Interim report on projects 2025039, 2026561, mid 3rd year

Numerical Simulation of Flutter Tests

Sponsored by the Civil Aviation Authority of Israel (CAAI), Ministry of Transportation

This research is done in collaboration with the ASSURE[1] program

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January 2022

[1] The FAA's Center of Excellence for UAS Research. ASSURE – Alliance for System Safety of UAS through Research Excellence.

Notice

EXECUTIVE SUMMARY

The study examines novel flutter prediction methodologies that support and enhance the safety of flutter flight tests. The project, done in collaboration with Dr. Matthew McCrink in the Aerospace Research Center of Ohio State University, includes the design and flutter testing of a dedicated UAS configuration. The testbed vehicle is designed to be a research and technology demonstrator, pushing the flutter envelope. Hence, some crashes in flight tests are expected. Taking advantage of 3D printing technology, the vehicle is designed for rapid manufacturing and assembly, in a low cost. The vehicle will be instrumented with inertial measurement units (IMUs) that measure three-axes rates and accelerations and with strain gauges. Data collected in flight will be used for the two proposed flutter prediction methods, which are briefly presented in the Introduction section of this report. The report summarizes the structural and aeroelastic analyses performed for aircraft design.

The focus of the vehicle design are the flexible wings, which are assembled of eight 3D-printed Nylon-12 segments connected by two 6061-T6 aluminum spars. The wings attach to a plywood fuselage with a Polyurethane foam empennage belonging to an existing UAS platform. The flight computer and control surface servo systems are off-the-shelf components. The vehicle's structure was designed to experience flutter within the flight envelope. A unique wing-tip pod with a shaker mechanism was developed for flutter prediction by the Parametric Flutter Margin (PFM) method. The shaker device's inertial properties and installation location were designed to significantly increase the vehicle's flutter speed (relative to that of the baseline configuration, without the shaker) and allow for safe flight at the baseline configuration's flutter speed. The shaker device collects force and acceleration data at a range of airspeeds, including the baseline configuration's flutter speed, from which the flutter speed of the baseline configuration is positively identified.

The report presents the workflow from a conceptual design and detailed Computer-Aided Design (CAD) model to create an accurate finite-element analysis (FEA) model, aeroelastic model, flutter solutions, and numerical flutter test simulations. The proposed vehicle configuration, albeit with stiffer wings, was built and assembled by Dr. McCrink's team at OSU and is currently at its preliminary flight test stage.

The vehicle's structure was modeled using the Nastran finite-element software. Free-vibration analysis provided the dynamical properties of the vehicle. An aerodynamic linear panel model was created in the ZAERO aeroelastic software, also used for flutter analysis.

The modal and aerodynamic models were imported to the Dynresp software, used for numerical flutter simulations and the PFM analyses. The Dynresp-based PFM analysis was expanded to include a sensitivity study of the variation of the flutter characteristics with the mass and location of the wingtip shaker pod. It was shown that the 26 m/s flutter onset speed of the baseline configuration could be pushed to about 34 m/s by moving the added mass location inside the wing tip pod towards the leading edge. Both velocities are inside the flight envelope, thus offering an excellent experimental test case for the safe flutter test methodology.

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1. INTRODUCTION

The purpose of the numerical simulations presented in this work, using the demonstrated tools, is to present an accurate yet agile method for building FEA models for numerical simulation of flutter test that are based on the Parametric Flutter Margin (PFM) method. [1] [2] [3]The first phase of the work is centered in using Solidworks for building an accurate assembly of the UAV with all the parts, from the wings and fuselage to servos, flight computers, and wheels. With that comes the need to define accurately the materials and properties used in the UAV parts. It is important to mention that using such models enables stress-strain analysis, in addition to the dynamic models used in the flutter test simulations.

Based on the CAD model and using FEMAP (NASTRAN Pre & Post Processor), it is possible to import the CAD assembly to FEMAP as geometry objects. Upon them I was able to accurately build and mimic the geometry of the CAD model using manually created FE elements. Deciding on each geometry how could I best represent it using FE, the geometry of every component, including wings, wheels, ailerons, and servos push rods, was transformed to that of the FEM. FEMAP was then used to set up the NASTRAN model, run it for normal modes analysis, and plot the resulted modes.

The f06 file generated using NASTRAN is then used in aeroelastic flutter analysis using ZAERO based on the g-method. [4] The ZAERO input requires the design of aerodynamic panel models for the various aerodynamic component. 3D body models are built for the fuselage and wing tip pods, and flat surfaces models for the wings and tail. Each surface is defined in the same coordinates system as the NASTRAN model and coupled with the respective grid points in the FEA FEMAP model using a proper spline. Then ZAERO can provide the numerical flutter result.

The ZAERO model is used to export the generalized unsteady aerodynamic matrices for subsequent flutter test simulations. Dynresp can then be executed with the NASTRAN's output (f06) file and the aero matrices from ZAERO as input files. Dynresp conducts numerical response simulations from which flutter characteristics are extracted using the PFM method which is explained later.

In its initial version, the PFM method is based on adding a single stabilizing parameter, such as a certain modal damping coefficient or a discrete mass, which increases the flutter stability margins. This version facilitated very efficient massive sensitivity studies with respect to selected stabilizing parameters [2]. Furthermore, it facilitated safer flutter tests where flutter or nonlinear limit-cycle oscillation (LCO) boundaries of a certain configuration are positively identified while testing a more stable configuration.

2. PFM METHOD REVIEW

2.1 Generalized parametric flutter margin (PFM) method

Linear ASE dynamic stability analysis techniques are aimed at finding the flight conditions that define the flutter boundary, at which there is a nontrivial solution to the homogeneous aeroelastic frequency-domain (FD) equation of motion,

$$\left[A(i\omega)\right]\left\{x_L(i\omega)\right\} = \left\{0\right\} \tag{1}$$

where $\left\{x_L(i\omega)\right\}$ is the FD vector of modal displacements, linear control-system states, and actuator states, $\left[A(i\omega)\right]$ is the closed-loop linear system matrix that includes the structural inertial, viscous and stiffness effects, the aerodynamic effects, and the control-system ones. While common flutter solutions, such as that of ZAERO are based on finding the conditions at which $\left|A(i\omega)\right| = (0.,0.)$, the Parametric Flutter Margin (PFM) method is based on FRFs with a stabilizing flutter parameter, p_f, added to the ASE system. Flutter margins are defined by the factored values of p_f that would cause flutter if removed from the modified system. At the flutter boundary of the original system, this factor would be 1.0.

The PFM method was first presented in [1] in its single-input-single-output (SISO) version, in which the selected p_f must be such that its effects can be removed by a SISO control feedback. The p_f parameter that will be used in the proposed flight tests is a concentrated mass at the forward zone of the wing-tip pod. It is assumed that only the vertical (Z) motion of this mass affects the flutter mechanism, such that the SISO PFM version can be used.

2.2 Linear SISO-PFM method

When the flutter parameter is limited to those that can be expresses by SISO feedback loops, a flutter solution that is based on SISO dynamic response functions without resorting to eigenvalue analysis is used. Another important application of the SISO-PFM scheme is in performing safe flutter tests, as discussed in the following chapters.

The input and output vectors in Eq. (2) become scalars in the SISO-PFM formulation,

$$\begin{gathered}\left[\bar{A}_v(i\omega) + B_f P_f C_f\ (i\omega)\right]\left\{x_v(i\omega)\right\} = \left\{B_f\right\} u_f(i\omega) \\ y_f(i\omega) = \left\lfloor C_f\ (i\omega)\right\rfloor\left\{x_v(i\omega)\right\}\end{gathered} \tag{2}$$

Where $\left[\bar{A}_v(i\omega)\right]$ is the original system matrix with all its actual control loops closed, when applicable. It is easy to see that if the open control loop in Eq. (7) is closed by the SISO gain P_f , such that

$$u_f\left(i\omega\right)=P_f y_f\left(i\omega\right) \tag{3}$$

we get the homogeneous equation

$$\left[\bar{A}_v(i\omega)\right]\left\{x_v(i\omega)\right\}=\left\{0\right\} \tag{4}$$

that yields a non-trivial solution at the flutter boundary when $\left|\bar{A}_v(i\omega)\right|=0$. This implies that the interpolated velocity-frequency pair, for which Eq. (4) is satisfied, forms the flutter velocity V_f and the flutter frequency ω_f.

The selected P_f , and the associated single output and single input parameters of Eq. (3), yield frequency response functions to sinusoidal inputs of amplitude $u_f(i\omega)=1.0$. The FRFs may presented as Bode plots by their gain and phase variations with frequency

$$G(\omega)=20\log\left|P_f y_f(i\omega)\right|[dB]; \quad \Phi(\omega)=\angle\left(P_f y_f(i\omega)\right)[\deg] \tag{5}$$

The original PFM method [1] used these gain and phase expressions as a basis for calculating flutter gain margins. The Bode plots are generated for selected points along a line in the flight envelop. The points can be of various air velocities at constant altitude, and various altitudes along a constant Mach line. In a search for non-match flutter conditions at constant altitude and Mach number, the phase function at each flight velocity is used for finding the associated phase-crossover frequencies ω_{co} at which $\Phi(\omega_{co})=\pm 360^o n$. The gains at these frequencies form the parametric flutter margins $PFM=-G(\omega_{pco})$. The velocity and phase-crossover frequency for which PFM=0dB are V_f and ω_f . The associated solution of Eq. (2) is the flutter mode $\left\{x_f(i\omega)\right\}$.

The Dynresp framework provides for using a selected ASE response parameter, y_f, which can be defined as a frequency-dependent linear combination of the system states and control inputs, as a "sensor". When the selected P_f is an actual control gain, the stability analysis in Dynresp provides the standard Nyquist SISO control gain and phase margins [8], with aeroelastic effects of course.

An alternative flutter margin, which may be more useful in flutter tests, is defined as the incremental flutter parameter ΔP_f that, if added to the nominal system, would bring it to the verge of flutter. This definition implies

$$\left(P_f - \Delta P_f\right) y_f(\omega_{co}) / u_f(\omega_{co}) = 1 \quad \Rightarrow \quad \Delta P_f = P_f - u_f(\omega_{co}) / y_f(\omega_{co}) \tag{6}$$

where $u_f(\omega_{co})$ is not necessarily (1., 0.), to accommodate arbitrary input amplitude and phase in the test.

An example of added flutter parameter P_f that can be practically used in the planned flutter flight tests is a concentrated mass located at a "good" place that increases the flutter velocity. It is assumed here that the mass effect of flutter is significant only in one direction, i.e., normal to the lifting surface. An excitation u_f force is applied at this location and a co-located acceleration measurement y_f is taken, both in the effective direction. The PFM method is applied with these parameters, at selected flight velocities, to find ω_{co} and calculate the increment ΔP_f of Eq. (6). This increment is now the added mass Δm that would cause flutter at the selected flight velocity. At flight conditions where $\Delta m < P_f$, the tested configuration is stable. However, the removal of $P_f - \Delta m$ would make it unstable. In this way, by testing a stable configuration, we can positively map the unstable regions of other configurations.

3. FLUTTER PREDICTION BY SYSTEM IDENTIFICATION AND A FLUTTER STABILITY CRITERION

The most straightforward and commonly used approach to flutter prediction is to characterize the dynamic aeroelastic system based on measured structural responses at sub-critical conditions and track the system's damping [5]. The drawbacks of this so called Modal Damping Extrapolation (MDE) approach are that the damping values are difficult to predict accurately, and that the significant decrease of damping might only occur very close to flutter onset. This could risk the platform in cases of hard flutter with abrupt switching from positive to negative damping. As a result, several flutter prediction methods were developed that rely on a stability parameter (other than the damping value) that varies as a known, smooth function of the dynamic pressure. The stability parameter can be estimated based on the structural response at lower, safe, dynamic pressures and tracked (extrapolated) to predict the flutter onset conditions.

The process of flutter prediction based on tracking a stability parameter can be divided in two: Learning the aeroelastic system's dynamics from structural responses at pre-flutter conditions, and computing and extrapolating the stability parameter to predict the flutter onset conditions.

Zimmerman and Weissenburger [6] proposed the Flutter Margin (FM) stability parameter that is computed from the identified frequencies and damping values of a two degrees of freedom (DOF) aeroelastic system. For a certain dynamic pressure value, the FM predicts how much stability is left in the system based on the measured system's frequencies and damping at that dynamic pressure. The FM reduces monotonically with the dynamic pressure, thus it is a better indicator of flutter closeness than the damping values. Zimmerman and Weissenburger show that when the terms of the characteristic equation of the system (from which the frequencies and damping values are computed) are expressed as analytical functions of the configuration parameters and the product $C_{L\alpha}q$ (lift coefficient times the dynamic pressure), the FM is a quadratic function of $C_{L\alpha}q$. For cases of fixed $C_{L\alpha}$, the expression for the FM, which Zimmerman and Weissenburger term 'the flutter prediction equation' is a quadratic function of the dynamic pressure itself. When this is the case, the quadratic flutter prediction equation can then be extrapolated to find the dynamic pressure for which FM=0, which is the estimated flutter onset speed. Thus, Zimmerman and Weissenburger's FM concept offers two valuable pieces of information: 1) the margin from flutter onset at a given dynamic pressure value, and 2) flutter dynamic pressure onset prediction by extrapolation of the FM function to zero. Zimmerman and Weissenburger's FM was derived under several restricting assumptions. Namely, it applies to aeroelastic systems that behave as analytical two DOF systems of fixed lift coefficient, fixed center of pressure, and with no structural damping. The derivation also neglects the oscillatory terms in the aerodynamic forces (to which Zimmerman and Weissenburger offer a correction, and note that the effect is small).

For discrete time description of the aeroelastic system, which suits measured responses in a wind-tunnel or flight tests, Matsuzaki and co-authors [7] proposed a flutter stability parameter that is a function of the Jury stability criterion. The aeroelastic system's dynamics is presented as an autoregressive moving-average (ARMA) process, with coefficients that are identified from time-history data of the system's dynamic response. The advantage of the ARMA modeling for flutter testing is that it is based on responses to initial conditions and therefore does not require a dedicated excitation system (this is in comparison to Zimmerman and Weissenburger, for example, where the system's dynamics were extracted from resonance responses). The ARMA model also accounts for excitation noise, e.g., atmospheric turbulence disturbances. The stability criterion is then computed from the AR coefficients. Matsuzaki and Ando also presented a modified stability parameter, the Fz, that is shown to behave similar to the FM parameter (for a two DOF system and small sampling times [8]). They demonstrate how extrapolation of a least-square straight-line fitting to the stability criterion at pre-flutter dynamic pressure values accurately points to the flutter onset. Because the stability criteria are derived for a two DOF system, the ARMA modeling was restricted to this model order (i.e., ARMA model of four). Several studies demonstrated the use of ARMA modeling together with the Jury stability criterion for flutter prediction based on computational or experimental data. [9] [10]

In experimental cases, the structural responses used for system identification are typically accelerations or strains, measured by several accelerometers or strain gauges attached to the structure. In the ARMA modeling approach, the ARMA model coefficients, and hence the system dynamic properties, are evaluated from a single response time history. When several responses are available, they have to be somehow accounted for simultaneously, to provide the best single representation of the system dynamics. Nahom-Jidovetski et al. [11] proposed a root-classification procedure that averages the ARMA model coefficients from data that yield roots that are stacked together closely. This approach was tested in a dedicated wind-tunnel experiment, in which accelerations and strains were recorded at several wing locations in response to turbulence excitation in the tunnel. The root classification technique, together with two DOF ARMA modeling, and the Fz and FM stability criteria, yielded accurate flutter predictions. This approach was also examined in an experimental study, conducted by the Israel Air Force [12], that assessed several advanced flutter flight-test techniques, including the ARMA modeling, with various stability parameters. Iovnovich et al. also examined an Operational Modal Analysis (OMA) approach, in which the aeroelastic dynamic parameters were estimated based on multiple response data and then used in the FM for flutter onset prediction. The study concluded that the ARMA approach was easier to implement and straightforward to use in real time. In this study too, the ARMA model was of order four, corresponding to two DOF modeling of the aeroelastic system, to fit the assumptions for which the stability criteria were derived.

Argaman and Raveh [10] suggested to use Multi-Output Autoregressive (MOAR) system identification. In this approach, several response data are used simultaneously to achieve the best single AR model of the system dynamics (this is, instead of averaging the dynamics from several ARMA models, as done in Refs. [11] and [12]). Argaman and Raveh demonstrated the method on three computational test cases. The Fz stability parameter was assessed based on the frequencies and damping values of the two modes that participate in flutter.

In the current study, we propose to use the ARMA system identification method with multiple channels experimental data for Multi-Output ARMA (MOARMA) identification of the aeroelastic system at pre-flutter speeds. We treat the system identification and flutter prediction parts separately. For the system identification, a best model-order is fitted, which physically accurately accounts for participation of several structural modes as well as for aerodynamic lag terms. The modes participating in flutter are tracked and their properties are used for flutter prediction using the FM. The detailed mathematical model is provided in

Ref. [10]. The method takes advantage of the large data that is nowadays available from fiber optic sensors (FOS) that could hold many sensors on a single fiber. Since the FOS interrogation system is highly expensive, the current study will be based on data from multiple strain gauges and IMUs.

4. CONCEPTUAL DESIGN AND FLUTTER ANALYSIS OF OSU VEHICLE

3.1 Conceptual design

The design concepts were discussed in a preliminary meeting held with Prof. Jim Gregory and Dr. Matt McCreenk of Ohio State University (OSU) at Technion, December 2018, at the SciTech conference in January 2020 and in Zoom meetings since. OSU has a UAV with single electric engine to which they are going to replace the wing with a 3.3*m*-span flexible one. It is planned to be a straight wing with two uniform spars on which 3D-printed segments, wrapped by a transparent skin, will be installed following the structural design concept of the wings of Technion's A3TB UAV. [13] A detailed SolidWorks CAD model was created by Dr. Matt McCrink and his team. Based on their CAD model I manually created highly detailed FEA model in FEMAP for further numerical analysis using NASTRAN.

A general view of the planned test vehicle is given in Figure 6. Each wing will be constructed with 8 segments. There will be two types of segments shown in Figure 7. Six of the segments will be without ailerons and 2 (No. 6 and 7 from the root) with ailerons. The two aileron segments will be interconnected and driven by a single actuator. The tip pods are designed to carry the shaker system with the needed batteries and controllers. As shown in the flutter analysis below, the shakers are placed in a forward point of each tip pod to move the flutter velocity up and provide the excitation needed for identifying the nominal flutter velocity using the PFM method. There is sufficient room in the tip pods to place the shaker components in a favorable symmetric or a-symmetric manner, as discussed later.

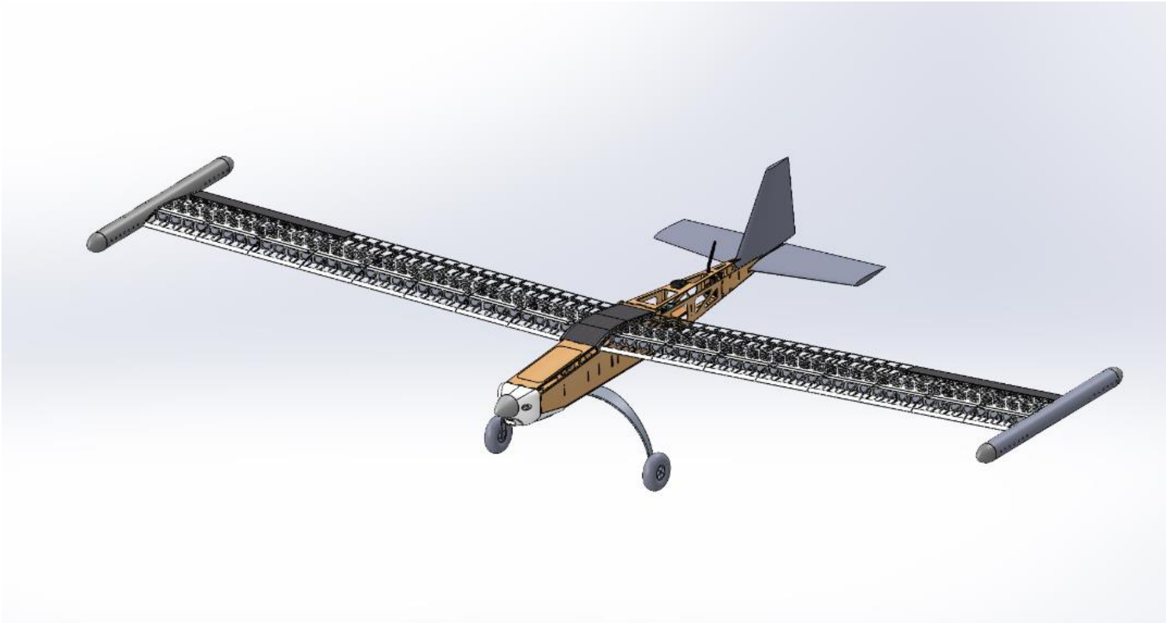
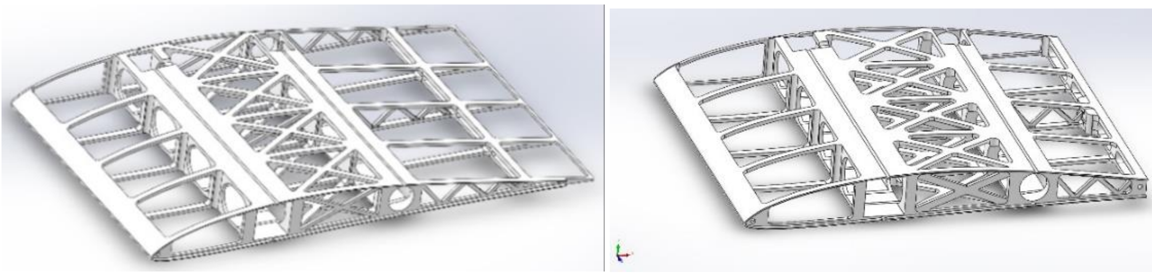


Figure 6: General view of the test vehicle CAD model



Figures 7-8: Two types of wing segments: without (right) and with (left) aileron.

3.2 Detailed finite element model

FEMAP was first used for manually constructing a detailed model that follows the CAD drawings while representing the actual structural parts by NASTRAN's finite elements. A general view of the detailed model is shown in Fig 9 and the vehicle general properties are listed in Table 1. Table 2 is the matching model weight table of the entire vehicle generated by NASTRAN in FEMAP. It is based on 9,162 grid points that yield more than 50,000 degrees of freedom (DOF). The tip pod is represented by a circular tube beam along its centerline. Seven different material properties are used: ULTEM 9085 for the Wing 3D-printed structure, OraCover Light for the wing cover, 6061-T6 (Aluminum Alloy) for the two wing spars and landing gear, Plywood for the fuselage, T300 carbon fiber for the wing flaps, E-Glass-Fiber for the wing tip pod case and Polyurethane Foam Rigid for the tail. The element material properties for the various parts are given in Table 3,4,5.

Specifications:	Value
Weight	12.5 Kg.

Wingspan	3500 mm
Aspect Ratio	10.51
Chord length	333 mm

Table 1: OSU-ASSURE specifications

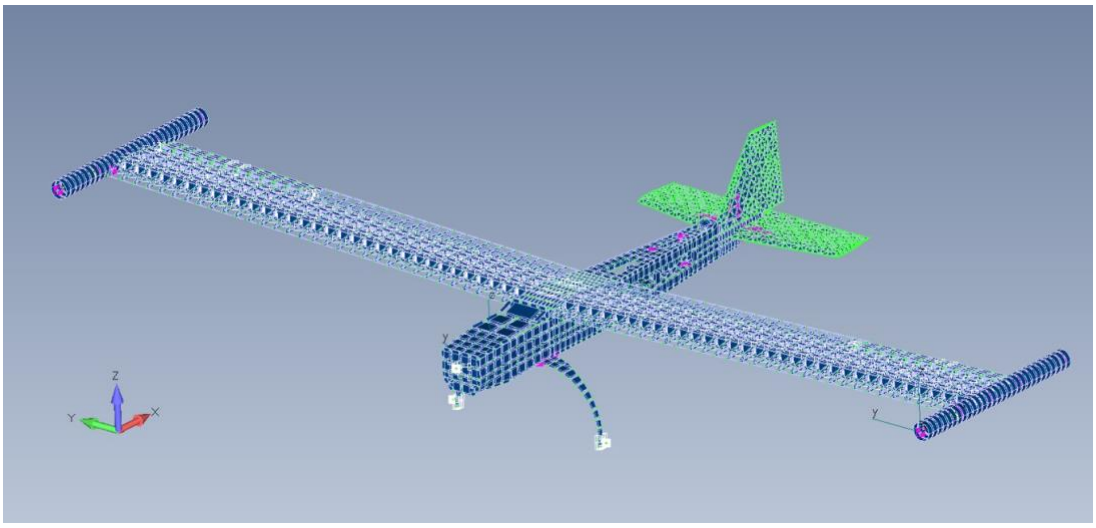


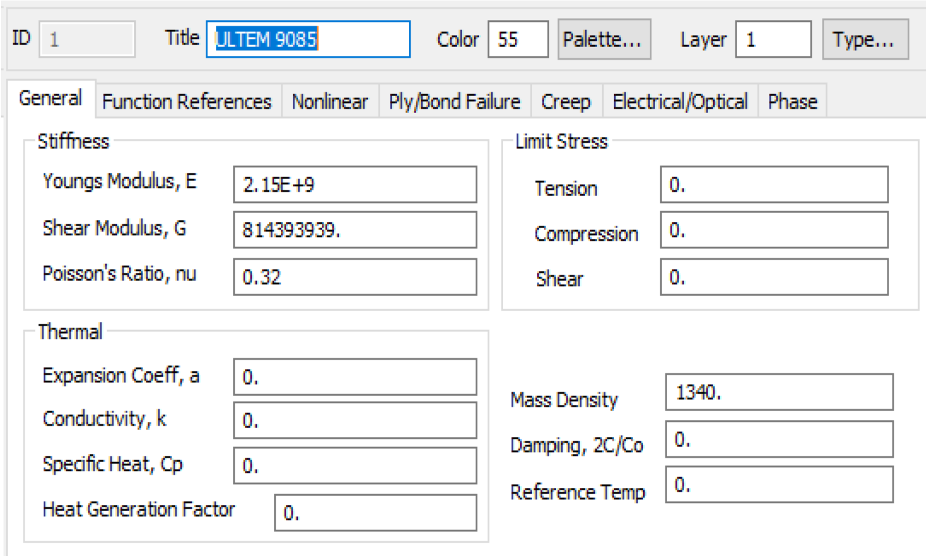
Figure 9: Detailed NASTRAN finite-element model in FEMAP

	Mass	X	Y	Z		
		Center of Gravity				
Structural	12.48715	0.399023	-2.4486E-5	0.0682939		
NonStructural	0.	0.213077	-0.704341	-1.108221		
Total	12.48715	0.399023	-2.4486E-5	0.0682939		
Inertias	Ixx	Iyy	Izz	Ixy	Iyz	Izx
About CSys	10.62637	3.31405	13.58358	0.00066646	-4.7877E-6	0.349063
About CG	10.56813	1.267612	11.59538	7.88466E-4	1.60939E-5	0.0087774

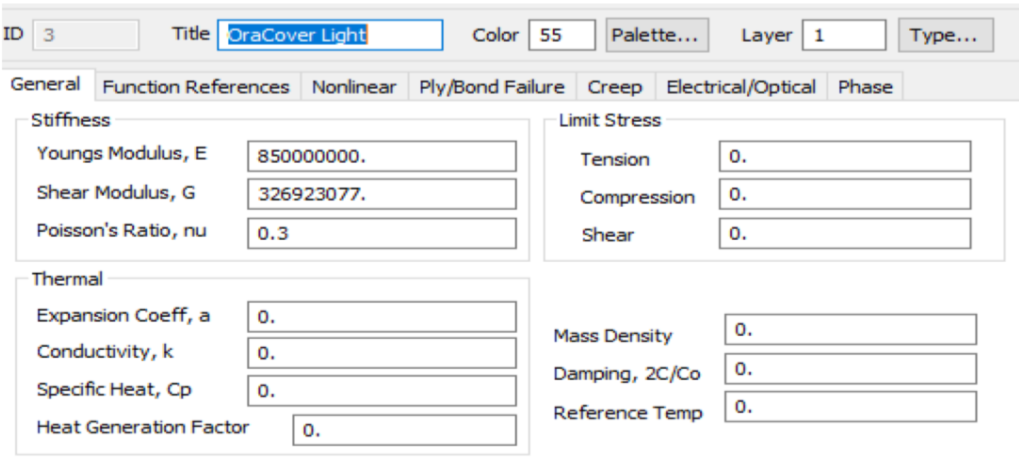
```
Total_Length (Line_Elements_only) =      145.5229
Total_Area   (Area_Elements_only) =       2.92616
Total_Volume (All_Elements)       =     0.0129546
```

Table 2: Model's mass table generated by FEMAP

- *ULTEM 9085 (Nylon 12)*: For the wing 3D-printed skeleton



- *OraCover Light*: For the wing skin



- *6061-T6:* for the wing spars and landing gear.

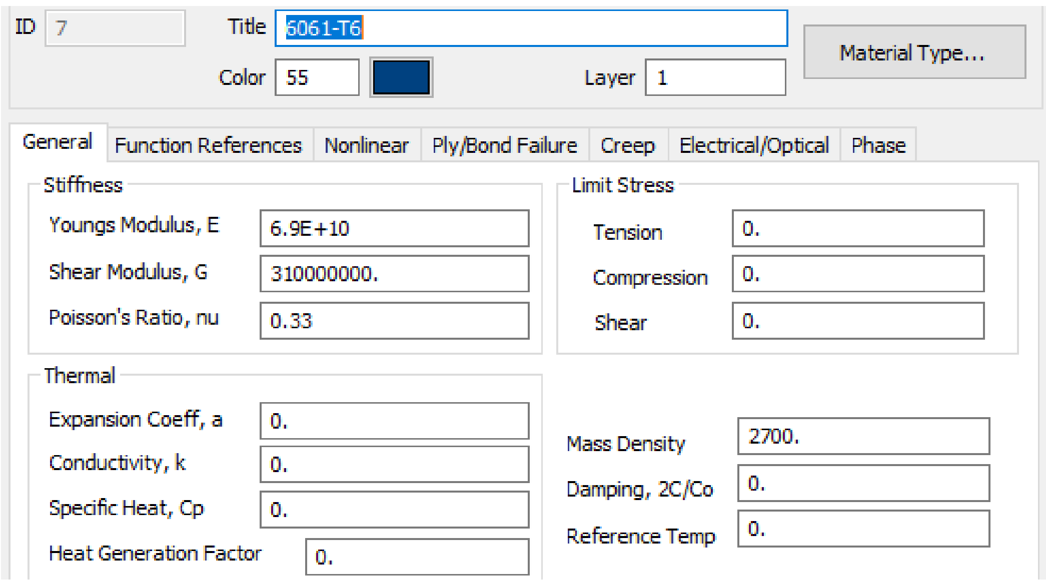
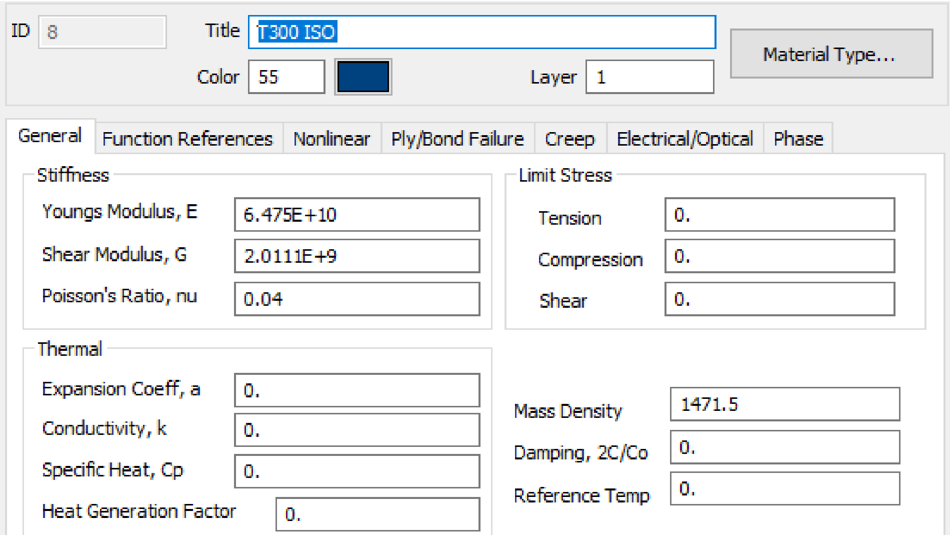
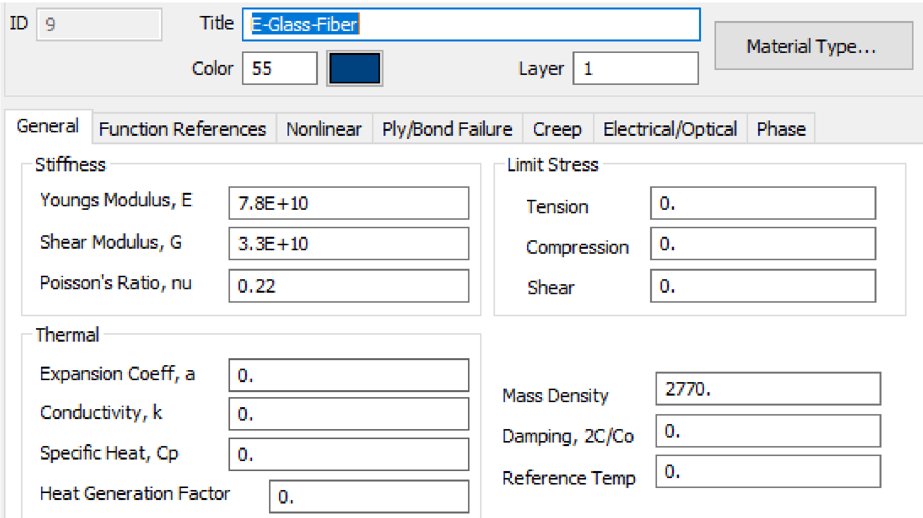


Table 3: Material properties, wing

- *T300 ISO*: For the wing Flaps



- *E-Glass-Fibre*: For the wing tip pod case



- *Polyurethane Foam Rigid*: for the Tail.

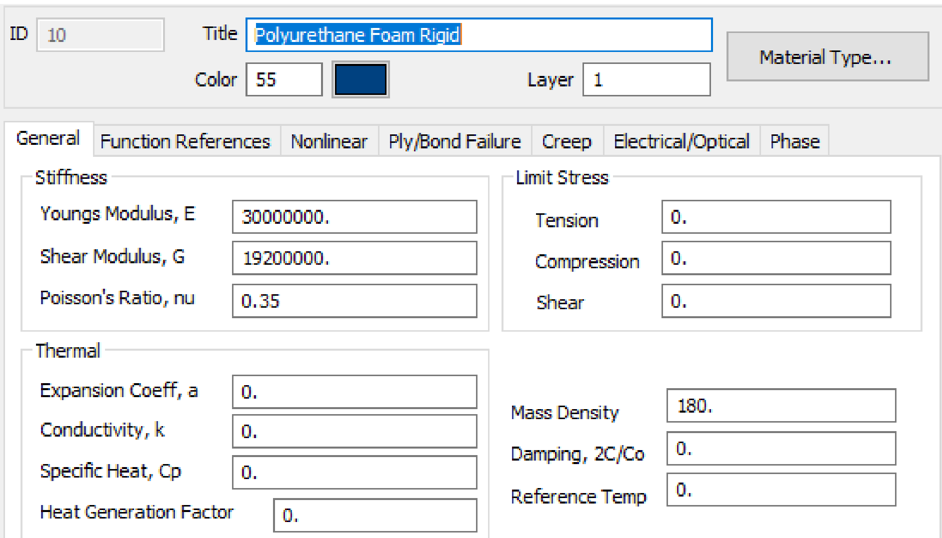


Table 4: Material properties, flaps, pod, and tail

- *Plywood*: For the fuselage

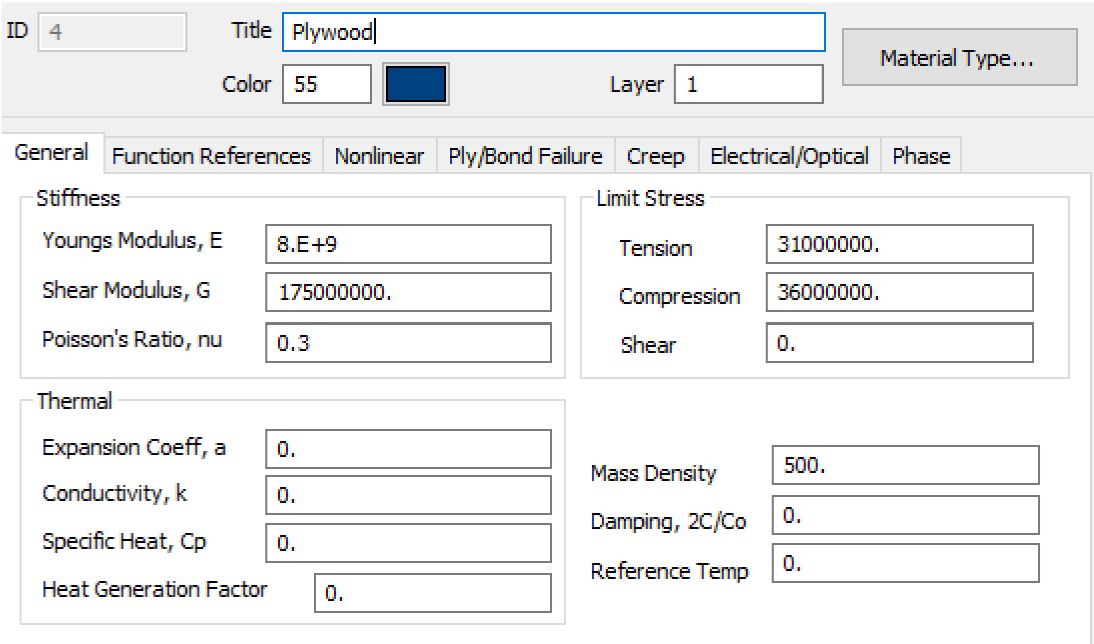


Table 5: Material properties, fuselage

3.2 Finite element model properties

The FEMAP model contains several main parts.

<u>The Wings:</u>

The wings are made from ULTEM 9085 3D-printed sections and 2 main 6061-T6 SS spars. In addition, carbon fibre flaps are attached to the wing last 4 sections. Thus, each wing is assembled from a total of 8 3D-Printed sections where the first 4 are without flaps TE cutout and the last 4 sections are with a proper cutout for the carbon fibre flaps. The model contains the actuators, hinges etc. the wing tip is made from E-Glass-Fibre and contains the masses of the internal components including the shaker. Figure 10 shows the complete FE NASTRAN model of the wings span, Including all the components. Table 6 is the matching model weight table of the entire wings span generated by NASTRAN in FEMAP.

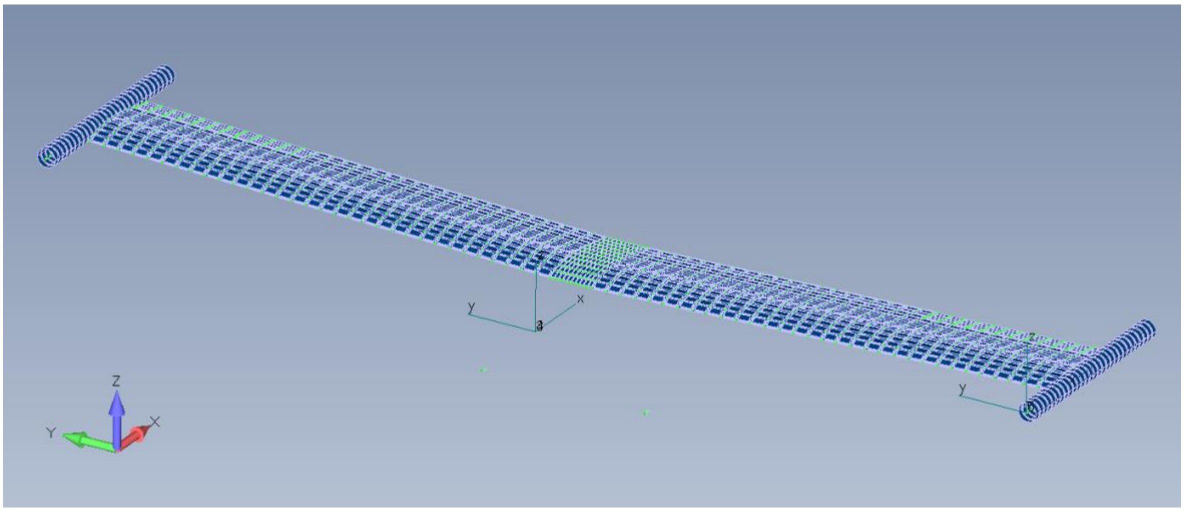


Figure 10: General view of the Wing finite-element model

		Center of Gravity				
	Mass	X	Y	Z		
Structural	6.969876	0.359399	-3.0348E-5	0.124985		
Nonstructural	0.	0.213077	-0.704341	-1.108221		
Total	6.969876	0.359399	-3.0348E-5	0.124985		
Inertias	Ixx	Iyy	Izz	Ixy	Iyz	Izx
About CSys	9.381027	1.084555	10.24142	7.24196E-4	-2.847E-5	0.313798
About CG	9.272149	0.0753938	9.341138	8.00217E-4	-2.0333E-6	7.15621E-4

Total_Length (Line_Elements_only) = 128.9138
Total_Area (Area_Elements_only) = 0.215364
Total_Volume (All_Elements) = 0.00351104

Table 6: Wings span model mass table generated by FEMAP

The Fuselage:

The Fuselage is made from Plywood, includes the front engine, landing gear with wheels, and the flight computer & servos mass. Figure 11 shows the complete FE NASTRAN model of the fuselage, Including all the components. Table 7 is the matching model weight table of the entire fuselage generated by NASTRAN in FEMAP.

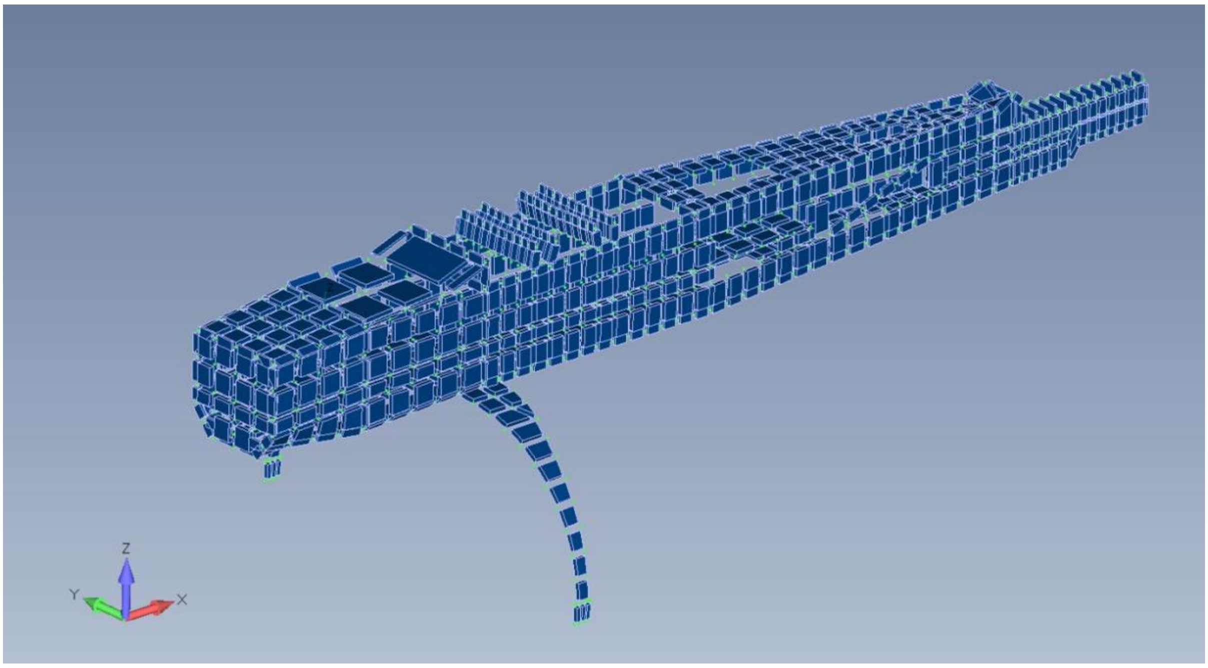


Figure 11: General view of the Fuselage finite-element model

	Mass	Center of Gravity X	Center of Gravity Y	Center of Gravity Z
Structural	3.681499	0.361012	2.92288E-5	-0.0450853
NonStructural	0.	0.213077	-0.704341	-1.108221
Total	3.681499	0.361012	2.92288E-5	-0.0450853

Inertias	Ixx	Iyy	Izz	Ixy	Iyz	Izx
About CSys	0.11062	1.035012	1.050031	2.32401E-4	5.39214E-5	-0.0231975
About CG	0.103137	0.547719	0.570222	1.93554E-4	5.87728E-5	0.0367239

Total_Length	(Line_Elements_only) =	16.19379
Total_Area	(Area_Elements_only) =	0.70319
Total_Volume	(All_Elements) =	0.00512123

Table 7: Fuselage model mass table generated by FEMAP

Wing-Tip pod Mass Configuration:

There are 3 suggested position configurations of the shaker and the batteries inside the wing tip pod, as presented in Figure 12. They will be referred to as cases 1-3. Marking reference are:

1 – Shaker = 133 gr

2 – Shaker Housing (including control board) = 80 gr

3 – Batteries = 150 gr

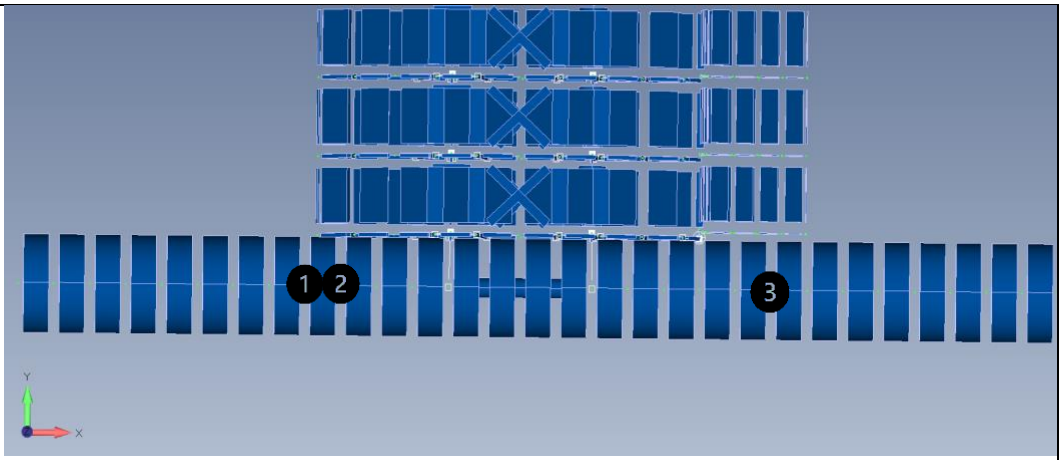
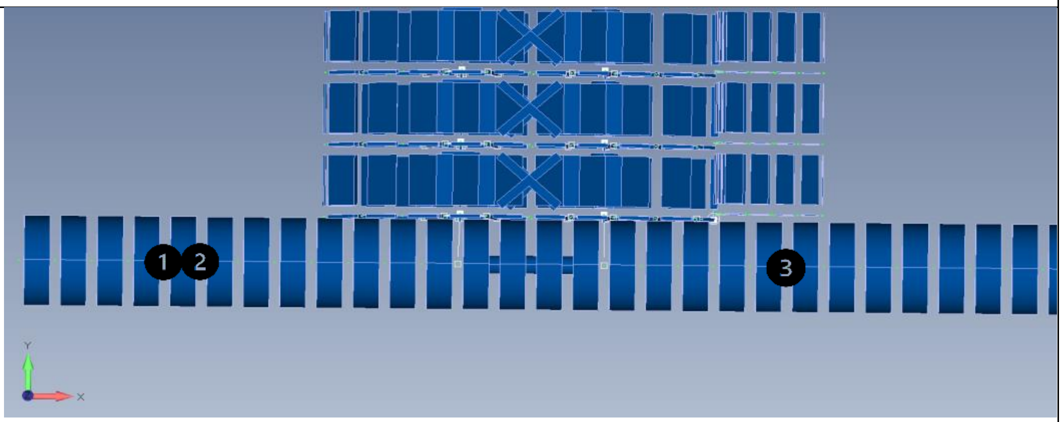
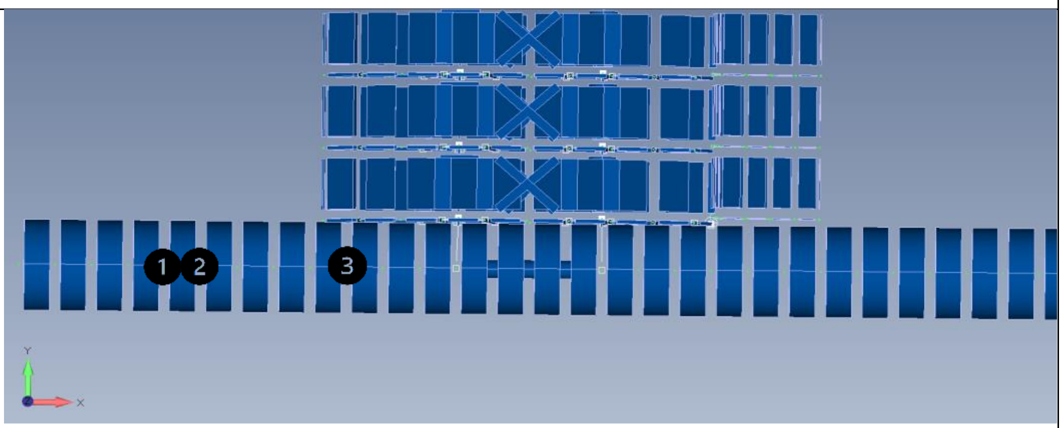
Case 1	
Case 2	
Case 3	

Figure 12: Mass configurations of the wing tip pod

3.3 Natural frequencies and normal modes

Normal modes were calculated for three mass configurations (Cases 1-3), the nominal one described above, and two modified ones with moved shaker/batteries mass at the forward point of the wing-tip pod section. The pod masses in these cases are placed symmetrically, such that the entire UAV is symmetric with respect to the center plane. As a result, all the natural modes are either symmetric (sym) or antisymmetric (Anti). The various configurations will be used later in the project to optimize the mass placement positions inside the pod. The resulting fundamental frequencies and mode descriptions are given in Table 8.

Mode Number	Case 1 [Hz]	Case 2 [Hz]	Case 3 [Hz]	Description
1-6	0.00	0.00	0.00	Rigid body
7	5.129	5.167	5.376	1st bending - Sym
8	6.135	6.177	6.569	1st torsion – Anti
9	6.464	6.717	6.846	1st torsion – Sym
10	14.10	14.21	14.19	1st bending – Anti
11	15.86	16.06	16.01	1st Tail bending - Anti
12	16.99	17.00	17.00	1st Tail bending - Sym

Table 8: OSU ASSURE Model fundamental natural frequencies

The eigenvalue table of NASTRAN's normal modes analysis of the nominal configuration (Case 1), with the natural frequencies, generalized masses and stiffness properties, are given in Table 9. The first 6 rigid-body frequencies are practically zero. The mode shapes associated with the first 6 non-zero frequencies are shown in Figure 13.

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	-7.993767E-06	2.827325E-03	4.499828E-04	1.000000E+00	-7.993767E-06
2	2	-2.072447E-06	1.439600E-03	2.291194E-04	1.000000E+00	-2.072447E-06
3	3	-9.395243E-07	9.692906E-04	1.542674E-04	1.000000E+00	-9.395243E-07
4	4	2.126359E-08	1.458204E-04	2.320804E-05	1.000000E+00	2.126359E-08
5	5	1.080220E-06	1.039336E-03	1.654155E-04	1.000000E+00	1.080220E-06
6	6	3.938488E-06	1.984562E-03	3.158529E-04	1.000000E+00	3.938488E-06
7	7	1.038882E+03	3.223169E+01	5.129832E+00	1.000000E+00	1.038882E+03
8	8	1.485936E+03	3.854784E+01	6.135080E+00	1.000000E+00	1.485936E+03
9	9	1.649962E+03	4.061972E+01	6.464830E+00	1.000000E+00	1.649962E+03
10	10	7.849723E+03	8.859866E+01	1.410091E+01	1.000000E+00	7.849723E+03
11	11	9.939616E+03	9.969763E+01	1.586737E+01	1.000000E+00	9.939616E+03
12	12	1.140404E+04	1.067897E+02	1.699611E+01	1.000000E+00	1.140404E+04
13	13	1.451592E+04	1.204820E+02	1.917531E+01	1.000000E+00	1.451592E+04
14	14	1.708518E+04	1.307103E+02	2.080319E+01	1.000000E+00	1.708518E+04
15	15	1.782722E+04	1.335186E+02	2.125015E+01	1.000000E+00	1.782722E+04
16	16	2.539453E+04	1.593566E+02	2.536239E+01	1.000000E+00	2.539453E+04
17	17	2.625681E+04	1.620395E+02	2.578939E+01	1.000000E+00	2.625681E+04
18	18	2.987933E+04	1.728564E+02	2.751095E+01	1.000000E+00	2.987933E+04
19	19	3.099014E+04	1.760402E+02	2.801766E+01	1.000000E+00	3.099014E+04
20	20	3.215843E+04	1.793277E+02	2.854089E+01	1.000000E+00	3.215843E+04
21	21	4.803369E+04	2.191659E+02	3.488134E+01	1.000000E+00	4.803369E+04
22	22	4.883419E+04	2.209846E+02	3.517079E+01	1.000000E+00	4.883419E+04
23	23	5.199020E+04	2.280136E+02	3.628949E+01	1.000000E+00	5.199020E+04
24	24	5.366305E+04	2.316529E+02	3.686870E+01	1.000000E+00	5.366305E+04
25	25	5.500435E+04	2.345301E+02	3.732662E+01	1.000000E+00	5.500435E+04

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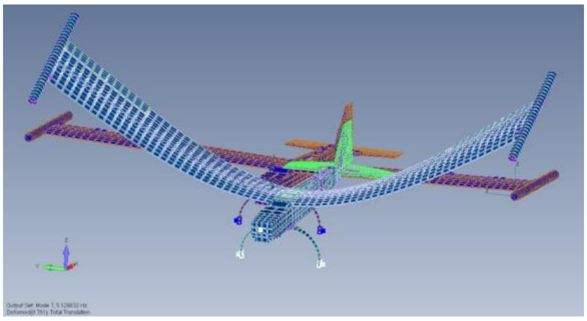
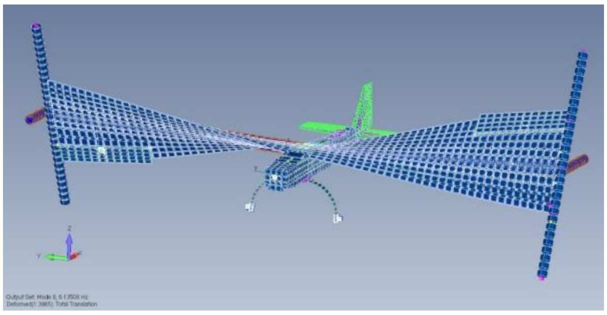
Table 9: Natural frequencies from normal-mode analysis

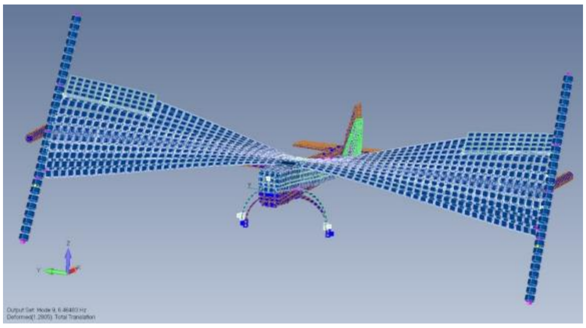
1. 1st Sym wing bending – 5.129832 Hz



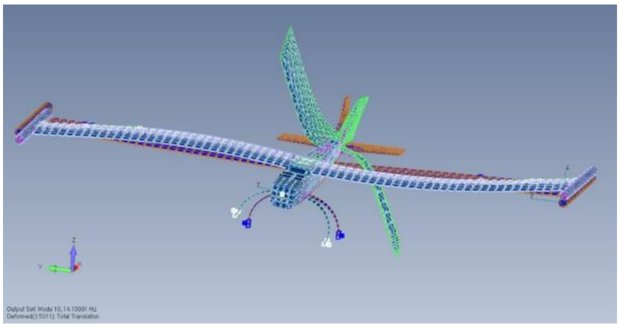
2. 1st Anti-Sym wing torsion – 6.13508 Hz



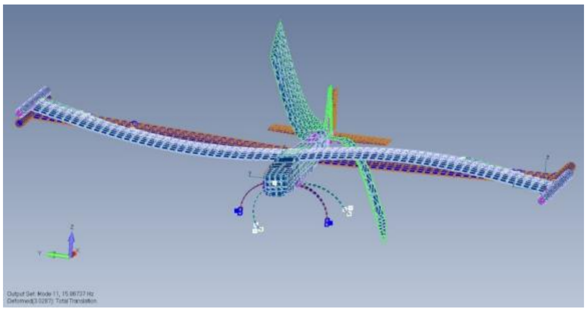
3. 1st Sym wing torsion – 6.46483 Hz



4. 1st Anti-Sym wing bending – 14.10091 Hz



5. 2nd Anti-Sym wing bending – 15.86737 Hz



6. 1st Tail mode – 16.99611 Hz

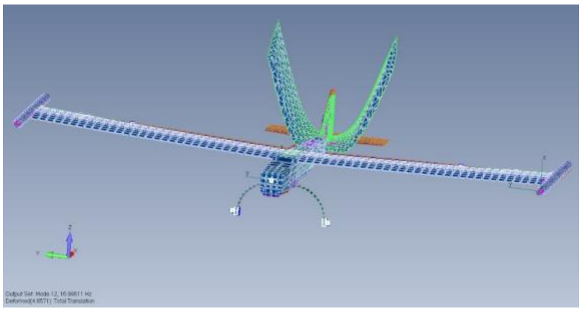


Figure 13: Mode shapes, 7-12, in the structural grid, Configuration 1

Case 2 is the mass position configuration of the shaker and the batteries where the shaker was moved further to the front section of the wing tip pod. The eigenvalue table of NASTRAN's normal modes analysis of the nominal configuration (Case 2), with the natural frequencies, generalized masses and stiffness properties, are given in Table 10. The first 6 rigid-body frequencies are practically zero. The mode shapes associated with the first 6 non-zero frequencies are shown in Figure 14.

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	-1.327245E-05	3.643137E-03	5.798233E-04	1.000000E+00	-1.327245E-05
2	2	-2.369365E-06	1.539274E-03	2.449831E-04	1.000000E+00	-2.369365E-06
3	3	-1.236953E-06	1.112184E-03	1.770096E-04	1.000000E+00	-1.236953E-06
4	4	-1.118509E-06	1.057596E-03	1.683216E-04	1.000000E+00	-1.118509E-06
5	5	3.962374E-07	6.294739E-04	1.001839E-04	1.000000E+00	3.962374E-07
6	6	1.429962E-06	1.195810E-03	1.903191E-04	1.000000E+00	1.429962E-06
7	7	1.054156E+03	3.246777E+01	5.167406E+00	1.000000E+00	1.054156E+03
8	8	1.506363E+03	3.881190E+01	6.177105E+00	1.000000E+00	1.506363E+03
9	9	1.781411E+03	4.220676E+01	6.717415E+00	1.000000E+00	1.781411E+03
10	10	7.977360E+03	8.931607E+01	1.421509E+01	1.000000E+00	7.977360E+03
11	11	1.018439E+04	1.009178E+02	1.606156E+01	1.000000E+00	1.018439E+04
12	12	1.141247E+04	1.068292E+02	1.700239E+01	1.000000E+00	1.141247E+04
13	13	1.461828E+04	1.209061E+02	1.924280E+01	1.000000E+00	1.461828E+04
14	14	1.714101E+04	1.309237E+02	2.083715E+01	1.000000E+00	1.714101E+04
15	15	1.819090E+04	1.348737E+02	2.146581E+01	1.000000E+00	1.819090E+04
16	16	2.551724E+04	1.597412E+02	2.542360E+01	1.000000E+00	2.551724E+04
17	17	2.789606E+04	1.670211E+02	2.658224E+01	1.000000E+00	2.789606E+04
18	18	3.040975E+04	1.743839E+02	2.775406E+01	1.000000E+00	3.040975E+04
19	19	3.114208E+04	1.764712E+02	2.808626E+01	1.000000E+00	3.114208E+04
20	20	3.313556E+04	1.820318E+02	2.897126E+01	1.000000E+00	3.313556E+04
21	21	4.802759E+04	2.191520E+02	3.487912E+01	1.000000E+00	4.802759E+04
22	22	4.879177E+04	2.208886E+02	3.515551E+01	1.000000E+00	4.879177E+04
23	23	5.201593E+04	2.280700E+02	3.629847E+01	1.000000E+00	5.201593E+04
24	24	5.366409E+04	2.316551E+02	3.686906E+01	1.000000E+00	5.366409E+04
25	25	5.508455E+04	2.347010E+02	3.735382E+01	1.000000E+00	5.508455E+04

1 FREQUENCY MODES - CASE 2 OCTOBER 25, 2021 SIMCENTER NASTRAN 3/12/20

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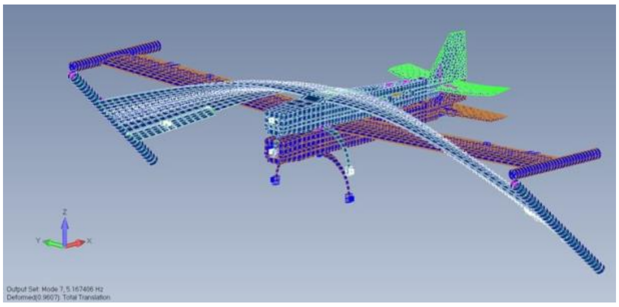
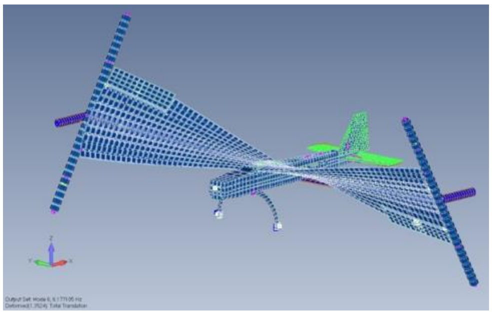
Table 10: Natural frequencies from normal-mode analysis

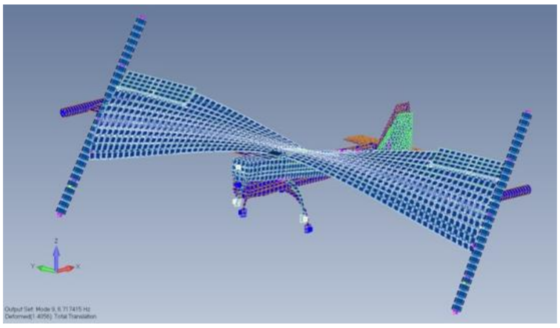
1. 1st Sym wing bending – 5.167406 Hz



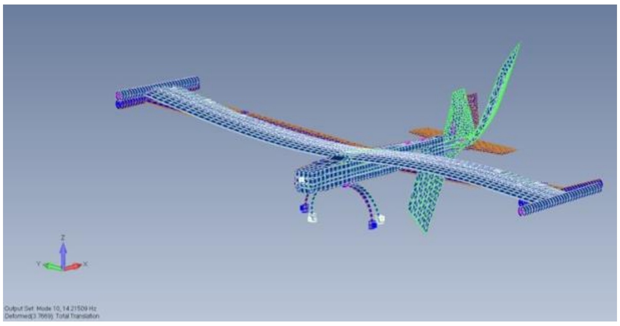
2. 1st Anti-Sym wing torsion – 6.177105 Hz



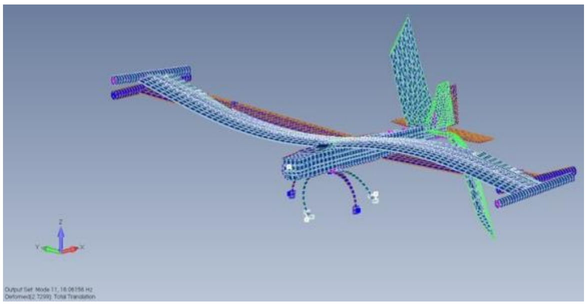
3. 1st Sym wing torsion – 6.717415 Hz



4. 1st Anti-Sym wing bending – 14.21509 Hz



5. 2nd Anti-Sym wing bending – 16.06156 Hz



6. 1st Tail mode – 17.00239 Hz

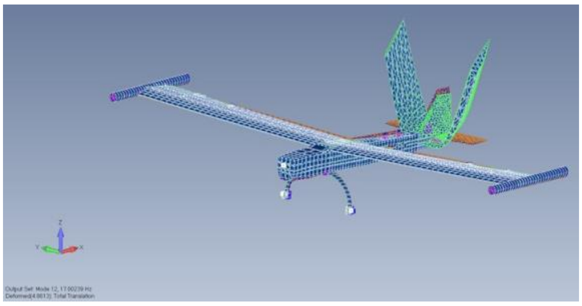


Figure 14: Mode shapes, 7-12, in the structural grid, Configuration 2

Case 3 is the mass position configuration of the shaker and the batteries where the shaker and the batteries were moved further to the front section of the wing tip pod. The eigenvalue table of NASTRAN’s normal modes analysis of the nominal configuration (Case 3), with the natural frequencies, generalized masses and stiffness properties, are given in Table 11. The first 6 rigid-body frequencies are practically zero. The mode shapes associated with the first 6 non-zero

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	-3.596406E-06	1.896419E-03	3.018245E-04	1.000000E+00	-3.596406E-06
2	2	-1.866675E-06	1.366263E-03	2.174475E-04	1.000000E+00	-1.866675E-06
3	3	-1.224559E-06	1.106598E-03	1.761206E-04	1.000000E+00	-1.224559E-06
4	4	-7.962245E-07	8.923141E-04	1.420162E-04	1.000000E+00	-7.962245E-07
5	5	3.456648E-08	1.859206E-04	2.959019E-05	1.000000E+00	3.456648E-08
6	6	1.089448E-06	1.043766E-03	1.661206E-04	1.000000E+00	1.089448E-06
7	7	1.141134E+03	3.378068E+01	5.376362E+00	1.000000E+00	1.141134E+03
8	8	1.703680E+03	4.127565E+01	6.569225E+00	1.000000E+00	1.703680E+03
9	9	1.850429E+03	4.301661E+01	6.846307E+00	1.000000E+00	1.850429E+03
10	10	7.953869E+03	8.918446E+01	1.419415E+01	1.000000E+00	7.953869E+03
11	11	1.012279E+04	1.006121E+02	1.601291E+01	1.000000E+00	1.012279E+04
12	12	1.141823E+04	1.068561E+02	1.700668E+01	1.000000E+00	1.141823E+04
13	13	1.461812E+04	1.209054E+02	1.924269E+01	1.000000E+00	1.461812E+04
14	14	1.712050E+04	1.308453E+02	2.082468E+01	1.000000E+00	1.712050E+04
15	15	1.810394E+04	1.345509E+02	2.141444E+01	1.000000E+00	1.810394E+04
16	16	2.551285E+04	1.597274E+02	2.542141E+01	1.000000E+00	2.551285E+04
17	17	2.787763E+04	1.669660E+02	2.657346E+01	1.000000E+00	2.787763E+04
18	18	3.097864E+04	1.760075E+02	2.801246E+01	1.000000E+00	3.097864E+04
19	19	3.168190E+04	1.779941E+02	2.832864E+01	1.000000E+00	3.168190E+04
20	20	3.280298E+04	1.811159E+02	2.882550E+01	1.000000E+00	3.280298E+04
21	21	4.809686E+04	2.193100E+02	3.490427E+01	1.000000E+00	4.809686E+04
22	22	4.905914E+04	2.214930E+02	3.525170E+01	1.000000E+00	4.905914E+04
23	23	5.202750E+04	2.280954E+02	3.630251E+01	1.000000E+00	5.202750E+04
24	24	5.366471E+04	2.316564E+02	3.686927E+01	1.000000E+00	5.366471E+04
25	25	5.508573E+04	2.347035E+02	3.735422E+01	1.000000E+00	5.508573E+04

FREQUENCY MODES - CASE 3 OCTOBER 25, 2021 SIMCENTER NASTRAN 3/12/20
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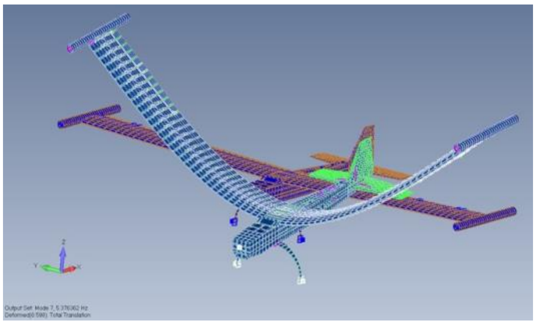
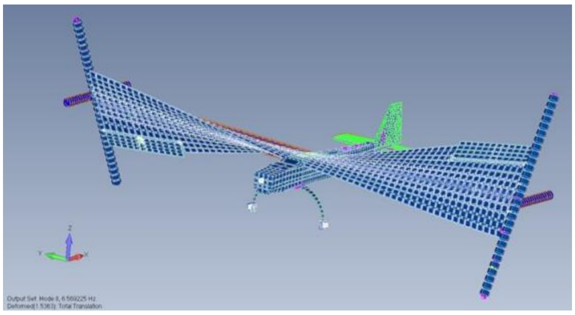
frequencies are shown in Figure 15.

Table 11: Natural frequencies from normal-mode analysis

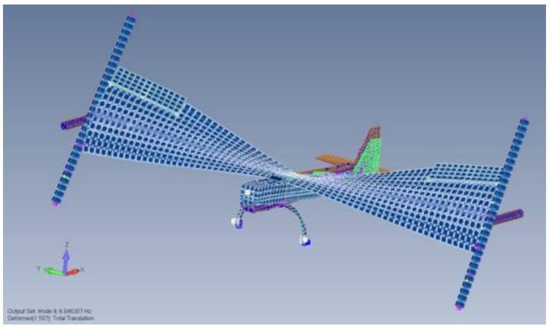
1. 1st Sym wing bending – 5.376362 Hz



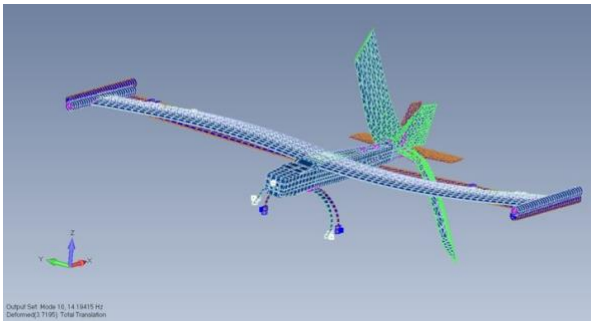
2. 1st Anti-Sym wing torsion – 6.569225 Hz



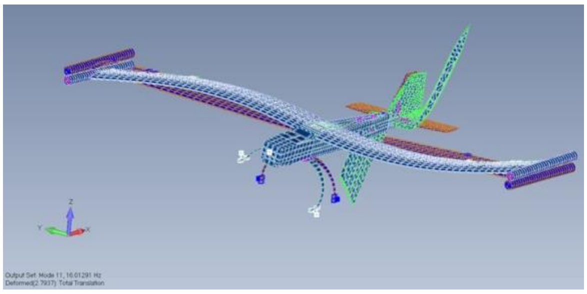
3. 1st Sym wing torsion – 6.846307 Hz



4. 1st Anti-Sym wing bending – 14.19415 Hz



5. 2nd Anti-Sym wing bending – 16.01291 Hz



6. 1st Tail mode – 17.00668 Hz

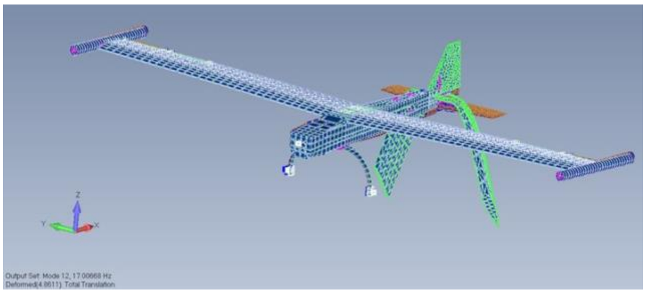


Figure 15: Mode shapes, 7-12, in the structural grid, Configuration 3

3.4 Conventional flutter analysis - ZAERO

The ZAERO aeroelastic code was used for constructing the panel model for the wing shown in Figure 12. The modal deflections of the previous section are projected to the aerodynamic model using the Infinite-Plate Spline (IPS) technique, based on the upper surface structural displacements.

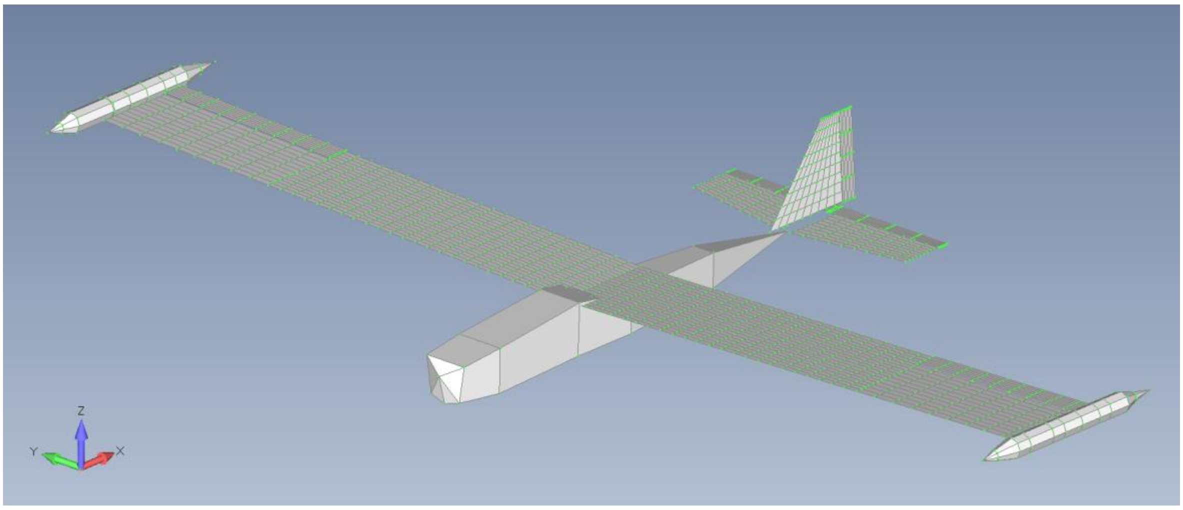


Figure 16: ZAERO aerodynamic model

The ZAERO aerodynamic model includes all main plane parts. The fuselage, the wings, the wing-tip pod, the flaps, the ailerons, and the tail unit are included. The analysis is an Open-loop flutter analysis that was performed using the g-method option of the ZAERO software package, assuming 2% structural damping with the 12 modes of Table 8 considered in each case. The damping and the frequency parts of the V-g plots of the nominal case 1 configuration are given in Figures 18 and 19 respectively. So does V-g plots of case 2 and case 3 are given in Figures 23-24 and 28-29 respectively. Snap shots of the obtained symmetric and antisymmetric flutter case 1 modes are shown Figures 20 and 21. So does snap shots of cases 2 and 3 are given in Figures 25-26 and 30-31 respectively. The resulting flutter characteristics are summarized in Table 12. The Flutter analysis results summary from ZAERO for cases 1-3 are presented in Figures 17,22,27 respectively.

Configuration	Mechanism Symmetry	Flutter velocity (m/s)	Flutter frequency (Hz.)	Flutter mechanism	Fig
Case 1	Anti	30.89	4.23	Wing torsion-roll	2
	Sym	26.69	5.49	Wing torsion-bending	2
Case 2	Anti	28.95	4.43	Wing torsion-roll	2
	Sym	26.56	5.71	Wing torsion-bending	2
Case 3	Anti	34.21	4.43	Wing torsion-roll	3
	Sym	36.32	5.64	Wing torsion-bending	3

Table 12: Cases 1-3 Flutter characteristics

It can be observed that the lowest flutter velocity in Cases 1 and 2 is the symmetric one with very small difference between the two (both about 26.6 m/s). The flutter mechanism is of a classic torsion-bending interaction. The anti-symmetric flutter mechanism is of the interaction of wing torsion and rigid-body roll, a mechanism that is often called “body-freedom flutter”. The critical flutter velocity increases in Case 3 by about 10%, with the anti-symmetric flutter becoming more critical, at 34.2 m/s. The exact mass locations at flutter tests will be determined after the model is verified by ground vibration test (GVT).

```
| FLUTTER AT MODE NO.:   8 | G= 0.00% | G= 0.50% | G= 1.00% | G= 1.50% | G= 2.00% | G= 2.50% | G= 3.00% | G= 3.50% | G= 4.00% |
| SPEED |UNITS=  M /  SEC  |  26.6923 |  27.0810 |  27.5326 |  27.9842 |  28.5112 |  29.0440 |  29.6124 |  30.1927 |  30.7985 |
| V/VREF|UNITS=    NONE    |  26.6923 |  27.0810 |  27.5326 |  27.9842 |  28.5112 |  29.0440 |  29.6124 |  30.1927 |  30.7985 |
|  FREQ |UNITS=      HZ    |   5.5015 |   5.4951 |   5.4880 |   5.4810 |   5.4708 |   5.4603 |   5.4463 |   5.4314 |   5.4146 |
| DYN P |UNITS=KG  /M /S**2| 4.363+02 | 4.491+02 | 4.643+02 | 4.796+02 | 4.978+02 | 5.166+02 | 5.370+02 | 5.583+02 | 5.809+02 |
| DYNAMIC PRESSURE AT G=0.0, W =      5.5015 HZ, V =  2.6692E+01 :
| COMPUTED =  4.3609E+02, INTERPOLATED =  4.3639E+02, ERROR = -6.8841E-02%. CORRESPONDING EIGENVECTOR OF   25 MODES =
| -1.938E-01  1.722E-01, -2.830E-02  1.688E-02,  1.855E-02 -2.100E-02, -1.805E-02  1.382E-02, -4.316E-01  3.564E-01,
|  4.915E-02 -1.578E-01,  1.000E+00  0.000E+00,  7.964E-02  1.298E-02,  3.493E-01 -8.080E-01,  2.267E-03  2.095E-03,
| -3.453E-03 -1.381E-03,  6.996E-03 -2.693E-03, -1.270E-03 -5.540E-04, -8.549E-03  9.087E-03,  4.263E-03 -9.252E-05,
|  4.898E-04  1.092E-04, -6.048E-03  5.029E-03,  1.637E-02 -1.256E-02, -1.254E-03  4.441E-05, -6.196E-03  1.730E-02,
| -5.943E-05  2.332E-04, -1.994E-03  3.448E-03,  1.071E-04  2.401E-05, -8.122E-05  1.509E-04,  1.022E-03 -1.123E-03,
| FLUTTER MODE TRACKING: 100% = PRIMARY MODE. 0% = NO CONTRIBUTION TO FLUTTER MODE.
| MODE(   1) =  26.7051%,  MODE(   2) =  17.3389%,  MODE(   3) =  17.2910%,  MODE(   4) =  17.3086%,  MODE(   5) =   8.4053%, |
| MODE(   6) =  16.2333%,  MODE(   7) =  43.0021%,  MODE(   8) =  17.8424%,  MODE(   9) = 100.0000%,  MODE(  10) =  17.3374%, |
| MODE(  11) =  17.3347%,  MODE(  12) =  16.7927%,  MODE(  13) =  17.3301%,  MODE(  14) =  17.4348%,  MODE(  15) =  17.3389%, |
| MODE(  16) =  17.3317%,  MODE(  17) =  17.3163%,  MODE(  18) =  18.0157%,  MODE(  19) =  17.3267%,  MODE(  20) =  17.7902%, |
| MODE(  21) =  17.3557%,  MODE(  22) =  18.3161%,  MODE(  23) =  17.3313%,  MODE(  24) =  17.3316%,  MODE(  25) =  17.5901%, |
```

```
| FLUTTER AT MODE NO.:   9 | G= 0.00% | G= 0.50% | G= 1.00% | G= 1.50% | G= 2.00% | G= 2.50% | G= 3.00% | G= 3.50% | G= 4.00% |
| SPEED |UNITS=  M /  SEC  |  30.8948 |  31.0791 |  31.2262 |  31.3734 |  31.5205 |  31.6676 |  31.8147 |  31.9618 |  32.0943 |
| V/VREF|UNITS=    NONE    |  30.8948 |  31.0791 |  31.2262 |  31.3734 |  31.5205 |  31.6676 |  31.8147 |  31.9618 |  32.0943 |
|  FREQ |UNITS=      HZ    |   4.2316 |   4.2089 |   4.1893 |   4.1697 |   4.1501 |   4.1305 |   4.1109 |   4.0913 |   4.0736 |
| DYN P |UNITS=KG  /M /S**2| 5.846+02 | 5.916+02 | 5.972+02 | 6.028+02 | 6.085+02 | 6.142+02 | 6.199+02 | 6.257+02 | 6.309+02 |
| DYNAMIC PRESSURE AT G=0.0, W =      4.2316 HZ, V =  3.0895E+01 :
| COMPUTED =  5.8451E+02, INTERPOLATED =  5.8462E+02, ERROR = -1.9262E-02%. CORRESPONDING EIGENVECTOR OF   25 MODES =
| -1.003E-02 -3.918E-03,  7.947E-02 -6.226E-03,  2.580E-02 -3.664E-03, -1.882E-02 -8.544E-03,  3.621E-01  7.636E-03,
|  1.000E+00  0.000E+00,  2.173E-02 -3.738E-03, -5.326E-01  1.732E-01,  5.490E-03 -2.152E-03, -3.059E-02 -1.141E-03,
|  3.760E-02 -5.009E-03,  5.232E-05  3.189E-05,  1.396E-02 -1.842E-03, -4.271E-03  3.124E-04, -2.687E-02  1.703E-03,
| -4.290E-03  2.130E-04, -4.697E-05 -1.419E-05,  5.082E-05 -6.204E-06,  1.393E-02 -6.824E-03, -4.381E-04  1.892E-04,
| -4.620E-03  1.207E-03, -5.909E-05  7.052E-06, -3.267E-04 -1.258E-04,  2.279E-05 -7.042E-04,  3.766E-05 -9.479E-05,
| FLUTTER MODE TRACKING: 100% = PRIMARY MODE. 0% = NO CONTRIBUTION TO FLUTTER MODE.
| MODE(   1) =   2.3317%,  MODE(   2) =   2.2516%,  MODE(   3) =   2.3223%,  MODE(   4) =   2.3239%,  MODE(   5) =   0.1821%, |
| MODE(   6) =  14.1605%,  MODE(   7) =   2.3263%,  MODE(   8) = 100.0000%,  MODE(   9) =   2.3306%,  MODE(  10) =   2.4765%, |
| MODE(  11) =   2.5018%,  MODE(  12) =   2.3307%,  MODE(  13) =   2.3588%,  MODE(  14) =   2.3350%,  MODE(  15) =   2.5236%, |
| MODE(  16) =   2.3341%,  MODE(  17) =   2.3307%,  MODE(  18) =   2.3307%,  MODE(  19) =   3.0788%,  MODE(  20) =   2.3298%, |
| MODE(  21) =   2.9211%,  MODE(  22) =   2.3305%,  MODE(  23) =   2.3347%,  MODE(  24) =   2.3386%,  MODE(  25) =   2.3307%, |
```

Figure 17: Case 1 Flutter velocity calculation using ZAERO

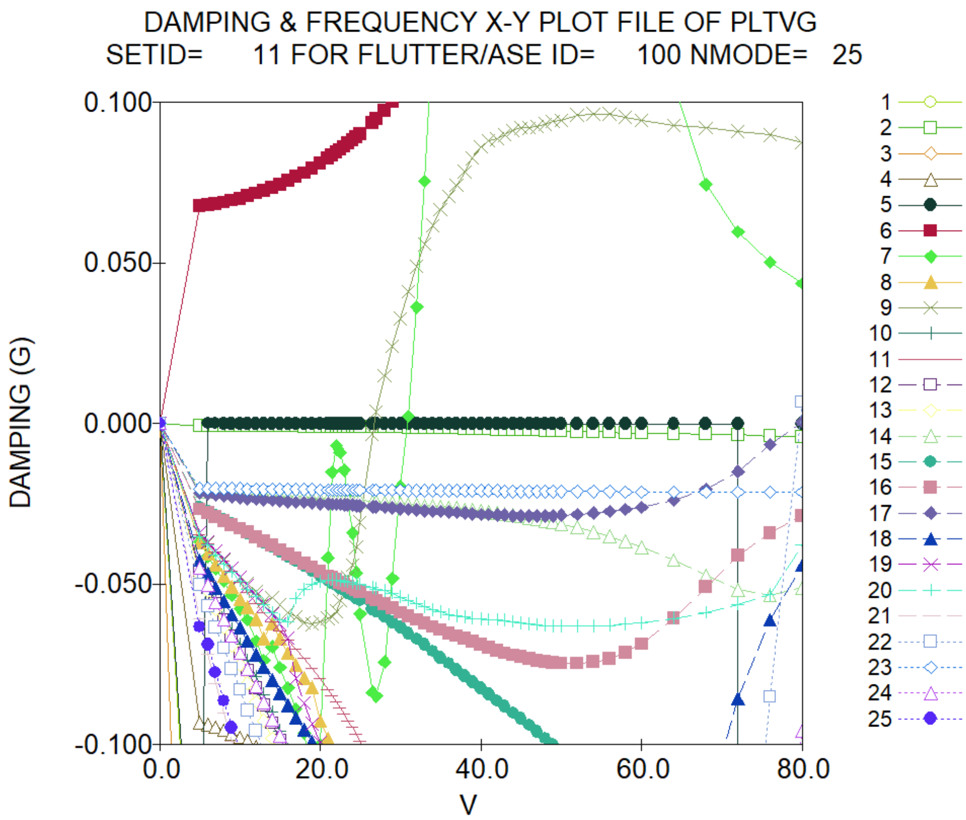


Figure 18: Case 1 Damping Plot

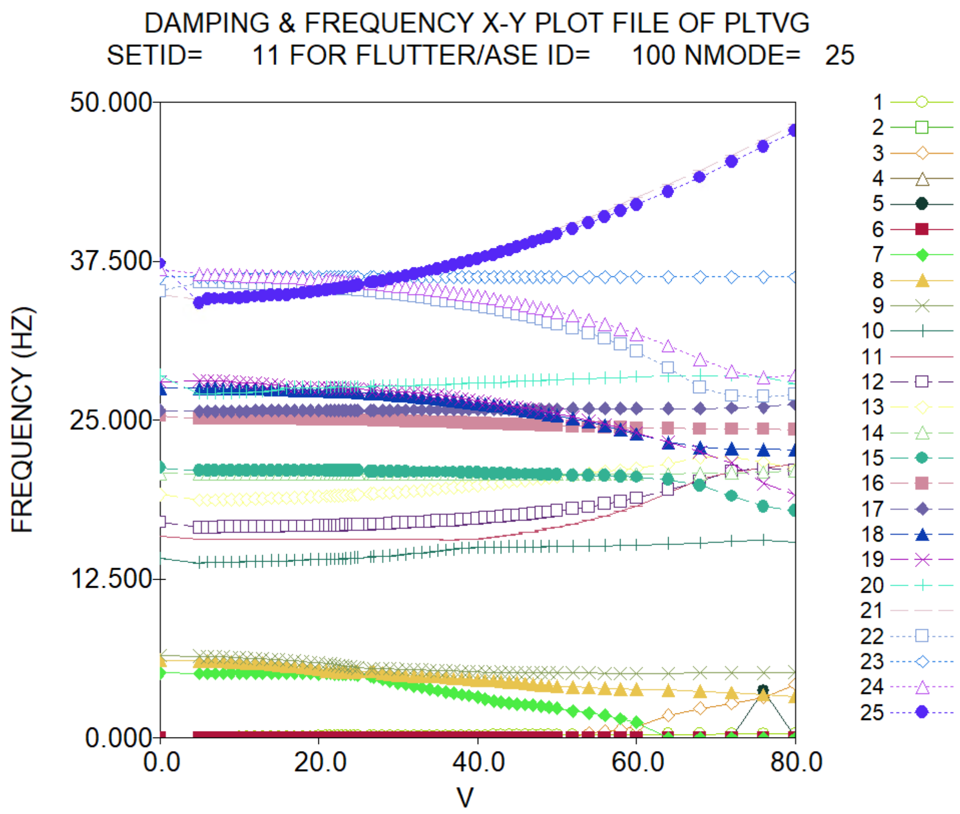


Figure 19: Case 1 Frequency Plot

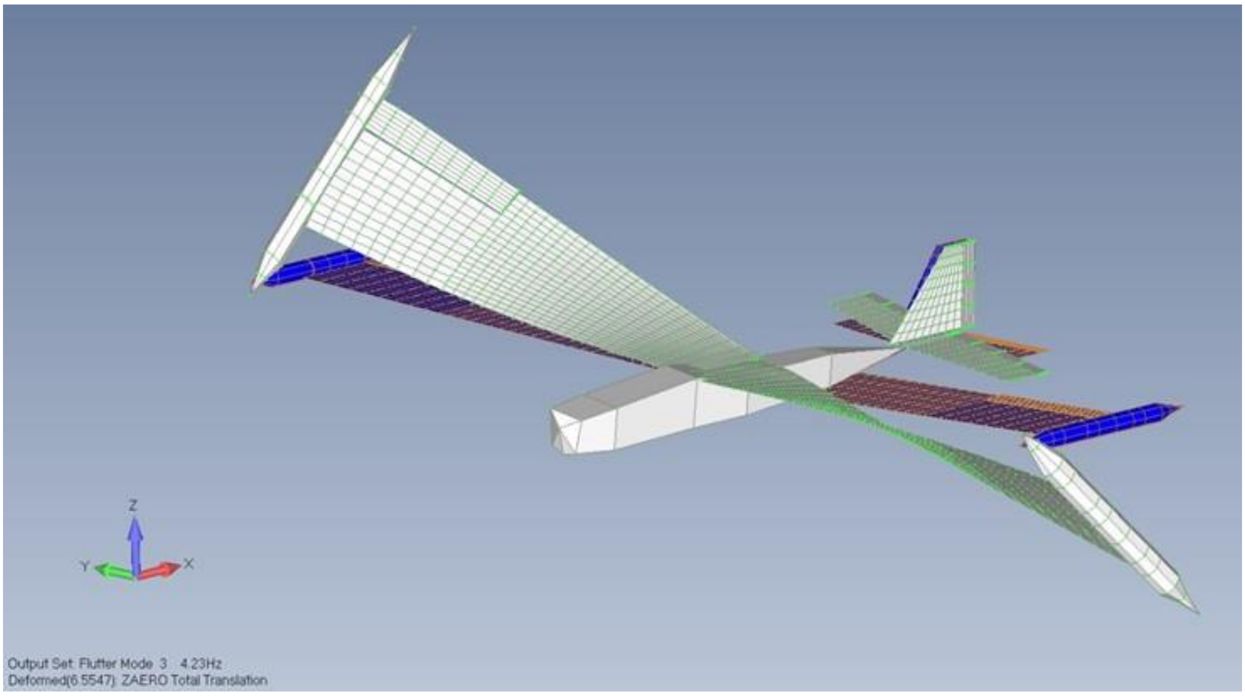


Figure 20: Case 1 Flutter mode 1 – 4.23 Hz

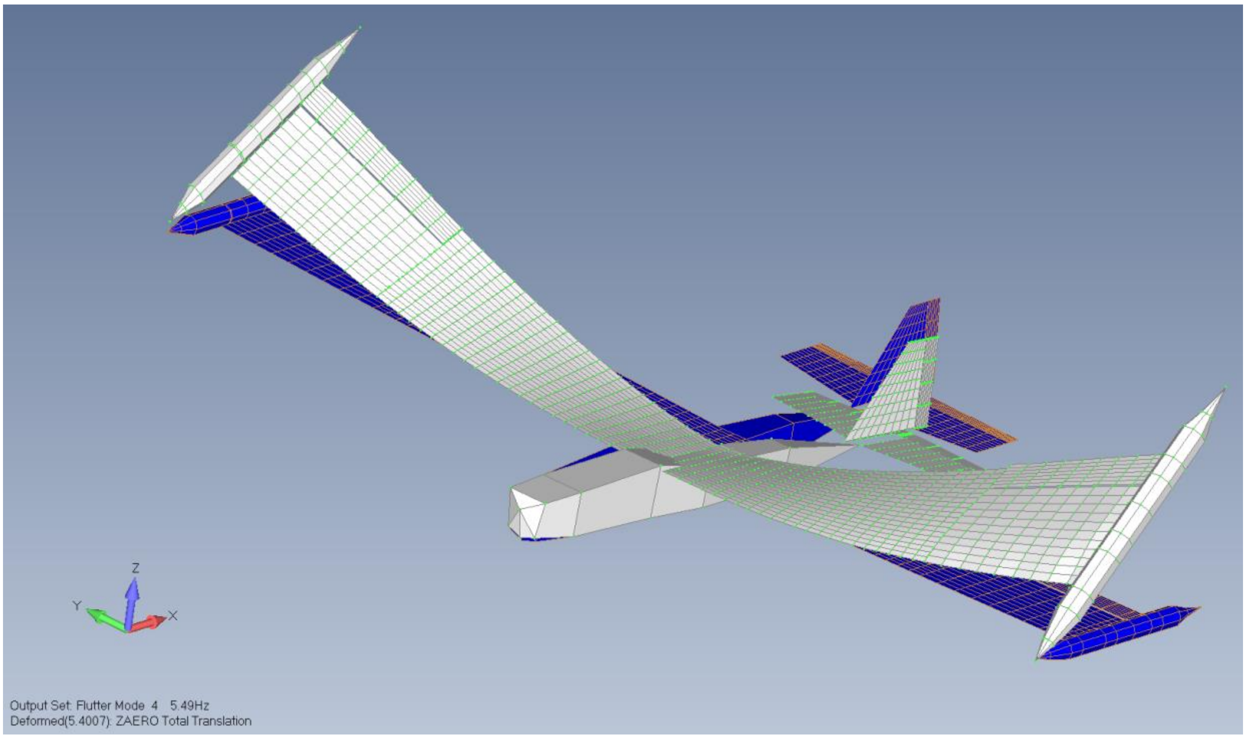


Figure 21: Case 1 Flutter mode 2 – 5.49 Hz

```
-----------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER AT MODE NO.:   9 | G= 0.00% | G= 0.50% | G= 1.00% | G= 1.50% | G= 2.00% | G= 2.50% | G= 3.00% | G= 3.50% | G= 4.00% |
-----------------------------------------------------------------------------------------------------------------------------------------
| SPEED |UNITS=  M /  SEC  |  26.5690 |  26.7406 |  26.9123 |  27.1024 |  27.3119 |  27.5214 |  27.7309 |  27.9404 |  28.1911 |
-----------------------------------------------------------------------------------------------------------------------------------------
| V/VREF|UNITS=    NONE    |  26.5690 |  26.7406 |  26.9123 |  27.1024 |  27.3119 |  27.5214 |  27.7309 |  27.9404 |  28.1911 |
-----------------------------------------------------------------------------------------------------------------------------------------
|  FREQ |UNITS=      HZ    |   5.7162 |   5.7110 |   5.7059 |   5.7016 |   5.6982 |   5.6948 |   5.6915 |   5.6881 |   5.6842 |
-----------------------------------------------------------------------------------------------------------------------------------------
| DYN P |UNITS=KG  /M /S**2| 4.323+02 | 4.379+02 | 4.436+02 | 4.499+02 | 4.568+02 | 4.639+02 | 4.710+02 | 4.781+02 | 4.867+02 |
-----------------------------------------------------------------------------------------------------------------------------------------
| DYNAMIC PRESSURE AT G=0.0, W =      5.7162 HZ, V =  2.6569E+01 :                                                                   |
| COMPUTED =  4.3205E+02, INTERPOLATED =  4.3237E+02, ERROR = -7.3963E-02%. CORRESPONDING EIGENVECTOR OF   25 MODES =                |
| -2.572E-01 -1.131E-01,  -1.780E-02  3.955E-03,   2.355E-02  6.139E-03,   2.664E-02  4.918E-03,   5.214E-01  2.285E-01,            |
|  3.370E-02 -1.173E-01,  -1.889E-01 -5.845E-01,  -1.365E-01 -1.016E-01,   1.000E+00  0.000E+00,   1.950E-03 -2.029E-03,            |
|  8.957E-06  3.666E-03,   6.070E-03  6.247E-03,   1.506E-04  1.572E-03,   1.083E-02  3.998E-03,   1.834E-03  4.700E-03,            |
| -2.808E-04 -6.319E-04,   7.096E-03  4.121E-03,  -1.042E-02 -9.805E-03,  -2.088E-03 -1.153E-03,  -2.325E-02 -5.609E-04,            |
| -9.079E-04 -2.383E-04,   5.261E-03  7.713E-04,  -1.234E-04 -1.882E-04,   1.912E-04 -3.754E-05,   1.711E-03  4.708E-04,            |
-----------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER MODE TRACKING: 100% = PRIMARY MODE. 0% = NO CONTRIBUTION TO FLUTTER MODE.                                                  |
| MODE(   1) =  17.9265%,  MODE(   2) =  12.1251%,  MODE(   3) =  12.1377%,  MODE(   4) =  12.1334%,  MODE(   5) =   2.4255%,       |
| MODE(   6) =  11.6093%,  MODE(   7) =  28.3007%,  MODE(   8) =   9.8361%,  MODE(   9) = 100.0000%,  MODE(  10) =  12.1558%,       |
| MODE(  11) =  12.1429%,  MODE(  12) =  11.8980%,  MODE(  13) =  12.1422%,  MODE(  14) =  12.2743%,  MODE(  15) =  12.1297%,       |
| MODE(  16) =  12.1434%,  MODE(  17) =  12.3370%,  MODE(  18) =  13.8167%,  MODE(  19) =  12.2380%,  MODE(  20) =  12.1123%,       |
| MODE(  21) =  12.2969%,  MODE(  22) =  14.1114%,  MODE(  23) =  12.1474%,  MODE(  24) =  12.1414%,  MODE(  25) =  12.0534%,       |
-----------------------------------------------------------------------------------------------------------------------------------------
```

```
-----------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER AT MODE NO.:   7 | G= 0.00% | G= 0.50% | G= 1.00% | G= 1.50% | G= 2.00% | G= 2.50% | G= 3.00% | G= 3.50% | G= 4.00% |
-----------------------------------------------------------------------------------------------------------------------------------------
| SPEED |UNITS=  M /  SEC  |  28.9506 |  29.0883 |  29.2238 |  29.3594 |  29.4949 |  29.6304 |  29.7660 |  29.9015 |  30.0337 |
-----------------------------------------------------------------------------------------------------------------------------------------
| V/VREF|UNITS=    NONE    |  28.9506 |  29.0883 |  29.2238 |  29.3594 |  29.4949 |  29.6304 |  29.7660 |  29.9015 |  30.0337 |
-----------------------------------------------------------------------------------------------------------------------------------------
|  FREQ |UNITS=      HZ    |   4.4301 |   4.4084 |   4.3877 |   4.3669 |   4.3462 |   4.3254 |   4.3047 |   4.2840 |   4.2642 |
-----------------------------------------------------------------------------------------------------------------------------------------
| DYN P |UNITS=KG  /M /S**2| 5.133+02 | 5.182+02 | 5.230+02 | 5.279+02 | 5.328+02 | 5.377+02 | 5.426+02 | 5.476+02 | 5.524+02 |
-----------------------------------------------------------------------------------------------------------------------------------------
| DYNAMIC PRESSURE AT G=0.0, W =      4.4301 HZ, V =  2.8951E+01 :                                                                   |
| COMPUTED =  5.1341E+02, INTERPOLATED =  5.1336E+02, ERROR =  9.9990E-03%. CORRESPONDING EIGENVECTOR OF   25 MODES =                |
| -5.769E-03 -2.412E-03,  -6.626E-02  8.659E-03,   7.934E-02  6.192E-03,   2.904E-02 -1.451E-03,  -2.118E-01 -1.457E-02,            |
|  1.000E+00  0.000E+00,  -5.528E-02  2.238E-02,   6.072E-01 -1.950E-01,   6.512E-02 -2.237E-02,   2.023E-02  2.756E-03,            |
| -3.161E-02  4.018E-03,   1.975E-04  8.560E-05,  -1.224E-02  1.687E-03,   3.036E-03 -2.873E-04,  -2.535E-02  1.276E-03,            |
|  4.016E-03 -3.772E-05,   9.794E-05  4.538E-05,   1.873E-04 -2.109E-04,   1.335E-02 -7.671E-03,  -1.366E-03  8.466E-04,            |
| -4.878E-03  1.424E-03,   2.922E-04 -9.584E-05,   3.122E-04  1.355E-04,  -3.346E-06  7.566E-04,   6.772E-05 -9.944E-05,            |
-----------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER MODE TRACKING: 100% = PRIMARY MODE. 0% = NO CONTRIBUTION TO FLUTTER MODE.                                                  |
| MODE(   1) =   1.9811%,  MODE(   2) =   1.9349%,  MODE(   3) =   1.8908%,  MODE(   4) =   1.9685%,  MODE(   5) =   1.2847%,       |
| MODE(   6) =  11.9090%,  MODE(   7) =   1.9925%,  MODE(   8) = 100.0000%,  MODE(   9) =   1.9182%,  MODE(  10) =   2.1211%,       |
| MODE(  11) =   2.1577%,  MODE(  12) =   1.9807%,  MODE(  13) =   2.0074%,  MODE(  14) =   1.9834%,  MODE(  15) =   2.2008%,       |
| MODE(  16) =   1.9881%,  MODE(  17) =   1.9806%,  MODE(  18) =   1.9800%,  MODE(  19) =   2.7727%,  MODE(  20) =   1.9801%,       |
| MODE(  21) =   2.2577%,  MODE(  22) =   1.9831%,  MODE(  23) =   1.9827%,  MODE(  24) =   1.9828%,  MODE(  25) =   1.9804%,       |
-----------------------------------------------------------------------------------------------------------------------------------------
```

Figure 22: Case 2 Flutter velocity calculation using ZAERO

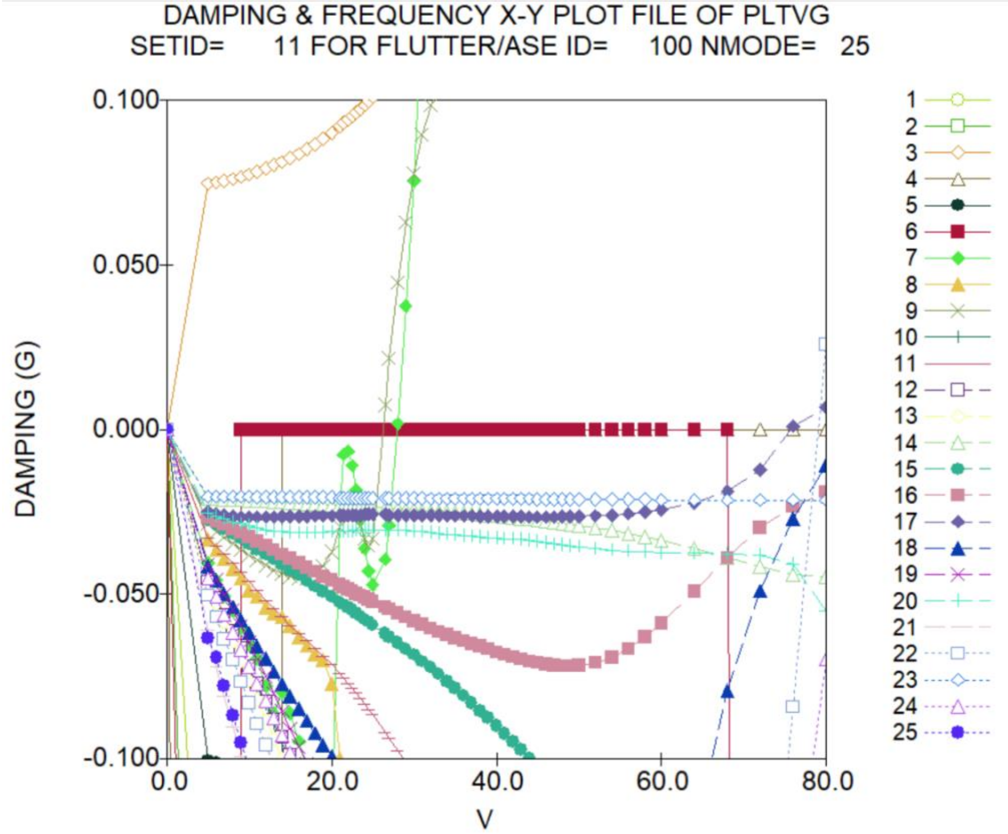


Figure 23: Case 2 Damping Plot

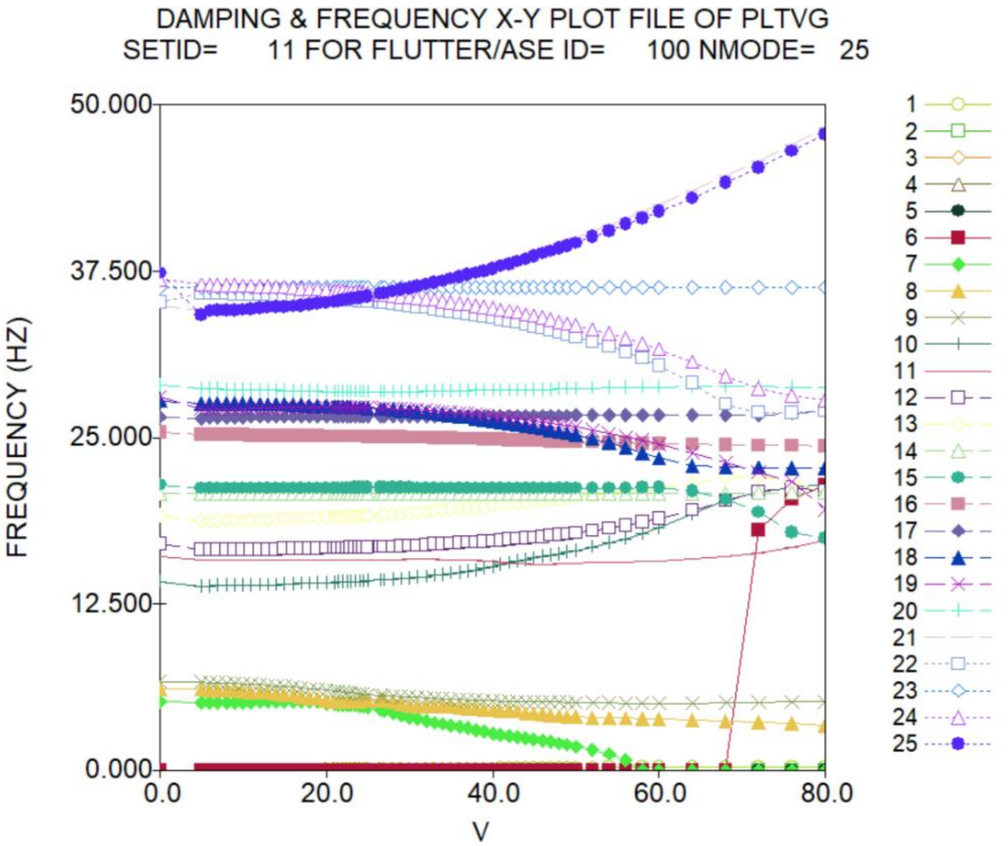


Figure 24: Case 2 Frequency Plot

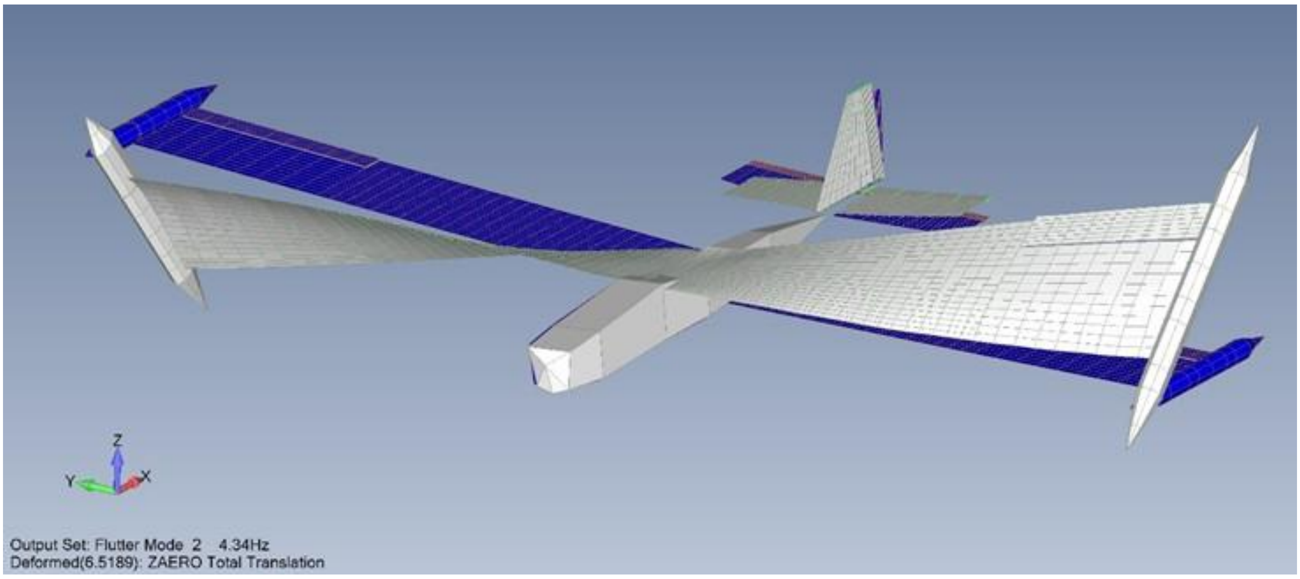


Figure 25: Case 2 Flutter mode 1 – 4.43 Hz

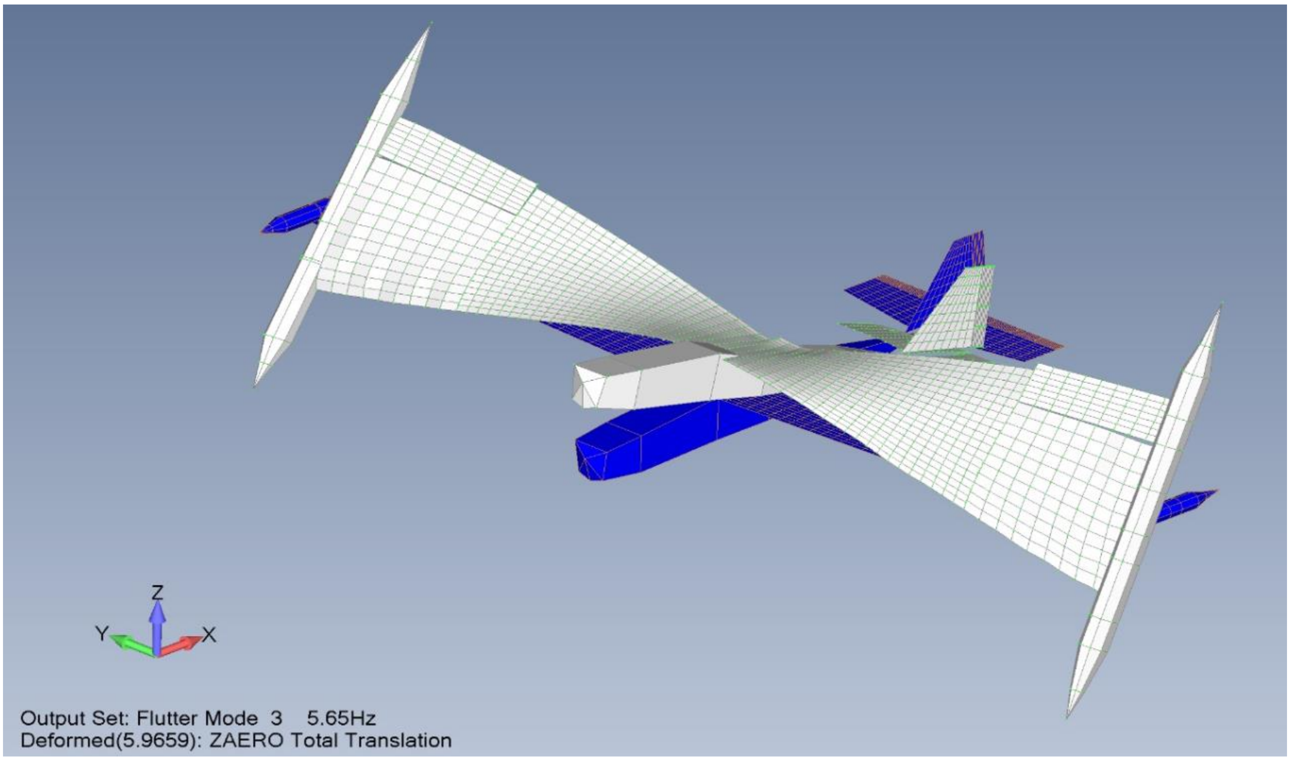


Figure 26: Case 2 Flutter mode 2 – 5.71 Hz

```
---------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER AT MODE NO.:    7 | G= 0.00% | G= 0.50% | G= 1.00% | G= 1.50% | G= 2.00% | G= 2.50% | G= 3.00% | G= 3.50% | G= 4.00% |
---------------------------------------------------------------------------------------------------------------------------------------
| SPEED |UNITS=  M /  SEC   |  34.2173 |  34.3489 |  34.4804 |  34.6120 |  34.7436 |  34.8752 |  35.0068 |  35.1391 |  35.2715 |
---------------------------------------------------------------------------------------------------------------------------------------
| V/VREF|UNITS=    NONE     |  34.2173 |  34.3489 |  34.4804 |  34.6120 |  34.7436 |  34.8752 |  35.0068 |  35.1391 |  35.2715 |
---------------------------------------------------------------------------------------------------------------------------------------
|  FREQ |UNITS=      HZ     |   4.4311 |   4.4134 |   4.3957 |   4.3780 |   4.3603 |   4.3426 |   4.3250 |   4.3094 |   4.2938 |
---------------------------------------------------------------------------------------------------------------------------------------
| DYN P |UNITS=KG  /M /S**2| 7.171+02 | 7.226+02 | 7.282+02 | 7.337+02 | 7.393+02 | 7.449+02 | 7.506+02 | 7.562+02 | 7.619+02 |
---------------------------------------------------------------------------------------------------------------------------------------
| DYNAMIC PRESSURE AT G=0.0, W =      4.4311 HZ, V =  3.4217E+01 :                                                                 |
| COMPUTED =  7.1680E+02, INTERPOLATED =  7.1713E+02, ERROR = -4.5985E-02%. CORRESPONDING EIGENVECTOR OF   25 MODES =              |
| -1.265E-03  3.862E-03,  -6.439E-02  9.641E-03,   9.279E-02  6.061E-03,   7.166E-02 -8.485E-04,  -4.719E-01 -3.685E-03,          |
|  1.000E+00  0.000E+00,   1.689E-02 -3.174E-03,  -4.294E-01  1.572E-01,   2.992E-03 -1.386E-03,  -2.934E-02 -9.910E-04,          |
| -4.116E-02  6.426E-03,  -4.207E-06  1.021E-06,   1.524E-02 -2.320E-03,   3.770E-03 -3.487E-04,   3.115E-02 -2.682E-03,          |
| -5.249E-03  4.764E-04,   5.935E-05  7.159E-06,   2.588E-06  1.428E-05,  -1.426E-02  6.670E-03,  -3.131E-04  1.173E-04,          |
|  5.001E-03 -1.331E-03,  -5.082E-06  9.023E-06,  -3.037E-04 -1.420E-04,   4.698E-06  7.931E-04,  -2.736E-05  1.046E-04,          |
---------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER MODE TRACKING: 100% = PRIMARY MODE. 0% = NO CONTRIBUTION TO FLUTTER MODE.                                                |
| MODE(   1) =    3.0651%,  MODE(   2) =    2.9993%,  MODE(   3) =    2.8712%,  MODE(   4) =    2.9471%,  MODE(   5) =    3.7438%, |
| MODE(   6) =   22.1815%,  MODE(   7) =    3.0654%,  MODE(   8) =  100.0000%,  MODE(   9) =    3.0659%,  MODE(  10) =    3.0542%, |
| MODE(  11) =    3.1748%,  MODE(  12) =    3.0672%,  MODE(  13) =    3.0794%,  MODE(  14) =    3.0692%,  MODE(  15) =    3.2978%, |
| MODE(  16) =    3.0641%,  MODE(  17) =    3.0671%,  MODE(  18) =    3.0673%,  MODE(  19) =    3.2110%,  MODE(  20) =    3.0659%, |
| MODE(  21) =    5.0996%,  MODE(  22) =    3.0679%,  MODE(  23) =    3.0778%,  MODE(  24) =    3.0952%,  MODE(  25) =    3.0677%, |
---------------------------------------------------------------------------------------------------------------------------------------
```

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---------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER AT MODE NO.:    9 | G= 0.00% | G= 0.50% | G= 1.00% | G= 1.50% | G= 2.00% | G= 2.50% | G= 3.00% | G= 3.50% | G= 4.00% |
---------------------------------------------------------------------------------------------------------------------------------------
| SPEED |UNITS=  M /  SEC   |  36.3293 |  37.0984 |  38.1105 |  40.0472 |  43.1838 |          |          |          |          |
---------------------------------------------------------------------------------------------------------------------------------------
| V/VREF|UNITS=    NONE     |  36.3293 |  37.0984 |  38.1105 |  40.0472 |  43.1838 |          |          |          |          |
---------------------------------------------------------------------------------------------------------------------------------------
|  FREQ |UNITS=      HZ     |   5.6399 |   5.6254 |   5.6096 |   5.5905 |   5.5622 |          |          |          |          |
---------------------------------------------------------------------------------------------------------------------------------------
| DYN P |UNITS=KG  /M /S**2| 8.083+02 | 8.429+02 | 8.896+02 | 9.823+02 | 1.142+03 |          |          |          |          |
---------------------------------------------------------------------------------------------------------------------------------------
| DYNAMIC PRESSURE AT G=0.0, W =      5.6399 HZ, V =  3.6329E+01 :                                                                 |
| COMPUTED =  8.0815E+02, INTERPOLATED =  8.0839E+02, ERROR = -2.9408E-02%. CORRESPONDING EIGENVECTOR OF   25 MODES =              |
|  8.021E-02 -9.201E-02,  -1.123E-02  9.321E-03,   9.730E-03 -1.016E-02,   2.447E-02 -2.322E-02,   2.922E-01 -2.419E-01,          |
|  1.065E-01 -1.039E-01,   1.000E+00  0.000E+00,   1.033E-02 -5.772E-03,   1.157E-01 -2.832E-01,   7.069E-04  1.004E-04,          |
|  1.007E-03 -3.118E-04,  -3.775E-03  3.189E-03,  -3.540E-04  9.322E-05,   6.153E-03 -6.552E-03,  -1.518E-03  9.100E-04,          |
|  1.927E-04 -7.899E-05,   4.741E-03 -4.741E-03,  -1.069E-02  1.110E-02,   8.588E-05 -1.712E-05,  -2.069E-03  7.518E-03,          |
| -5.754E-05 -3.852E-06,  -8.914E-04  2.004E-03,   1.629E-05  2.752E-07,   3.146E-05 -6.390E-05,  -5.110E-04  7.619E-04,          |
---------------------------------------------------------------------------------------------------------------------------------------
| FLUTTER MODE TRACKING: 100% = PRIMARY MODE. 0% = NO CONTRIBUTION TO FLUTTER MODE.                                                |
| MODE(   1) =   46.4064%,  MODE(   2) =   32.5679%,  MODE(   3) =   32.5845%,  MODE(   4) =   32.5985%,  MODE(   5) =   32.8275%, |
| MODE(   6) =   29.0555%,  MODE(   7) =   64.0434%,  MODE(   8) =   32.5768%,  MODE(   9) =  100.0000%,  MODE(  10) =   32.6723%, |
| MODE(  11) =   32.6676%,  MODE(  12) =   31.5176%,  MODE(  13) =   32.6658%,  MODE(  14) =   32.8423%,  MODE(  15) =   32.6696%, |
| MODE(  16) =   32.6688%,  MODE(  17) =   32.6688%,  MODE(  18) =   34.3596%,  MODE(  19) =   32.6648%,  MODE(  20) =   31.3207%, |
| MODE(  21) =   32.6873%,  MODE(  22) =   37.0854%,  MODE(  23) =   32.6683%,  MODE(  24) =   32.6652%,  MODE(  25) =   32.9200%, |
---------------------------------------------------------------------------------------------------------------------------------------
```

Figure 27: Case 3 Flutter velocity calculation using ZAERO

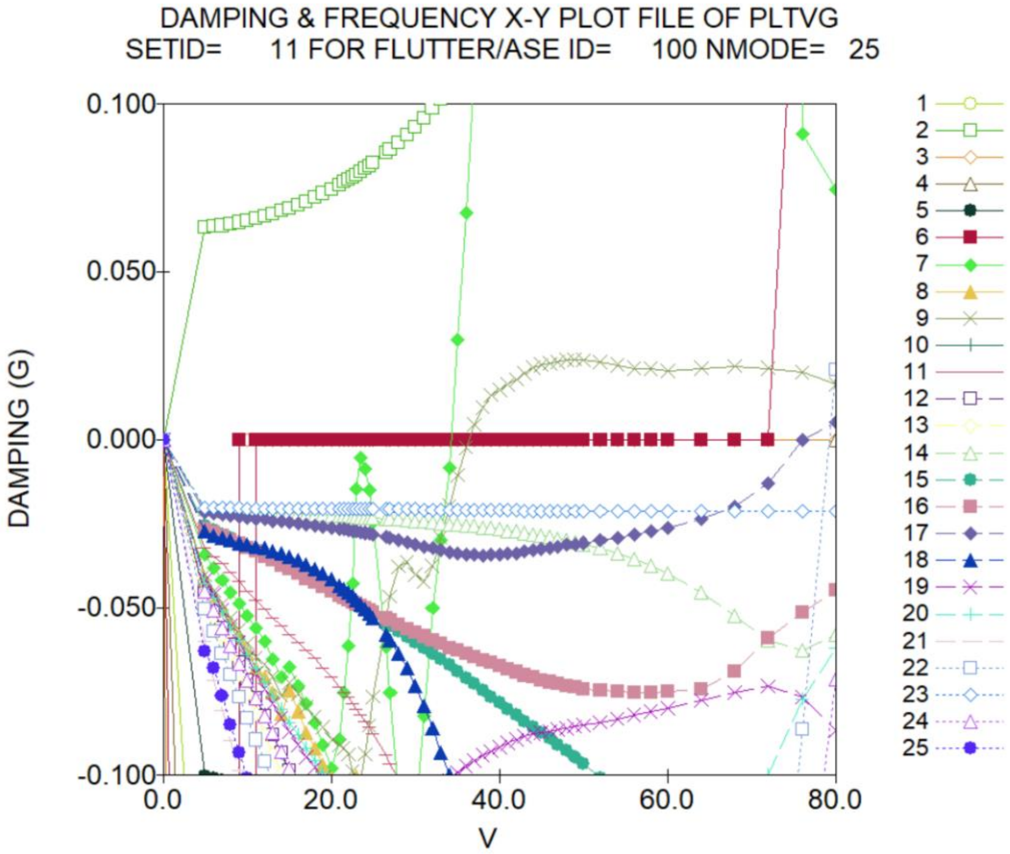


Figure 28: Case 3 Damping Plot

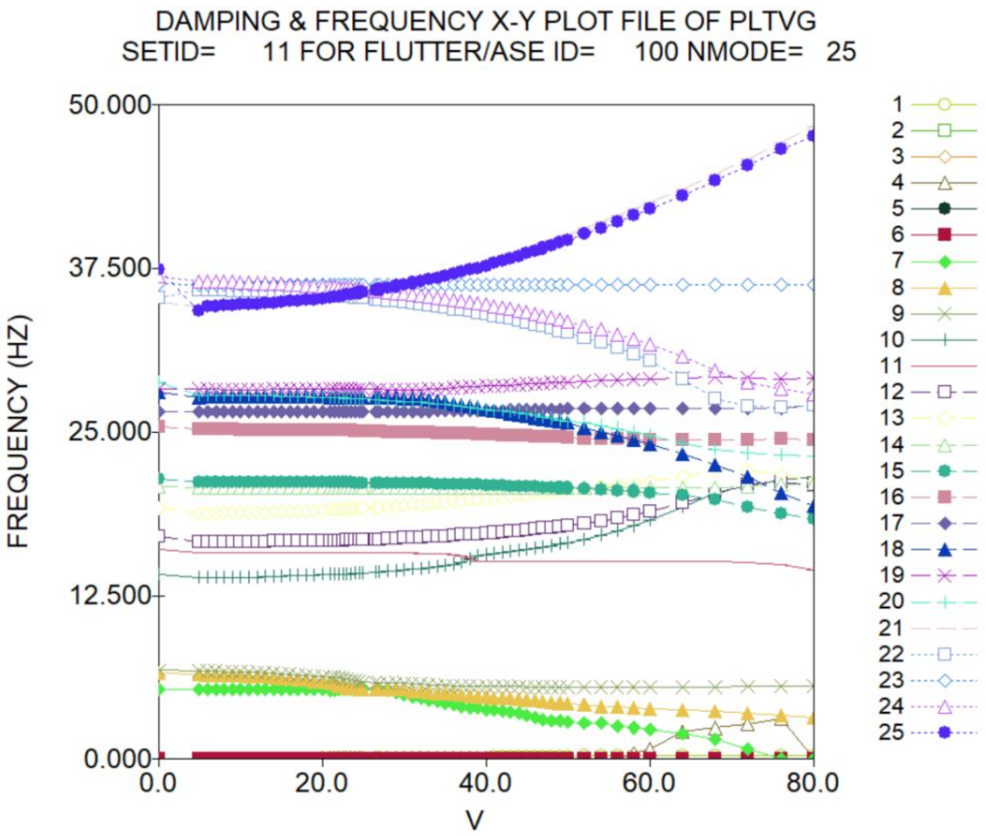


Figure 29: Case 3 Frequency Plot

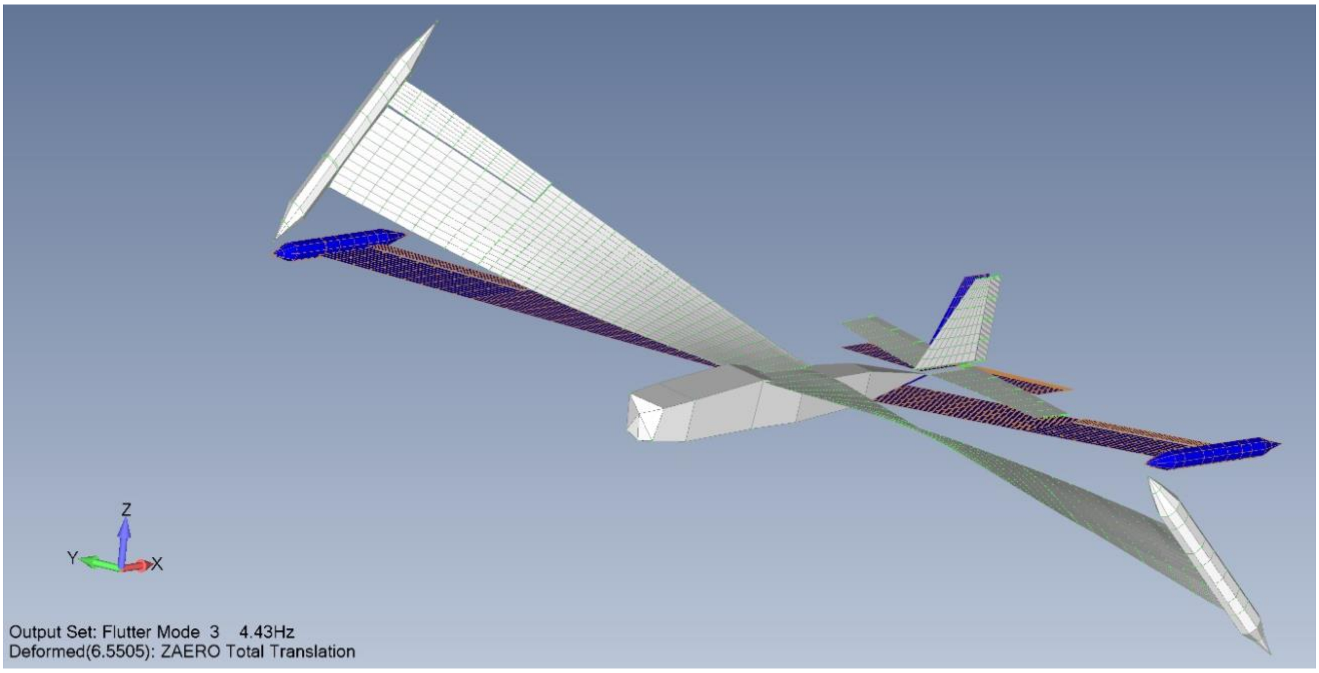


Figure 30: Case 3 Flutter mode 1 – 4.43 Hz

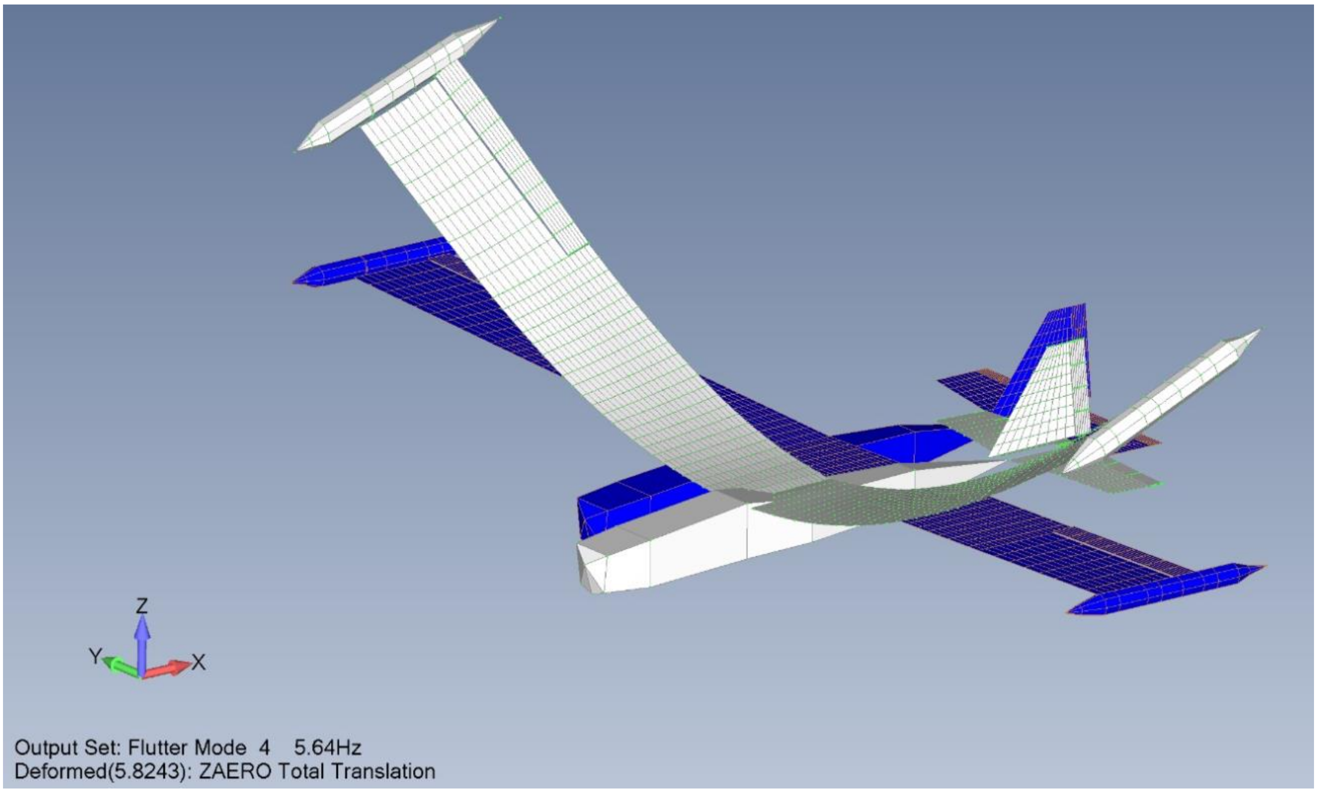
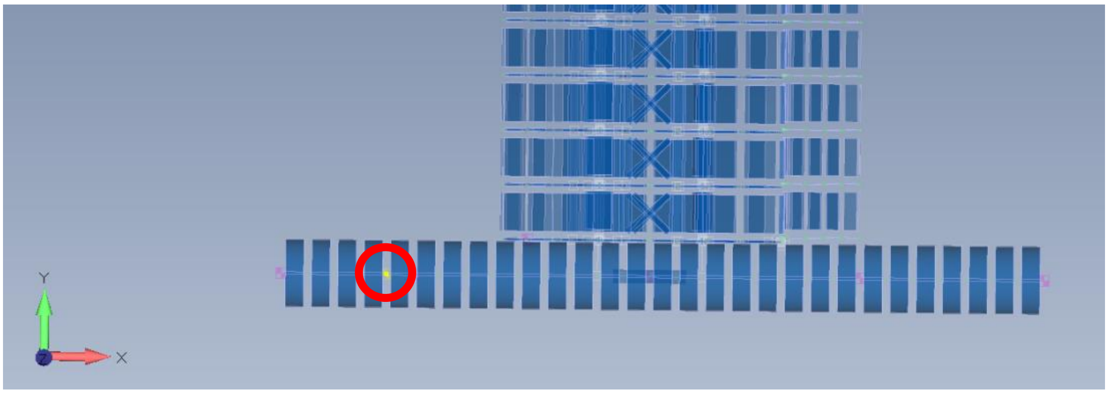


Figure 31: Case 3 Flutter mode 2 – 5.63 Hz

3.5 Dynresp Flutter analysis

The PFM method for flutter analysis [1] is applied using the Dynresp code such that it forms the basis to the planned flutter flight tests. The flutter parameter, P_f, is selected to be a mass term of 0.7Kg in the Z (vertical) direction, located at the right-wing, tip-section, leading-edge shaker mass grid point (1547). The added mass is applied in Dynresp by a SISO zero-order control system that reads the selected acceleration, y, multiplies it by P_f, and closed the loop by $u=P_f\, y$ to create the system matrix in Eq. (2). These input and output are also kept open for calculating the PFM response of Eq. (2). PFM plots and flutter characteristics are given in following section. ZAERO-Dynresp flutter results summery and comparison in given in Table 13. The Flutter analysis results



summary from Dynresp out files for cases 1-3 are presented in Figures 33,35,37 respectively.

Figure 32: GRID 1547 location in the wing-tip pod section

ZAERO Vs Dynresp results comparison

		ZAERO		Dynresp (SISO)	
Case	**Symmetry**	Flutter velocity (m/s)	Flutter frequency (Hz.)	Flutter velocity (m/s)	Flutter frequency (Hz.)
Case 1	**Anti**	30.89	4.23	30.91	4.20
	Sym	26.69	5.49	26.28	5.52
Case 2	**Anti**	28.95	4.43	27.80	4.33
	Sym	26.56	5.71	24.74	5.71
Case 3	**Anti**	34.21	4.43	34.12	4.41
	Sym	36.32	5.64	34.41	5.66

Table 13: Flutter velocities and frequencies in ZAERO and Dynresp

```
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
        FLUTTER SUMMARY
 IDGAIN = 33
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
 THERE ARE 2       FLUTTER POINTS
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
 # 1        FLUTTER POINT
 VELOCITY  26.28991
 DENSITY   1.225
 FREQUENCY 5.528622
 THE FLUTTER MODE IS :
<--1---><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><--10-->
        -.17378 .150696 -.019615.0163111.0207054-.018613-.013513.0118009+
+       -.3854  .326035 .131845 -.12476 1.      .0      8.5918-34.3139-3+
+       .33072  -.71904 1.9967-43.8554-4-3.479-4-2.125-46.1055-3-2.469-3+
+       -4.711-5-1.234-4-8.303-38.01-3  1.4849-3-9.425-46.8696-5-6.494-6+
+       -5.585-34.4648-3.0150075-.0111217.8669-5-2.442-4-6.336-3.0152325+
+       6.0914-64.1161-5-1.417-32.8919-32.834-6 1.0953-5-8.093-56.0732-5+
+       9.7201-4-9.655-4
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
 # 2        FLUTTER POINT
 VELOCITY  30.89482
 DENSITY   1.225
 FREQUENCY 4.206216
 THE FLUTTER MODE IS :
<--1---><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><--10-->
        -7.473-3-2.898-3.0801038-5.869-3.0259613-3.349-3-.018035-7.966-3+
+       .363778 5.7656-31.      .0      .0157222-2.409-3-.52522 .154561 +
+       1.7276-3-2.198-3-.029975-9.333-4.0372037-4.6-3  2.0649-5-3.922-6+
+       .0138717-1.715-3-4.16-3 2.8456-4-.0265431.588-3 -4.231-32.0154-4+
+       -7.901-6-7.566-6-4.624-5-2.278-5.0140115-6.083-3-3.361-41.4843-4+
+       -4.575-31.0878-3-2.65-6 1.2514-5-3.177-4-1.12-4 6.6539-5-6.325-4+
+       3.6784-5-9.008-5
********************************************************************************
```

Figure 33: Case 1 Flutter velocity calculation using Dynresp

The FRFs $y_f(V;i\omega)$ were calculated in Dynresp for selected air velocities between 18 and 55 m/s. Cross-over frequencies, ω_{co}, at which $\Phi = \angle\left(y_f(i\omega)\right) = \pm 360^o n$, and the corresponding gains $y_f(\omega_{co})$, which are positive real numbers, were used for calculating ΔP_f of Eq. (6), were calculated for each velocity. In our case, ΔP_f is the mass increment Δm needed to cause the current velocity to become a flutter-boundary point V_f. Every velocity may yield several cross-over frequencies that correspond to different Δm values associated with different flutter mechanisms.

The variations of $\Delta m = \Delta P_f$ and $f = \omega_{co}$ with air velocity, corresponding to all the velocity point at which one or more phase-cross-over frequency points exist, are shown in Figure 34. Since the baseline NASTRAN model in this case is with the added moving mass of the shaker, control board and batteries, the corresponding flutter velocities are those at which a Δm branch crosses the zero line. These velocities, and the corresponding flutter frequencies are compared to the ZAERO results, demonstrating practically identical results.

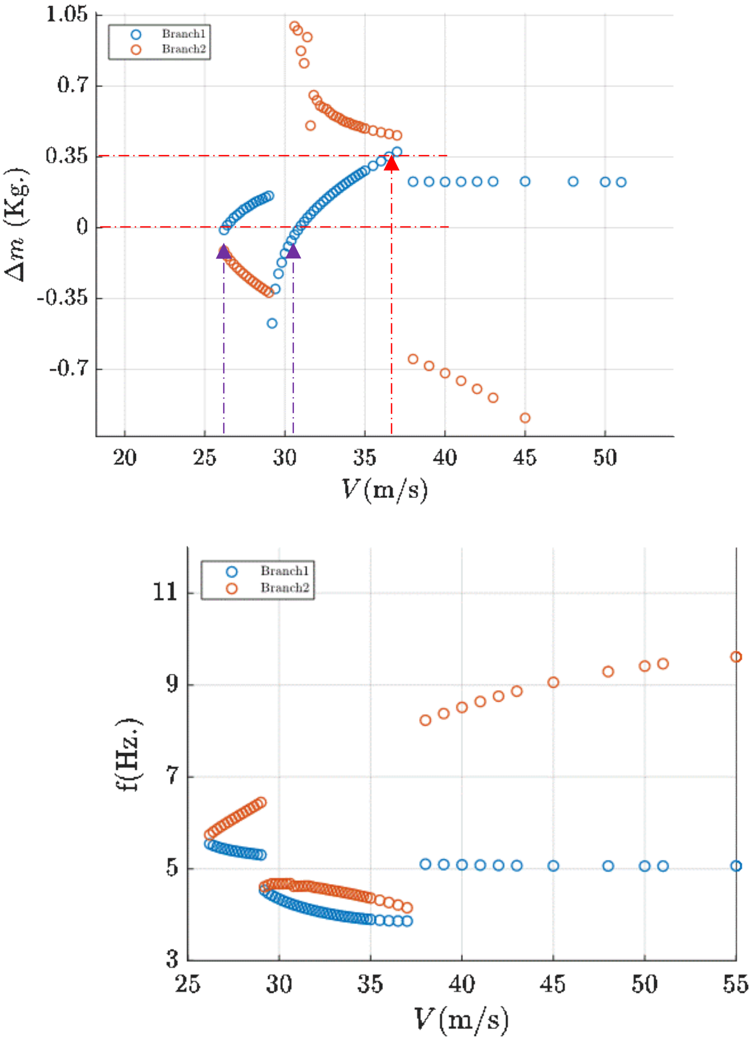


Figure 34: Dynresp flutter V-Delta and V-f plots starting with case 1 mass configuration.

The plots in Figures 34 also reveal the flutter sensitivity to variations in Δm. As with 0 to 350 grams addition the flutter velocity is increased up to 37 m/s (as the red markings indicate). The flutter velocities and frequencies expected, for example, for the nominal structure are those at which a Δm branch crosses the -0 line (as the purple markings indicate). The resulting flutter characteristics are V_f =26.29 m/s, ω_f =5.52 Hz for symmetric flutter mode and V_f =30.89 m/s, ω_f =4.20 Hz for the antisymmetric flutter mode. It is important to note that the used SISO-PFM method allows the removal of mass in one direction only (obviously, we removed the mass in the Z direction).

```
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
       FLUTTER SUMMARY
 IDGAIN = 33
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
 THERE ARE 2       FLUTTER POINTS
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
 # 1         FLUTTER POINT
 VELOCITY  24.74812
 DENSITY   1.225
 FREQUENCY 5.71814
 THE FLUTTER MODE IS :
<--1---><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><--10-->
        -.21497 -.089723-.023191-4.987-3-.027307-9.506-3.01010392.0585-3+
+       -.44506 -.16515 .0808608.0786693-.18812 -.51283 -.018093-.03921 +
+       1.      .0      7.7918-4-4.992-4-4.905-5-1.035-34.8853-35.0619-3+
+       7.6951-54.4649-48.8593-33.4417-31.2762-31.7897-3-1.519-4-2.229-4+
+       -5.649-3-3.347-3-6.594-3-7.945-3-2.042-4-2.123-4-.02021 -1.103-3+
+       -3.538-4-1.988-43.8149-32.9891-4-4.698-5-7.75-5 -1.114-4-1.044-5+
+       1.4578-34.1634-4
.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-.-
 # 2         FLUTTER POINT
 VELOCITY  27.80094
 DENSITY   1.225
 FREQUENCY 4.335121
 THE FLUTTER MODE IS :
<--1---><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><--10-->
        -5.307-33.873-3 .0671876-8.042-3.07432245.9846-34.275-3 3.9652-3+
+       .104968 -8.491-31.      .0      .0346318-6.982-3-.64813 .185402 +
+       -6.978-33.1921-3-.017587-2.501-3-.0287393.2444-3-1.06-4 -5.923-5+
+       .0112792-1.433-3-2.766-31.7869-4.0232906-1.023-3-3.663-3-4.532-6+
+       9.6296-52.09-5  -1.736-41.2432-4-.0132936.8174-35.9155-4-2.471-4+
+       4.5686-3-1.173-3-1.505-41.3534-5-2.93-4 -1.087-4-5.624-56.4564-4+
+       -5.359-58.4828-5
********************************************************************************
```

Figure 35: Case 2 Flutter velocity calculation using Dynresp

The Δm and frequency plots of case 2 are given in Figures 36. The location of the shaker and control board further towards the pod tip decreases the flutter velocity from 26.28 m/s and 30.91 m/s to 24.27 m/s and 27.80 m/s with the flutter frequency remaining the same. With 0 to 350 grams the flutter velocity is increased up to 32.5 m/s (as the red markings indicate).

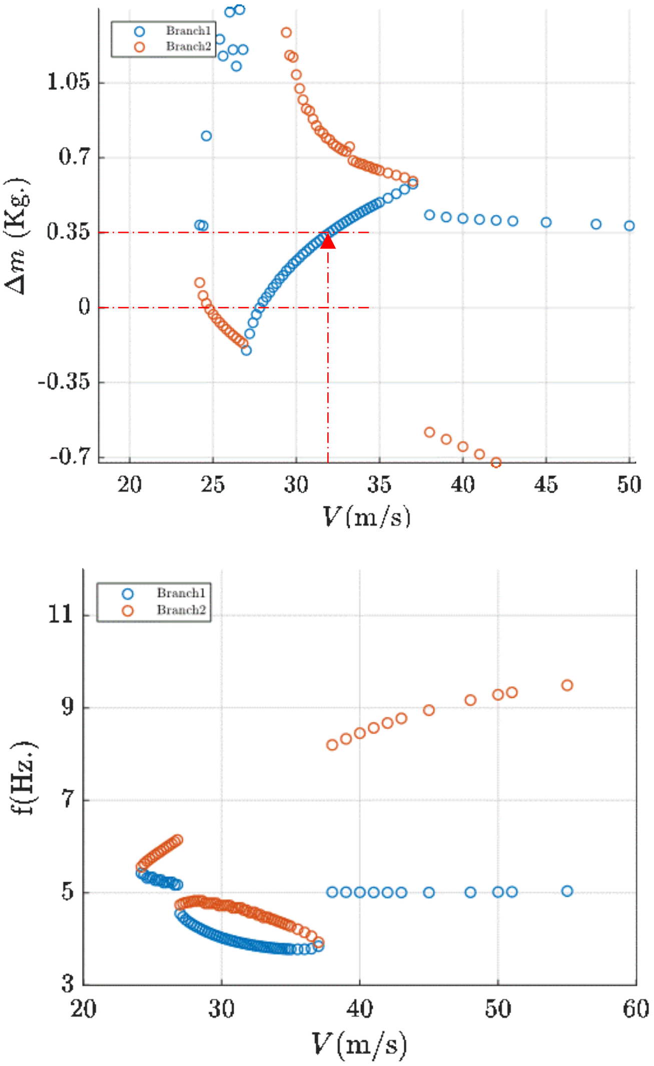


Figure 36: Dynresp flutter V-Delta and V-f plots starting with case 2 mass configuration.

```
 # 2        FLUTTER POINT
 VELOCITY  34.12957
 DENSITY   1.225
 FREQUENCY 4.411695
 THE FLUTTER MODE IS :
<--1---><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><--10-->
        -1.885-33.3696-3-.0650868.9941-3.09239655.6619-3.0716905-7.87-4 +
+       -.47187 -3.134-31.      .0      .0147747-1.774-3-.42767 .140414 +
+       2.0667-3-1.48-3 -.028846-8.687-4-.0408925.8123-3-3.155-71.2944-5+
+       .0151924-2.125-33.7211-3-3.15-4 .0308881-2.431-3-5.203-34.3063-4+
+       4.2748-52.1028-64.1157-52.5372-5-.0143955.9639-3-3.049-49.7667-5+
+       4.9775-3-1.191-37.3106-68.9209-6-2.947-4-1.267-4-4.331-57.1419-4+
+       -3.426-59.7844-5
 # 3        FLUTTER POINT
 VELOCITY  34.41823
 DENSITY   1.225
 FREQUENCY 5.660467
 THE FLUTTER MODE IS :
<--1---><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><-REAL-><-IMAG-><--10-->
        .0832311-.082537-.01157 9.8007-3.0109802-.010286.0255959-.022694+
+       .301247 -.22523 .114747 -.10935 1.      .0      .0119993-5.461-4+
+       .154966 -.28846 5.329-4 3.7139-49.1071-41.6084-4-3.799-32.7491-3+
+       -3.106-4-8.98-5 6.4465-3-6.238-3-1.447-34.6832-41.797-4 -1.461-5+
+       5.0009-3-4.446-3-.011449.01050341.1614-41.6139-4-2.606-37.3183-3+
+       -5.501-5-2.551-5-1.084-31.9009-31.307-5 9.2205-64.6388-5-5.695-5+
+       -5.762-46.7271-4
```

Figure 37: Case 3 Flutter velocity calculation using Dynresp

The Δm and frequency plots for case 3 are given in Figures 38. The displacement of the **batteries**, the shaker, and the control board further towards the pod tip increases the flutter velocity from 26.28 m/s and 30.91 m/s to 34.12 m/s and 34.41m/s with the flutter frequency remaining the same. With 0 to 350 grams the flutter velocity is increased to 38 m/s (as the red markings indicate).

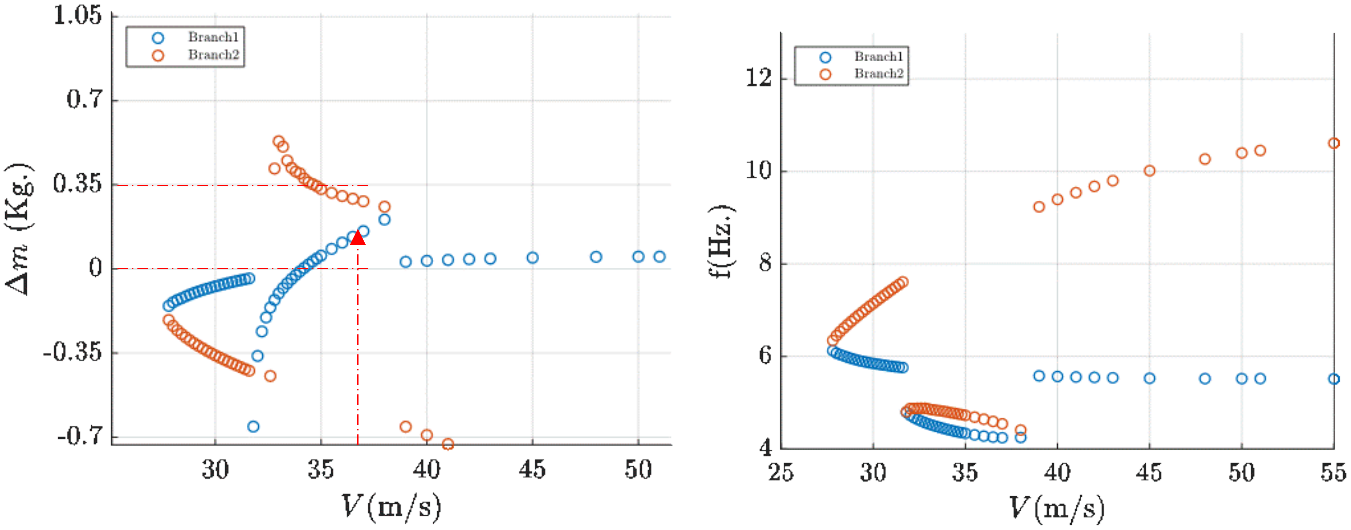


Figure 38: Dynresp flutter V-Delta and V-f plots starting with case 3 mass configuration.

5. PRELIMINARY SHAKER SELECTION

The preliminary voice-coil shaker of Figure 39, which may be adequate for the frequency range of 5-15Hz with resulting force of ~2,5N, was selected by OSU based on our preliminary specifications. The overall height is ~2.75”, and 1” in diameter: http://www.moticont.com/HVCM-025-038-003-02.htm. The moving mass is 98g, and the coil is 35g, for an all-up weight of 133g. The design currently has 1 accelerometer on the moving mass, and one on the boom attached to the wing.

Figure 39: Voice-coil shaker

A driver and closed-loop controller to provide excitation, resulting in the theoretical response curves for the moving mass at 12 Hz shown in Figure 40, was designed. By changing the position and frequency commands, a constant resultant force which is independent of excitation frequency (constant power spectra) can be designed. The housing was designed to support the shaker and allow us to reposition it along the chord of the wing. The assembly in the tip pod is depicted in Figure 41.

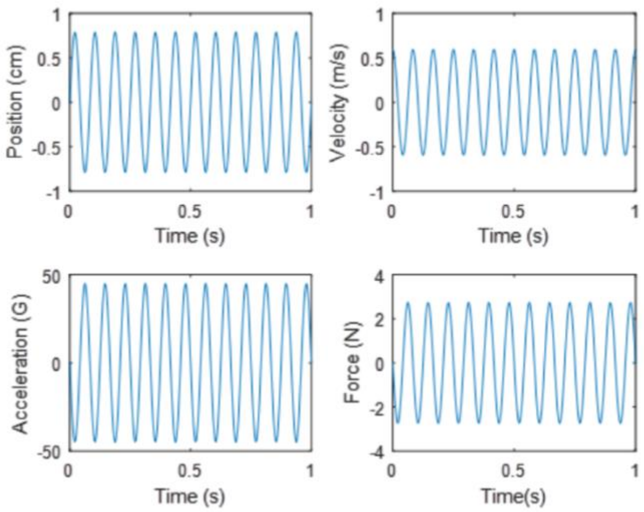


Figure 40: Acceleration and position response to 12 Hz excitation

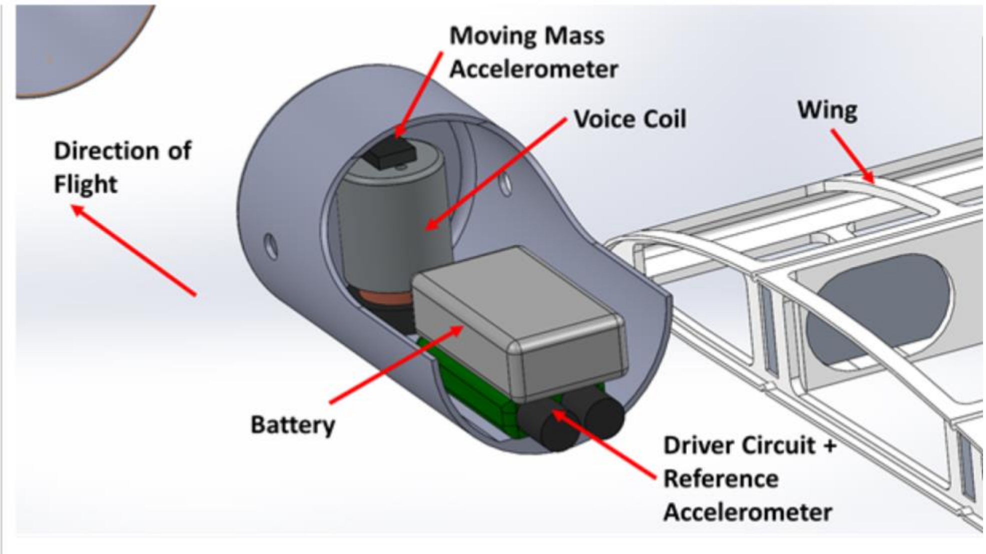


Figure 41: Shaker location in the tip pod

6. CONCLUSIONS

1. An agile method for conceptual design and flutter analysis is presented and discussed. This method enables rapid design changes to be taken into consideration with ease.
2. The PFM method formulation was adapted to consider an experimental application using moving mass and voice-coils for online flutter reduction. The method results were also compared to the traditional ZAERO commercial software analysis.
3. Moving the batteries, the shaker, and the control board forward increases the symmetric and antisymmetric flutter velocities from 26.28 m/s and 30.91 m/s to 34.12 m/s and 34.41m/s with the flutter frequencies remain 4.4 and 5.7 Hz. respectively.

7. BIBLIOGRAPHY

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8. APPENDIX

File repository

The file repository for the project can be found and downloaded on the following link:

https://1drv.ms/u/s!AgC19zrr4eAqpMsnOaya1PsXHcHZQA?e=Kbdi3Y

Repository structure

1. Dynresp – Files for the Dynresp Flutter analysis
   a. Case 1
      i. MATR – Aerodynamic matrices from ZAERO needed for the Dynresp analysis
      ii. aerocards.dat – Aerodynamic matrices location redirect file
      iii. Assure_FullSpan_Gen2_Dynresp_case1_v2.inp – Dynresp analysis input file
      iv. Assure_FullSpan_Gen2_Dynresp_case1_v2.out – analysis out file and result summery
      v. Assure_FullSpan_Gen2_Dynresp_case1_v2.f58 - Frequency-domain structural, aerodynamic and control outputs $\{y_v(i\omega)\}$ of the main linear block, including nonlinear effects when applicable.
      vi. Assure_FullSpan_Gen2_Dynresp_case1_v2.f118 – Output associated with stability analysis
      vii. pro-assureguy_fullplane2_v35-005.f06 – NASTRAN structural f06 file needed for the analysis
      viii. struct.dat – Aerodynamic matrices location redirect file
   b. Case 2
      i. MATR – Aerodynamic matrices from ZAERO needed for the Dynresp analysis
      ii. aerocards.dat – Aerodynamic matrices location redirect file
      iii. Assure_FullSpan_Gen2_Dynresp_case2_v2.inp – Dynresp analysis input file
      iv. Assure_FullSpan_Gen2_Dynresp_case2_v2.out – analysis out file and result summery
      v. Assure_FullSpan_Gen2_Dynresp_case2_v2.f58 - Frequency-domain structural, aerodynamic and control outputs $\{y_v(i\omega)\}$ of the main linear block, including nonlinear effects when applicable.
      vi. Assure_FullSpan_Gen2_Dynresp_case2_v2.f118 – Output associated with stability analysis
      vii. pro-assureguy_fullplane2_v37-003.f06 – NASTRAN resulted structural modes f06 file needed for the analysis
      viii. struct.dat – Aerodynamic matrices location redirect file
   c. Case 3
      i. MATR – Aerodynamic matrices from ZAERO needed for the Dynresp analysis
      ii. aerocards.dat – Aerodynamic matrices location redirect file
      iii. Assure_FullSpan_Gen2_Dynresp_case3_v2.inp – Dynresp analysis input file
      iv. Assure_FullSpan_Gen2_Dynresp_case3_v2.out – analysis out file and result summery

v. Assure_FullSpan_Gen2_Dynresp_case3_v2.f58 - Frequency-domain structural, aerodynamic and control outputs $\{y_v(i\omega)\}$ of the main linear block, including nonlinear effects when applicable.
vi. Assure_FullSpan_Gen2_Dynresp_case3_v2.f118 – Output associated with stability analysis
vii. pro-assureguy_fullplane2_v37-002.f06 – NASTRAN structural f06 file needed for the analysis
viii. struct.dat – Aerodynamic matrices location redirect file

2. Matlab - Files for the Dynresp results analysis in Matlab
a. Assure_FullSpan_Gen2_Dynresp_case1_v2.out – out file from Dynresp case 1 run
b. Assure_FullSpan_Gen2_Dynresp_case1_v2_1.f58 – F58 file from Dynresp case 1 run
c. Assure_FullSpan_Gen2_Dynresp_case2_v2_1.f58 – F58 file from Dynresp case 2 run
d. Assure_FullSpan_Gen2_Dynresp_case3_v2_1.f58 – F58 file from Dynresp case 3 run
e. Documentation.docx – Matlab code documentation.
f. dynresp_f58analysis_main.m – Main file for the Matlab analysis
g. dynresp_output_read.m – Matlab secondary function
h. dynresp_output_read_f58.m – Matlab secondary function
i. plot_comparison.m – Matlab secondary function
j. plot_f58_results.m – Matlab secondary function

3. NASTRAN – FEMAP - Files for the normal modes analysis in NASTRAN using FEMAP
a. Case 1
i. PRO-AssureGuy_FullPlane2_V35-005.dat – NASTRAN normal modes analysis input file
ii. pro-assureguy_fullplane2_v35-005.f04 – NATRAN module execution log
iii. pro-assureguy_fullplane2_v35-005.f06 – NASTRAN resulted structural modes f06
iv. pro-assureguy_fullplane2_v35-005.log – NASTRAN log
v. pro-assureguy_fullplane2_v35-005.mon1 – NASTRAN temp
vi. pro-assureguy_fullplane2_v35-005.mon2 – NASTRAN temp
vii. pro-assureguy_fullplane2_v35-005.op2 – NASTRAN temp
b. Case 2
i. PRO-AssureGuy_FullPlane2_V37-003.dat – NASTRAN normal modes analysis input file
ii. pro-assureguy_fullplane2_v37-003.f04 – NATRAN module execution log
iii. pro-assureguy_fullplane2_v37-003.f06 – NASTRAN resulted structural modes f06
iv. pro-assureguy_fullplane2_v37-003.log – NASTRAN log
v. pro-assureguy_fullplane2_v37-003.mon1 – NASTRAN temp
vi. pro-assureguy_fullplane2_v37-003.mon2 – NASTRAN temp
vii. pro-assureguy_fullplane2_v37-003.op2 – NASTRAN temp
c. Case 3
i. PRO-AssureGuy_FullPlane2_V37-002.dat – NASTRAN normal modes analysis input file
ii. pro-assureguy_fullplane2_v37-002.f04 – NATRAN module execution log
iii. pro-assureguy_fullplane2_v37-002.f06 – NASTRAN resulted structural modes f06
iv. pro-assureguy_fullplane2_v37-002.log – NASTRAN log
v. pro-assureguy_fullplane2_v37-002.mon1 – NASTRAN temp
vi. pro-assureguy_fullplane2_v37-002.mon2 – NASTRAN temp
vii. pro-assureguy_fullplane2_v37-002.op2 – NASTRAN temp
d. PRO-AssureGuy_FullPlane2_V37.modfem – The latest version of the FEA model in FEMAP

4. ZAERO - Files for the ZAERO Flutter analysis
a. Case 1
i. MATR – Aerodynamic matrices output needed for the Dynresp analysis later
ii. Assure_FullSpan_Gen2_SurfNpod_V5.inp – ZAERO flutter analysis input file

iii. Assure_FullSpan_Gen2_SurfNpod_V5.log – ZAERO flutter analysis log file
iv. Assure_FullSpan_Gen2_SurfNpod_V5.out – ZAERO flutter analysis output file
v. FLUT1MOFT.NEU – Flutter mode number 1 plot file for FEMAP
vi. FLUT2MOFT.NEU – Flutter mode number 2 plot file for FEMAP
vii. FLUT3MOFT.NEU – Flutter mode number 3 plot file for FEMAP
viii. FLUT4MOFT.NEU – Flutter mode number 4 plot file for FEMAP
ix. FLUT5MOFT.NEU – Flutter mode number 5 plot file for FEMAP
x. FLUT6MOFT.NEU – Flutter mode number 6 plot file for FEMAP
xi. FLUT7MOFT.NEU – Flutter mode number 7 plot file for FEMAP
xii. FLUT8MOFT.NEU – Flutter mode number 8 plot file for FEMAP
xiii. FLUT9MOFT.NEU – Flutter mode number 9 plot file for FEMAP
xiv. FLUT10MOFT.NEU – Flutter mode number 10 plot file for FEMAP
xv. FLUT11MOFT.NEU – Flutter mode number 11 plot file for FEMAP
xvi. FLUT12MOFT.NEU – Flutter mode number 12 plot file for FEMAP
xvii. pro-assureguy_fullplane2_v35-005.f06 – NASTRAN structural f06 file needed for the analysis
xviii. VG_CLMP.PLT – V-g plot data for VGPlot.exe

b. Case 2
i. MATR – Aerodynamic matrices output needed for the Dynresp analysis later
ii. Assure_FullSpan_Gen2_SurfNpod_V5_case2.inp – ZAERO flutter analysis input file
iii. Assure_FullSpan_Gen2_SurfNpod_V5_case2.log – ZAERO flutter analysis log file
iv. Assure_FullSpan_Gen2_SurfNpod_V5_case2.out – ZAERO flutter analysis output file
v. FLUT1MOFT.NEU – Flutter mode number 1 plot file for FEMAP
vi. FLUT2MOFT.NEU – Flutter mode number 2 plot file for FEMAP
vii. FLUT3MOFT.NEU – Flutter mode number 3 plot file for FEMAP
viii. FLUT4MOFT.NEU – Flutter mode number 4 plot file for FEMAP
ix. FLUT5MOFT.NEU – Flutter mode number 5 plot file for FEMAP
x. FLUT6MOFT.NEU – Flutter mode number 6 plot file for FEMAP
xi. FLUT7MOFT.NEU – Flutter mode number 7 plot file for FEMAP
xii. FLUT8MOFT.NEU – Flutter mode number 8 plot file for FEMAP
xiii. FLUT9MOFT.NEU – Flutter mode number 9 plot file for FEMAP
xiv. pro-assureguy_fullplane2_v37-003.f06 – NASTRAN structural f06 file needed for the analysis
xv. VG_CLMP.PLT – V-g plot data for VGPlot.exe

c. Case 3
i. MATR – Aerodynamic matrices output needed for the Dynresp analysis later
ii. Assure_FullSpan_Gen2_SurfNpod_V5_case3.inp – ZAERO flutter analysis input file
iii. Assure_FullSpan_Gen2_SurfNpod_V5_case3.log – ZAERO flutter analysis log file
iv. Assure_FullSpan_Gen2_SurfNpod_V5_case3.out – ZAERO flutter analysis output file
v. FLUT1MOFT.NEU – Flutter mode number 1 plot file for FEMAP
vi. FLUT2MOFT.NEU – Flutter mode number 2 plot file for FEMAP
vii. FLUT3MOFT.NEU – Flutter mode number 3 plot file for FEMAP
viii. FLUT4MOFT.NEU – Flutter mode number 4 plot file for FEMAP
ix. FLUT5MOFT.NEU – Flutter mode number 5 plot file for FEMAP
x. FLUT6MOFT.NEU – Flutter mode number 6 plot file for FEMAP
xi. FLUT7MOFT.NEU – Flutter mode number 7 plot file for FEMAP
xii. FLUT8MOFT.NEU – Flutter mode number 8 plot file for FEMAP
xiii. FLUT9MOFT.NEU – Flutter mode number 9 plot file for FEMAP
xiv. FLUT10MOFT.NEU – Flutter mode number 10 plot file for FEMAP

xv. pro-assureguy_fullplane2_v37-002.f06 – NASTRAN structural f06 file needed for the analysis
xvi. VG_CLMP.PLT – V-g plot data for VGPlot.exe
d. VGPlot.exe – ZAERO freeware for V-g plotting

Case 1 – ZAERO Code

```
$
MEMORY 8192MB
CPU 16
ASSIGN FEM=pro-assureguy_fullplane2_v35-005.f06,BOUNDARY=ASYM,FORM=MSC, PRINT=0
CEND
$
TITLE =  OSU_ASSURE
ECHO = SORT
SUBCASE = 1
        SUBTITLE= FLUTTER ANALYSIS, M=0.0, SEA LEVEL
        FLUTTER=100
BEGIN BULK
$
$-------------------------------------------------------------------------$
$                                                                         $
$                 * AERO PARAMETERS / FEM MODEL UNITS *                   $
$                                                                         $
$-------------------------------------------------------------------------$
$                                                                         $
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$       ACSID   XZSYM   FLIP    FMMUNIT FMLUNIT REFC    REFB    REFS    $
AEROZ           NO      NO      KG      M       0.333   3.33    1.07    +AE1
+AE1    0.444   0.0     0.076
$                                                                         $
$                   AERODYNAMIC AIC MATRIX GENERATION                     $
$                                                                         $
$                         * * * MACH = 0.0 * * *                          $
$                                                                         $
$       IDMK    MACH    METHOD  IDFLT   SAVE    <--FILENAME-->  PRINT   $
MKAEROZ 100     0.00    0       0       SAVE    AERCLP.0                +MK1
+MK1    0.00    0.02    0.03    0.04    0.05    0.06    0.07    0.1     +MK2
+MK2    0.12    0.125   0.13    0.14    0.15    0.2     0.25    0.28    +MK3
+MK3    0.3     0.4     0.5     0.6     0.7     0.8     0.9     1.0     +MK4
+MK4    1.5     2.5     3.0     4.0     5.0     10.0
$
$
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1       LWING1          25      20                              +W1L1
+W1L1   -7.091-30.7043411.1909290.333908                                +W1L2
+W1L2   -7.078-3-.3876191.2264910.333908
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  557     LWING2          10      12                              +W2L1
+W2L1   -7.078-3-.3876191.2264910.261137                                +W2L2
+W2L2   -7.078-3-.9986391.2478280.261137
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  757     FLAP2           10      8                               +W3L1
+W3L1   0.254015-0.387571.2310120.072771                                +W3L2
+W3L2    0.25402-0.998581.2523490.072771

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1001    RWING1          25      20                              +W1R1
+W1R1   -7.091-3 .7043411.190929 .333908                                +W1R2
+W1R2   -7.078-31.7963021.226491 .333908
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1557    RWING2          10      12                              +W2R1
+W2R1   -7.078-31.7963021.2264910.261137                                +W2R2
+W2R2   -7.078-32.4073161.2478280.261137
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1757    FLAP1           10      8                               +W3R1
+W3R1   0.254015 1.796261.2310120.072771                                +W3R2
+W3R2    0.254022.4072741.2523490.072771

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  2001    LTAIL           10      10                              +F1L1
+F1L1   0.9421670.6809521.11267 0.189609                                +F1L2
+F1L2   1.0078110.3109591.11267 0.137705
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  2501    LTAIL_F         5       10                              +F2L1
+F2L1   1.1310250.697809 1.112670.054803                                +F2L2
+F2L2   1.1455160.3109591.1126490.040094
```

```
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  3001    RTAIL           10      10                              +F1R1
+F1R1   0.9421670.7273921.11267 0.189609                                +F1R2
+F1R2   1.0078111.0973861.11267 0.137705
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  3501    RTAIL_F         5       10                              +F2R1
+F2R1   1.1310250.7105361.11267 0.054803                                +F2R2
+F2R2   1.1455161.0973861.11269 0.040094

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  4001    VerTail         10      10                              +F2U1
+F2U1   0.8810280.7051191.1269570.308827                                +F2U2
+F2U2   1.0892990.7031231.4063570.075708
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  4501    VerTail2        5       10                              +F3U1
+F3U1   1.1898410.7021591.1269570.051852                                +F3U2
+F3U2   1.1650030.7023971.4063570.051852

$--------------------------------------------------------------------------------
$               SPLINE & PANLST - BODY + WING
$--------------------------------------------------------------------------------
$       EID     MODEL   CP      SETK    SETG    DZ
$ Femap Aero Spline 2 : LWing
SPLINE1 11      LWing1          201     2       0.0
PANLST1 201     1       1       456
SPLINE1 111     LWing2          202     2       0.0
PANLST1 202     557     557     655
SPLINE1 1111    FLAP2           203     700     0.0
PANLST1 203     757     757     819
$
$ Femap Aero Spline 1 : Rwing
SPLINE1 12      Rwing1          101     1       0.0
PANLST1 101     1001    1001    1456
SPLINE1 122     Rwing2          102     1       0.0
PANLST1 102     1557    1557    1655
SPLINE1 1222    FLAP1           103     600     0.0
PANLST1 103     1757    1757    1819
$
$ Femap Aero Spline 3 : RTail
SPLINE1 13      RTail            301     4       0.0
PANLST1 301     3001    3001    3081
SPLINE1 14      RTail_F          351     7       0.0
PANLST1 351     3501    3501    3536
$
$ Femap Aero Spline 4 : LTail
SPLINE1 15      LTail            401     5       0.0
PANLST1 401     2001    2001    2081
SPLINE1 16      LTail_F          451     8       0.0
PANLST1 451     2501    2501    2536
$
$ Femap Aero Spline 5 : VTail
SPLINE1 17      VTail            501     3       0.0
PANLST1 501     4001    4001    4081
SPLINE1 18      VTail_F          551     6       0.0
PANLST1 551     4501    4501    4536
$
$
$
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$--------------------------------------------------------------------------------
$              Set for the Body & Wing
$--------------------------------------------------------------------------------
SET1           1     858     952     959     960     979     980     988+
+            995     996     999    1000    1170    1177    1183    1188+
+           1196    1234    1272    1341    1799    1801    1806    1807+
+           1810    1815    1990    2021    2070    2241    2260    2272+
+           2386    2439    2447    2450    2495    2500    2564    2614+
+           2666    2678    2728    2792    2837    2842    2846    2903+
+           2906    2956    3008    3015    3017    3020    3070    3074+
+           3122    3134    3184    3188    3236    3248    3293    3297+
+           3299    3305    3351    3359    3407    3413    3416    3521+
+           3522    3527    3530    3579    3640    3643    3644    3692+
+           3749    3750    3754    3758    3807    3815    3863    3866+
+           3868    3872    3921    3929    3977    3978    3980    3982+
+           3984    3986
$ Femap Aero Spline 1 : Rwing
SET1           2     158     164     170     304     532     837    1343+
+           1547    1602    1672    1751    2122    2262    2368    2424+
+           2437    2477    2485    2523    2533    2544    2546    2601+
```

```
+           2647    2657    2744    2811    2836    2923    2972    3000+
+           4010    4015    4063    4069    4117    4124    4127    4175+
+           4243    4288    4291    4296    4345    4353    4403    4461+
+           4469    4471    4516    4524    4630    4639    4688    4690+
+           4694    4696    4751    4753    4756    4860    4866    4870+
+           4915    4975    4980    5036    5041    5086    5145    5150+
+           5257    5260    5372    5374    5378    5485    5549    5601+
+           5656    5770    5777
$ Femap Aero Spline 2 : LWing
SET1           4    6398    6399    6400    6402    6404    6407    6425+
+           6429    6432    6434    6437    6441    6443    6446    6447+
+           6449    6450    6558    6561    6562    6563    6568    6578+
+           6617    8371    8388    8448    8560    8594    8701    8732+
+           8782    8785    8793    8794    8845    8859    8880    8894+
+           8903    8926    8940    8976    9005    9040    9054    9059+
+           9102    9117
$ Femap Aero Spline 3 : RTail
SET1           5    6074    6083    6086    6089    6092    6093    6096+
+           6098    6101    6104    6106    6108    6113    6117    6120+
+           6123    6126    6131    6142    6145    6147    6158    6161+
+           6177    6188    6190    6196    6201    6206    6218    6220+
+           6222    6787    6790    6797    6809    6829    6862    6882+
+           6896    6959    6965    6968    6978    7059    7064    7115+
+           7146
$ Femap Aero Spline 4 : LTail
SET1           3    2652    2869    3114    3153    3178    3200    3201+
+           3209    3217    3220    3225    3227    3229    3396    3418+
+           3435    3452    3462    3861    3884    4200    4204    4212+
+           4272    4328    4329    4394    4485    4593    4613    4680+
+           4722    4778    4863    4888    4919    4960    4963    5003+
+           5105
$ Femap Aero Spline 5 : VTail
$
SET1           7    6407    6439    6440    6441    6442    6443    6444+
+           6445    6446    6447    6448    6449    6450    6451    6571+
+           6603    8862    8966    9018    9096
$ Femap Aero Spline 6 : RTail_F
SET1           8    6083    6084    6115    6116    6117    6118    6119+
+           6120    6121    6122    6123    6124    6125    6126    6127+
+           6128    6136    6152    6168    6184    6200    6216
$ Femap Aero Spline 7 : LTail_F
SET1           6    2869    3209    3226    3227    3228    3229    3230+
+           3231    3234    3394    3444    3453    3458    4329
$ Femap Aero Spline 8 : VTail_F
$--------------------------------------------------------------------------------
$               Set for the Flaps
$--------------------------------------------------------------------------------
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$ Flap 1 :
SET1    600     1955    1980    2197    2195    2175    2177    2157    +
+       2155    2136    2134    2116    2114    2096    2094    2011    +
+       2009    1988    1986    1967    1963    1935    1931    1861
$
$ Flap 2 :
SET1    700     1536    1441    1442    1537    1538    1465    1479    +
+       1539    1540    1502    1541    1503    1542    1513    1543    +
+       1514    1544    1515    1545    1516    1546    1517    1169

$-------------------------------------------------------------------------------$
$-------------------------------------------------------------------------------$
$                         ASECONT Definition                                    $
$-------------------------------------------------------------------------------$
$-------------------------------------------------------------------------------$

CORD2R  401             0.6186  0.394   0.0     1.0816  1.524   0.0      +CR11
+CR11   1.0816  1.524   0.5

$-------------------------------------------------------------------------------$
$                         Surf modeling                                         $
$-------------------------------------------------------------------------------$
$-ACTU-><--ID--><--A0--><--A1--><--A2-->
ACTU    601     2.151E+64.772E+4 586.8
ACTU    602     2.151E+64.772E+4 586.8
ACTU    603     2.151E+64.772E+4 586.8
ACTU    604     2.151E+64.772E+4 586.8
ACTU    605     2.151E+64.772E+4 586.8
$
$AESURFZ<LABEL-><TYPE--><-CID--><-SETK-><-SETG-><-ACTID->
AESURFZ VTAIL_F ASYM     -401     551     6       601
```

```
AESURFZ RTAIL_F ASYM     -401     351     7       602
AESURFZ LTAIL_F ASYM     -401     451     8       603
AESURFZ FLAP1   ASYM     -401     103     600     604
AESURFZ FLAP2   ASYM     -401     203     700     605

SURFSET 350     VTAIL_F RTAIL_F LTAIL_F FLAP1   FLAP2

$-----------------------------------------------------------------------$
$                        * BODY Elements *                              $
$-----------------------------------------------------------------------$
$
$ FUSELAGE SPLINE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 10              10      10
SET1    10      2688    343     714     709     704     699     694     2494
PANLST2 10      10001   10001   THRU    10030
$
$ Right AIM9-P MISSILE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 70              70      50
SET1    50      858     1166    1173    1179    1187    1196    1226    1341
PANLST2 70      40001   40001   THRU    40088
$
$
$ Left AIM9-P MISSILE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 71              71      51
SET1    51      1343    1547    1602    1669    1723    1751    2354    2465
PANLST2 71      41001   41001   THRU    41088
$
$ FUSELAGE
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD        10-0.358980.7041721.096798     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7     10001FUSELAGE              10       1   10001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    10001       7       6                                        +SEG10
+SEG10         3-0.17190                             98      99         +SEG11
+SEG11         3-0.14592                            101     102         +SEG12
+SEG12         30.0                                 103     104         +SEG13
+SEG13         30.343016                            105     106         +SEG14
+SEG14         30.570651                            107     108         +SEG15
+SEG15         30.955669                            109     110         +SEG16
+SEG16         31.328021                            111     112
$                                                                        +SEG17
$+SEG17         30.954842                            113     114         +SEG18
$+SEG18         31.074291                            115     116         +SEG19
$+SEG19         31.301778                            117     118
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
AEFACT        98     0.0     0.0     0.0     0.0     0.0     0.0
AEFACT        990.0203320.0203320.0203320.0203320.0203320.020332
AEFACT       1010.0     0.05    0.069   -0.07   -0.054  0.0
AEFACT       102-0.07   -0.053  0.06    0.06    -0.053  -0.07
AEFACT       1030.0     0.0762  0.0762  -0.0762 -0.0762 0.0
AEFACT       104-0.061  -0.061  0.0762  0.0762  -0.061  -0.061
AEFACT       1050.0     0.069   0.072   -0.072  -0.069  0.0
AEFACT       106-0.054  -0.054  0.109   0.109   -0.054  -0.054
AEFACT       107-0.0    0.069   0.069   -0.068  -0.069  -0.0
AEFACT       108-0.054  -0.054  0.076   0.076   -0.054  -0.054
AEFACT       1090.0     0.038   0.038   -0.037  -0.037  0.0
AEFACT       110-0.043  -0.043  0.065   0.065   -0.043  -0.043
AEFACT       1110.013   0.013   0.013   0.013   0.013   0.013
AEFACT       1120.003   0.003   0.003   0.003   0.003   0.003
$
$
$ Tip Shaker Pod R
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD       40 -0.210742.4399491.261518     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7     40001TipPodR       13      40       1   40001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PBODY7        13       1    -0.2
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    40001      12       9                                        +SEG11
+SEG11         1 0.00232     0.0     0.0                                +SEG12
+SEG12         1 0.05206     0.0 0.01550                                +SEG13
+SEG13         1 0.10041     0.0 0.03175                                +SEG14
+SEG14         1 0.24756     0.0 0.03175                                +SEG15
+SEG15         1 0.25214     0.0 0.03175                                +SEG16
```

```
+SEG16         1 0.32112     0.0 0.03175                                           +SEG17
+SEG17         1 0.39469     0.0 0.03175                                           +SEG18
+SEG18         1 0.46827     0.0 0.03175                                           +SEG19
+SEG19         1 0.51731     0.0 0.03175                                           +SEG20
+SEG20         1 0.56636     0.0 0.03175                                           +SEG21
+SEG21         1 0.63986     0.0 0.01550                                           +SEG22
+SEG22         1 0.71351     0.0     0.0
$ Tip Shaker Pod L
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD       41 -0.2115 -1.031641.261518     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7      41001TipPodL       14      41       1   41001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PBODY7        14       1    -0.2
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    41001      12       9                                                   +SEG11
+SEG11         10.001568     0.0     0.0                                           +SEG12
+SEG12         10.050668     0.0 0.01550                                           +SEG13
+SEG13         10.124148     0.0 0.03175                                           +SEG14
+SEG14         10.173198     0.0 0.03175                                           +SEG15
+SEG15         10.271268     0.0 0.03175                                           +SEG16
+SEG16         10.320268     0.0 0.03175                                           +SEG17
+SEG17         10.393868     0.0 0.03175                                           +SEG18
+SEG18         10.467468     0.0 0.03175                                           +SEG19
+SEG19         10.516468     0.0 0.03175                                           +SEG20
+SEG20         10.590068     0.0 0.03175                                           +SEG21
+SEG21         10.639068     0.0 0.01550                                           +SEG22
+SEG22         10.712668     0.0     0.0
$----------------------------------------------------------------------$
$                        * FLUTTER ANALYSIS *                          $
$----------------------------------------------------------------------$
$                                                                      $
$       SETID   SYM     FIX     NMODE   TABDMP  MLIST   CONMLST NKSTEP
FLUTTER 100     ASYM    100     25      20                      30
$
$
TABDMP1 20                                                             +
+       0.00    0.00    0.99    0.00    1.00    0.02    100.0    0.02
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
FIXMDEN 100     100     1.225   KG      M       1.0     0       1      +
+       5.0     6.0     7.0     8.0     9.0     10.0    11.0    12.0   +
+       13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0   +
+       21.0    21.5    22.0    22.5    23.0    23.5    24.0    24.5   +
+       25.0    26.5    27.0    28.0    29.0    30.0    31.0    32.0   +
+       33.0    34.0    35.0    36.0    37.0    38.0    39.0    40.0   +
+       41.0    42.0    43.0    44.0    45.0    46.0    47.0    48.0   +
+       49.0    50.0    52.0    54.0    56.0    58.0    60.0    64.0   +
+       68.0    72.0    76.0    80.0
$
$ PLTVG TO PLOT FREQUENCY & DAMPING V.S. VELOCITY                      $
$                                                                      $
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9--->
$       SETID   IDFLUT  NMODE   XAXIS   FORM        FILENM             $
PLTVG   11      100     25      V               VG_CLMP.PLT

PLTFLUT 10      100     1       10      20.0    FEMAP    FLUT1MOFT.NEU
PLTFLUT 20      100     2       10      20.0    FEMAP    FLUT2MOFT.NEU
PLTFLUT 30      100     3       10      20.0    FEMAP    FLUT3MOFT.NEU
PLTFLUT 40      100     4       10      20.0    FEMAP    FLUT4MOFT.NEU
PLTFLUT 50      100     5       10      20.0    FEMAP    FLUT5MOFT.NEU
PLTFLUT 60      100     6       10      20.0    FEMAP    FLUT6MOFT.NEU
PLTFLUT 70      100     7       10      20.0    FEMAP    FLUT7MOFT.NEU
PLTFLUT 80      100     8       10      20.0    FEMAP    FLUT8MOFT.NEU
PLTFLUT 90      100     9       10      20.0    FEMAP    FLUT9MOFT.NEU
PLTFLUT 100     100     10      10      20.0    FEMAP    FLUT10MOFT.NEU
PLTFLUT 110     100     11      10      20.0    FEMAP    FLUT11MOFT.NEU
PLTFLUT 120     100     12      10      20.0    FEMAP    FLUT12MOFT.NEU
$
OUTPUT4 SMHH    MATR/SMHH.DAT
OUTPUT4 SKHH    MATR/SKHH.DAT
OUTPUT4 QHHS0101MATR/QHH01.DAT
OUTPUT4 QHHS0102MATR/QHH02.DAT
OUTPUT4 QHHS0103MATR/QHH03.DAT
OUTPUT4 QHHS0104MATR/QHH04.DAT
OUTPUT4 QHHS0105MATR/QHH05.DAT
OUTPUT4 QHHS0106MATR/QHH06.DAT
OUTPUT4 QHHS0107MATR/QHH07.DAT
OUTPUT4 QHHS0108MATR/QHH08.DAT
OUTPUT4 QHHS0109MATR/QHH09.DAT
```

```
OUTPUT4 QHHS0110MATR/QHH10.DAT
OUTPUT4 QHHS0111MATR/QHH11.DAT
OUTPUT4 QHHS0112MATR/QHH12.DAT
OUTPUT4 QHHS0113MATR/QHH13.DAT
OUTPUT4 QHHS0114MATR/QHH14.DAT
OUTPUT4 QHHS0115MATR/QHH15.DAT
OUTPUT4 QHHS0116MATR/QHH16.DAT
OUTPUT4 QHHS0117MATR/QHH17.DAT
OUTPUT4 QHHS0118MATR/QHH18.DAT
OUTPUT4 QHHS0119MATR/QHH19.DAT
OUTPUT4 QHHS0120MATR/QHH20.DAT
OUTPUT4 QHHS0121MATR/QHH21.DAT
OUTPUT4 QHHS0122MATR/QHH22.DAT
OUTPUT4 QHHS0123MATR/QHH23.DAT
OUTPUT4 QHHS0124MATR/QHH24.DAT
OUTPUT4 QHHS0125MATR/QHH25.DAT
OUTPUT4 QHHS0126MATR/QHH26.DAT
OUTPUT4 QHHS0127MATR/QHH27.DAT
OUTPUT4 QHHS0128MATR/QHH28.DAT
OUTPUT4 QHHS0129MATR/QHH29.DAT
OUTPUT4 QHHS0130MATR/QHH30.DAT
$
$
ENDDATA
```

Case 2 – ZAERO Code

```
$
MEMORY 8192MB
CPU 16
ASSIGN FEM=pro-assureguy_fullplane2_v37-000.f06,BOUNDARY=ASYM,FORM=MSC, PRINT=0
CEND
$
TITLE =  OSU_ASSURE
ECHO = SORT
SUBCASE = 1
        SUBTITLE= FLUTTER ANALYSIS, M=0.0, SEA LEVEL
        FLUTTER=100
BEGIN BULK
$
$-----------------------------------------------------------------------$
$                                                                       $
$                * AERO PARAMETERS / FEM MODEL UNITS *                  $
$                                                                       $
$-----------------------------------------------------------------------$
$                                                                       $
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$       ACSID   XZSYM   FLIP    FMMUNIT FMLUNIT REFC    REFB    REFS    $
AEROZ           NO      NO      KG      M       0.333   3.33    1.07    +AE1
+AE1    0.444   0.0     0.076
$                                                                       $
$                  AERODYNAMIC AIC MATRIX GENERATION                    $
$                                                                       $
$                        * * * MACH = 0.0 * * *                         $
$                                                                       $
$       IDMK    MACH    METHOD  IDFLT   SAVE    <--FILENAME-->  PRINT   $
MKAEROZ 100     0.00    0       0       SAVE    AERCLP.0                +MK1
+MK1    0.00    0.02    0.03    0.04    0.05    0.06    0.07    0.1     +MK2
+MK2    0.12    0.125   0.13    0.14    0.15    0.2     0.25    0.28    +MK3
+MK3    0.3     0.4     0.5     0.6     0.7     0.8     0.9     1.0     +MK4
+MK4    1.5     2.5     3.0     4.0     5.0     10.0
$
$
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1       LWING1          25      20                              +W1L1
+W1L1   -7.091-30.7043411.1909290.333908                                +W1L2
+W1L2   -7.078-3-.3876191.2264910.333908
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  557     LWING2          10      12                              +W2L1
+W2L1   -7.078-3-.3876191.2264910.261137                                +W2L2
+W2L2   -7.078-3-.9986391.2478280.261137
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  757     FLAP2           10      8                               +W3L1
+W3L1   0.254015-0.387571.2310120.072771                                +W3L2
+W3L2    0.25402-0.998581.2523490.072771

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1001    RWING1          25      20                              +W1R1
+W1R1   -7.091-3 .7043411.190929 .333908                                +W1R2
+W1R2   -7.078-31.7963021.226491 .333908
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1557    RWING2          10      12                              +W2R1
+W2R1   -7.078-31.7963021.2264910.261137                                +W2R2
+W2R2   -7.078-32.4073161.2478280.261137
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1757    FLAP1           10      8                               +W3R1
+W3R1   0.254015 1.796261.2310120.072771                                +W3R2
+W3R2    0.254022.4072741.2523490.072771

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  2001    LTAIL           10      10                              +F1L1
+F1L1   0.9421670.6809521.11267 0.189609                                +F1L2
+F1L2   1.0078110.3109591.11267 0.137705
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  2501    LTAIL_F         5       10                              +F2L1
+F2L1   1.1310250.697809 1.112670.054803                                +F2L2
+F2L2   1.1455160.3109591.1126490.040094

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  3001    RTAIL           10      10                              +F1R1
+F1R1   0.9421670.7273921.11267 0.189609                                +F1R2
+F1R2   1.0078111.0973861.11267 0.137705
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
```

```
CAERO7  3501    RTAIL_F         5       10                                      +F2R1
+F2R1   1.1310250.7105361.11267 0.054803                                        +F2R2
+F2R2   1.1455161.0973861.11269 0.040094

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  4001    VerTail         10      10                                      +F2U1
+F2U1   0.8810280.7051191.1269570.308827                                        +F2U2
+F2U2   1.0892990.7031231.4063570.075708
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  4501    VerTail2        5       10                                      +F3U1
+F3U1   1.1898410.7021591.1269570.051852                                        +F3U2
+F3U2   1.1650030.7023971.4063570.051852

$-------------------------------------------------------------------------------
$                SPLINE & PANLST - BODY + WING
$-------------------------------------------------------------------------------
$       EID     MODEL   CP      SETK    SETG    DZ
$ Femap Aero Spline 2 : LWing
SPLINE1 11      LWing1          201     2       0.0
PANLST1 201     1       1       456
SPLINE1 111     LWing2          202     2       0.0
PANLST1 202     557     557     655
SPLINE1 1111    FLAP2           203     700     0.0
PANLST1 203     757     757     819
$
$ Femap Aero Spline 1 : Rwing
SPLINE1 12      Rwing1          101     1       0.0
PANLST1 101     1001    1001    1456
SPLINE1 122     Rwing2          102     1       0.0
PANLST1 102     1557    1557    1655
SPLINE1 1222    FLAP1           103     600     0.0
PANLST1 103     1757    1757    1819
$
$ Femap Aero Spline 3 : RTail
SPLINE1 13      RTail            301     4       0.0
PANLST1 301     3001    3001    3081
SPLINE1 14      RTail_F          351     7       0.0
PANLST1 351     3501    3501    3536
$
$ Femap Aero Spline 4 : LTail
SPLINE1 15      LTail            401     5       0.0
PANLST1 401     2001    2001    2081
SPLINE1 16      LTail_F          451     8       0.0
PANLST1 451     2501    2501    2536
$
$ Femap Aero Spline 5 : VTail
SPLINE1 17      VTail            501     3       0.0
PANLST1 501     4001    4001    4081
SPLINE1 18      VTail_F          551     6       0.0
PANLST1 551     4501    4501    4536
$
$
$
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$-------------------------------------------------------------------------------
$               Set for the Body & Wing
$-------------------------------------------------------------------------------
SET1           1     858     952     959     960     979     980     988+
+            995     996     999    1000    1170    1177    1183    1188+
+           1196    1234    1272    1341    1799    1801    1806    1807+
+           1810    1815    1990    2021    2070    2241    2260    2272+
+           2386    2439    2447    2450    2495    2500    2564    2614+
+           2666    2678    2728    2792    2837    2842    2846    2903+
+           2906    2956    3008    3015    3017    3020    3070    3074+
+           3122    3134    3184    3188    3236    3248    3293    3297+
+           3299    3305    3351    3359    3407    3413    3416    3521+
+           3522    3527    3530    3579    3640    3643    3644    3692+
+           3749    3750    3754    3758    3807    3815    3863    3866+
+           3868    3872    3921    3929    3977    3978    3980    3982+
+           3984    3986
$ Femap Aero Spline 1 : Rwing
SET1           2     158     164     170     304     532     837    1343+
+           1547    1602    1672    1751    2122    2262    2368    2424+
+           2437    2477    2485    2523    2533    2544    2546    2601+
+           2647    2657    2744    2811    2836    2923    2972    3000+
+           4010    4015    4063    4069    4117    4124    4127    4175+
+           4243    4288    4291    4296    4345    4353    4403    4461+
+           4469    4471    4516    4524    4630    4639    4688    4690+
+           4694    4696    4751    4753    4756    4860    4866    4870+
```

```
+           4915    4975    4980    5036    5041    5086    5145    5150+
+           5257    5260    5372    5374    5378    5485    5549    5601+
+           5656    5770    5777
$ Femap Aero Spline 2 : LWing
SET1           4    6398    6399    6400    6402    6404    6407    6425+
+           6429    6432    6434    6437    6441    6443    6446    6447+
+           6449    6450    6558    6561    6562    6563    6568    6578+
+           6617    8371    8388    8448    8560    8594    8701    8732+
+           8782    8785    8793    8794    8845    8859    8880    8894+
+           8903    8926    8940    8976    9005    9040    9054    9059+
+           9102    9117
$ Femap Aero Spline 3 : RTail
SET1           5    6074    6083    6086    6089    6092    6093    6096+
+           6098    6101    6104    6106    6108    6113    6117    6120+
+           6123    6126    6131    6142    6145    6147    6158    6161+
+           6177    6188    6190    6196    6201    6206    6218    6220+
+           6222    6787    6790    6797    6809    6829    6862    6882+
+           6896    6959    6965    6968    6978    7059    7064    7115+
+           7146
$ Femap Aero Spline 4 : LTail
SET1           3    2652    2869    3114    3153    3178    3200    3201+
+           3209    3217    3220    3225    3227    3229    3396    3418+
+           3435    3452    3462    3861    3884    4200    4204    4212+
+           4272    4328    4329    4394    4485    4593    4613    4680+
+           4722    4778    4863    4888    4919    4960    4963    5003+
+           5105
$ Femap Aero Spline 5 : VTail
$
SET1           7    6407    6439    6440    6441    6442    6443    6444+
+           6445    6446    6447    6448    6449    6450    6451    6571+
+           6603    8862    8966    9018    9096
$ Femap Aero Spline 6 : RTail_F
SET1           8    6083    6084    6115    6116    6117    6118    6119+
+           6120    6121    6122    6123    6124    6125    6126    6127+
+           6128    6136    6152    6168    6184    6200    6216
$ Femap Aero Spline 7 : LTail_F
SET1           6    2869    3209    3226    3227    3228    3229    3230+
+           3231    3234    3394    3444    3453    3458    4329
$ Femap Aero Spline 8 : VTail_F
$--------------------------------------------------------------------------------
$               Set for the Flaps
$--------------------------------------------------------------------------------
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$ Flap 1 :
SET1    600     1955    1980    2197    2195    2175    2177    2157    +
+       2155    2136    2134    2116    2114    2096    2094    2011    +
+       2009    1988    1986    1967    1963    1935    1931    1861
$
$ Flap 2 :
SET1    700     1536    1441    1442    1537    1538    1465    1479    +
+       1539    1540    1502    1541    1503    1542    1513    1543    +
+       1514    1544    1515    1545    1516    1546    1517    1169

$------------------------------------------------------------------------------$
$------------------------------------------------------------------------------$
$                        ASECONT Definition                                    $
$------------------------------------------------------------------------------$
$------------------------------------------------------------------------------$

CORD2R  401             0.6186  0.394   0.0     1.0816  1.524   0.0      +CR11
+CR11   1.0816  1.524   0.5

$------------------------------------------------------------------------------$
$                        Surf modeling                                         $
$------------------------------------------------------------------------------$
$-ACTU-><--ID--><--A0--><--A1--><--A2-->
ACTU    601     2.151E+64.772E+4 586.8
ACTU    602     2.151E+64.772E+4 586.8
ACTU    603     2.151E+64.772E+4 586.8
ACTU    604     2.151E+64.772E+4 586.8
ACTU    605     2.151E+64.772E+4 586.8
$
$AESURFZ<LABEL-><TYPE--><-CID--><-SETK-><-SETG-><-ACTID->
AESURFZ VTAIL_F ASYM     -401     551     6       601
AESURFZ RTAIL_F ASYM     -401     351     7       602
AESURFZ LTAIL_F ASYM     -401     451     8       603
AESURFZ FLAP1   ASYM     -401     103     600     604
AESURFZ FLAP2   ASYM     -401     203     700     605
```

```
SURFSET 350     VTAIL_F RTAIL_F LTAIL_F FLAP1   FLAP2

$-----------------------------------------------------------------------$
$                        * BODY Elements *                              $
$-----------------------------------------------------------------------$
$

$ FUSELAGE SPLINE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 10              10      10
SET1    10      2688    343     714     709     704     699     694     2494
PANLST2 10      10001   10001   THRU    10030
$
$ Right AIM9-P MISSILE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 70              70      50
SET1    50      858     1166    1173    1179    1187    1196    1226    1341
PANLST2 70      40001   40001   THRU    40088
$
$
$ Left AIM9-P MISSILE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 71              71      51
SET1    51      1343    1547    1602    1669    1723    1751    2354    2465
PANLST2 71      41001   41001   THRU    41088
$
$ FUSELAGE
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD        10-0.358980.7041721.096798     0.0     0.0     0.0
$ACOORD        10-0.384970.7041721.128554     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7      10001FUSELAGE              10       1   10001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    10001       7       6                                        +SEG10
+SEG10          3-0.17190                            98      99         +SEG11
+SEG11          3-0.14592                           101     102         +SEG12
+SEG12          30.0                                103     104         +SEG13
+SEG13          30.343016                           105     106         +SEG14
+SEG14          30.570651                           107     108         +SEG15
+SEG15          30.955669                           109     110         +SEG16
+SEG16          31.328021                           111     112
$                                                                        +SEG17
$+SEG17          30.954842                           113     114         +SEG18
$+SEG18          31.074291                           115     116         +SEG19
$+SEG19          31.301778                           117     118
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
AEFACT        98     0.0     0.0     0.0     0.0     0.0     0.0
AEFACT        990.0203320.0203320.0203320.0203320.0203320.020332
AEFACT       1010.0     0.05    0.069   -0.07   -0.054  0.0
AEFACT       102-0.07   -0.053  0.06    0.06    -0.053  -0.07
AEFACT       1030.0     0.0762  0.0762  -0.0762 -0.0762 0.0
AEFACT       104-0.061  -0.061  0.0762  0.0762  -0.061  -0.061
AEFACT       1050.0     0.069   0.072   -0.072  -0.069  0.0
AEFACT       106-0.054  -0.054  0.109   0.109   -0.054  -0.054
AEFACT       107-0.0    0.069   0.069   -0.068  -0.069  -0.0
AEFACT       108-0.054  -0.054  0.076   0.076   -0.054  -0.054
AEFACT       1090.0     0.038   0.038   -0.037  -0.037  0.0
AEFACT       110-0.043  -0.043  0.065   0.065   -0.043  -0.043
AEFACT       1110.013   0.013   0.013   0.013   0.013   0.013
AEFACT       1120.003   0.003   0.003   0.003   0.003   0.003
$
$ Tip Shaker Pod R
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD       40 -0.210742.4399491.261518     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7      40001TipPodR       13      40       1   40001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PBODY7       13       1    -0.2
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    40001      12       9                                        +SEG11
+SEG11          1 0.00232     0.0     0.0                               +SEG12
+SEG12          1 0.05206     0.0 0.01550                               +SEG13
+SEG13          1 0.10041     0.0 0.03175                               +SEG14
+SEG14          1 0.24756     0.0 0.03175                               +SEG15
+SEG15          1 0.25214     0.0 0.03175                               +SEG16
+SEG16          1 0.32112     0.0 0.03175                               +SEG17
+SEG17          1 0.39469     0.0 0.03175                               +SEG18
+SEG18          1 0.46827     0.0 0.03175                               +SEG19
+SEG19          1 0.51731     0.0 0.03175                               +SEG20
```

```
+SEG20         1 0.56636     0.0 0.03175                                      +SEG21
+SEG21         1 0.63986     0.0 0.01550                                      +SEG22
+SEG22         1 0.71351     0.0     0.0
$ Tip Shaker Pod L
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD       41 -0.2115 -1.031641.261518     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7      41001TipPodL       14      41       1   41001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PBODY7        14       1    -0.2
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    41001      12       9                                              +SEG11
+SEG11         10.001568     0.0     0.0                                      +SEG12
+SEG12         10.050668     0.0 0.01550                                      +SEG13
+SEG13         10.124148     0.0 0.03175                                      +SEG14
+SEG14         10.173198     0.0 0.03175                                      +SEG15
+SEG15         10.271268     0.0 0.03175                                      +SEG16
+SEG16         10.320268     0.0 0.03175                                      +SEG17
+SEG17         10.393868     0.0 0.03175                                      +SEG18
+SEG18         10.467468     0.0 0.03175                                      +SEG19
+SEG19         10.516468     0.0 0.03175                                      +SEG20
+SEG20         10.590068     0.0 0.03175                                      +SEG21
+SEG21         10.639068     0.0 0.01550                                      +SEG22
+SEG22         10.712668     0.0     0.0
$-----------------------------------------------------------------------$
$                       * FLUTTER ANALYSIS *                             $
$-----------------------------------------------------------------------$
$                                                                       $
$       SETID   SYM     FIX     NMODE   TABDMP  MLIST   CONMLST NKSTEP
FLUTTER 100     ASYM    100     25      20                      30
$
$
TABDMP1 20                                                              +
+       0.00    0.00    0.99    0.00    1.00    0.02    100.0    0.02
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
FIXMDEN 100     100     1.225   KG      M       1.0     0       1       +
+       5.0     6.0     7.0     8.0     9.0     10.0    11.0    12.0    +
+       13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0    +
+       21.0    21.5    22.0    22.5    23.0    23.5    24.0    24.5    +
+       25.0    26.5    27.0    28.0    29.0    30.0    31.0    32.0    +
+       33.0    34.0    35.0    36.0    37.0    38.0    39.0    40.0    +
+       41.0    42.0    43.0    44.0    45.0    46.0    47.0    48.0    +
+       49.0    50.0    52.0    54.0    56.0    58.0    60.0    64.0    +
+       68.0    72.0    76.0    80.0
$
$ PLTVG TO PLOT FREQUENCY & DAMPING V.S. VELOCITY                        $
$                                                                       $
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9--->
$       SETID   IDFLUT  NMODE   XAXIS   FORM        FILENM              $
PLTVG   11      100     25      V               VG_CLMP.PLT

PLTFLUT 10      100     1       10      20.0    FEMAP    FLUT1MOFT.NEU
PLTFLUT 20      100     2       10      20.0    FEMAP    FLUT2MOFT.NEU
PLTFLUT 30      100     3       10      20.0    FEMAP    FLUT3MOFT.NEU
PLTFLUT 40      100     4       10      20.0    FEMAP    FLUT4MOFT.NEU
PLTFLUT 50      100     5       10      20.0    FEMAP    FLUT5MOFT.NEU
PLTFLUT 60      100     6       10      20.0    FEMAP    FLUT6MOFT.NEU
PLTFLUT 70      100     7       10      20.0    FEMAP    FLUT7MOFT.NEU
PLTFLUT 80      100     8       10      20.0    FEMAP    FLUT8MOFT.NEU
PLTFLUT 90      100     9       10      20.0    FEMAP    FLUT9MOFT.NEU
PLTFLUT 100     100     10      10      20.0    FEMAP    FLUT10MOFT.NEU
PLTFLUT 110     100     11      10      20.0    FEMAP    FLUT11MOFT.NEU
PLTFLUT 120     100     12      10      20.0    FEMAP    FLUT12MOFT.NEU
$
OUTPUT4 SMHH    MATR/SMHH.DAT
OUTPUT4 SKHH    MATR/SKHH.DAT
OUTPUT4 QHHS0101MATR/QHH01.DAT
OUTPUT4 QHHS0102MATR/QHH02.DAT
OUTPUT4 QHHS0103MATR/QHH03.DAT
OUTPUT4 QHHS0104MATR/QHH04.DAT
OUTPUT4 QHHS0105MATR/QHH05.DAT
OUTPUT4 QHHS0106MATR/QHH06.DAT
OUTPUT4 QHHS0107MATR/QHH07.DAT
OUTPUT4 QHHS0108MATR/QHH08.DAT
OUTPUT4 QHHS0109MATR/QHH09.DAT
OUTPUT4 QHHS0110MATR/QHH10.DAT
OUTPUT4 QHHS0111MATR/QHH11.DAT
OUTPUT4 QHHS0112MATR/QHH12.DAT
OUTPUT4 QHHS0113MATR/QHH13.DAT
```

```
OUTPUT4 QHHS0114MATR/QHH14.DAT
OUTPUT4 QHHS0115MATR/QHH15.DAT
OUTPUT4 QHHS0116MATR/QHH16.DAT
OUTPUT4 QHHS0117MATR/QHH17.DAT
OUTPUT4 QHHS0118MATR/QHH18.DAT
OUTPUT4 QHHS0119MATR/QHH19.DAT
OUTPUT4 QHHS0120MATR/QHH20.DAT
OUTPUT4 QHHS0121MATR/QHH21.DAT
OUTPUT4 QHHS0122MATR/QHH22.DAT
OUTPUT4 QHHS0123MATR/QHH23.DAT
OUTPUT4 QHHS0124MATR/QHH24.DAT
OUTPUT4 QHHS0125MATR/QHH25.DAT
OUTPUT4 QHHS0126MATR/QHH26.DAT
OUTPUT4 QHHS0127MATR/QHH27.DAT
OUTPUT4 QHHS0128MATR/QHH28.DAT
OUTPUT4 QHHS0129MATR/QHH29.DAT
OUTPUT4 QHHS0130MATR/QHH30.DAT
$
$
ENDDATA
```

Case 3 – ZAERO Code

```
$
MEMORY 8192MB
CPU 16
ASSIGN FEM=pro-assureguy_fullplane2_v37-001.f06,BOUNDARY=ASYM,FORM=MSC, PRINT=0
CEND
$
TITLE =  OSU_ASSURE
ECHO = SORT
SUBCASE = 1
        SUBTITLE= FLUTTER ANALYSIS, M=0.0, SEA LEVEL
        FLUTTER=100
BEGIN BULK
$
$-------------------------------------------------------------------------$
$                                                                         $
$                * AERO PARAMETERS / FEM MODEL UNITS *                    $
$                                                                         $
$-------------------------------------------------------------------------$
$                                                                         $
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$       ACSID   XZSYM   FLIP    FMMUNIT FMLUNIT REFC    REFB    REFS    $
AEROZ           NO      NO      KG      M       0.333   3.33    1.07    +AE1
+AE1    0.444   0.0     0.076
$                                                                       $
$                   AERODYNAMIC AIC MATRIX GENERATION                   $
$                                                                       $
$                         * * * MACH = 0.0 * * *                        $
$                                                                       $
$       IDMK    MACH    METHOD  IDFLT   SAVE    <--FILENAME-->  PRINT   $
MKAEROZ 100     0.00    0       0       SAVE    AERCLP.0                +MK1
+MK1    0.00    0.02    0.03    0.04    0.05    0.06    0.07    0.1     +MK2
+MK2    0.12    0.125   0.13    0.14    0.15    0.2     0.25    0.28    +MK3
+MK3    0.3     0.4     0.5     0.6     0.7     0.8     0.9     1.0     +MK4
+MK4    1.5     2.5     3.0     4.0     5.0     10.0
$
$
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1       LWING1          25      20                              +W1L1
+W1L1   -7.091-30.7043411.1909290.333908                                +W1L2
+W1L2   -7.078-3-.3876191.2264910.333908
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  557     LWING2          10      12                              +W2L1
+W2L1   -7.078-3-.3876191.2264910.261137                                +W2L2
+W2L2   -7.078-3-.9986391.2478280.261137
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  757     FLAP2           10      8                               +W3L1
+W3L1   0.254015-0.387571.2310120.072771                                +W3L2
+W3L2    0.25402-0.998581.2523490.072771

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1001    RWING1          25      20                              +W1R1
+W1R1   -7.091-3 .7043411.190929 .333908                                +W1R2
+W1R2   -7.078-31.7963021.226491 .333908
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1557    RWING2          10      12                              +W2R1
+W2R1   -7.078-31.7963021.2264910.261137                                +W2R2
+W2R2   -7.078-32.4073161.2478280.261137
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  1757    FLAP1           10      8                               +W3R1
+W3R1   0.254015 1.796261.2310120.072771                                +W3R2
+W3R2    0.254022.4072741.2523490.072771

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  2001    LTAIL           10      10                              +F1L1
+F1L1   0.9421670.6809521.11267 0.189609                                +F1L2
+F1L2   1.0078110.3109591.11267 0.137705
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  2501    LTAIL_F         5       10                              +F2L1
+F2L1   1.1310250.697809 1.112670.054803                                +F2L2
+F2L2   1.1455160.3109591.1126490.040094

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  3001    RTAIL           10      10                              +F1R1
+F1R1   0.9421670.7273921.11267 0.189609                                +F1R2
+F1R2   1.0078111.0973861.11267 0.137705
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  3501    RTAIL_F         5       10                              +F2R1
```

```
+F2R1   1.1310250.7105361.11267 0.054803                                +F2R2
+F2R2   1.1455161.0973861.11269 0.040094

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  4001    VerTail         10      10                              +F2U1
+F2U1   0.8810280.7051191.1269570.308827                                +F2U2
+F2U2   1.0892990.7031231.4063570.075708
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
CAERO7  4501    VerTail2        5       10                              +F3U1
+F3U1   1.1898410.7021591.1269570.051852                                +F3U2
+F3U2   1.1650030.7023971.4063570.051852

$-------------------------------------------------------------------------------
$                SPLINE & PANLST - BODY + WING
$-------------------------------------------------------------------------------
$       EID     MODEL   CP      SETK    SETG    DZ
$ Femap Aero Spline 2 : LWing
SPLINE1 11      LWing1          201     2       0.0
PANLST1 201     1       1       456
SPLINE1 111     LWing2          202     2       0.0
PANLST1 202     557     557     655
SPLINE1 1111    FLAP2           203     700     0.0
PANLST1 203     757     757     819
$
$ Femap Aero Spline 1 : Rwing
SPLINE1 12      Rwing1          101     1       0.0
PANLST1 101     1001    1001    1456
SPLINE1 122     Rwing2          102     1       0.0
PANLST1 102     1557    1557    1655
SPLINE1 1222    FLAP1           103     600     0.0
PANLST1 103     1757    1757    1819
$
$ Femap Aero Spline 3 : RTail
SPLINE1 13      RTail            301     4       0.0
PANLST1 301     3001    3001    3081
SPLINE1 14      RTail_F          351     7       0.0
PANLST1 351     3501    3501    3536
$
$ Femap Aero Spline 4 : LTail
SPLINE1 15      LTail            401     5       0.0
PANLST1 401     2001    2001    2081
SPLINE1 16      LTail_F          451     8       0.0
PANLST1 451     2501    2501    2536
$
$ Femap Aero Spline 5 : VTail
SPLINE1 17      VTail            501     3       0.0
PANLST1 501     4001    4001    4081
SPLINE1 18      VTail_F          551     6       0.0
PANLST1 551     4501    4501    4536
$
$
$
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$-------------------------------------------------------------------------------
$               Set for the Body & Wing
$-------------------------------------------------------------------------------
SET1           1     858     952     959     960     979     980     988+
+            995     996     999    1000    1170    1177    1183    1188+
+           1196    1234    1272    1341    1799    1801    1806    1807+
+           1810    1815    1990    2021    2070    2241    2260    2272+
+           2386    2439    2447    2450    2495    2500    2564    2614+
+           2666    2678    2728    2792    2837    2842    2846    2903+
+           2906    2956    3008    3015    3017    3020    3070    3074+
+           3122    3134    3184    3188    3236    3248    3293    3297+
+           3299    3305    3351    3359    3407    3413    3416    3521+
+           3522    3527    3530    3579    3640    3643    3644    3692+
+           3749    3750    3754    3758    3807    3815    3863    3866+
+           3868    3872    3921    3929    3977    3978    3980    3982+
+           3984    3986
$ Femap Aero Spline 1 : Rwing
SET1           2     158     164     170     304     532     837    1343+
+           1547    1602    1672    1751    2122    2262    2368    2424+
+           2437    2477    2485    2523    2533    2544    2546    2601+
+           2647    2657    2744    2811    2836    2923    2972    3000+
+           4010    4015    4063    4069    4117    4124    4127    4175+
+           4243    4288    4291    4296    4345    4353    4403    4461+
+           4469    4471    4516    4524    4630    4639    4688    4690+
+           4694    4696    4751    4753    4756    4860    4866    4870+
+           4915    4975    4980    5036    5041    5086    5145    5150+
```

```
+           5257    5260    5372    5374    5378    5485    5549    5601+
+           5656    5770    5777
$ Femap Aero Spline 2 : LWing
SET1           4    6398    6399    6400    6402    6404    6407    6425+
+           6429    6432    6434    6437    6441    6443    6446    6447+
+           6449    6450    6558    6561    6562    6563    6568    6578+
+           6617    8371    8388    8448    8560    8594    8701    8732+
+           8782    8785    8793    8794    8845    8859    8880    8894+
+           8903    8926    8940    8976    9005    9040    9054    9059+
+           9102    9117
$ Femap Aero Spline 3 : RTail
SET1           5    6074    6083    6086    6089    6092    6093    6096+
+           6098    6101    6104    6106    6108    6113    6117    6120+
+           6123    6126    6131    6142    6145    6147    6158    6161+
+           6177    6188    6190    6196    6201    6206    6218    6220+
+           6222    6787    6790    6797    6809    6829    6862    6882+
+           6896    6959    6965    6968    6978    7059    7064    7115+
+           7146
$ Femap Aero Spline 4 : LTail
SET1           3    2652    2869    3114    3153    3178    3200    3201+
+           3209    3217    3220    3225    3227    3229    3396    3418+
+           3435    3452    3462    3861    3884    4200    4204    4212+
+           4272    4328    4329    4394    4485    4593    4613    4680+
+           4722    4778    4863    4888    4919    4960    4963    5003+
+           5105
$ Femap Aero Spline 5 : VTail
$
SET1           7    6407    6439    6440    6441    6442    6443    6444+
+           6445    6446    6447    6448    6449    6450    6451    6571+
+           6603    8862    8966    9018    9096
$ Femap Aero Spline 6 : RTail_F
SET1           8    6083    6084    6115    6116    6117    6118    6119+
+           6120    6121    6122    6123    6124    6125    6126    6127+
+           6128    6136    6152    6168    6184    6200    6216
$ Femap Aero Spline 7 : LTail_F
SET1           6    2869    3209    3226    3227    3228    3229    3230+
+           3231    3234    3394    3444    3453    3458    4329
$ Femap Aero Spline 8 : VTail_F
$
$--------------------------------------------------------------------------------
$               Set for the Flaps
$--------------------------------------------------------------------------------
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
$ Flap 1 :
SET1    600     1955    1980    2197    2195    2175    2177    2157    +
+       2155    2136    2134    2116    2114    2096    2094    2011    +
+       2009    1988    1986    1967    1963    1935    1931    1861
$
$ Flap 2 :
SET1    700     1536    1441    1442    1537    1538    1465    1479    +
+       1539    1540    1502    1541    1503    1542    1513    1543    +
+       1514    1544    1515    1545    1516    1546    1517    1169

$-------------------------------------------------------------------------------$
$-------------------------------------------------------------------------------$
$                         ASECONT Definition                                    $
$-------------------------------------------------------------------------------$
$-------------------------------------------------------------------------------$

CORD2R  401             0.6186  0.394   0.0     1.0816  1.524   0.0      +CR11
+CR11   1.0816  1.524   0.5

$-------------------------------------------------------------------------------$
$                         Surf modeling                                         $
$-------------------------------------------------------------------------------$
$-ACTU-><--ID--><--A0--><--A1--><--A2-->
ACTU    601     2.151E+64.772E+4 586.8
ACTU    602     2.151E+64.772E+4 586.8
ACTU    603     2.151E+64.772E+4 586.8
ACTU    604     2.151E+64.772E+4 586.8
ACTU    605     2.151E+64.772E+4 586.8
$
$AESURFZ<LABEL-><TYPE--><-CID--><-SETK-><-SETG-><-ACTID->
AESURFZ VTAIL_F ASYM     -401     551     6       601
AESURFZ RTAIL_F ASYM     -401     351     7       602
AESURFZ LTAIL_F ASYM     -401     451     8       603
AESURFZ FLAP1   ASYM     -401     103     600     604
AESURFZ FLAP2   ASYM     -401     203     700     605
```

```
SURFSET 350     VTAIL_F RTAIL_F LTAIL_F FLAP1   FLAP2

$-----------------------------------------------------------------------$
$                        * BODY Elements *                              $
$-----------------------------------------------------------------------$
$

$ FUSELAGE SPLINE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 10              10      10
SET1    10      2688    343     714     709     704     699     694     2494
PANLST2 10      10001   10001   THRU    10030
$
$ Right AIM9-P MISSILE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 70              70      50
SET1    50      858     1166    1173    1179    1187    1196    1226    1341
PANLST2 70      40001   40001   THRU    40088
$
$
$ Left AIM9-P MISSILE (BEAM SPLINE)
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SPLINE2 71              71      51
SET1    51      1343    1547    1602    1669    1723    1751    2354    2465
PANLST2 71      41001   41001   THRU    41088
$
$ FUSELAGE
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD        10-0.358980.7041721.096798     0.0     0.0     0.0
$ACOORD        10-0.384970.7041721.128554     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7      10001FUSELAGE             10       1   10001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    10001      7       6                                         +SEG10
+SEG10         3-0.17190                             98      99         +SEG11
+SEG11         3-0.14592                            101     102         +SEG12
+SEG12         30.0                                 103     104         +SEG13
+SEG13         30.343016                            105     106         +SEG14
+SEG14         30.570651                            107     108         +SEG15
+SEG15         30.955669                            109     110         +SEG16
+SEG16         31.328021                            111     112
$                                                                        +SEG17
$+SEG17         30.954842                            113     114         +SEG18
$+SEG18         31.074291                            115     116         +SEG19
$+SEG19         31.301778                            117     118
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
AEFACT        98     0.0     0.0     0.0     0.0     0.0     0.0
AEFACT        990.0203320.0203320.0203320.0203320.0203320.020332
AEFACT       1010.0     0.05    0.069   -0.07   -0.054  0.0
AEFACT       102-0.07   -0.053  0.06    0.06    -0.053  -0.07
AEFACT       1030.0     0.0762  0.0762  -0.0762 -0.0762 0.0
AEFACT       104-0.061  -0.061  0.0762  0.0762  -0.061  -0.061
AEFACT       1050.0     0.069   0.072   -0.072  -0.069  0.0
AEFACT       106-0.054  -0.054  0.109   0.109   -0.054  -0.054
AEFACT       107-0.0    0.069   0.069   -0.068  -0.069  -0.0
AEFACT       108-0.054  -0.054  0.076   0.076   -0.054  -0.054
AEFACT       1090.0     0.038   0.038   -0.037  -0.037  0.0
AEFACT       110-0.043  -0.043  0.065   0.065   -0.043  -0.043
AEFACT       1110.013   0.013   0.013   0.013   0.013   0.013
AEFACT       1120.003   0.003   0.003   0.003   0.003   0.003
$
$ Tip Shaker Pod R
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD       40 -0.210742.4399491.261518     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7      40001TipPodR       13      40       1   40001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PBODY7       13       1    -0.2
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    40001      12       9                                        +SEG11
+SEG11         1 0.00232     0.0     0.0                                +SEG12
+SEG12         1 0.05206     0.0 0.01550                                +SEG13
+SEG13         1 0.10041     0.0 0.03175                                +SEG14
+SEG14         1 0.24756     0.0 0.03175                                +SEG15
+SEG15         1 0.25214     0.0 0.03175                                +SEG16
+SEG16         1 0.32112     0.0 0.03175                                +SEG17
+SEG17         1 0.39469     0.0 0.03175                                +SEG18
+SEG18         1 0.46827     0.0 0.03175                                +SEG19
+SEG19         1 0.51731     0.0 0.03175                                +SEG20
```

```
+SEG20         1 0.56636     0.0 0.03175                                  +SEG21
+SEG21         1 0.63986     0.0 0.01550                                  +SEG22
+SEG22         1 0.71351     0.0     0.0
$ Tip Shaker Pod L
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
ACOORD       41 -0.2115 -1.031641.261518     0.0     0.0     0.0
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
BODY7      41001TipPodL       14      41       1   41001
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
PBODY7        14       1    -0.2
$...1..|...2...|...3...|...4...|...5...|...6...|...7...|...8...|...9...|...10..|
SEGMESH    41001      12       9                                          +SEG11
+SEG11         10.001568     0.0     0.0                                  +SEG12
+SEG12         10.050668     0.0 0.01550                                  +SEG13
+SEG13         10.124148     0.0 0.03175                                  +SEG14
+SEG14         10.173198     0.0 0.03175                                  +SEG15
+SEG15         10.271268     0.0 0.03175                                  +SEG16
+SEG16         10.320268     0.0 0.03175                                  +SEG17
+SEG17         10.393868     0.0 0.03175                                  +SEG18
+SEG18         10.467468     0.0 0.03175                                  +SEG19
+SEG19         10.516468     0.0 0.03175                                  +SEG20
+SEG20         10.590068     0.0 0.03175                                  +SEG21
+SEG21         10.639068     0.0 0.01550                                  +SEG22
+SEG22         10.712668     0.0     0.0
$-----------------------------------------------------------------------$
$                        * FLUTTER ANALYSIS *                           $
$-----------------------------------------------------------------------$
$                                                                       $
$       SETID   SYM     FIX     NMODE   TABDMP  MLIST   CONMLST NKSTEP
FLUTTER 100     ASYM    100     25      20                      30
$
$
TABDMP1 20                                                              +
+       0.00    0.00    0.99    0.00    1.00    0.02    100.0    0.02
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
FIXMDEN 100     100     1.225   KG      M       1.0     0       1       +
+       5.0     6.0     7.0     8.0     9.0     10.0    11.0    12.0    +
+       13.0    14.0    15.0    16.0    17.0    18.0    19.0    20.0    +
+       21.0    21.5    22.0    22.5    23.0    23.5    24.0    24.5    +
+       25.0    26.5    27.0    28.0    29.0    30.0    31.0    32.0    +
+       33.0    34.0    35.0    36.0    37.0    38.0    39.0    40.0    +
+       41.0    42.0    43.0    44.0    45.0    46.0    47.0    48.0    +
+       49.0    50.0    52.0    54.0    56.0    58.0    60.0    64.0    +
+       68.0    72.0    76.0    80.0
$
$ PLTVG TO PLOT FREQUENCY & DAMPING V.S. VELOCITY                       $
$                                                                       $
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9--->
$       SETID   IDFLUT  NMODE   XAXIS   FORM        FILENM              $
PLTVG   11      100     25      V               VG_CLMP.PLT

PLTFLUT 10      100     1       10      20.0    FEMAP    FLUT1MOFT.NEU
PLTFLUT 20      100     2       10      20.0    FEMAP    FLUT2MOFT.NEU
PLTFLUT 30      100     3       10      20.0    FEMAP    FLUT3MOFT.NEU
PLTFLUT 40      100     4       10      20.0    FEMAP    FLUT4MOFT.NEU
PLTFLUT 50      100     5       10      20.0    FEMAP    FLUT5MOFT.NEU
PLTFLUT 60      100     6       10      20.0    FEMAP    FLUT6MOFT.NEU
PLTFLUT 70      100     7       10      20.0    FEMAP    FLUT7MOFT.NEU
PLTFLUT 80      100     8       10      20.0    FEMAP    FLUT8MOFT.NEU
PLTFLUT 90      100     9       10      20.0    FEMAP    FLUT9MOFT.NEU
PLTFLUT 100     100     10      10      20.0    FEMAP    FLUT10MOFT.NEU
PLTFLUT 110     100     11      10      20.0    FEMAP    FLUT11MOFT.NEU
PLTFLUT 120     100     12      10      20.0    FEMAP    FLUT12MOFT.NEU
$
OUTPUT4 SMHH    MATR/SMHH.DAT
OUTPUT4 SKHH    MATR/SKHH.DAT
OUTPUT4 QHHS0101MATR/QHH01.DAT
OUTPUT4 QHHS0102MATR/QHH02.DAT
OUTPUT4 QHHS0103MATR/QHH03.DAT
OUTPUT4 QHHS0104MATR/QHH04.DAT
OUTPUT4 QHHS0105MATR/QHH05.DAT
OUTPUT4 QHHS0106MATR/QHH06.DAT
OUTPUT4 QHHS0107MATR/QHH07.DAT
OUTPUT4 QHHS0108MATR/QHH08.DAT
OUTPUT4 QHHS0109MATR/QHH09.DAT
OUTPUT4 QHHS0110MATR/QHH10.DAT
OUTPUT4 QHHS0111MATR/QHH11.DAT
OUTPUT4 QHHS0112MATR/QHH12.DAT
OUTPUT4 QHHS0113MATR/QHH13.DAT
```

```
OUTPUT4 QHHS0114MATR/QHH14.DAT
OUTPUT4 QHHS0115MATR/QHH15.DAT
OUTPUT4 QHHS0116MATR/QHH16.DAT
OUTPUT4 QHHS0117MATR/QHH17.DAT
OUTPUT4 QHHS0118MATR/QHH18.DAT
OUTPUT4 QHHS0119MATR/QHH19.DAT
OUTPUT4 QHHS0120MATR/QHH20.DAT
OUTPUT4 QHHS0121MATR/QHH21.DAT
OUTPUT4 QHHS0122MATR/QHH22.DAT
OUTPUT4 QHHS0123MATR/QHH23.DAT
OUTPUT4 QHHS0124MATR/QHH24.DAT
OUTPUT4 QHHS0125MATR/QHH25.DAT
OUTPUT4 QHHS0126MATR/QHH26.DAT
OUTPUT4 QHHS0127MATR/QHH27.DAT
OUTPUT4 QHHS0128MATR/QHH28.DAT
OUTPUT4 QHHS0129MATR/QHH29.DAT
OUTPUT4 QHHS0130MATR/QHH30.DAT
$
$
ENDDATA
```

Case 1 – Dynresp

```
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
SOURCE  ZAERO
AERDATA aerocards.dat
STRMOD  struct.dat
CSDATA  pro-assureguy_fullplane2_v35-005.f06
ENDINMAT
TITLE   OSU_ASSURE_FullSpan
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
SUBCASE 1
TIMESET 1
STABLE  1
DAMPING 20
AEROSET 1
FCS     1
OUTRES                                  FORMAT                          +FORM
+FORM                   FORMAT
BEGIN BULK
$ For smaller steps:
MARGIN  1       FLUTTER 100     ALT     80                              +
+       18      19      20      21      21.5    22      22.5    23      +
+       23.5    24      24.2    24.4    24.6    24.8    25      25.2    +
+       25.4    25.6    25.8    26      26.2    26.4    26.6    26.8    +
+       27      27.2    27.4    27.6    27.8    28      28.2    28.4    +
+       28.6    28.8    29      29.2    29.4    29.6    29.8    30.     +
+       30.2    30.4    30.6    30.8    31      31.2    31.4    31.6    +
+       31.8    32      32.2    32.4    32.6    32.8    33      33.2    +
+       33.4    33.6    33.8    34      34.2    34.4    34.6    34.8    +
+       35      35.5    36      36.5    37      38      39      40      +
+       41      42      43      45      48      50      51      55
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
AERO    1       30.     1.225   L       1000
MKAEROZ 1000    0.15    0.3                                             +MK1
+MK1    0.00    0.02    0.03    0.04    0.05    0.06    0.07    0.1     +MK2
+MK2    0.12    0.125   0.13    0.14    0.15    0.2     0.25    0.3     +MK3
+MK3    0.4     0.5     0.6     0.7     0.8     0.9     1.0     1.5

$     2.5     3.0     4.0     5.0     10.0

TIMEF1  1       200     3.      .05
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
TABDMP  20                                                              +
+       0.00    0.00    0.99    0.00    1.00    0.02    50.0    0.02
$+       0.00    0.00    0.99    0.00    1.00    0.00    50.0    0.00
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->

ASECONT 1               180             910
SENSET  180     102
$  Acceleration at added mass point
ASESNSR 102     2       1547    3
GAINSET 910     31
$  Zero gain to define the Pf connections
ASEGAIN 31      102     1       301     1       0.0
$ selected gain that reflect added m of 0.7Kg
GAINSET 100     33
ASEGAIN 33      102     1       301     1       0.7
$  Unit excitation force
CFORCE  301     1547    3       1.0
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->

ENDDATA
```

Case 2– Dynresp

```
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
SOURCE  ZAERO
AERDATA aerocards.dat
STRMOD  struct.dat
CSDATA  pro-assureguy_fullplane2_v37-003.f06
ENDINMAT
TITLE   OSU_ASSURE_FullSpan

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
SUBCASE 1
TIMESET 1
STABLE  1
DAMPING 20
AEROSET 1
FCS     1
OUTRES                                  FORMAT                          +FORM
+FORM                   FORMAT

BEGIN BULK

$ For smaller steps:
MARGIN  1       FLUTTER 100     ALT     80                              +
+       18      19      20      21      21.5    22      22.5    23      +
+       23.5    24      24.2    24.4    24.6    24.8    25      25.2    +
+       25.4    25.6    25.8    26      26.2    26.4    26.6    26.8    +
+       27      27.2    27.4    27.6    27.8    28      28.2    28.4    +
+       28.6    28.8    29      29.2    29.4    29.6    29.8    30.     +
+       30.2    30.4    30.6    30.8    31      31.2    31.4    31.6    +
+       31.8    32      32.2    32.4    32.6    32.8    33      33.2    +
+       33.4    33.6    33.8    34      34.2    34.4    34.6    34.8    +
+       35      35.5    36      36.5    37      38      39      40      +
+       41      42      43      45      48      50      51      55
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
AERO    1       30.     1.225   L       1000
MKAEROZ 1000    0.15    0.3                                             +MK1
+MK1    0.00    0.02    0.03    0.04    0.05    0.06    0.07    0.1     +MK2
+MK2    0.12    0.125   0.13    0.14    0.15    0.2     0.25    0.3     +MK3
+MK3    0.4     0.5     0.6     0.7     0.8     0.9     1.0     1.5

TIMEF1  1       200     3.      .05
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
TABDMP  20                                                              +
+       0.00    0.00    0.99    0.00    1.00    0.02    50.0    0.02
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
ASECONT 1               180             910
SENSET  180     102
$  Acceleration at added mass point
ASESNSR 102     2       1547    3
GAINSET 910     31
$  Zero gain to define the Pf connections
ASEGAIN 31      102     1       301     1       0.0
$ selected gain that reflect added m of 0.7Kg
GAINSET 100     33
ASEGAIN 33      102     1       301     1       0.7
$  Unit excitation force
CFORCE  301     1547    3       1.0
ENDDATA
```

Case 3 – Dynresp

```
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
SOURCE  ZAERO
AERDATA aerocards.dat
STRMOD  struct.dat
CSDATA  pro-assureguy_fullplane2_v37-002.f06
ENDINMAT
TITLE   OSU_ASSURE_FullSpan

$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
SUBCASE 1
TIMESET 1
STABLE  1
DAMPING 20
AEROSET 1
FCS     1
OUTRES                                  FORMAT                          +FORM
+FORM                   FORMAT

BEGIN BULK

$ For smaller steps:
MARGIN  1       FLUTTER 100     ALT     80                              +
+       18      19      20      21      21.5    22      22.5    23      +
+       23.5    24      24.2    24.4    24.6    24.8    25      25.2    +
+       25.4    25.6    25.8    26      26.2    26.4    26.6    26.8    +
+       27      27.2    27.4    27.6    27.8    28      28.2    28.4    +
+       28.6    28.8    29      29.2    29.4    29.6    29.8    30.     +
+       30.2    30.4    30.6    30.8    31      31.2    31.4    31.6    +
+       31.8    32      32.2    32.4    32.6    32.8    33      33.2    +
+       33.4    33.6    33.8    34      34.2    34.4    34.6    34.8    +
+       35      35.5    36      36.5    37      38      39      40      +
+       41      42      43      45      48      50      51      55
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
AERO    1       30.     1.225   L       1000
MKAEROZ 1000    0.15    0.3                                             +MK1
+MK1    0.00    0.02    0.03    0.04    0.05    0.06    0.07    0.1     +MK2
+MK2    0.12    0.125   0.13    0.14    0.15    0.2     0.25    0.3     +MK3
+MK3    0.4     0.5     0.6     0.7     0.8     0.9     1.0     1.5
TIMEF1  1       200     3.      .05
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
TABDMP  20                                                              +
+       0.00    0.00    0.99    0.00    1.00    0.02    50.0    0.02
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->
ASECONT 1               180             910
SENSET  180     102
$  Acceleration at added mass point
ASESNSR 102     2       1547    3
GAINSET 910     31
$  Zero gain to define the Pf connections
ASEGAIN 31      102     1       301     1       0.0
$ selected gain that reflect added m of 0.7Kg
GAINSET 100     33
ASEGAIN 33      102     1       301     1       0.7
$  Unit excitation force
CFORCE  301     1547    3       1.0
$--1---><--2---><--3---><--4---><--5---><--6---><--7---><--8---><--9---><--10-->

ENDDATA
```

F58 Plotter Code - Matlab

```
clear variables
clc
set(groot,'defaulttextinterpreter','latex');
set(groot, 'defaultAxesTickLabelInterpreter','latex');
```

parameters

```
path = '.\'; % path of the .out file
n_cases = 1; % please limit number of cases to run together to 1 right now
if_compare = 0; % if you also want to compare .f58 results with .out results
if_add_f58 = 1; % if you also want to add gust and stability output responses
max_freq = 300; % max number of frequecnies that can be expected in any .f58 file
max_vel = 40; % max number of velocities that the user will provide in the inout file
n_maxbranches = 200; % max number of branches, I don't expect more cross-overs even for
significant fluctuations
```

loop over multiple cases

for case_id = 1:n_cases % this option cannot be used right now

```
case_id = 1; % this is fixed unitl further update is made
%     if(if_add_f58 == 1)
%         analysis_type = ["STABLE";"GUST"];
%         filenames = [strcat(path,"flutterv4_sym_Pfp3_1.f58");
%             strcat(path,"flutterv4_sym_gust_1.f58")];
    if(if_add_f58 == 1)
        analysis_type = "STABLE";
        filenames = strcat(path,"Assure_FullSpan_Gen2_Dynresp_case1_v3_1.f58");
    elseif(if_compare == 1)
        analysis_type = "STABLE"; % add the analysis types of the matrix
        filenames = strcat(path,"Assure_FullSpan_Gen2_Dynresp_case1_v3_1.f58");
    else
        analysis_type = ["STABLE";"STABLE"]; % add the analysis types of the matrix
        filenames =
[strcat(path,"flutqterv4_sym_Pfp3_1.f58");strcat(path,"fluttaerv4_sym_case1_1.f58")];
    end
    if(if_compare == 1)
        filenameout = strcat(path,"Assure_FullSpan_Gen2_Dynresp_case1_v3.out");
        % calling function to read dynresp .out file
        [DELTAm,PCOf,VEL,PF,n_subcases,pos_subcase_change] = dynresp_output_read(filenameout);
    else
        n_subcases = length(filenames);
        if(if_add_f58 == 1)
            PF = 0.7*ones(n_subcases,1); % or provide actual PF vector
        else
            PF = [0.7;0.7];
        end
    end
    V58 = zeros(max_vel,n_subcases);
    Freq = zeros(max_freq,n_subcases);
    Y   = zeros(max_freq,max_vel,n_subcases);
    for isc = 1:n_subcases
        if(analysis_type(isc) == "STABLE")
            f58_plot_ind = [1;1;1;1]; % non-zero entry means plot is desired
        else
            f58_plot_ind = [0;0;1;1];
        end
        filenamef58 = filenames(isc);
        [Vtemp,Ftemp,Ytemp] = dynresp_output_read_f58(filenamef58,analysis_type(isc));
        V58(1:length(Vtemp),isc) = Vtemp;
        Freq(1:length(Ftemp),isc) = Ftemp;
        Y(1:size(Ytemp,1),1:size(Ytemp,2),isc) = Ytemp;
        G = abs(Ytemp);
        Phi = atan(imag(Ytemp)./real(Ytemp))*180/pi;
        PCOf58 = -999*ones(length(Vtemp),n_maxbranches);
        DeltaPF58 = 999*ones(length(Vtemp),n_maxbranches);
        ypco = zeros(length(Vtemp),n_maxbranches);
        % modifying phases with incorrect quadrants
        for j=1:length(Vtemp)
            for i=1:length(Ftemp)-1
                if (Phi(i,j)<0)
                    if (imag(Ytemp(i,j))/G(i,j)>0)
                        Phi(i,j) = Phi(i,j) + 180;
                    end
                else
                    if (imag(Ytemp(i,j))/G(i,j)<0)
                        Phi(i,j) = Phi(i,j) - 180;
                    end
                end
            end
        end
        for j=1:length(Vtemp)
```

```
            count = 0;
            for i=1:length(Ftemp)-1
                if( (sign(Phi(i,j))~=sign(Phi(i+1,j))) )
                    count = count + 1;
                    ypco(j,count) = real(Ytemp(i,j)) + ...
                        (real(Ytemp(i+1,j))-
real(Ytemp(i,j)))*abs(Phi(i,j))/(abs(Phi(i,j))+abs(Phi(i+1,j)));
                    DeltaPF58(j,count) = PF(isc) - ...
                        1/ypco(j,count);
                    PCOf58(j,count) = Ftemp(i) + (Ftemp(i+1)-
Ftemp(i))*abs(Phi(i,j))/(abs(Phi(i,j))+abs(Phi(i+1,j)));
                end
            end
        end
        ypco = ypco(:,1:count);
        DeltaPF58 = DeltaPF58(:,1:count);
        PCOf58 = PCOf58(:,1:count);
        fig_id = case_id*10000 + isc*100;
        if (isc~=n_subcases) % this part is used for 1st to n-1th subcases if n_subcases>1
            plot_f58_results(Vtemp,DeltaPF58,PCOf58,G,Phi,Ftemp,PF(isc),fig_id,f58_plot_ind) %
plotting .f58 figures
            if(if_compare == 1)
                plot_comparison(VEL(pos_subcase_change(isc):pos_subcase_change(isc+1)-1),...
                    DELTAm(pos_subcase_change(isc):pos_subcase_change(isc+1)-1,:),...
                    PCOf(pos_subcase_change(isc):pos_subcase_change(isc+1)-1,:),...
                    Vtemp,DeltaPF58,PCOf58,PF(isc),fig_id) % plotting comparison
            end
        else % this part is used for the n-th subcase if n_subcases>1, or if n_subcases=1
            plot_f58_results(Vtemp,DeltaPF58,PCOf58,G,Phi,Ftemp,PF(isc),fig_id,f58_plot_ind) %
plotting figures
            if(if_compare == 1)
                plot_comparison(VEL(pos_subcase_change(isc):end),...
                    DELTAm(pos_subcase_change(isc):end,:),...
                    PCOf(pos_subcase_change(isc):end,:),Vtemp,DeltaPF58,PCOf58,PF(isc),fig_id) %
plotting comparison
            end
        end
    end
```

Analyzing the modified solution

```
    if(if_add_f58 == 1)
        V_add = 30; % in case of adding gust responses to unit sinsuidoal response, what velocity
you want to use
        fstart = 3.0; % starting frequency
        fend = 12.8; % ending frequency
        DF = 0.05; % frequency step size
        norm_fact = 0.1; % normalization factor for any gust response
        Vind = find(V58(:,1) == V_add);
        fstartind = find(Freq(:,1) == fstart);
        fendind = find(Freq(:,1) == fend);
        Fmod = Freq(fstartind:fendind,1);
        Ymod = Y(fstartind:fendind,Vind,1) + norm_fact*Y((fstart-(Freq(1,2)))/DF+1:(fend-
(Freq(1,2)))/DF+1,1,2);
        G = abs(Ymod);
        Phi = atan(imag(Ymod)./real(Ymod))*180/pi;
        PCOf58 = -999*ones(1,n_maxbranches);
        DeltaPF58 = 999*ones(1,n_maxbranches);
        ypco = zeros(1,n_maxbranches);
        % modifying phases with incorrect quadrants
        j = 1; % length of velocity vector is 1, it is just the velocity V_add
        for i=1:length(Fmod)-1
            if (Phi(i,j)<0)
                if (imag(Ymod(i,j))/G(i,j)>0)
                    Phi(i,j) = Phi(i,j) + 180;
                end
            else
                if (imag(Ymod(i,j))/G(i,j)<0)
                    Phi(i,j) = Phi(i,j) - 180;
                end
            end
        end
        count = 0;
        for i=1:length(Fmod)-1
            if( (sign(Phi(i,j))~=sign(Phi(i+1,j))) )
                count = count + 1;
                ypco(j,count) = real(Ymod(i,j)) + (real(Ymod(i+1,j))-
real(Ymod(i,j)))*abs(Phi(i,j))/(abs(Phi(i,j))+abs(Phi(i+1,j)));
                DeltaPF58(j,count) = PF(1) - ...
                    1/ypco(j,count);
                PCOf58(j,count) = Freq(i) + (Freq(i+1)-
Freq(i))*abs(Phi(i,j))/(abs(Phi(i,j))+abs(Phi(i+1,j)));
            end
        end
        ypco = ypco(:,1:count);
        DeltaPF58 = DeltaPF58(:,1:count);
        PCOf58 = PCOf58(:,1:count);
        f58_plot_ind = [0;0;1;1];
```

```
        fig_id = 20000;
        plot_f58_results(V_add,DeltaPF58,PCOf58,G,Phi,Fmod,PF(1),fig_id,f58_plot_ind)
    end

% end
```

```
function [V,Freq,Y] = dynresp_output_read_f58(filename,analysis_type)
fid = fopen(filename,'r');
A=fscanf(fid,'%c');
fclose(fid);
```

parameters

```
if(analysis_type=="STABLE")
    str1 = 'NDFO_VRQ1P,5E16.9';
else
    str1 = '4NP_DF    1P,5E16.9';
end
str2 = 'SENSORW 1P,5E16.9';
```

extracting the required data

```
id_str1_strt = strfind(A,str1);
id_str2_strt = strfind(A,str2);
NF = str2double(A(id_str1_strt(1) + length(str1) + 3*8 + 4:id_str1_strt(1) + length(str1) + 3*8 +
19));
DF = str2double(A(id_str1_strt(1) + length(str1) + 3*8 + 20:id_str1_strt(1) + length(str1) + 3*8
+ 35));
V = zeros(size(id_str1_strt,1),1);
Y = zeros(NF,size(id_str1_strt,1));
Freq = zeros(NF,1);
if(analysis_type=="STABLE")
    freq1 = ...
    str2double(A(id_str1_strt(1) + length(str1) + 2*(3*8 + 2) + 34 + 2:id_str1_strt(1) +
length(str1) +  2*(3*8 + 2) + 34 + 17));
else
    freq1 = 0.0;
end

for i=1:length(id_str1_strt)
    if(analysis_type=="STABLE")
        V(i) = str2double(A(id_str1_strt(i) + length(str1) + 3*(3*8 + 2) + 34*2 + 2:...
            id_str1_strt(i) + length(str1) +  3*(3*8 + 2) + 34*2 + 17));
    end
    for j=1:NF
        Y(j,i) = str2double(A(id_str2_strt(i) + length(str2) + j*(3*8 + 2) + (j-1)*34 + 2:...
        id_str2_strt(i) + length(str2) +  j*(3*8 + 2) + (j-1)*34 + 17)) + ...
         1i*str2double(A(id_str2_strt(i) + length(str2) + j*(3*8 + 2) + (j-1)*34 + 18:...
         id_str2_strt(i) + length(str2) +  j*(3*8 + 2) + (j-1)*34 + 33));
    end
end
for j=1:NF
    Freq(j) = freq1 + (j-1)*DF;
end
end
```

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```
function [DELTAm,PCOf,VEL,PF,n_subcases,pos_subcase_change] = dynresp_output_read(filename)
fid = fopen(filename,'r');
A=fscanf(fid,'%c');
fclose(fid);
```

```
Not enough input arguments.

Error in dynresp_output_read (line 3)
fid = fopen(filename,'r');
```

parameters

```
target_string1 = 'WPCO_HZ ';
target_string2 = 'DELTA   ';
target_string3 = 'VEL     ';
target_string4 = 'PF      ';
```

```
target_string5 = 'SUBCASE ';
tab_size = 8;
```

gathering ID and no. of branches information

```
id_WPCO_HZ = strfind(A,target_string1)';
id_DELTA = strfind(A,target_string2)';
id_VEL = strfind(A,target_string3)';
id_PF = strfind(A,target_string4)';
id_SUBCASE = strfind(A,target_string5)';
n_subcases = length(id_SUBCASE);
n_branches = round((id_DELTA - id_WPCO_HZ)/2/tab_size - 1);
```

storing PCOf, DELTAm, relevant VEL values, etc.

```
PCOf = -999*ones(length(id_WPCO_HZ),max(n_branches));
DELTAm = 999*ones(length(id_WPCO_HZ),max(n_branches));
VEL = zeros(length(id_WPCO_HZ),1);
PF = zeros(n_subcases,1);
pos_subcase_change = zeros(n_subcases,1);
for i=1:length(id_WPCO_HZ)
    for j=1:n_branches(i)
        PCOf(i,j) = str2double(A(id_WPCO_HZ(i)+tab_size+(j-
1)*tab_size:id_WPCO_HZ(i)+tab_size+j*tab_size-1));
        temp = A(id_DELTA(i)+tab_size+(j-1)*tab_size:id_DELTA(i)+tab_size+j*tab_size-1);
        if(contains(temp(2:end),'-'))
            pos = strfind(temp(2:end),'-');
            DELTAm(i,j) = str2double(strcat(temp(1:pos),'e',temp(pos+1:end)));
        elseif(contains(temp(2:end),'+'))
            pos = strfind(temp(2:end),'+');
            DELTAm(i,j) = str2double(strcat(temp(1:pos),'e',temp(pos+1:end)));
        else
            DELTAm(i,j) = str2double(temp);
        end
    end
    temp = A(id_VEL(i+length(id_VEL)-length(id_WPCO_HZ))+tab_size:id_VEL(i+length(id_VEL)-
length(id_WPCO_HZ))+2*tab_size-1);
    pos = strfind(temp,' ');
    if(isempty(pos))
        VEL(i) = str2double(temp);
    else
        VEL(i) = str2double(temp(1:pos(1)-1));
    end
end
diff = id_WPCO_HZ(1) - id_SUBCASE(1);
for subcase_i = 1:n_subcases
    temp = A(id_PF(length(id_PF)/n_subcases*(subcase_i - 1) + 1)+tab_size:...
        id_PF(length(id_PF)/n_subcases*(subcase_i - 1) + 1)+2*tab_size-1);
    pos = strfind(temp,' ');
    if(isempty(pos))
        PF(subcase_i) = str2double(temp);
    else
        PF(subcase_i) = str2double(temp(1:pos(1)-1));
    end
    pos_subcase_change(subcase_i) = find(id_WPCO_HZ-id_SUBCASE(subcase_i)==diff);
end
end
```

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```
function plot_comparison(V,DELTAm,PCOf,V58,DeltaPF58,PCOf58,PF,fig_id)

figure(fig_id+8)
hold on
grid on
xlabel('$V$(m/s)','FontName','Arial','FontSize',20)
ylabel('$\Delta m$ (Kg.)','FontName','Arial','FontSize',20)
plot1 = plot(V,DELTAm,'^','LineWidth',1);
for i=1:size(PCOf,2)
    set(plot1(i),'DisplayName',strcat('Branch',num2str(i)));
end
plot(V58,DeltaPF58(:,1:size(DELTAm,2)),'o','LineWidth',1);
yticks(PF*floor(min(min(DELTAm))/PF):PF/2:3*PF)
ylim([PF*floor(min(min(DELTAm))/PF) 3*PF])
hleg1 = legend('show','Location','northwest');
set(hleg1,'FontName','Arial','FontSize',8,'Interpreter','latex')
ax = gca;
ax.FontSize = 16;
hold off

figure(fig_id+9)
hold on
grid on
xlabel('$V$(m/s)','FontName','Arial','FontSize',20)
```

```
ylabel('f(Hz.)','FontName','Arial','FontSize',20)
plot1 = plot(V,PCOf,'^','LineWidth',1);
for i=1:size(PCOf,2)
    set(plot1(i),'DisplayName',strcat('Branch',num2str(i)));
end
yticks(floor(min(min(abs(PCOf)))):round((ceil(1.5*max(max(PCOf))) -
floor(min(min(abs(PCOf)))))/6):ceil(1.5*max(max(PCOf))))
ylim([floor(min(min(abs(PCOf)))) ceil(1.5*max(max(PCOf)))])
plot(V58,PCOf58(:,1:size(PCOf,2)),'o','LineWidth',1);
hleg1 = legend('show');
set(hleg1,'FontName','Arial','FontSize',8,'Interpreter','latex','Location','northwest')
ax = gca;
ax.FontSize = 16;
hold off

end
```

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```
function plot_f58_results(V58,DeltaPF58,PCOf58,G,Phi,Freq,PF,fig_id,f58_plot_ind)

if(f58_plot_ind(1)~=0)
figure(fig_id+3)
hold on
grid on
xlabel('$V$(m/s)','FontName','Arial','FontSize',20)
ylabel('$\Delta m$ (Kg.)','FontName','Arial','FontSize',20)
plot1 = plot(V58,DeltaPF58,'o','LineWidth',1);
for i=1:size(DeltaPF58,2)
    set(plot1(i),'DisplayName',strcat('Branch',num2str(i)));
end
yticks(PF*floor(min(min(DeltaPF58))/PF):PF/2:2*PF)
ylim([PF*floor(min(min(DeltaPF58))/PF) 2*PF])
hleg1 = legend('show','Location','northwest');
set(hleg1,'FontName','Arial','FontSize',8,'Interpreter','latex')
ax = gca;
ax.FontSize = 16;
hold off
end

if(f58_plot_ind(2)~=0)
figure(fig_id+4)
hold on
grid on
xlabel('$V$(m/s)','FontName','Arial','FontSize',20)
ylabel('f(Hz.)','FontName','Arial','FontSize',20)
yticks(floor(min(min(abs(PCOf58)))):round((ceil(1.2*max(max(PCOf58))) -
floor(min(min(abs(PCOf58)))))/6):ceil(1.2*max(max(PCOf58))))
ylim([floor(min(min(abs(PCOf58)))) ceil(1.2*max(max(PCOf58)))])
plot1 = plot(V58,PCOf58,'o','LineWidth',1);
for i=1:size(DeltaPF58,2)
    set(plot1(i),'DisplayName',strcat('Branch',num2str(i)));
end
hleg1 = legend('show');
set(hleg1,'FontName','Arial','FontSize',8,'Interpreter','latex','Location','northwest')
ax = gca;
ax.FontSize = 16;
hold off
end

if(f58_plot_ind(3)~=0)
figure(fig_id+5)
hold on
grid on
xlabel('Freq. (Hz.)','FontName','Arial','FontSize',20)
ylabel('$|G| (m/s^2)$','FontName','Arial','FontSize',20)
% yticks(floor(min(min(abs(PCOf)))):round((ceil(1.2*max(max(PCOf))) -
floor(min(min(abs(PCOf)))))/6):ceil(1.2*max(max(PCOf))))
% ylim([floor(min(min(abs(PCOf)))) ceil(1.2*max(max(PCOf)))])
plot(Freq,G,'o','LineWidth',1,'MarkerSize',4);
hleg1 = legend('Gust');
set(hleg1,'FontName','Arial','FontSize',8,'Interpreter','latex','Location','northwest')
ax = gca;
ax.FontSize = 16;
hold off
end

if(f58_plot_ind(4)~=0)
figure(fig_id+6)
hold on
grid on
xlabel('Freq. (Hz.)','FontName','Arial','FontSize',20)
ylabel('$\Phi$ (degrees)','FontName','Arial','FontSize',20)
% yticks(floor(min(min(abs(PCOf)))):round((ceil(1.2*max(max(PCOf))) -
floor(min(min(abs(PCOf)))))/6):ceil(1.2*max(max(PCOf))))
ylim([-180 180])
plot(Freq,Phi,'o','LineWidth',1,'MarkerSize',4);
```

```
% hleg1 = legend('show');
hleg1 = legend('Gust');
set(hleg1,'FontName','Arial','FontSize',8,'Interpreter','latex','Location','northwest')
ax = gca;
ax.FontSize = 16;
hold off
end

end
```

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