A CRITIQUE OF THE MSC/NASTRAN FLUTTER ANALYSIS CAPABILITY

by

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Flutter analysis requirements of the cruise missile program demanded use of three dimensional aerodynamic theory. Use of the solution 45 flutter analysis available within MSC/NASTRAN provided convenient access to the doublet lattice aerodynamic theory, since all the finite element models used for modal analyses had been constructed using NASTRAN. This use prompted listing of the concerns shown in Figure 1, which address Doublet Lattice Method (DLM) N5KA and the SOL 45 flutter algorithm. Concerns are based on the premise that the user will be a relatively inexperienced flutter analyst, in that companies which require flutter analyses on a regular basis have their own in-house capability and will not use SOL 45. Prior to using SOL 45 it is recommended that the analyst review the documents shown in Figure 2. While acknowledging that a rigorous DMAP alter sequence can achieve virtually any end result, the means, convenient to the user, are desired to address the following areas:

> User Visibility - The need to look at the static (zero reduced frequency) aerodynamic data and to determine whether the spline is good.
>
> Solution Control - The need to perform mode deletion flutter analyses.
>
> Efficiency Improvement - In some cases a significant reduction in user cost could be achieved by using an aerodynamic influence coefficient approach to calculating the aerodynamic matrices.

Figures 3 and 4 show modifications to the solution sequence which could achieve these enhancements. The ensuing discussion provides examples for each of these items.

The only way to assess the validity of the aerodynamic model is to look at model aerodynamic data at a zero reduced frequency (k=0.0) prior to performing the flutter analysis. To illustrate this point, static aerodynamic data was calculated using Doublet Lattice Method H7WB for the representative aerodynamic planform of an all-movable horizontal tail, shown in Figure 5. For the purposes of this discussion consider the mode wherein the all-movable portion pitches about the spindle. Figure 6 shows the resulting spanwise load distributions with Mach number as a parameter. Of special interest is the tabulation of total lift coefficient $C_{L\alpha}$ Vs. Mach number. Frequently the analyst is able to compare this calculated data with corresponding experimental or predicted data. Discrepancies are not unusual, and the comparison can aid the user in either revising his aerodynamic representation or adjusting his flutter solution results. Of interest, but of lesser significance, are the data shown in Figure 7, which define the aerodynamic center location Vs. span, with Mach number as a parameter.

A spline is required in SOL 45 to transfer deflections from the structural to the aerodynamic degrees of freedom. Use of the surface spline option can be perplexing, since the user controls the structural (G set) grid point set and smoothing parameters used to calculate the curve fit coefficients, and has only the V-g and V-ω plots on which to base a judgement of whether he has achieved a good curve fit. It is deemed desirable that the analyst look at the structural point to aerodynamic point interpolation matrix and the resulting aerodynamic point (K set) deflections prior to performing the flutter analysis. This can be accomplished by using the lengthy DMAP Alter sequence developed by E.D. Bellinger of MSC. This Alter is defined in Figure 8.

Figure 9 shows a typical V-ω plot for a cruise missile type air vehicle. The critical flutter mechanism appears to involve only the fin bending and torsion modes, with no interaction with the wing and body modes. To confirm this I would have liked very much to have performed the analysis using only the two fin modes.

This solution could be achieved at minimal cost through restart, if the capability were provided in SOL 45.

User cost of SOL 45 is relatively high. Aerodynamic Influence Coefficients (AIC) could be calculated by using unit values for the surface fit coefficients. These AIC would be valid for the given aerodynamic model, Mach number and reduced frequency set. Aerodynamic matrices (R and I) for use in the flutter solution are then calculated through a triple matrix product of the actual spline coefficients with the AIC, at approximately one-fifth the cost of a single SOL 45 flutter solution. This procedure is detailed in Figure 4.

In summary, SOL 45 did provide access to the doublet lattice aerodynamic theory. As shown in Figure 10, the complication of a surface fit and lack of a capability to calculate static aerodynamic data with N5KA are detractions. The inability to perform mode deletion analyses and to calculate AIC independent of the physical mode shape detract from user convenience and user cost.

FIGURE 1

USE OF MSC/NASTRAN SOL 45 FLUTTER ALGORITHM

ADVANTAGE	● CONVENIENT ACCESS TO DOUBLET LATTICE AERODYNAMICS
CONCERNS	● USER VISIBILITY
	● SOLUTION CONTROL
	● EFFICIENCY IMPROVEMENT

FIGURE 2

NASTRAN FLUTTER ANALYSIS BACKGROUND MATERIAL

PRELIMINARY DOCUMENTATION - NASTRAN AEROELASTICITY

NASTRAN DEMONSTRATION PROBLEM MANUAL

AFFDL-TR-71-5 SUBSONIC UNSTEADY AERODYNAMICS FOR GENERAL CONFIGURATIONS, PART II, VOLUME II, COMPUTER PROGRAM N5KA, J. P. GIESING, T. P. KALMAN, W. P. RODDEN, APRIL 1972

AEROELASTIC ADDITION TO NASTRAN, MSR-55, AUGUST 1978

AERODYNAMIC INFLUENCE COEFFICIENTS BY THE DOUBLET LATTICE METHOD FOR INTERFERING NON PLANAR LIFTING SURFACES OSCILLATING IN A SUBSONIC FLOW, DOUGLAS AIRCRAFT COMPANY REPORT DAC 67977, T. P. KALMAN, W. P. RODDEN, J. P. GIESING (PROPRIETARY) REFERRED TO IN TEXT AS DOUBLET LATTICE METHOD H7WB

FIGURE 3
MSC/NASTRAN FLUTTER SOLUTION SCHEME
DOUBLET LATTICE METHOD N5KA

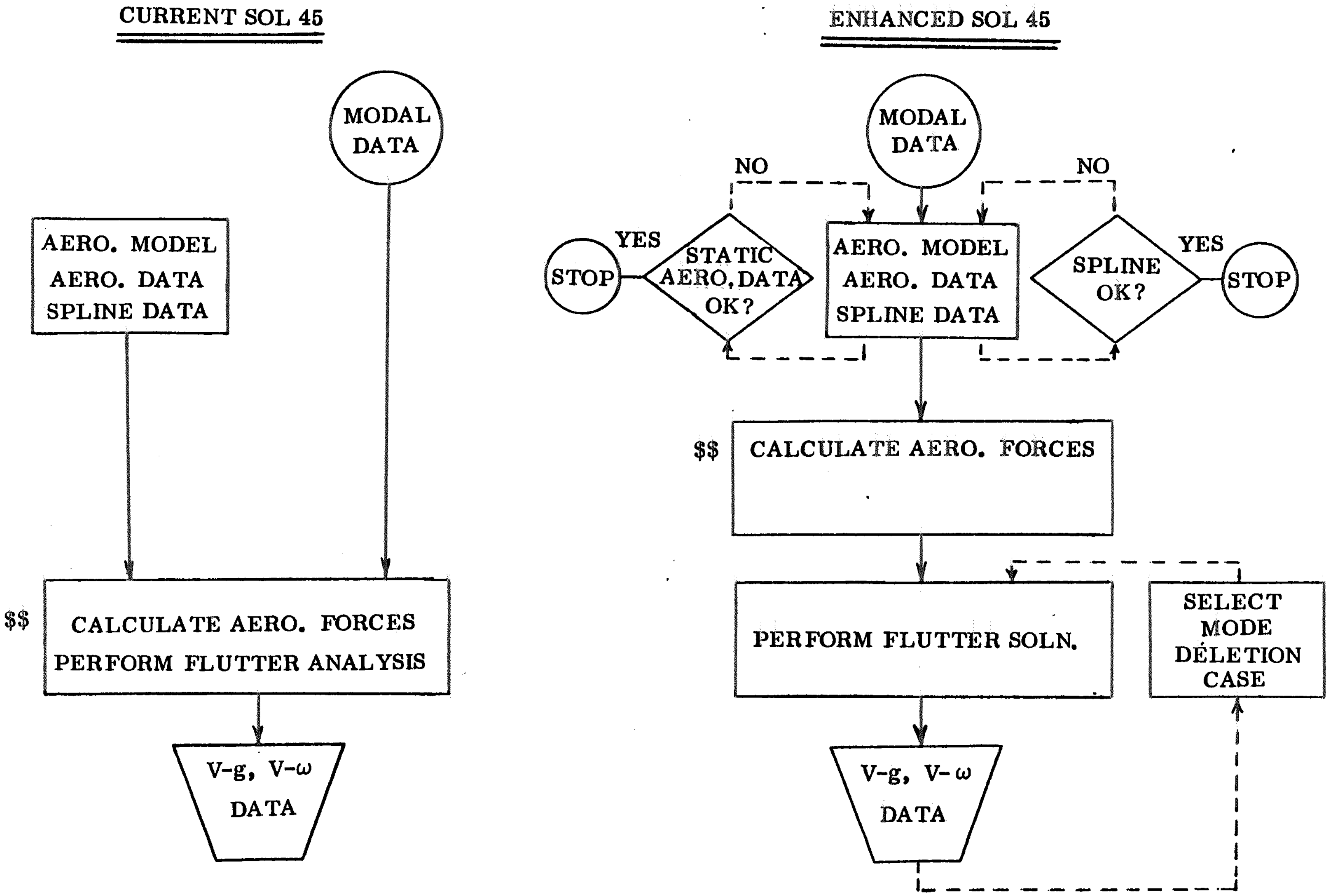

FIGURE 4

FLUTTER SOLUTION USING AERODYNAMIC INFLUENCE COEFFICIENTS
DOUBLET LATTICE METHOD N5KA

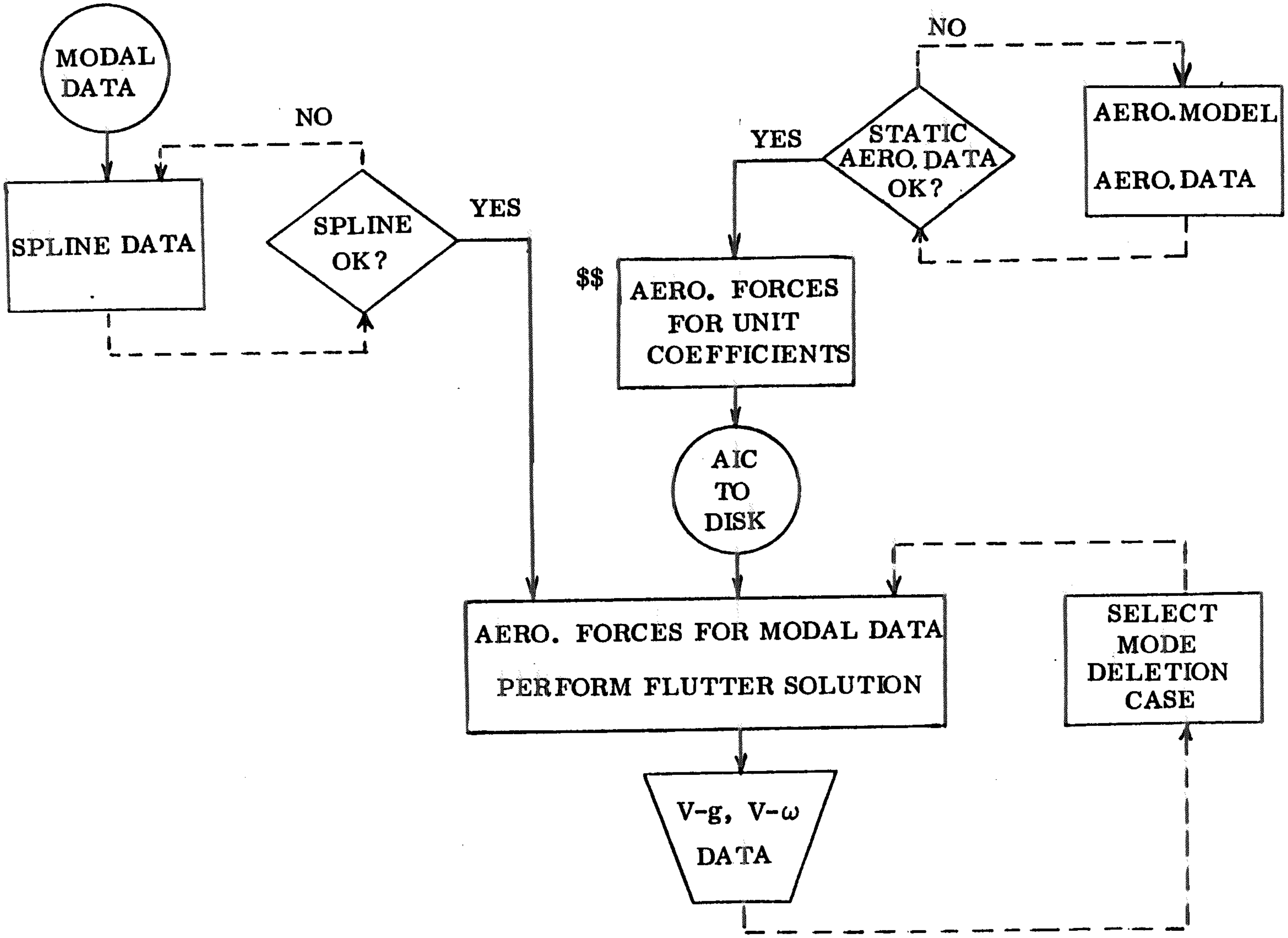

FIGURE 5

HORIZONTAL TAIL PLANFORM

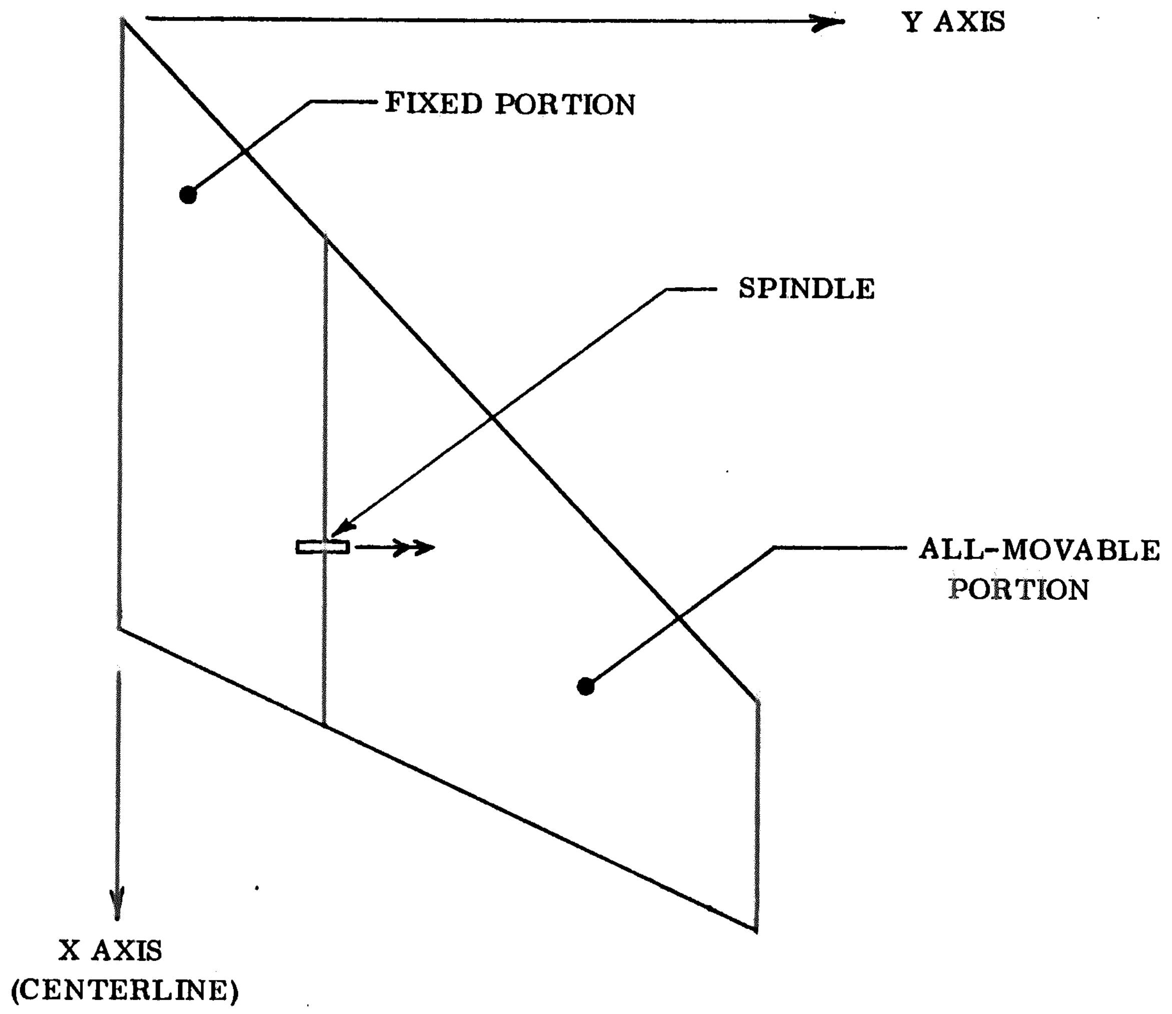

FIGURE 6

HORIZONTAL TAIL LOAD DISTRIBUTIONS - PITCH ABOUT SPINDLE

DOUBLE LATTICE METHOD H7WB

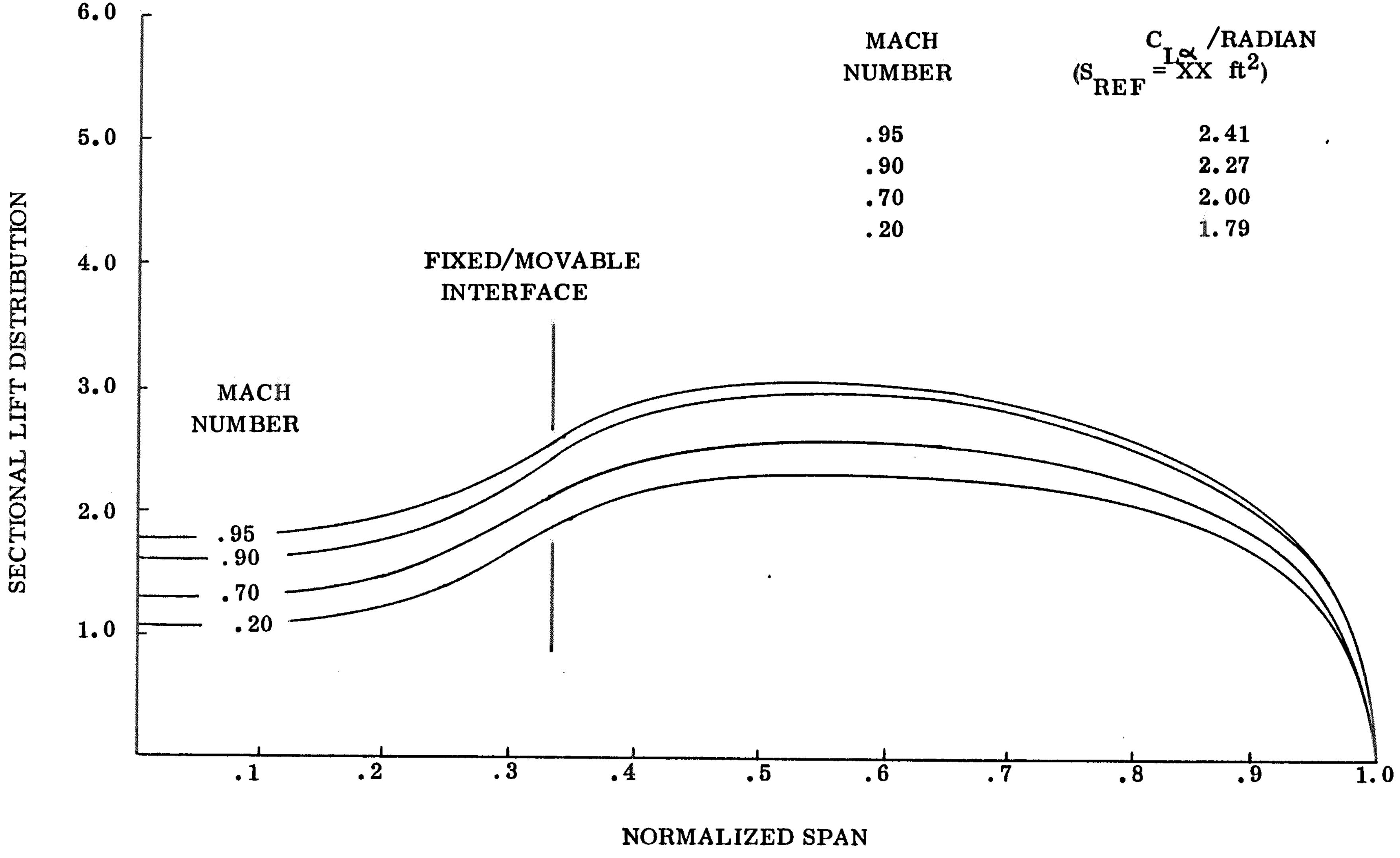

FIGURE 7

HORIZONTAL TAIL AERODYNAMIC CENTER LOCATION - PITCH ABOUT SPINDLE
DOUBLET LATTICE METHOD H7WB

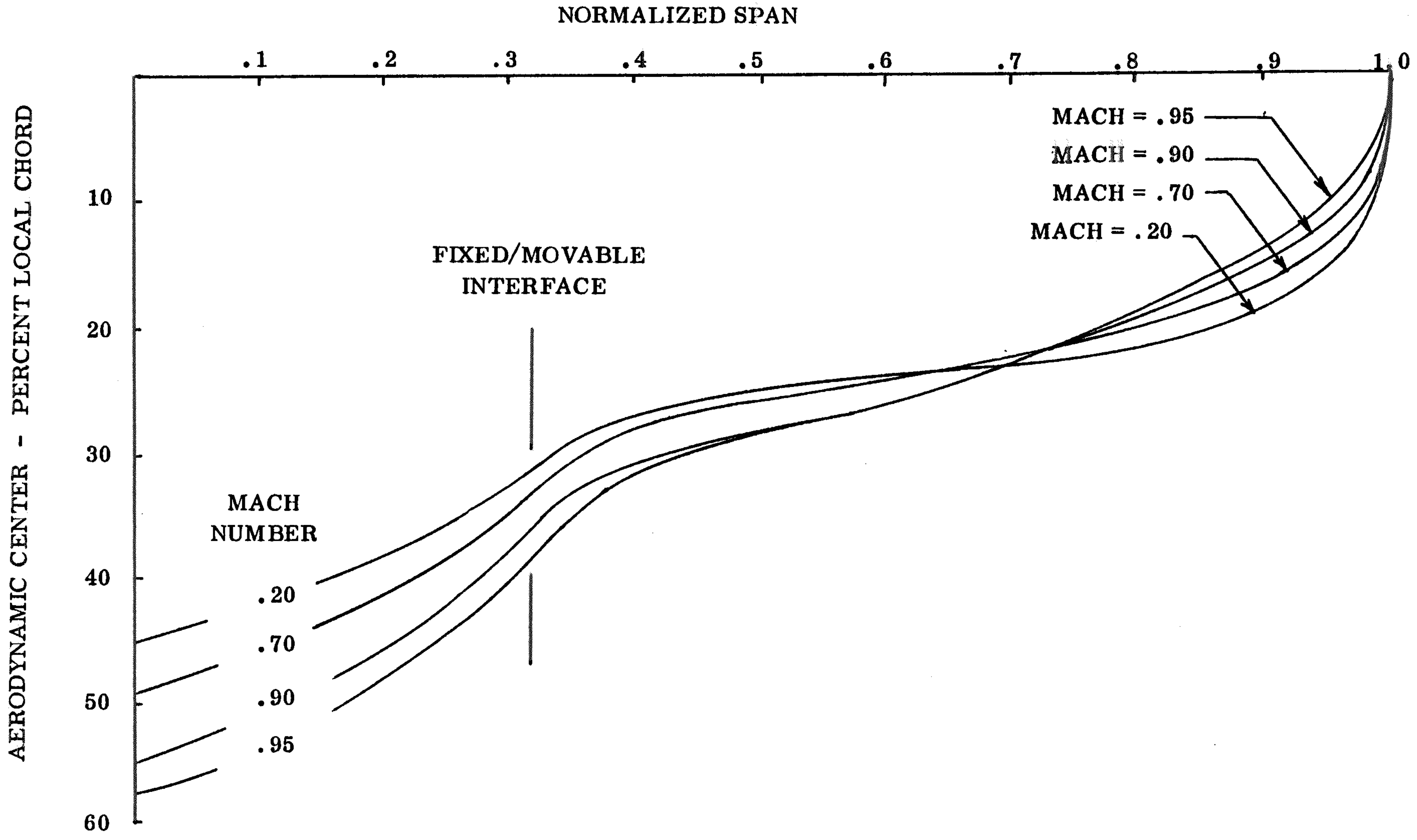

FIGURE 8

DMAP ALTER TO CHECK THE SPLINE

```
ALTER 96 $
        PARAM     //C,N,AND/V,N,OPPHI/V,Y,OPPHIG=-1/V,Y,OPPHIB=-1 $
        COND      SPPHI,OPPHI $ - - - - - - - - - - - - - - - - - - - - - -
        SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIG,,/1/REIG $                 -
        COND      SPPHIG,OPPHIG $- - - - - - - - - - - - - - - - - - - - -
        MATGPR    GPL,USET,SIL,PHIG//C,N,H/C,N,G $                          -
LABEL     SPPHIG $ - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$                                                                           -
        COND      SPPHI,OPPHIB $ - - - - - - - - - - - - - - - - - - - - -
        VECPLOT   PHIG,BGPDT,EQEXIN,CSTM,CASECC,/PHIB/0/0/1 $               -
        MATGPR    GPL,USET,SIL,PHIB//C,N,H/C,N,G $                          -
LABEL     SPPHI $ - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
ALTER 116,117 $
        COND      SPGEOM,OPGEOM $ - - - - - - - - - - - - - - - - - - - - -
        PARAM     //C,N,NOP/V,Y,OPGEOM=-1 $                                 -
        TABPT.    EQAERO // $                                               -
        TABPRT    USETA,EQAERO // C,N,USET $                                -
        TABPRT    CSTMA // C,N,CSTM $                                       -
        TABPRT    BGPA // C,N,BGPDT $                                       -
        TABPT     SPLINE // $                                               -
LABEL     SPGEOM $ - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        PARAM     //ADD/V,N,MSO/0/0 $
        COND      NOMPCS,MPCF1 $ - - - - - - - - - - - - - - - - - - - - -
        PARAM     //ADD/MSO/MSO/1 $                                         -
LABEL     NOMPCS $- - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        COND      NOSPCS,SINGLE $- - - - - - - - - - - - - - - - - - - - -
        PARAM     //ADD/MSO/MSO/2 $                                         -
LABEL     NOSPCS $- - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        COND      NOOMITS,OMIT $ - - - - - - - - - - - - - - - - - - - - -
        PARAM     //ADD/MSO/MSO/4 $                                         -
LABEL     NOOMITS $- - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        PARAML    USET//C,N,TRAILER/4/V,N,WORD4 $
        PARAM     //SUB/WORD4/WORD4/MSO $
        MODTRL    USET/////WORD4 $
        GI        SPLINE,USET,CSTMA,BGPA,SIL,,GM,GO/
                  GTKG/
                  V,N,NK/V,N,LUSET $
        EQUIV     GTKG,GTKA/NOA $
        CHKPNT    GTKA $
        PARAM     //ADD/WORD4/WORD4/MSO $
        MODTRL    USET/////WORD4 $
        COND      SPGTKG,OPGTKG $ - - - - - - - - - - - - - - - - - - - - -
        PARAM     //C,N,NOP/V,Y,OPGTKG=-1 $                                 -
        MATGPR    GPLA,USETA,SILA,GTKG//C,N,K/C,N,G $                       -
LABEL     SPGTKG $ - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        COND      SPGMT,OPGMTGO $ - - - - - - - - - - - - - - - - - - - - -
        PARAM     //C,N,NOP/V,Y,OPGMTGO=-1 $                                -
        TRNSP     GM/GMT $                                                  -
        MATGPR    GPL,USET,SIL,GMT // C,N,M/C,N,N $                         -
        MATGPR    GPL,USET,SIL,GO // C,N,A/C,N,O $                          -
LABEL     SPGMT $ - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        COND     SPRED,NOA $ - - - - - - - - - - - - - - - - - - - - - - -
        SSG2      USET,GM,,,GO,,GTKG/,,,GTKA $                              -
LABEL     SPRED $ - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        CHKPNT    GTKA $
        COND      SPGTKA,OPGTKA $ - - - - - - - - - - - - - - - - - - - - -
        PARAM     //C,N,NOP/V,Y,OPGTKA=-1 $                                 -
        MATGPR    GPLA,USETA,SILA,GTKA//C,N,K/C,N,A $                       -
LABEL     SPGTKA $ - - - - - - - - - - - - - - - - - - - - - - - - - - - -
$
        COND      SPPHIKH,OPPHIKH $ - - - - - - - - - - - - - - - - - - - -
        PARAM     //C,N,NOP/V,Y,OPPHIKH=-1 $                                -
        MPYAD     GTKA,PHIA,/PHIKH/1 $                                      -
        MATGPR    GPLA,USETA,SILA,PHIKH//C,N,H/C,N,K $                      -
LABEL     SPPHIKH $ - - - - - - - - - - - - - - - - - - - - - - - - - - -
$$$       END OF ALTER
ENDALTER
```

INTERPOLATION
MATRIX G SET T
K SET

MODAL DEFLEC
AT THE AEROD
MIC GRID POIN

FIGURE 9

TOTAL MODEL FLUTTER - MSC/NASTRAN DOUBLET LATTICE - M = .7

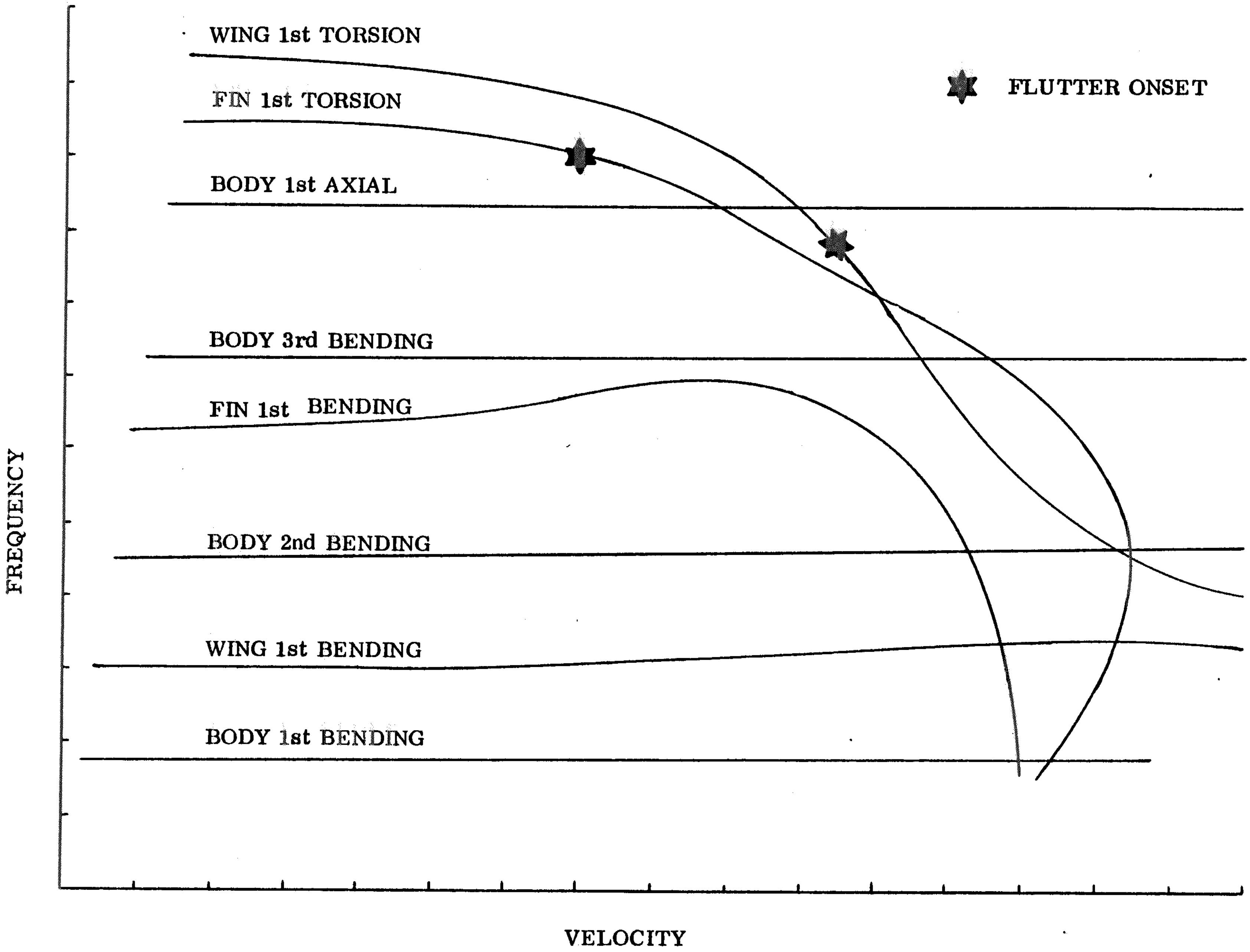

FIGURE 10

DESIRED FLUTTER ANALYSIS CAPABILITY
NOT READILY AVAILABLE IN SOL 45

- OPTION TO LOOK AT STATIC AERODYNAMIC DATA
- CONVENIENT METHOD FOR ASSESSING VALIDITY OF THE CURVE FIT
- OPTION OF DOING MODE DELETION FLUTTER SOLUTION ANALYSES
- OPTION OF CALCULATING AND SAVING AERODYNAMIC INFLUENCE COEFFICIENTS WHICH ARE INDEPENDENT OF THE MODAL DATA