MSES Analysis Interface Module (AIM) Manual

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0.1 Introduction

0.1.1 MSES AIM Overview

A module in the Computational Aircraft Prototype Syntheses (CAPS) has been developed to interact (through input files) with the airfoil analysis tool MSES. MSES is not open-source and not freely available. However, a 'lite' version of MSES is provided with EngSketchPad that supports analysis of a single airfoil element.

An outline of the AIM's inputs and outputs are provided in AIM Inputs and AIM Outputs, respectively.

The AIM preAnalysis generates the mesh by calling the 'mset' executable, and generats an msesInput.txt file containing the instructions for executing mses.

The MSES AIM can automatically execute MSES, with details provided in AIM Execution.

0.1.2 Assumptions

MSES inherently assumes the airfoil cross-section is in the x-y plane, if it isn't an attempt is made to automatically rotate the provided body.

0.1.2.1 Airfoils in ESP

Within **OpenCSM** there are a number of airfoil generation UDPs (User Defined Primitives). These include NACA 4 series, a more general NACA 4/5/6 series generator, Sobieczky's PARSEC parameterization and Kulfan's CST parameterization. All of these UDPs generate **EGADS** *FaceBodies* where the *Face*'s underlying *Surface* is planar and the bounds of the *Face* is a closed set of *Edges* whose underlying *Curves* contain the airfoil shape.

Important Airfoil Geometry Assumptions

- There must be a *Node* that represents the *Leading Edge* point
- For a sharp trailing edge, there must be a *Nodes* at the *Trailing Edge*
- For a blunt trailing edge, the airfoil curve may be open, or closed by a single *Edge* connecting the upper/lower *Nodes*
- For a *FaceBody*, the airfoil coordinates traverse counter-clockwise around the *Face* normal. The **OpenCSM** *REORDER* operation may be used to flip the *Face* normal.
- For a *WireBody*, the airfoil coordinates traverse in the order of the loop

Note: Additional spurious *Nodes* on the upper and lower *Edges* of the airfoil are acceptable.

It should be noted that general construction in either **OpenCSM** or even **EGADS** will be supported as long as the topology described above is used. But care should be taken when constructing the airfoil shape so that a discontinuity (i.e., simply C^0) is not generated at the *Node* representing the *Leading Edge*. This can be done by splining the entire shape as one and then intersecting the single *Edge* to place the LE *Node*.

0.2 AIM Inputs

The following list outlines the MSES inputs along with their default values available through the AIM interface.

- **Mach = NULL**
  Mach number.
- **Re = 0.0**
  Reynolds number. Use 0.0 for an inviscid calculation.
- **Alpha = NULL**
  Angle of attack [degree].
- **CL = NULL**
  Prescribed coefficient of lift.
- **Acrit = 9.0**
  Critical amplification factor "n" for the e^n envelope transition model. 9.0 is the standard model.
- **xTransition_Upper = NULL**
  List of forced transition location on the upper surface of each blade element. Must be equal in length to the number of blade elements.
- **xTransition_Lower = NULL**
  List of forced transition location on the lower surface of each blade element.
  Must be equal in length to the number of blade elements.
- **Mcrit = 0.98**
  "critical" Mach number above which artifical dissipation is added.
  0.99 usually for weak shocks
  0.90 for exceptionally strong shocks
- **MuCon = 1.0**
  artificial dissipation coefficient (1.0 works well),
  (A negative value disables the 2nd-order dissipation.
  This is a “last-resort” option for difficult cases.)
- **ISMOM = 4**
  MSES ISMOM input to select the momentum equation. Valid inputs: [1-4]
  1 -> use S-momentum equation
  2 -> use isentropic condition
  3 -> use S-momentum equation, with isentropic condition only near leading edge
  4 -> use isentropic condition, with S-momentum equation only where dissipation is active
- **IFFBC = 2**
  MSES IFFBC input to select the Farfield BC. Valid inputs: [1-5]
- **Coarse_Iteration = 200**
  Maximum number of coarse mesh iterations (can help convergence).
- **Fine_Iteration = 200**
  Maximum number of fine mesh iterations.
- **GridAlpha = 0.0**
  Angle of attack used to generate the grid.
- **Airfoil_Points = 201**
  Number of airfoil grid points created with mset
- **Inlet_Points = NULL**
  Inlet points on leftmost airfoil streamline created with mset
  If NULL, set to ∼Airfoil_Points/4

- **Outlet_Points = NULL**
  Outlet points on rightmost airfoil streamline created with mset
  If NULL, set to ∼Airfoil_Points/4
- **Upper_Stremlines = NULL**
  Number of streamlines in top of domain created with mset
  If NULL, set to ∼Airfoil_Points/8
- **Upper_Stremlines = NULL**
  Number of streamlines in bottom of domain created with mset
  If NULL, set to ∼Airfoil_Points/8
- **xGridRange = [-1.75, 2.75]**
  x-min and x-max values for the grid domain size.
- **xGridRange = [-2.5, 2.5]**
  x-min and x-max values for the grid domain size.
- **Design_Variable = NULL**
  The design variable tuple is used to input design variable information for the model optimization, see cfd↩DesignVariable for additional details. Must be NULL of Cheby_Modes is not NULL.
- **Cheby_Modes = NULL**
  List of Chebyshev shape mode values for shape optimization (must be even length with max length 40). Must be NULL if Design_Variable is not NULL

0.3 AIM Execution

If auto execution is enabled when creating an MSES AIM, the AIM will execute MSES just-in-time with the command line:

```
mses airfoil < msesInput.txt > msesOutput.txt
```

where preAnalysis generated the file "msesInput.txt" which contains the input information.

The analysis can be also be explicitly executed with caps_execute in the C-API or via Analysis.runAnalysis in the pyCAPS API.

Calling preAnalysis and postAnalysis is NOT allowed when auto execution is enabled.

Auto execution can also be disabled when creating an MSES AIM object. In this mode, caps_execute and Analysis.runAnalysis can be used to run the analysis, or MSES can be executed by calling preAnalysis, system call, and posAnalysis as demonstrated below with a pyCAPS example:

```
print ("\n\preAnalysis......")
mses.preAnalysis()
print ("\n\nRunning......")
mses.system("mses airfoil < msesInput.txt > msesOutput.txt"); # Run via system call
print ("\n\postAnalysis......")
mses.postAnalysis()
```

0.4 AIM Outputs

The following list outlines the MSES outputs available through the AIM interface.

Angle of attack and coefficients have derivatives w.r.t Alpha, Mach, and Re

- **Alpha =** Angle of attack value(s).

- **CL =** Coefficient of lift value(s).
- **CD =** Coefficient of drag value(s).
- **CD_p =** Coefficient of drag value, pressure contribution.
- **CD_v =** Coefficient of drag value(, viscous contribution.
- **CD_w =** Coefficient of drag value, inviscid (wave) drag from shock entropy wake.
- **CM =** Moment coefficient value(s).
- **Mcrit =** Critical Mach number by solving:

$$C_{p,min} = \frac{2}{\gamma M_{crit}^2}\left[\left(\frac{1+[(\gamma-1)/2]M_{crit}^2}{1+(\gamma-1)/2}\right)^{\gamma/(\gamma-1)} - 1\right]$$

- **Cheby_Modes =**
  Chebyshev shape mode values for shape optimization.