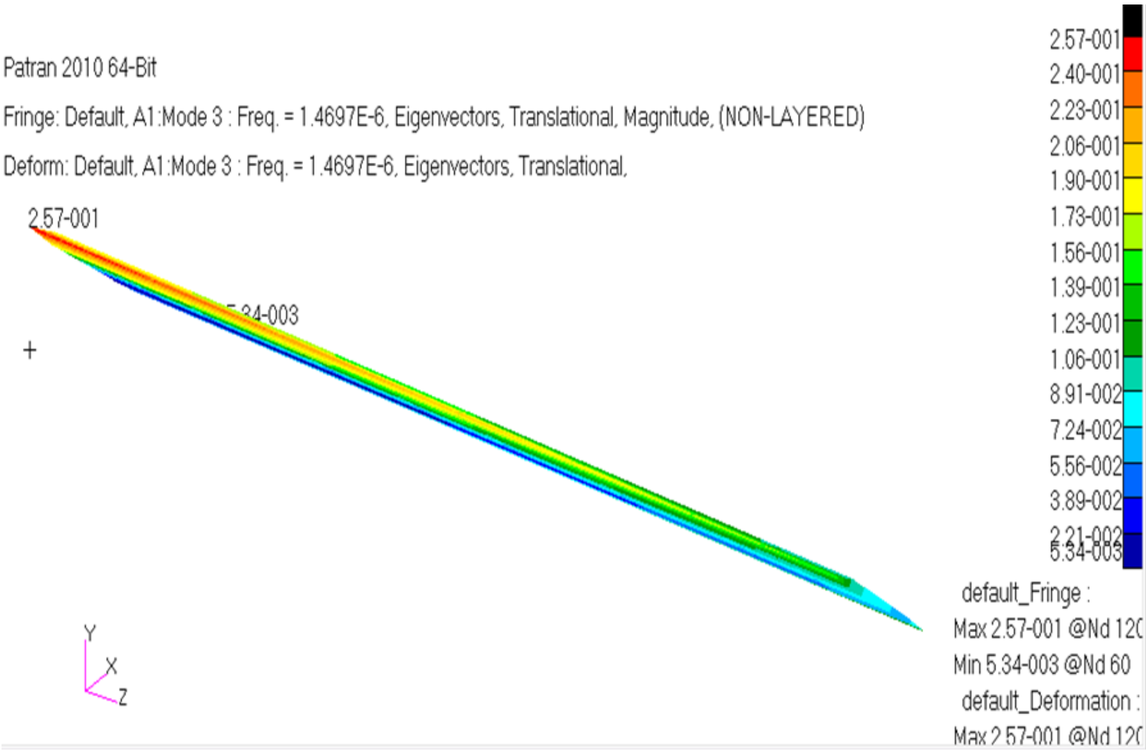

Fig.8 Rotation along X axis

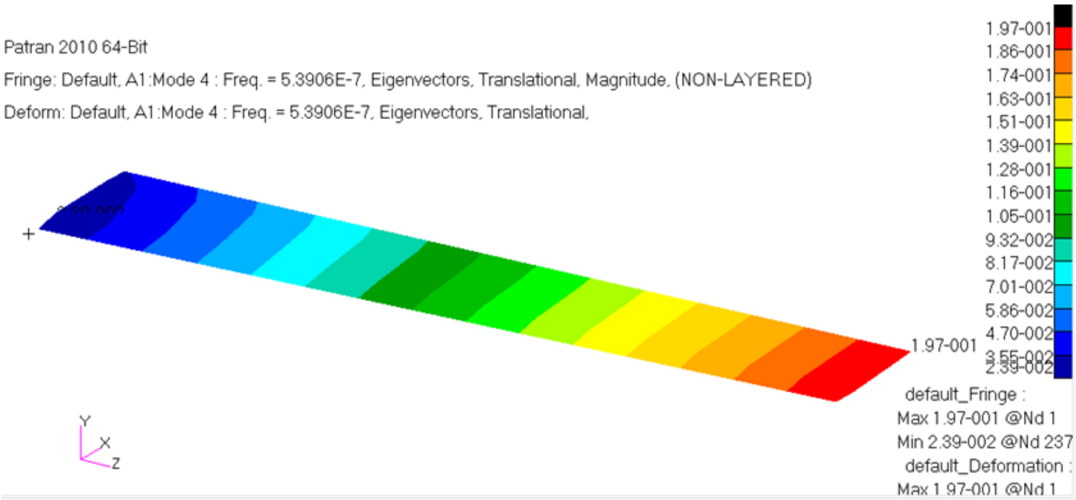

Fig.9 Translation along X axis

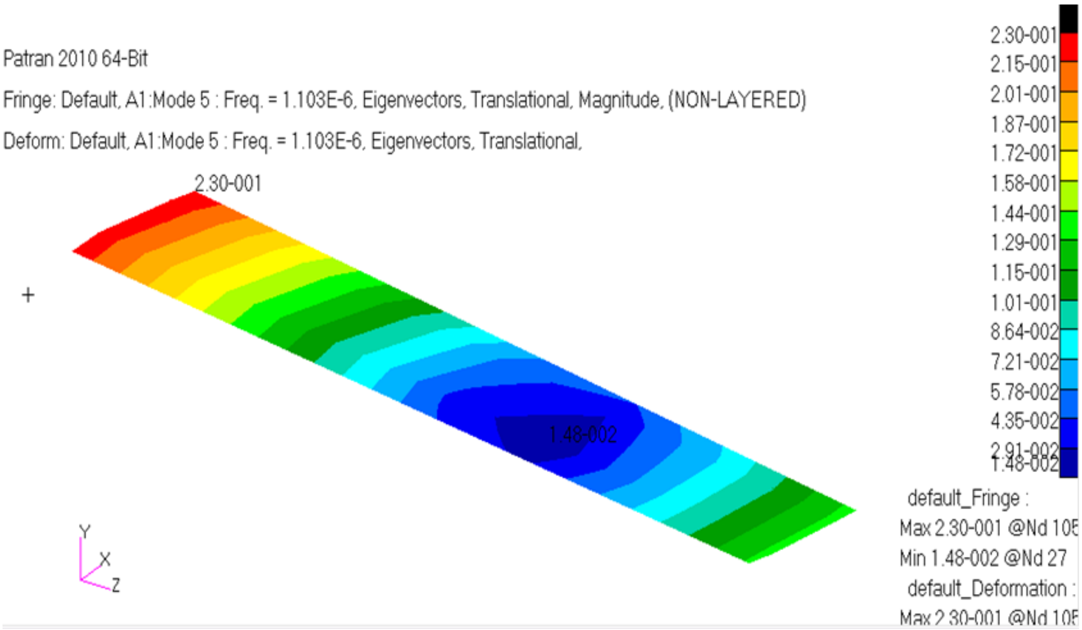

Fig.10 Rotation along Y axis

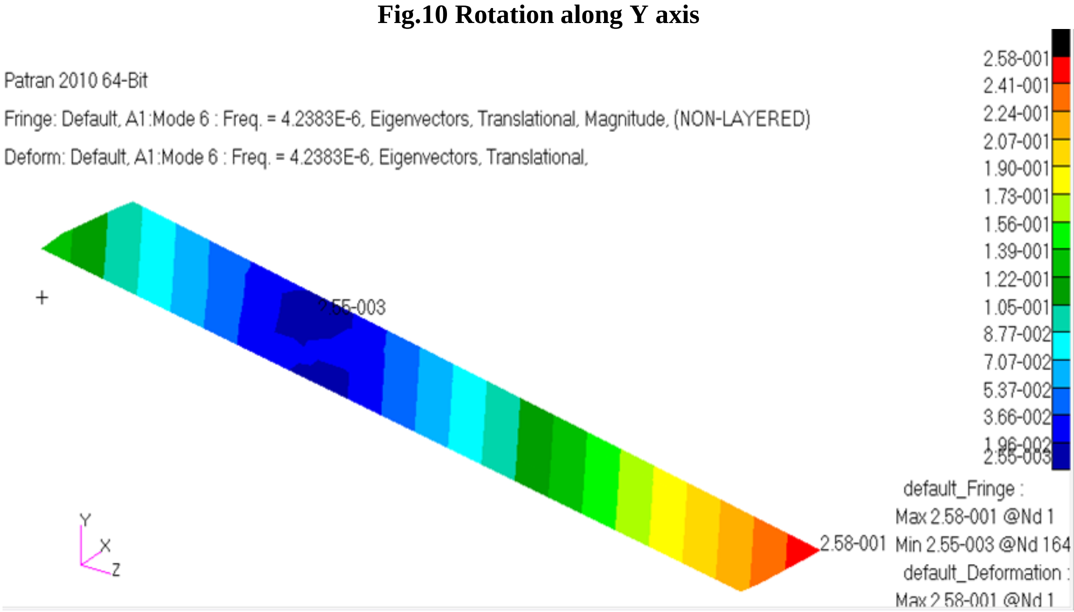

Fig.11 Translation along Y axis

IX. NATURAL FREQUENCY ANALYSIS

They are 6 lateral mode 1st lateral bending mode 2nd lateral torsion 3rd lateral bending 4th lateral torsion mode 5th lateral bending mode 6th lateral torsion mode.

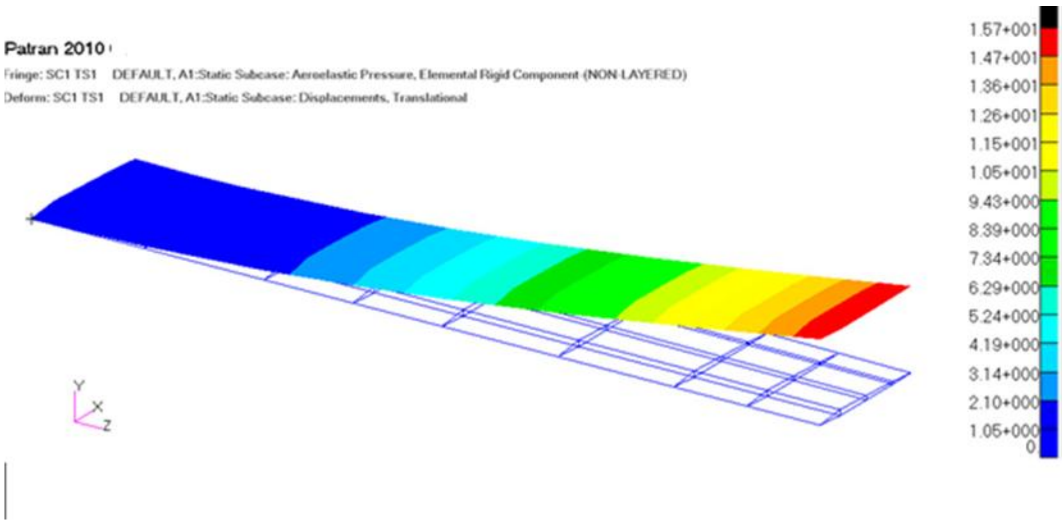

Fig.12 Test result after the design change

Change of sign in damping values from positive to negative. Corresponding speed value for change in sign from positive to negative is the flutter. Maximum displacement occurred on wing tip, and is acceptable

X. RESULTS

From the analysis it is sure that the model is proper, we can go ahead with SOL 103 analysis (Normal mode). In our analysis, we got all the 6 rigid modes in proper manner. This showing that our modelling of aircraft wing is matching with the reality. Always wing will give up with 6 rigid body modes and it the 7th mode should follow the cantilever beam mode shape pattern.

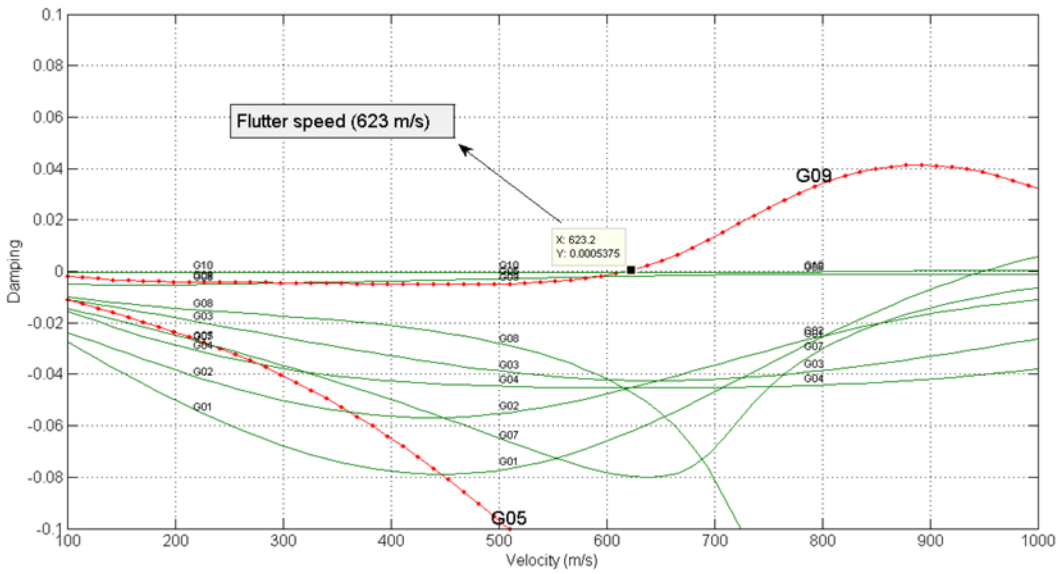

Fig.13 Result

XI. CONCLUSIONS

Based on the evidence and the review of the project we can infer that the rigidity of ZODIAC CH 601XL aircraft wing is very weak. These tests revealed that the wing structure could not sustain the manufacturer's original design loads. This may be one of the primary root causes for the wing's structural deformations and subsequent failures, and may be a potential link to the flutter or vibrations experienced by CH 601 XL operators in flight. Because of the problems with the wing construction, structural rigidity may have affected the wing's fluttering characteristics. It is clear that owners and operators may not fully understand the necessary process.

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