CBAero Analysis Interface Module (AIM) Manual

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0.1 Introduction

0.1.1 CBAero AIM Overview

A module in the Computational Aircraft Prototype Syntheses (CAPS) has been developed to interact (primarily through input files) with NASA Ames's CBAero [1]. CBAero (Configuration Based Aerodynamics) software package is an engineering level aero-thermodynamics tool for predicting the aerodynamic and aero-thermodynamic environments of general vehicle configurations. Currently only a subset of CBAero's input options have been exposed in the analysis interface module (AIM), but features can easily be included as future needs arise.

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

Geometric attributes recognized by the AIM are provided in Attribution.

The accepted and expected geometric representation are detailed in Geometry Representation.

0.2 Attribution

The following list of attributes drives the CBAero geometric definition.

- **capsLength** This attribute defines the length units that the ∗.csm file is generated in. CBAero grids MUST be in units of meter, as such the geometry is scaled accordingly based on this value.
- **capsReferenceArea** [Optional] This attribute may exist on any *Body*. Its value will be used as the reference area in CBAero's input file with its units assumed to be consistent with the attribute "capsLength". No conversion takes place if "capsLength" isn't set. This value may be alternatively set through an input value, "ReferenceArea" (see AIM Inputs)
- **capsReferenceChord** and **capsReferenceSpan** [Optional] These attribute may exist on any *Body*. Their value will be used as the reference moment lengths in CBAero's input file with their units assumed to be consistent with the attribute "capsLength". No conversion takes place if "capsLength" isn't set. These values may be alternatively set through an input value, "Moment_Length" (see AIM Inputs)
- **capsReferenceX**, **capsReferenceY**, and **capsReferenceZ** [Optional] These attribute may exist on any *Body*. Their value will be used as the center of gravity (CG) location in CBAero's input file with their units assumed to be consistent with the attribute "capsLength". No conversion takes place if "capsLength" isn't set. These values may be alternatively set through an input value, "Moment_Center" (see AIM Inputs)

0.3 CBAero Material Group

Structure for the Material_Group tuple = ("Material Name", "Value"). The "Value" must be a JSON String dictionary.

If no Material_Group is specified, a default material of "Non Catalytic" with emissity of "1.0" is applied to all caps↩ Groups.

0.3.1 Material Group JSON String Dictionary

For the JSON string "Value" dictionary (e.g. "Value" = {"surfaceType": 1, "emissivity": 0.8}) the following keywords (= default values) may be used:

- **surfaceType**
  The surface type must be a string integer, e.g. "0" or "10,
  or a case insensitive partial match to one of:
  - "Non Catalytic"
  - "Fully Catalytic"
  - "RCG"
  - "TUFI"
  - "ORCC Coated ACC"
  - "PCC Coated NEXTEL 440"
  - "RLV Design Goal"
  - "SIRCA"
  - "TABI"
  - "Grey C-9 Coated NEXTEL 440"
  - "SiC – SiC"
  - "C-CAT"
  - "LVP Coated ACC"
  - "SiC Coated Carbon – Russian"
  - "INCONEL 617 PreOxidized"
  - "Mars Fully Catalytic, No O2 Recombination"
  - "Venus Fully Catalytic, No CO Oxidation"
- **emissivity**
  Emissivity of the material [0 - 1]
- **groupName = "(no default)"**
  Single or list of `capsGroup` names on which to apply the material (e.g. "Name1" or ["Name1","Name2",...]).

0.4 Geometry Representation

The geometric representation for the CBAero AIM requires that the body be either a solid body (SOLIDBODY) or a manifold sheet body (SHEETBODY).

0.5 AIM Inputs

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

- **Proj_Name = "cbaero_CAPS"**
  This corresponds to the project "root" name.
- **Mach = 0.0 (default) or [0.0, ... , 0.0]**
  Mach number (can be a single or array of values).
- **Dynamic_Pressure = 0.0 (default) or [0.0, ... , 0.0]**
  Dynamic pressure [bar] value (can be a single or array of values).
- **Alpha = 0.0 (default) or [0.0, ... , 0.0]**
  Angle of attack [degree] (can be a single or array of values).
- **Beta = 0.0 (default) or [0.0, ... , 0.0]**
  Sideslip angle (can be a single or array of values).
- **ReferenceArea = NULL**
  This sets the reference area for used in force and moment calculations. Alternatively, the geometry (body) attribute (see Attribution) "capsReferenceArea" maybe used to specify this variable (note: values set through the AIM input will supersede the attribution value).
- **ReferenceChord = NULL**
  This sets the reference chord for used in force and moment calculations. Alternatively, the geometry (body) attribute (see Attribution) "capsReferenceChord" maybe used to specify this variable (note: values set through the AIM input will supersede the attribution value).
- **ReferenceSpan = NULL**
  This sets the reference span for used in force and moment calculations. Alternatively, the geometry (body) attribute (see Attribution) "capsReferenceSpan" maybe used to specify this variable (note: values set through the AIM input will supersede the attribution value).
- **Moment_Center = [0.0, 0.0, 0.0] (NULL)**
  Array values correspond to the x, y, and z center of gravity (CG) locations [meter]. Alternatively, the geometry (body) attributes (see Attribution) "capsReferenceX", "capsReferenceY", and "capsReferenceZ" may be used to specify the center of gravity, respectively (note: values set through the AIM input will supersede the attribution values).
- **Flow_Type = "Inviscid"**
  Type of flow to consider. Options (=corresponding integer code): FreeTransition(=0), Laminar(=1), Turbulent(=2), Inviscid(=3).
- **Critical_Transition = 220.0**
  Critical ratio of Re-theta (Reynolds based on momentum thickness) and Ma (Mach number) for transition.
- **Planet = "EARTH"**
  Planet type. Options include “MERCURY”, “VENUS”, “EARTH”, “MARS”, “JUPITER”, “SATURN”, “URANUS”, “NEPTUNE”, and “PLUTO”.

- **Default_Body_Method = "ModifiedNewtonian"**
  Default hypersonic base method. Options (=corresponding integer code): ModifiedNewtonian(=3), Tangent↩Cone(=21), TangentConeNormalShock(=22), TangentWedge(=31), TangentWedgeNormalShock(=32), FreeMolecular(=99).

- **Default_Wing_Method = "ModifiedNewtonian"**
  Default hypersonic aerodynamic wing method. Options (=corresponding integer code): Modified↩Newtonian(=3), TangentCone(=21), TangentConeNormalShock(=22), TangentWedge(=31), Tangent↩WedgeNormalShock(=32), FreeMolecular(=99).

- **Default_Low_Speed_Method = "FastPanel"**
  Default low speed method. Options (=corresponding integer code): FastPanel(=1), LowAR(=2).

- **Leading_Edge_Suction = 1.00**
  Default low speed method integer tag. Range [-1.0, 1.0]

- **Aero_Surface = NULL**
  Defines the type of aero. surface by associating a "capsGroups" attribute name with a particular panel method - ("capsGroup Name", "Value"), where "Value" can either be "Body", "Base", "Wing", "Inlet", "Cowl", or "↩Nozzle". If a capsGroup panel method is not defined it will be assumed to be a "Body".

- **Material_Group = NULL**
  Defines the type of aero. surface by associating a "capsGroups" attributes with a particular material group - ("Material Name", "Value"), where "Value" must be a JSON String dictionary, see CBAero Material Group for additional details.

- **NumParallelCase = 1**
  Set CBAero -mp to define number of Mach, dynamic pressure, and angle of attack cases to solve simultaneously.
  May be used in conjunction with NumThreadPerCase.

- **NumThreadPerCase = 1**
  Set CBAero -omp to define number of threads to solve a each Mach, dynamic pressure, and angle of attack cases.
  May be used in conjunction with NumParallelCase.

- **Mesh_Morph = False**
  Project previous surface mesh onto new geometry.

- **Surface_Mesh = NULL**
  A Surface_Mesh link.

0.6 AIM Execution

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

```
cbaero $(cat cbaeroInput.txt) > cbaeroOutput.txt
```

where preAnalysis generated the file "cbaeroInput.txt" which contains commandline arguments for cbaero.

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 refine AIM object. In this mode, caps_execute and Analysis.↩runAnalysis can be used to run the analysis, or refine can be executed by calling preAnalysis, system call, and posAnalysis as demonstrated below with a pyCAPS example:

```
print ("\n\preAnalysis......")
cbaero.preAnalysis()
print ("\n\nRunning......")
cbaero.system("cbaero $(cat cbaeroInput.txt) > cbaeroOutput.txt"); # Run via system call
print ("\n\postAnalysis......")
cbaero.postAnalysis()
```

0.7 AIM Outputs

The following list outlines the CBAero outputs available through the AIM interface. All variables currently correspond to values found in the $*$.plt file

Reiterate inputs (based on cases):

- **Beta** = Sideslip [degree].
- **Alpha** = Angle of attack [degree].
- **Dynamic_Pressure** = Dynamic pressure [bar].
- **Mach** = Mach number.

Per-Trb:

- **PerTrb** = PerTrb.

Net Forces - Pressure + Viscous:

- **CLtot** = The lift coefficient.
- **CDtot** = The drag coefficient.
- **CMYtot** = The moment coefficient about the y-axis.
- **LoDtot** = Lift to drag ratio.

Pressure Forces:

- **CL_p** = The lift coefficient - pressure contribution only.
- **CD_p** = The drag coefficient - pressure contribution only.

Viscous Forces:

- **CL_v** = The lift coefficient - viscous contribution only.
- **CD_v** = The drag coefficient - viscous contribution only.

Aero-thermal:

- **Stagnation_Temperature** = Stagnation temperature [K].
- **Stagnation_Radius** = = Stagnation radius [m].
- **Convective_Flux** = Convective heat flux [W/cm^2].
- **Radiative_Flux** = Radiation heat flux [W/cm^2].

Trefftz:

- **CL_Trefftz** = Trefftz lift coefficient.
- **CD_Trefftz** = Trefftz drag coefficient.

Bibliography

[1] David Kinney. Aero-thermodynamics for conceptual design. Number AIAA-2004-31, Reno, NV, Jan. 2004. 42nd AIAA Aerospace Sciences Meeting and Exhibit. 1