Initial Implementation of VG Source Terms in FUN3D

Background

- Spent ~3 days on the implementation at a user's recent request – seems to be working, but have not spent significant time evaluating its use
  - Looking for users to try, provide feedback
- Implementation based on these references:
  - Bender, E.E., Anderson, B.H., and Yagle, P.J., "Vortex Generator Modeling for Navier-Stokes Codes," 3rd Joint ASME/JSME Fluids Engineering Conference, San Francisco, CA, 1999.
  - Waithe, K., "Source Term Model for Vortex Generator Vanes in a Navier-Stokes Computer Code," AIAA 2004-1236, January 2004.
  - Jirasek, A., "A Vortex Generator Model and its Application to Flow Control," AIAA 2004-4965, August 2004.

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Details

- Will be available in v12.2
- Only intended for static grid computations currently
- Implementation supports as many vortex generators as user desires (up to 1000)
- Through the new `&vortex_generator` namelist, user provides the number of VG's, the model calibration constant, and the following values for each VG:
  - Planform area
  - Height
  - Approximate locations of two points on the surface defining the base of the VG
  - Intended boundary patches each of these points should be associated to during projection
  - Optional: have FUN3D reverse the orientations of the assumed $\mathbf{t}$ and $\mathbf{n}$ unit vectors
- Implemented for all element types
- Source terms are treated fully implicit

Initial Implementation of VG Source Terms in FUN3D

Sample Namelist

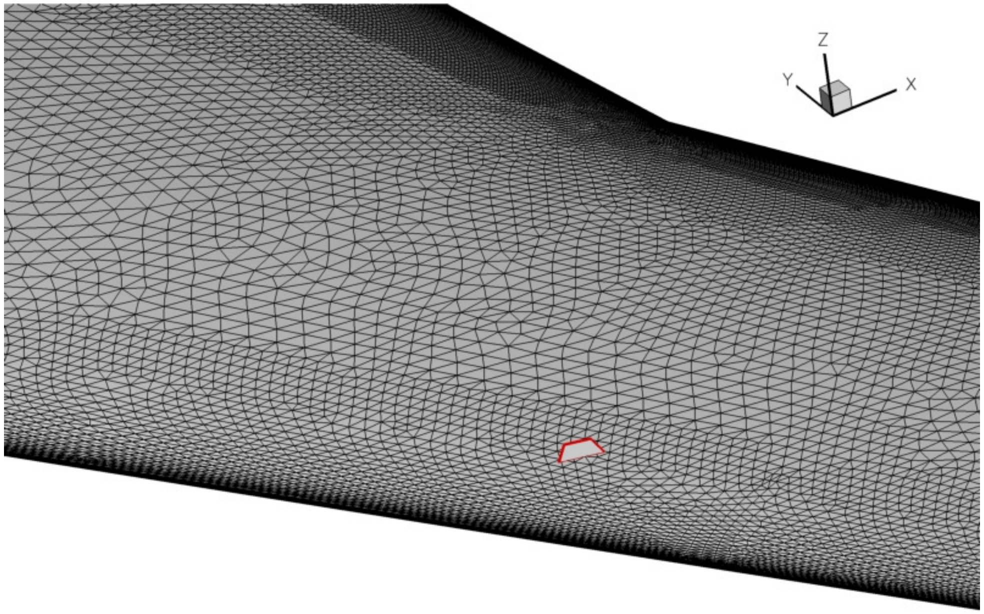
- Used f6fx2b_0.1 VGRID mesh available on DPW-3 website (5.6M nodes)
- Free-handed a rough VG for testing, using the following namelist

```
&vortex_generator
  number_of_vgs           = 1
  calibration_constant(1) = 100.
  planform_area(1)        = 12.0
  height(1)               = 2.5
  boundary_patch1(1)      = 31
  point1_xcoord(1)        = 176.1
  point1_ycoord(1)        = -319.59
  point1_zcoord(1)        = 32.40
  boundary_patch2(1)      = 31
  point2_xcoord(1)        = 181.50
  point2_ycoord(1)        = -322.30
  point2_zcoord(1)        = 33.06
  reverse_t(1)            = .false.
  reverse_n(1)            = .false.
/
```

Initial Implementation of VG Source Terms in FUN3D

Setup Process

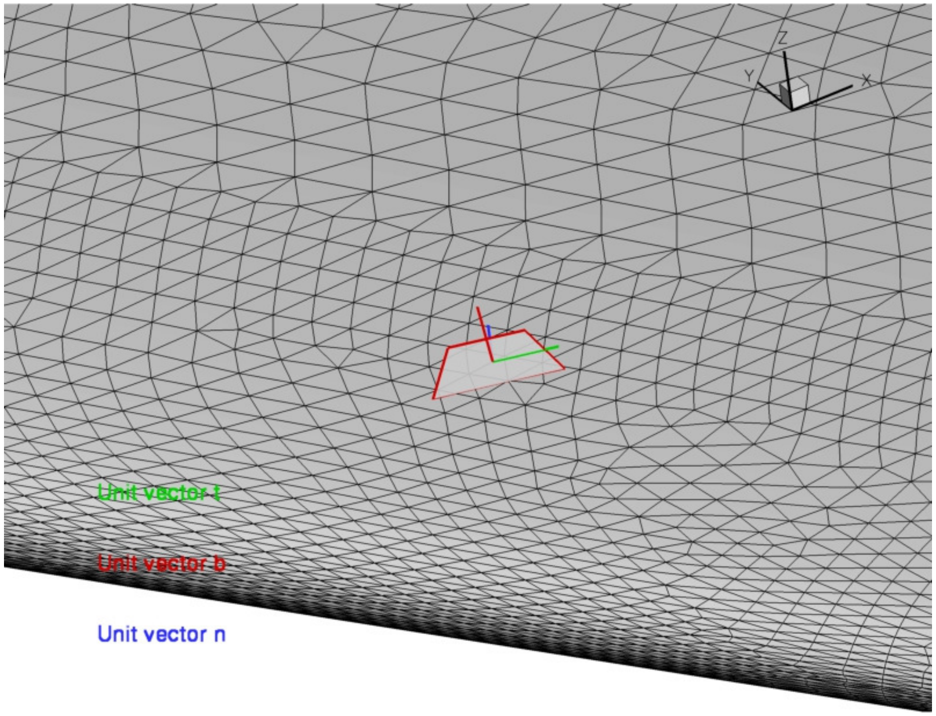
- After setting up the namelist, do a single cycle with the CLO '—animation_freq -1' and look at the provided data for the VG's
  - Load in f6fx2b_0.1_tec_boundary.dat
  - Then load in f6fx2b_vg_geometry.dat on top of it, which contains the geometries FUN3D constructed for each of your VG's



Initial Implementation of VG Source Terms in FUN3D

Setup Process

- Now verify that the unit vectors for the source term formulation are oriented as intended
    - Load in f6fx2b_vg_vectors.dat on top of everything so far – this contains the unit vectors $\mathbf{b}$, $\mathbf{t}$, and $\mathbf{n}$ that will be used for the formulation in the references
    - The $\mathbf{b}$ vector is uniquely defined by the local boundary orientation
    - However, the directions of $\mathbf{t}$ and $\mathbf{n}$ are guessed by FUN3D based on the freestream direction – they may be backwards if the local flow direction is substantially different. Use the namelist inputs to flip these two vectors as needed.



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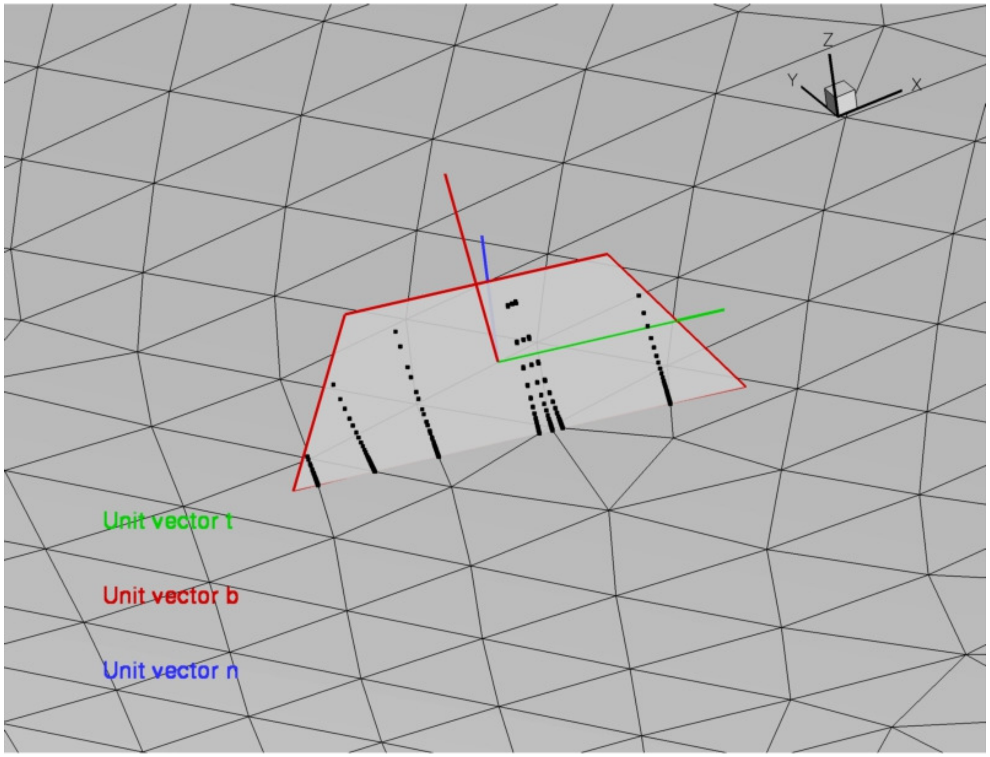
Setup Process

- Finally, if desired, load in f6fx2b_vg_source_locations.dat – this file can be used to scatter plot the actual locations where the source terms are computed.
- These locations are determined by intersections of grid edges with the VG geometry. The source terms are computed here and distributed to residuals at either end of the intersecting edge.



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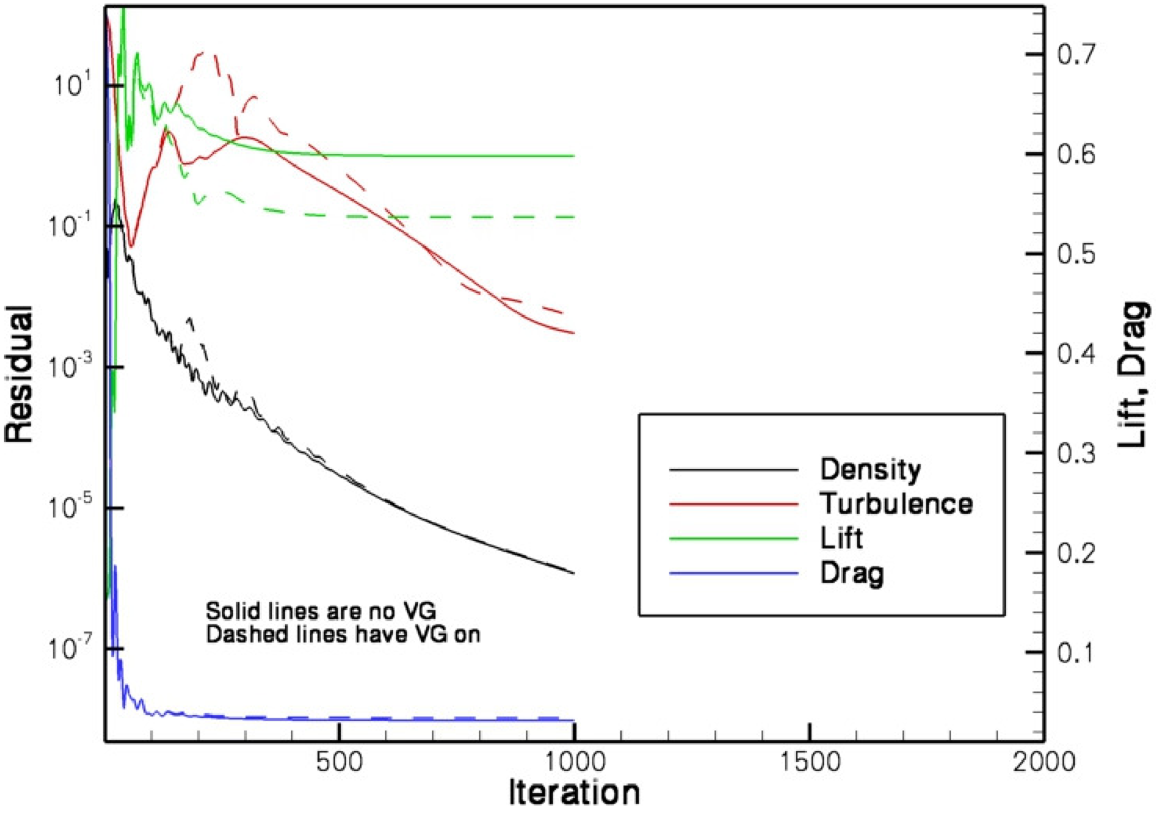
Execution

- Run solution to desired convergence as normal. Plot below shows convergence histories with and without VG turned on for this case.



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Visualization

- Physical interpretation, validation left as an exercise for the reader ☺
- Would think significant mesh resolution would still be needed even to capture the effects of the modeled VG's (?)

Density contours with and without VG