ACTE Wing Loads Analysis

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About Me

• The Ohio State University, Columbus, OH
• 3rd year student
• Double Major: Aerospace Engineering & Aviation

• AERO Institute
• Code RS: Aerostructures
• Mentor: Josué Cruz
Background

- ACTE – Adaptive Compliant Trailing Edge
- Joint project between NASA, AFRL, FlexSys
- Modified GIII
- Flexible Flap – Seamless Transition
- Multifunctional Structure contributes to:
  - Noise Reduction
  - Wing Load Alleviation
  - Cruise Drag Optimization
- ACTE Project Goal: Prove full scale flap structure could be manufactured and flown in a relevant flight environment
Background

• Wing Loads Analysis needed with new modification
• Includes CFD analysis and flight tests
• Important load characteristics include: shear force, bending and torsion moments
• Previously TRANAIR used as CFD software
• Worked well for initial testing at lower Mach numbers
• Higher fidelity code required for testing at higher Mach numbers (near transition region)
• Star-CCM+ chosen for further testing
• Outputs TECPLOT format
Objective

• CFD output is ran through MATLAB utility
• Calculates wing loads from aerodynamic and inertial data
• Needed updating/replacement to work with TECPLOT format before further flight testing could be conducted
Star-CCM+ Output

• Outputs data file in TECPLOT format
• Post-processing tool
• Many CFD programs output in this format
• Contains data for free-stream and aircraft
• Surrounding air is unnecessary – only need GIII surface data
TECPLLOT

• Original file only contains node and $C_P$ data
• TECPLLOT used to calculate other important variables
• Saved as ASCII format
• New file contains all variables
TECPLOT Output

**File Header**

```
TITLE = "ACTE_20degflap_M0.30H10kft_4.0AoA0.0AoS"
VARIABLES = "X"
  "Y"
  "Z"
  "Pressure Coefficient"
  "Cell Volume"
  "X Grid K Unit Normal"
  "Y Grid K Unit Normal"
  "Z Grid K Unit Normal"
  "X_center"
  "Y_center"
  "Z_center"

ZONE T="Region 1:wing"
  STRANDID=3, SOLUTIONTIME=0
  Nodes=692661, Faces=1047496, Elements=354834, ZONETYPE=FEPolygon
  DATAPACKING=BLOCK
  VARLOCATION=(
    [4-11]=CELLCENTERED)
  NumConnectedBoundaryFaces=0, TotalNumBoundaryConnections=0
  DT=(DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE DOUBLE )
```

**Zone Header**

```
1.309661787E+001 1.309531916E+001 1.309375143E+001 1.309303646E+001 1.309375143E+001
1.309498318E+001 1.309357208E+001 1.309716251E+001 1.309570962E+001 1.309789396E+001
1.309823756E+001 1.309677409E+001 1.309989295E+001 1.309696464E+001 1.309889874E+001
1.309503726E+001 1.309498318E+001 1.309357208E+001 1.309716251E+001 1.309570962E+001
1.309407097E+001 1.309629902E+001 1.309528563E+001 1.309375143E+001 1.309291962E+001
1.309630228E+001 1.309498318E+001 1.309357208E+001 1.309716251E+001 1.309570962E+001
1.30931643E+001 1.309089163E+001 1.309675545E+001 1.309287135E+001 1.310179459E+001
1.31014392E+001 1.309609816E+001 1.309675545E+001 1.310034621E+001 1.310327025E+001
1.31031643E+001 1.310093249E+001 1.310169554E+001 1.310169554E+001 1.310169554E+001
1.309802742E+001 1.309472228E+001 1.309325384E+001 1.309665941E+001 1.309612846E+001
1.309753282E+001 1.309704733E+001 1.309834718E+001 1.310042634E+001 1.310186334E+001
1.310223578E+001 1.309977391E+001 1.310069604E+001 1.310169798E+001 1.310169798E+001
1.309930575E+001 1.309792568E+001 1.309776139E+001 1.309872672E+001 1.309862095E+001
1.309796273E+001 1.310096249E+001 1.310111608E+001 1.310252726E+001 1.310271202E+001
1.310487740E+001 1.310725745E+001 1.311247704E+001 1.311192579E+001 1.311709924E+001
1.310507603E+001 1.310065120E+001 1.310595965E+001 1.310575741E+001 1.310361101E+001
1.310098249E+001 1.310424269E+001 1.310796986E+001 1.310461847E+001 1.310889502E+001
1.31101457E+001 1.310432472E+001 1.310304547E+001 1.310834198E+001 1.310834734E+001
1.310659294E+001 1.312362694E+001 1.312089807E+001 1.311960537E+001 1.312125180E+001
1.312374310E+001 1.312529521E+001 1.311848754E+001 1.311536953E+001 1.311343005E+001
1.311406975E+001 1.311640057E+001 1.311829852E+001 1.311714953E+001 1.311338876E+001
```
Extract.m

- Prompts user for inputs: file name, zones, translation/rotation, scaling
- ACTE custom input

extract_TECPLLOT.m

- Checks file format for correct variables
- Extracts data from selected zones
- Scales then removes data inboard BL 45
- Translates & rotates data

Output

- Saves data as MATLAB file
- Includes within each zone: panel center, \(C_P\), area, unit normal vector
ACTE_Load_Case_M_TECPLOT.m

Prompts User for Inputs

Calculate Aerodynamic Forces

Calculate Inertial Forces

Data Output

Calculate Loads (Shear, Bending, & Torsion)

Transform to Other Coordinate Systems
Load Case: Inputs

• Old program required manual input (physically changing script each time)

• New program: Just hit “run”

• Prompts User:
  • File from Extract.m output
  • Wing Weights File(s)
  • Flight Conditions:
    • Dynamic Pressure (q)
    • Maneuvering Load (Nz)
    • CG & Roll Rate/Acceleration (only for rolling maneuvers)
  • Wing Stations for Load Analysis
Load Case: Forces

• Aerodynamic Force:
  • $F = C_p \times q \times \text{Area} \times \text{Unit Norm}$

• Inertial Force:
  • $F = ma$
  • No Roll:
    • $F = \rho \times \text{Area} \times Nz$
  • With Roll:
    • Lots more math…
Load Case: Coordinate Sys

- Points/Forces need to be transformed to new coordinate system

- GIII reference frame is located at nose
  - Useless for wing loads

- New reference systems created to give loads with reasonable values
  - Un-swept
  - Swept
  - ACTE
Load Case: Calculate Loads

• Sum forces/moments created by each panel
• Shear = $\sum F_Z$
• Bending =
  $\sum [(F_Z \times Y) - (F_Y \times Z)]$
• Torsion =
  $\sum [(F_X \times Z) - (F_Z \times X)]$
Data Output

- Displays total wing loads as well as loads for specific stations
- Graphs shear, bending, and torsion in un-swept, swept, and ACTE reference frames
- Saves load data as MATLAB file
- Saves graphs as .png
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