



# Vortex Visualisation in ANSYS Fluent

## Part 2: *RANS*

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*Prepared and compiled by*

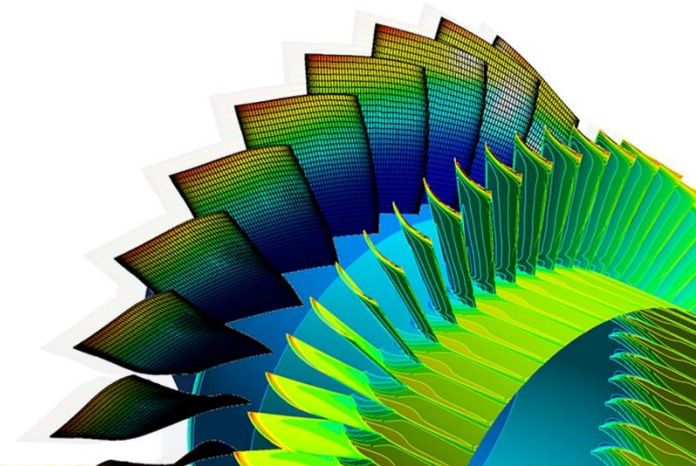
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**Solution 2042110**



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Please note that this document is accompanied by a scheme file [\*q\\_crit\\_and\\_norm\\_q\\_crit\\_ag.scm\*](#) which contains the derivations of functions: [\*q\\_criterion\\_ag\*](#), [\*q\\_crit\\_normalised\\_ag\*](#), [\*q\\_crit\\_norm\\_alt\*](#) and by an animation [\*Normalised\\_q\\_criterion.mpg\*](#)

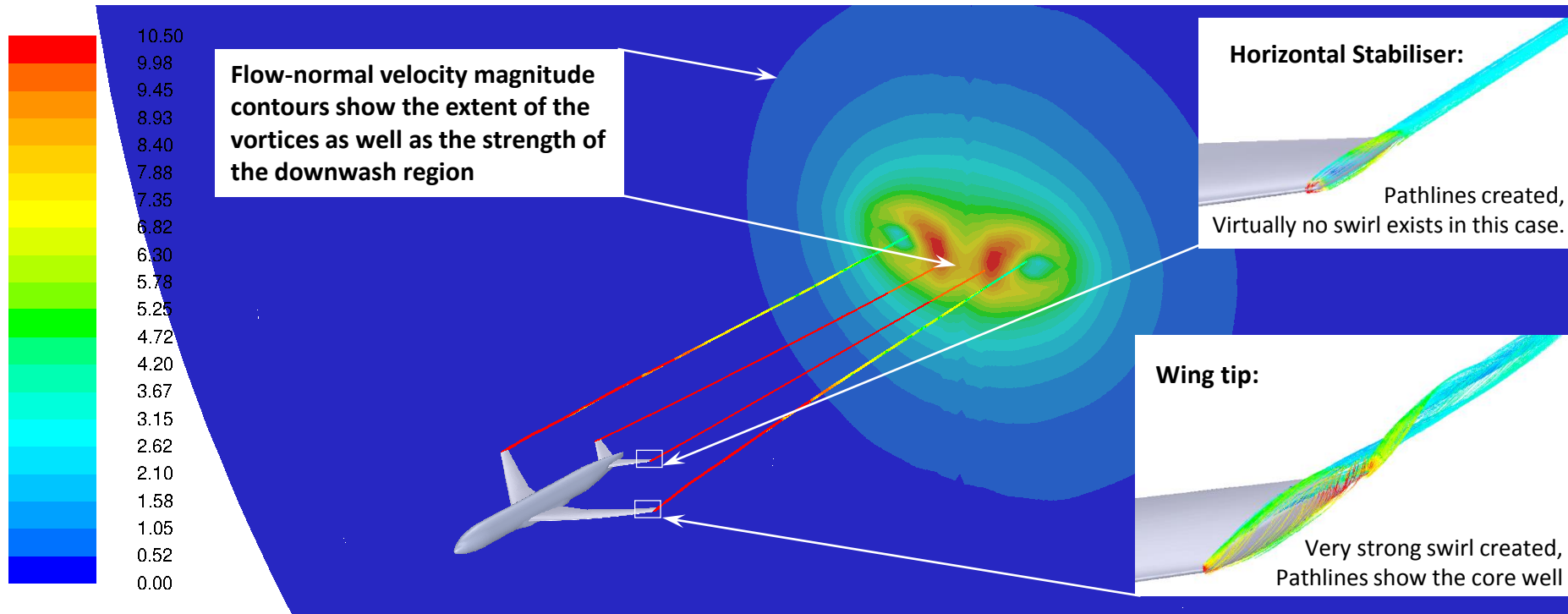
For more information and derivations please also visit Solution 2041496 on ANSYS Customer Portal:  
[\*Vortex Visualisation in ANSYS Fluent, Part 1: Scale-Resolving Simulations\*](#)

# Typical ways to visualise vortical structures in RANS

- Some individual wakes and vortical structures can be visualised by considering velocity contour plots and/or vector plots at various postprocessing surfaces.
  - Certain postprocessing planes can be created so that the vortex axis lies on the plane, albeit this is limited to very simple cases.
  - Cross-sectional planes can also be created such that the cross-sectional velocity components can be shown either with contour plots or with vectors. This is a good approach, but might not be good enough if multiple vortices are interacting with each other.
- The flow pathlines can be created and originated from a slightly upstream location or from slightly offset rakes or planes.
  - Can be a very neat way to visualise vortices, however, a very careful manual assessment is needed, since the pathlines would still exist once the vortex has died out.
  - Can be quite a labour-intensive process, in terms of finding adequate seeding locations.
  - Difficult to make judgement on the strength of the vortex and on possible interaction for multiple vortices.

# Typical ways to visualise vortical structures: Limitations

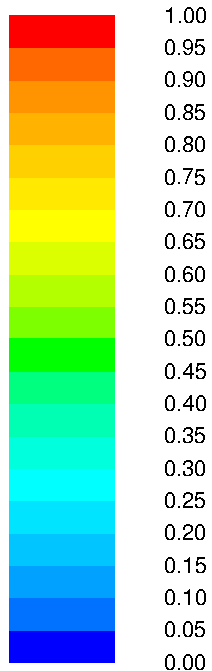
- Flow-normal velocity component magnitude  $\sqrt{V_y^2 + V_z^2}$  on a downstream plane:
  - Useful, however, the entire vortex is not shown.
  - Velocity components need to be carefully assessed and evaluated for different AoA.



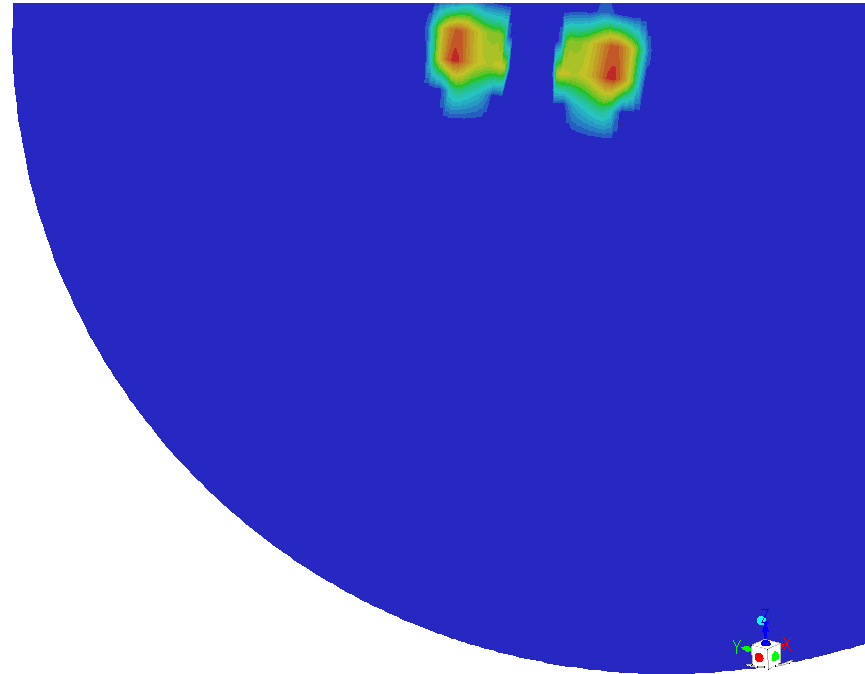
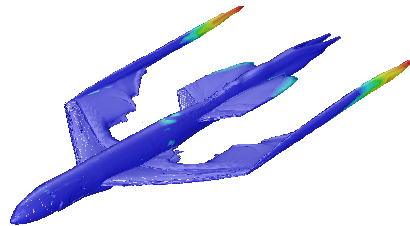
- Pathlines:
  - Choice and creation of seeding surfaces is crucial and can be time-consuming.
  - Vortex spreading rate is virtually impossible to capture and to visualise with the pathlines.
  - Vortex might straighten but the pathlines will continue. Careful manual monitoring is required.

# Vorticity magnitude

- Vorticity magnitude iso-surfaces can be used and the values can be adjusted so that the areas of intensive swirl are visible.



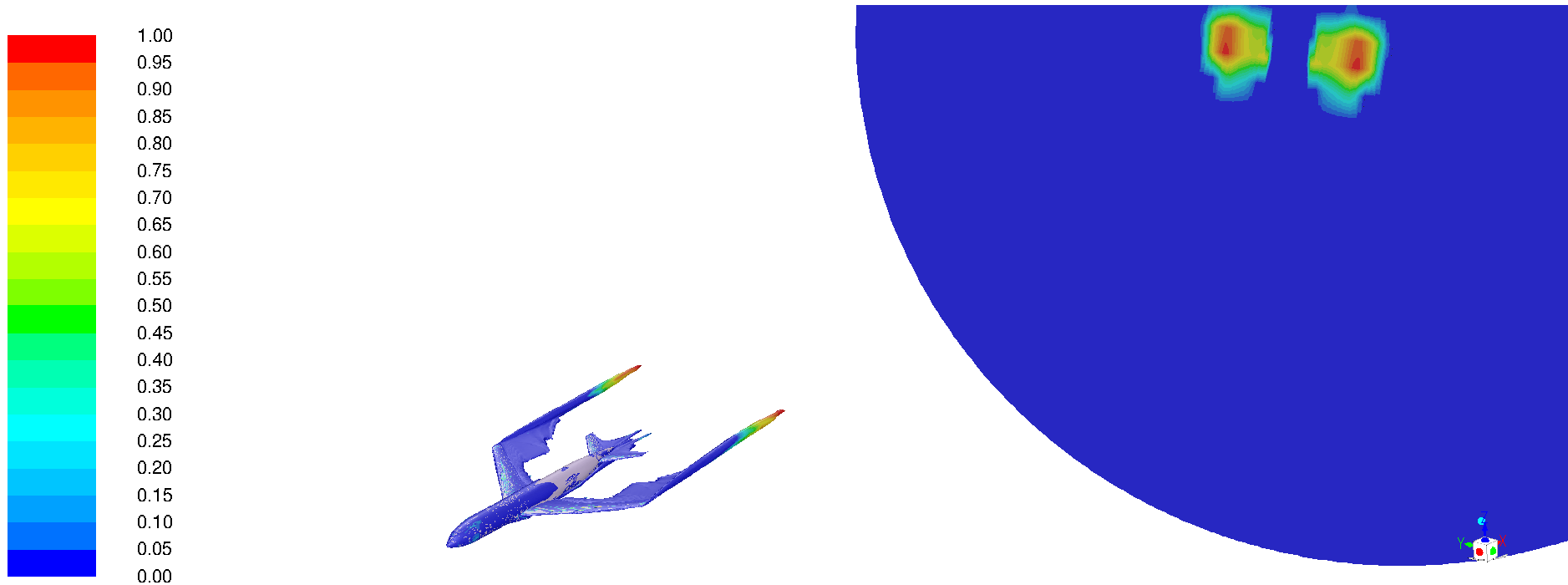
Vorticity is a standard post-processing quantity:  $\xi = \nabla \times \vec{V}$   
It represents a measure of rotation of a fluid element as it moves in the flow field.



- Some experimentation with the choice of iso-values is needed.
- Above contour plots are coloured with Normalised Q-criterion.
- Please note that the vortices do exist far beyond the shown regions.

# X-Vorticity magnitude

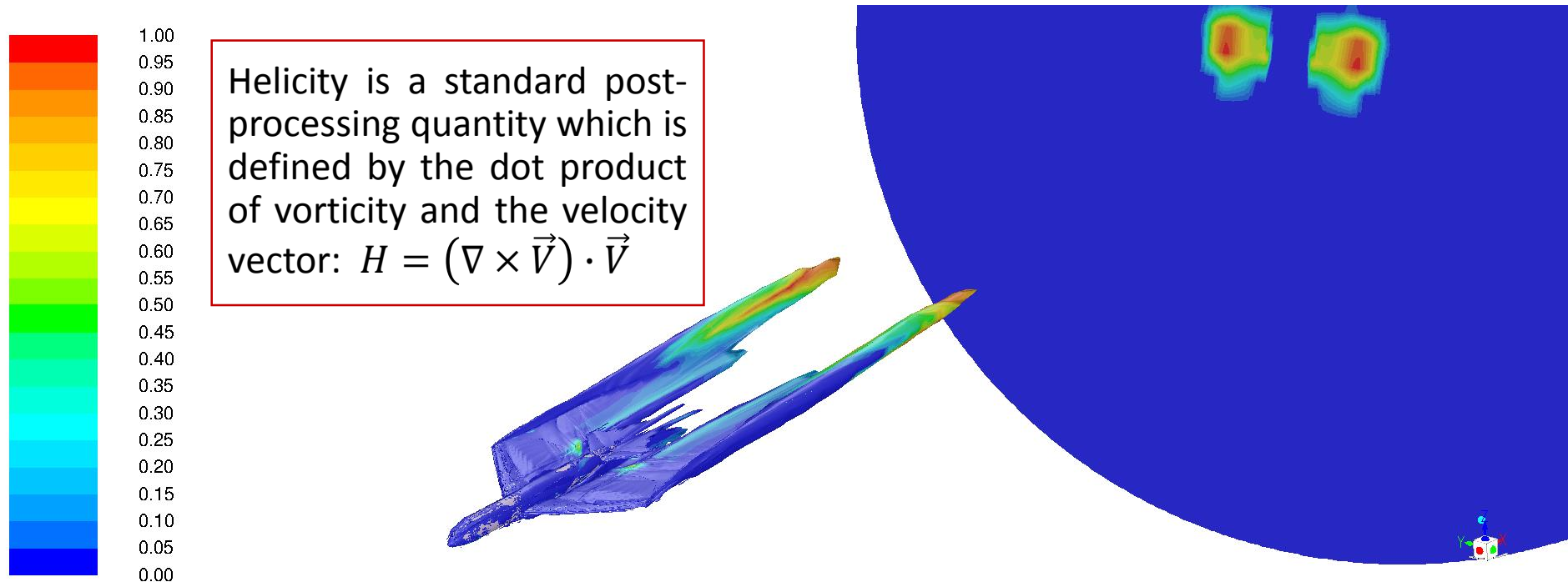
- In some cases, the individual components of the vorticity magnitude can show a clearer picture about the presence of intense swirling.



- Above contour plots are coloured with Normalised Q-criterion.

# Helicity

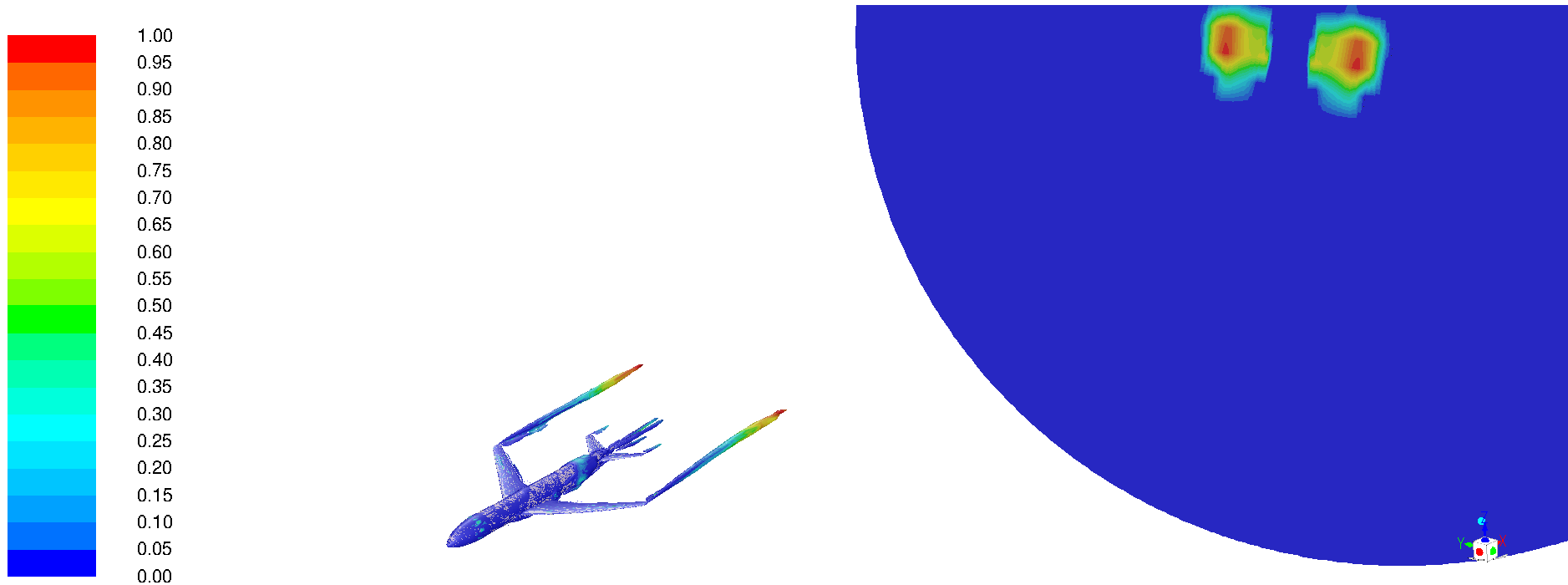
- Helicity iso-surfaces can show the regions of intensive swirling and the wake effects behind the object, including separation and recirculation.



- Some experimentation with the choice of iso-values is needed
  - This is considerably easier and quicker than the creation of suitable pathlines.
- More useful for impeller/propeller flow visualisation than for Aero cases.
- Above contour plots are coloured with Normalised Q-criterion.

## Q-criterion: $q\_criterion\_ag$

- Isosurfaces of Q-criterion can also provide a much clearer picture of the regions with intense swirling.

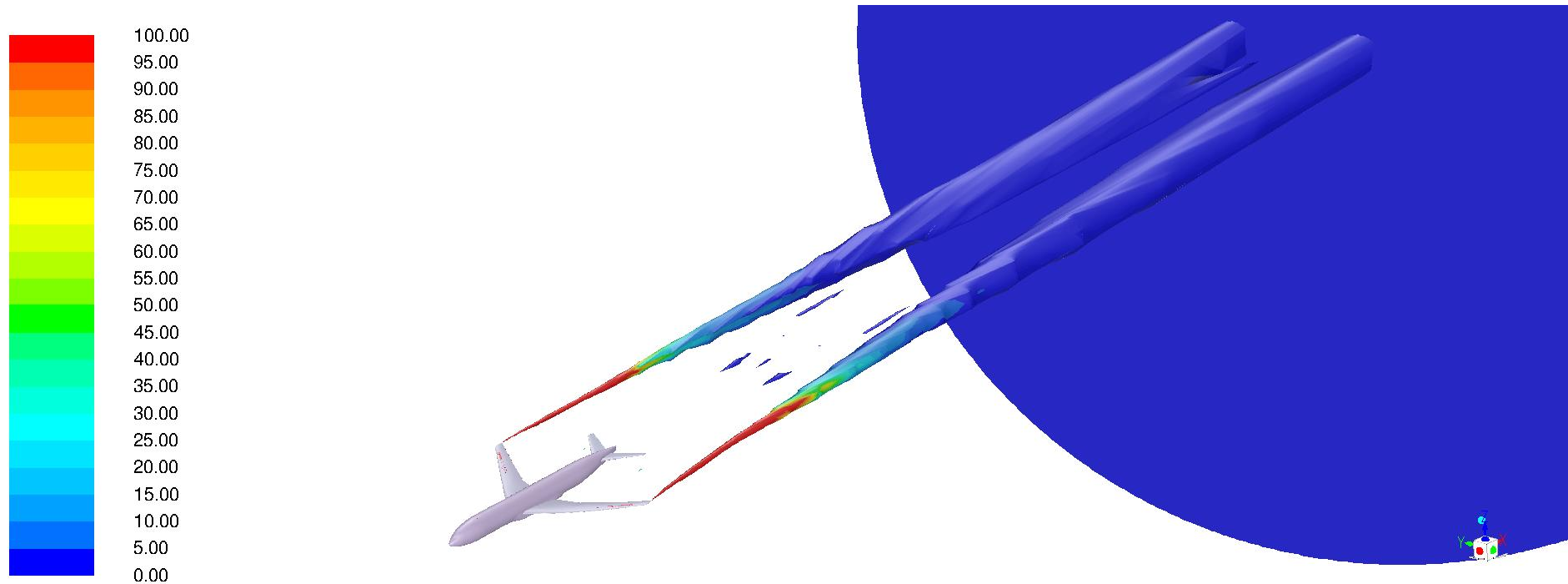


- Please note that neither the Q-criterion nor Normalised Q-criterion are available under standard postprocessing options in RANS.
- Please run the accompanying scheme script `q-crit_and_norm-q-crit_ag.scm` to make these quantities available.



# Normalised Q-criterion: $q_{crit\_normalised\_ag}$

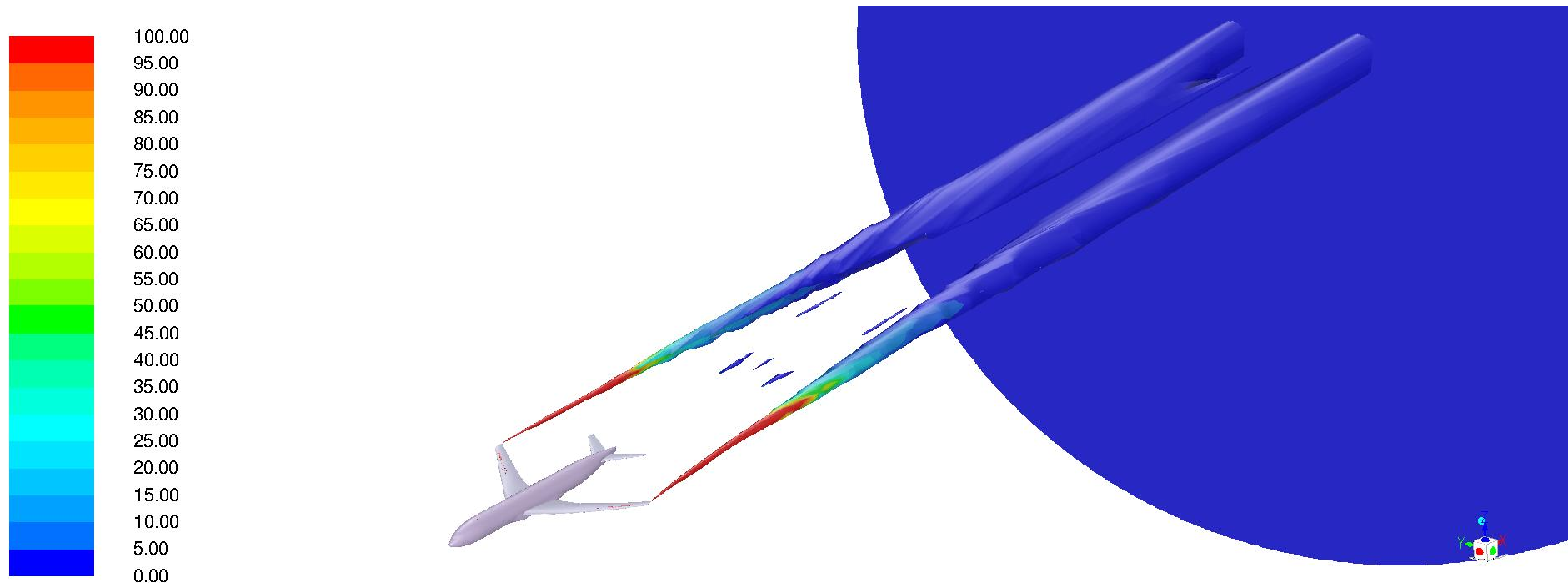
- The Normalised Q-criterion can show the full extent of the vortex.



- The regions of higher vortex strength can be emphasized by colouring the Normalised Q-criterion isosurfaces with the values of conventional Q-criterion.

# Normalised Q-criterion: $q\_crit\_norm\_alternative$

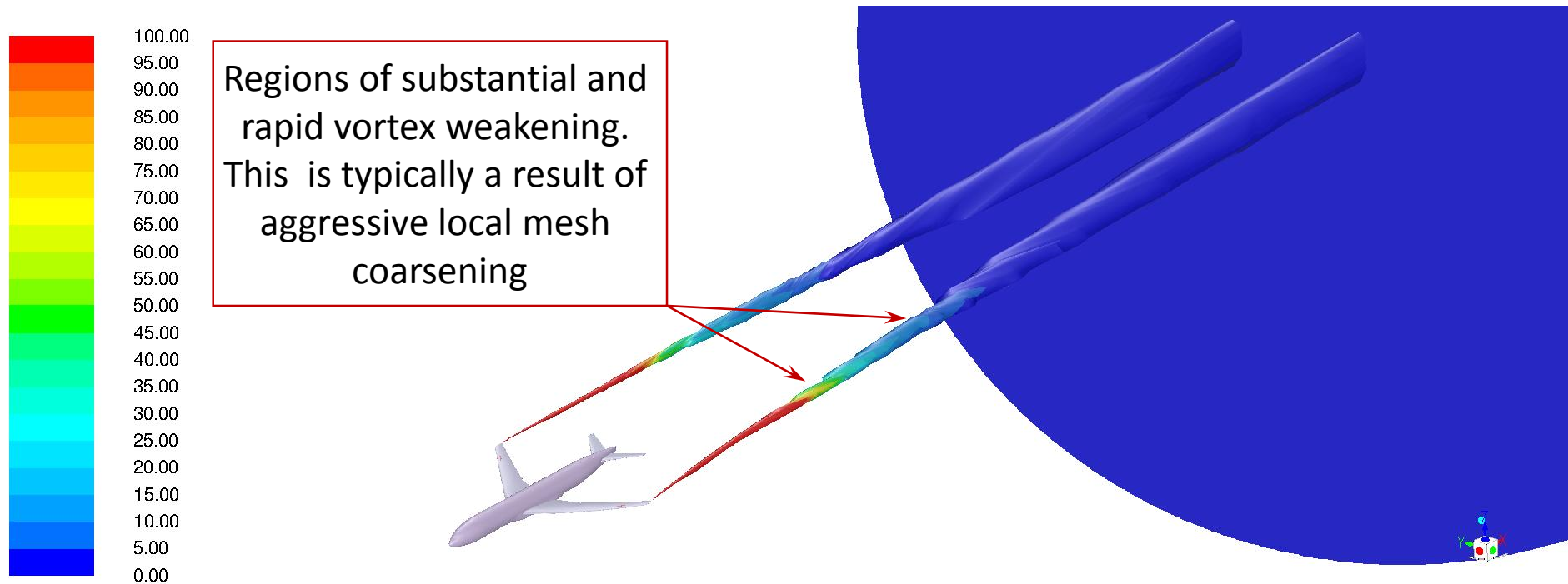
- An alternative formulation of the Normalised Q-criterion is also available in the script and shows a very similar picture.



- The Normalised Q-criterion values change from 0 to 1.
  - Low values show wider extent of the vortex
  - Higher values close to 1 highlight the core of the vortex

# Normalised Q-criterion (as coded in Fluent for SRS)

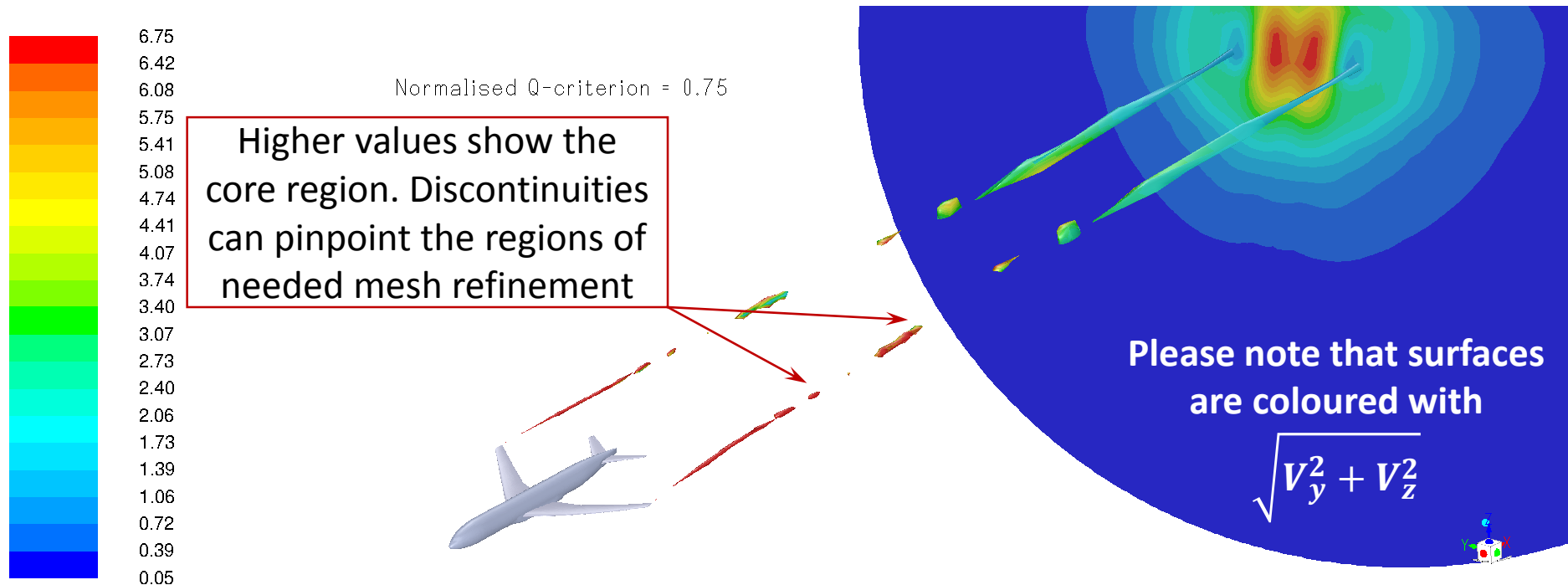
- Please note that this quantity is not available automatically with RANS.
- Results are similar to the other Normalised versions of Q-criterion.



- Please note the regions where the vortex weakens significantly, as shown by colours of the conventional Q-criterion.

# Normalised Q-criterion: Vortex core visualisation

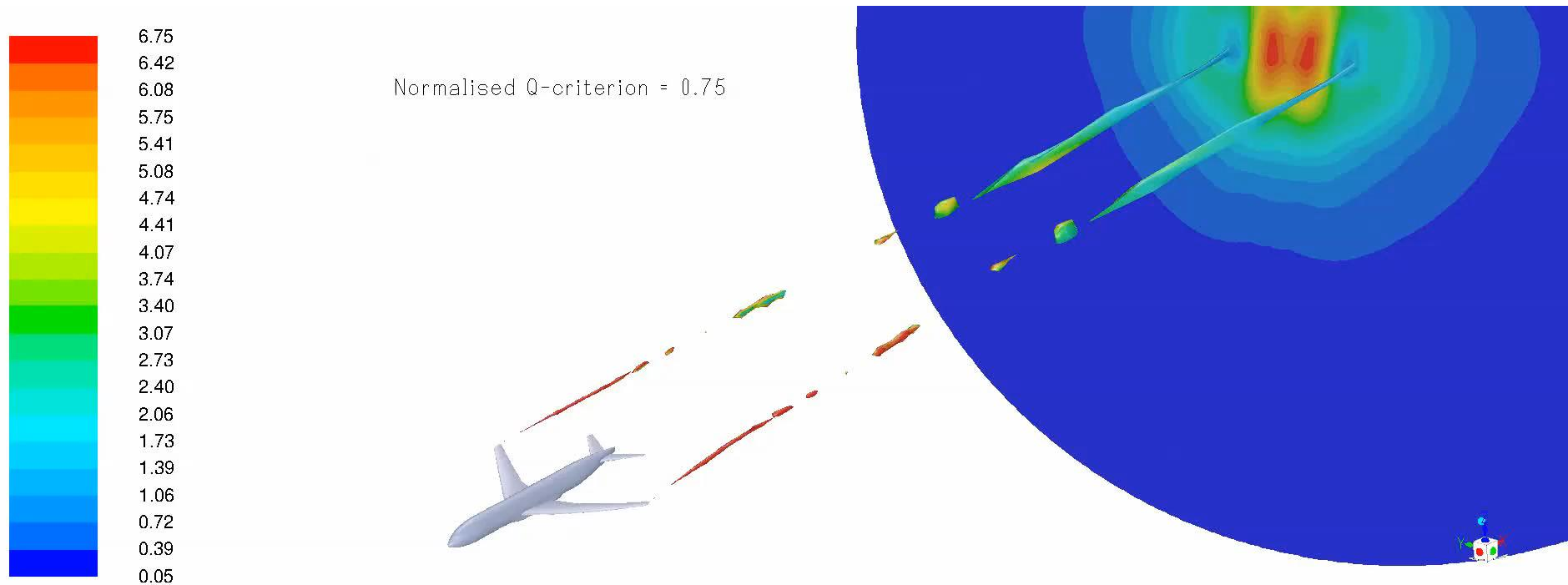
- Very often wing tip vortices and wakes remain under-resolved. This has an adverse effect on accuracy.



- In such cases the full benefit of turbulence closures, including RSM can not be materialised without an adequate mesh refinement.
- The Normalised Q-criterion can show where these regions are and can be used as a nice pin-pointing mesh adaption tool.

# Normalised Q-criterion

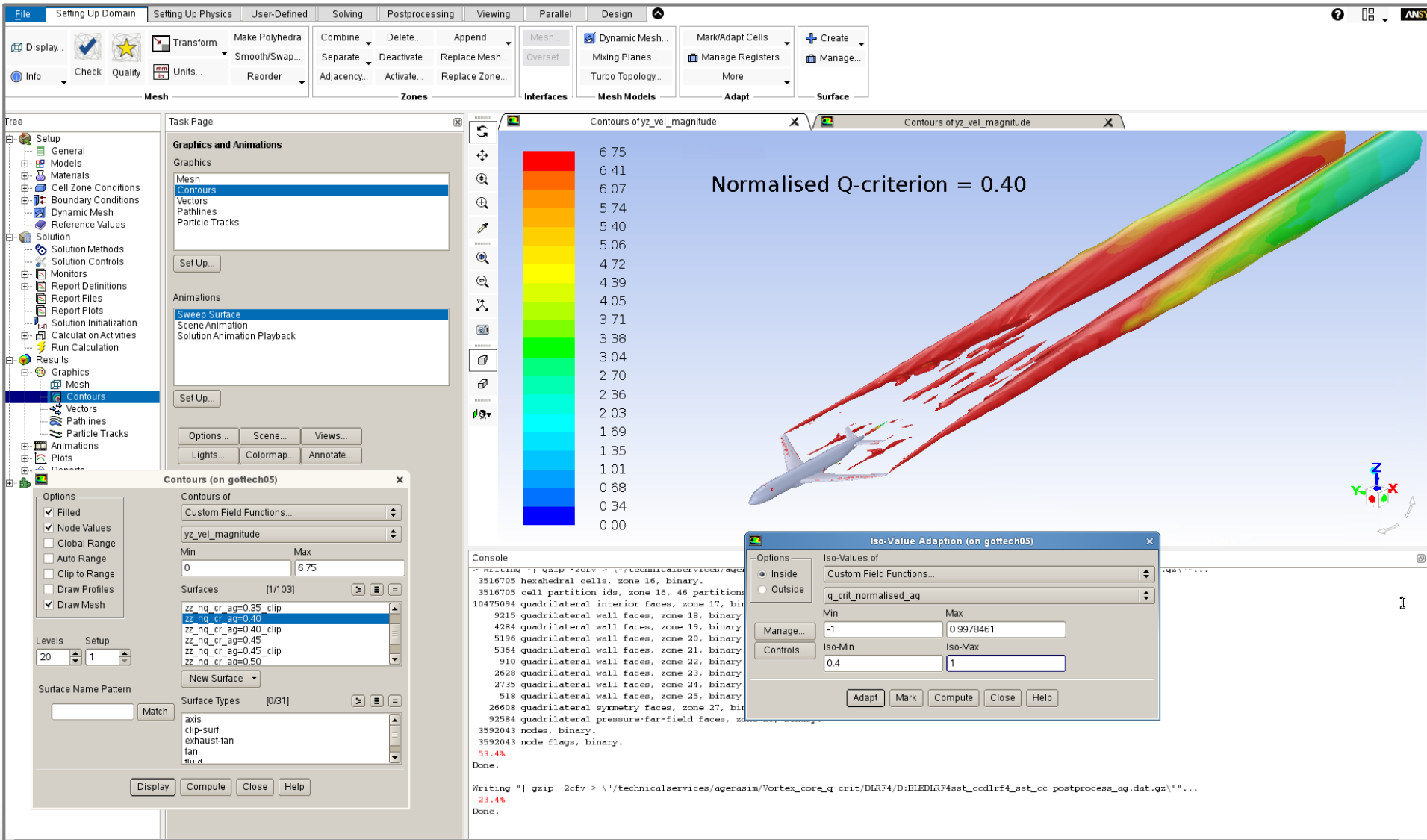
- **Embedded Video: Normalised Q-criterion iso-surface change from low to high value.**



- **For viewers of the PDF version – Please see attached animation:**  
*Normalised\_q\_criterion.mpg*

# Vortex-targeting mesh adaption

- Low value Normalised Q-criterion surface can be used for mesh adaption.



# Other Considerations

- **Mesh adaption does not work on all types of meshes.**
- **Lower values of the Normalised Q-criterion can pick up regions outside of the main vortex where the adaption is either non-beneficial or, yet worse, can slow the convergence.**
- **Remeshing can be a better, albeit slower, option in some cases.**
- **An iso-surface of the Normalised Q-criterion can be exported from ANSYS Fluent, or via CFD-Post, and then used as a “body of influence” in the pre-processor. This way, typically, a much better quality mesh can be generated.**
- **The data simulated on coarser meshes can still be recycled by means of using the interpolation files in ANSYS Fluent.**
- **CFD-Post offers visualisation of the conventional Q-criterion with RANS, but the Normalised Q-criterion can either be evaluated in CFD-Post or exported from ANSYS Fluent to CFD-Post.**



# Conclusions

- Q-criterion and Normalised Q-criterion can be very valuable in RANS for visualising vortical structures and their cores.
- Normalised Q-criterion can be used to show the extent of the vortex and the location of the vortex core.
- Conventional Q-criterion is good for highlighting the areas where the swirl is most energetic.
- Q-criterion and Normalised Q-criterion are not available for postprocessing with RANS models in ANSYS Fluent R17.
- Please run a scheme script that comes with this solution to make these quantities available for postprocessing.
- Full description and evaluation of the Conventional and Normalised Q-criterion is given in Solution 2041496 on ANSYS Customer Portal:  
*[Vortex Visualisation in ANSYS Fluent, Part 1: Scale-Resolving Simulations](#)*