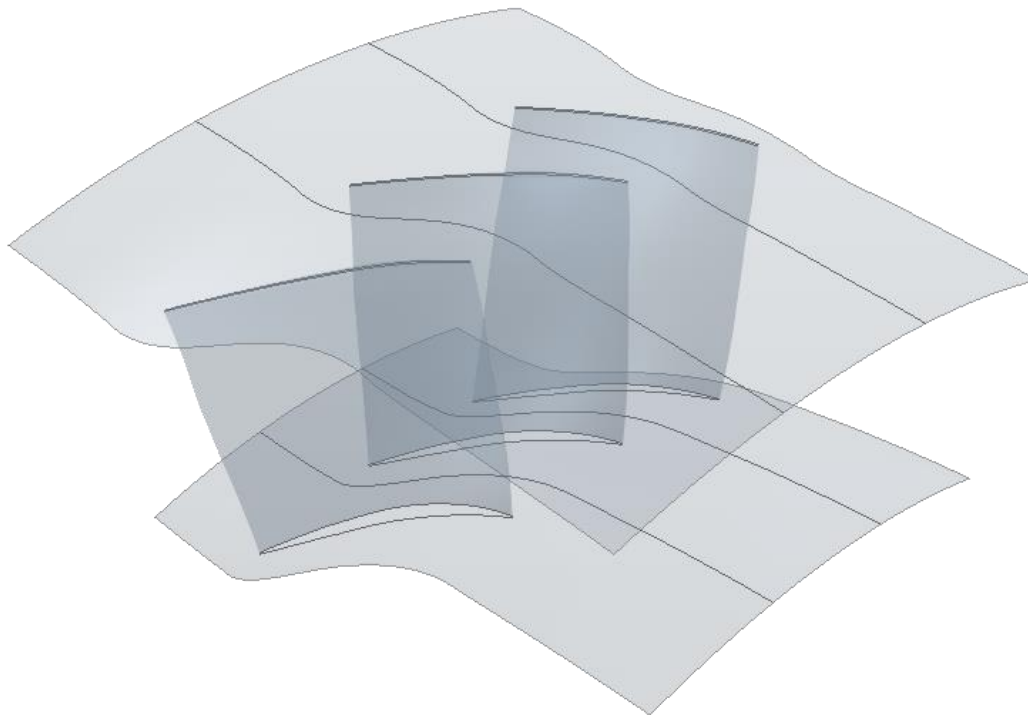


CFD applied to Turbomachinery

Francesco Romanò

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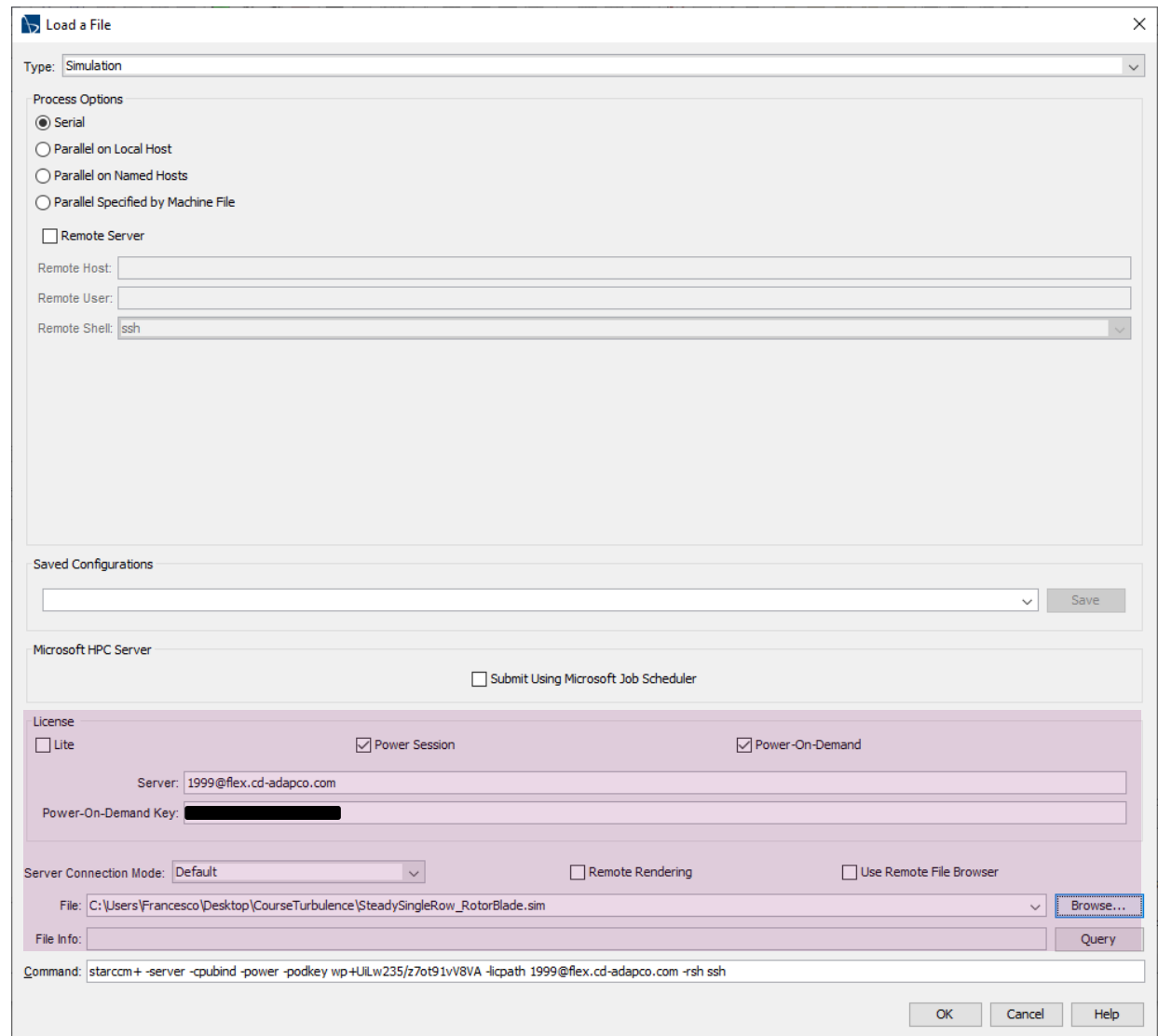
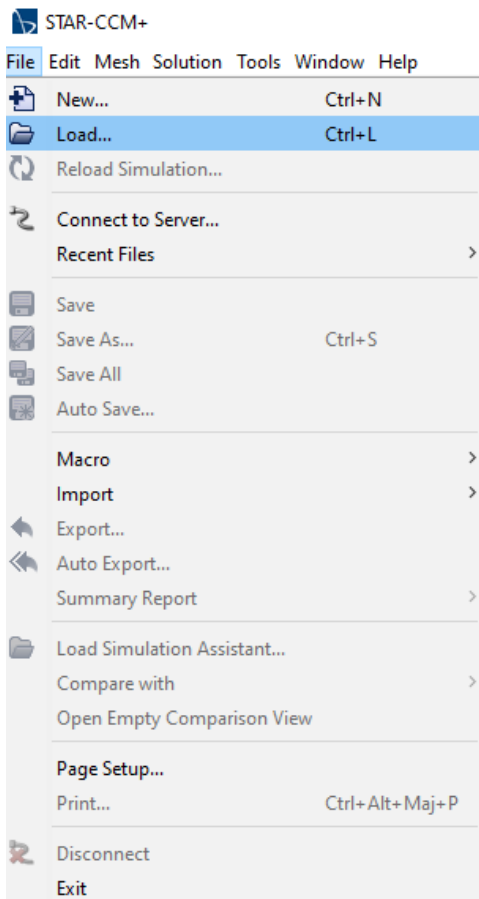
Laboratoire de Mécanique des Fluides Lille, Arts et Métiers Institute of Technology, 59800, Lille, France



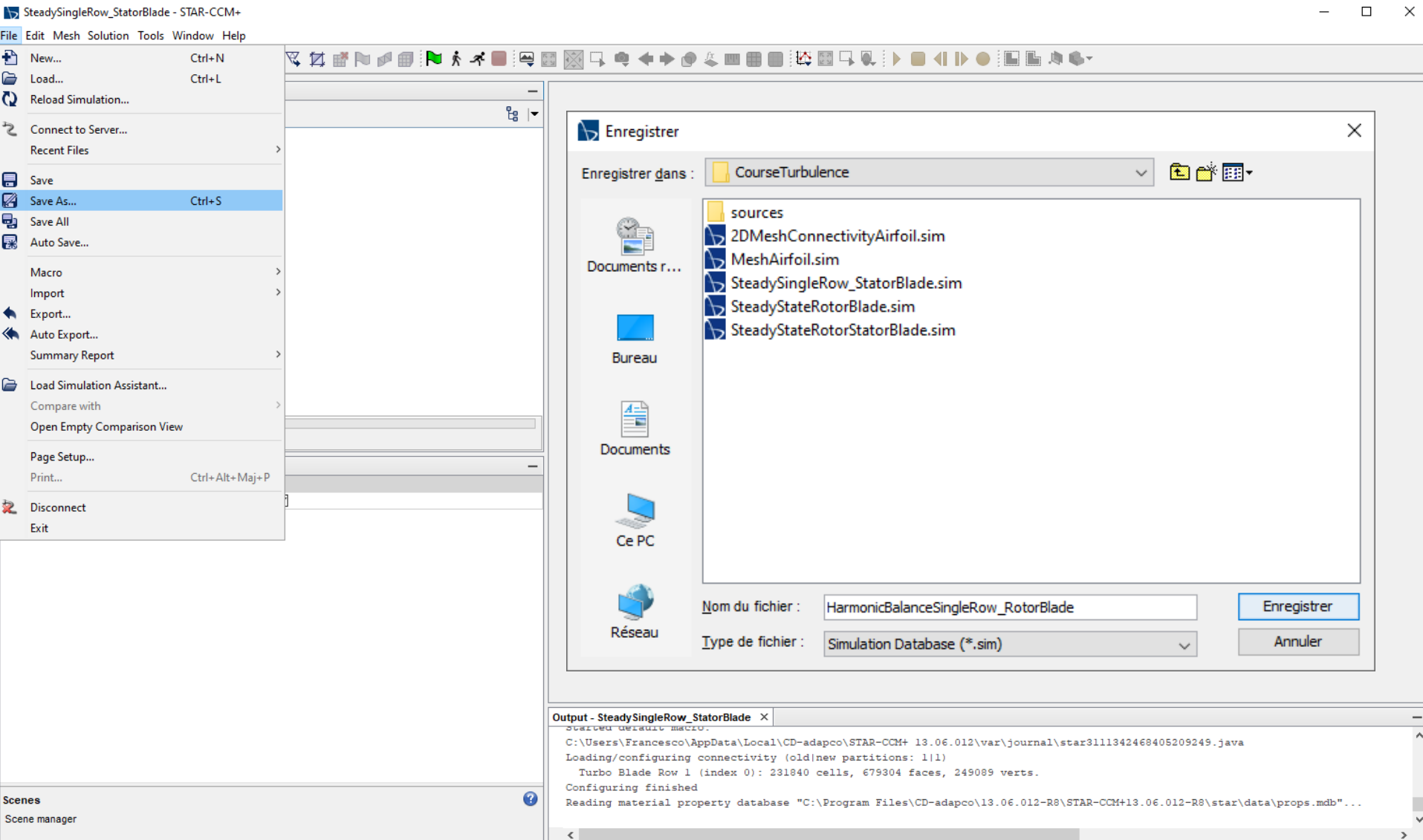
March 17, 2021, International Master of Turbulence



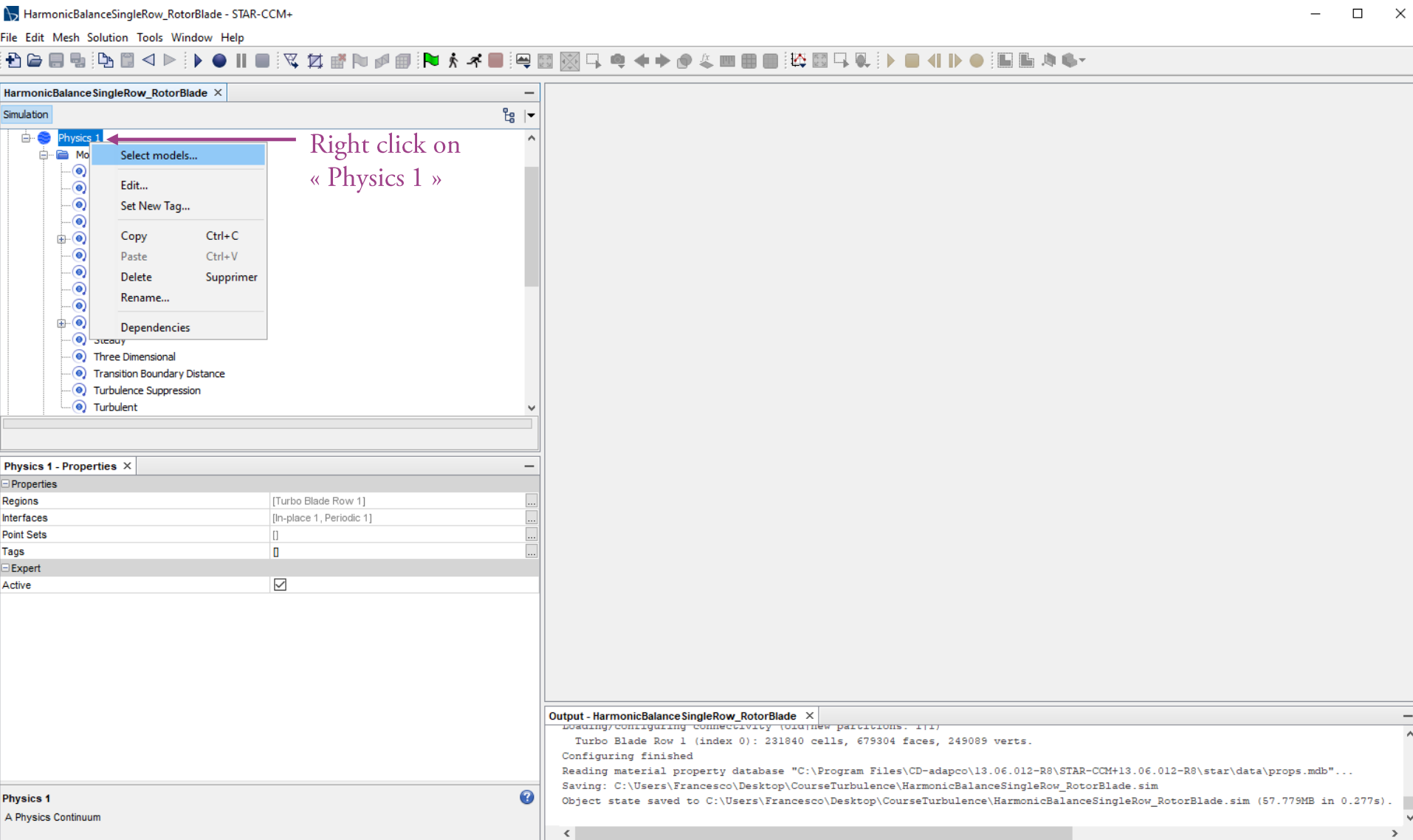
Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+



HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation

Physics 1

Select models...
Edit...
Set New Tag...
Copy Ctrl+C
Paste Ctrl+V
Delete Supprimer
Rename...
Dependencies

Right click on « Physics 1 »

Physics 1 - Properties

Properties

Regions	[Turbo Blade Row 1]
Interfaces	[In-place 1, Periodic 1]
Point Sets	[]
Tags	[]
Expert	
Active	<input checked="" type="checkbox"/>

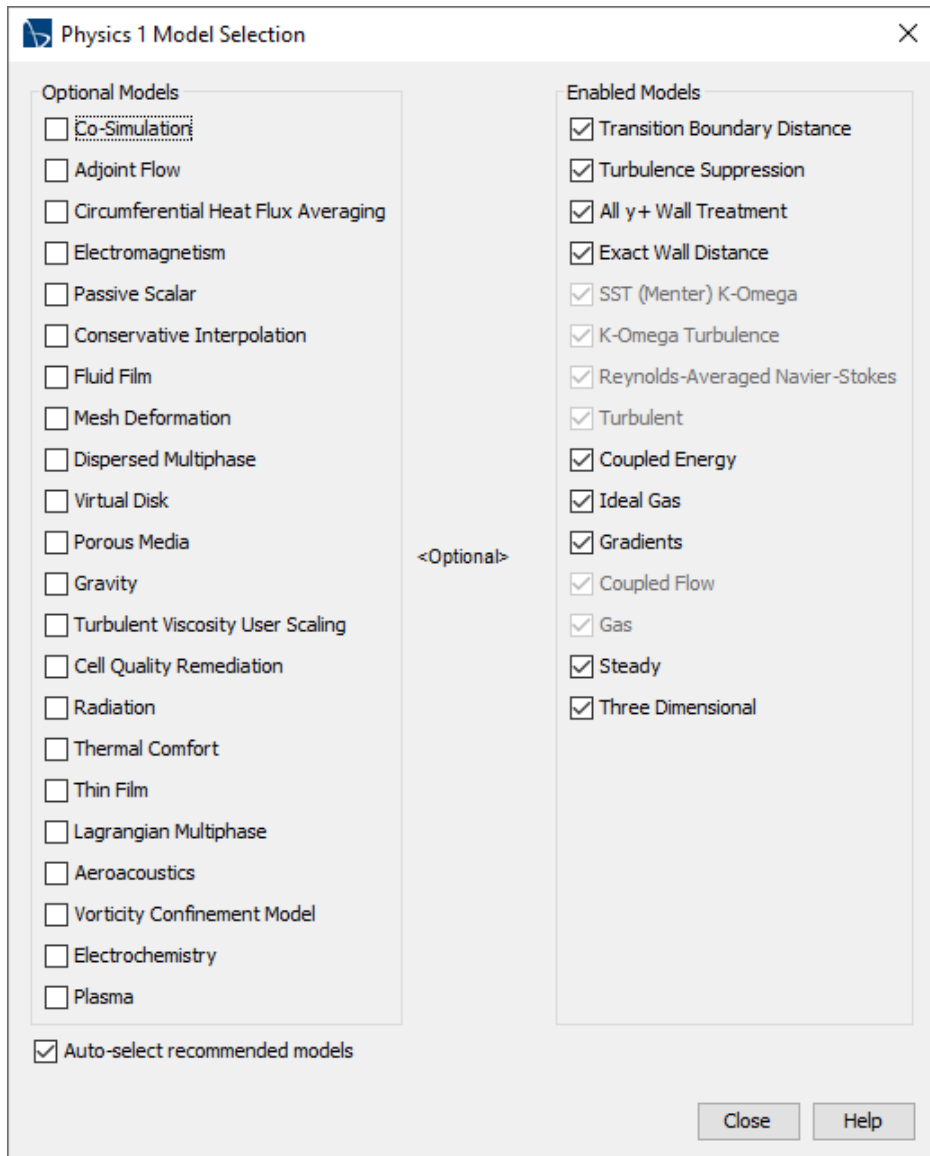
Physics 1
A Physics Continuum

Output - HarmonicBalanceSingleRow_RotorBlade

```
loading/configuring connectivity (old/new partitions: 1/1)
Turbo Blade Row 1 (index 0): 231840 cells, 679304 faces, 249089 verts.
Configuring finished
Reading material property database "C:\Program Files\CD-adapco\13.06.012-R8\STAR-CCM+13.06.012-R8\star\data\props.mdb"...
Saving: C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim
Object state saved to C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim (57.779MB in 0.277s).
```



Harmonic Balance for Rotor Blade in StarCCM+

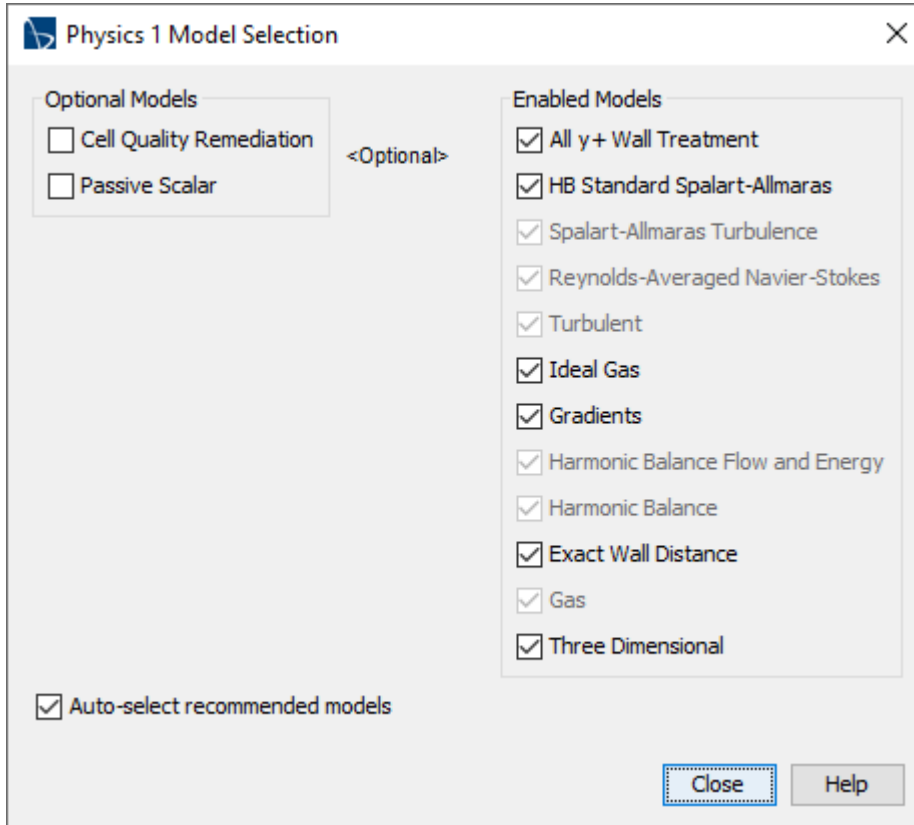


Deactivate:

- Transition Boundary Distance
- Turbulence Suppression
- All y+ Wall Treatment
- SST (Menter) K-Omega
- K-Omega Turbulence
- Reynolds-Averaged Navier-Stokes
- Turbulent
- Coupled Energy
- Ideal Gas
- Coupled Flow
- Steady



Harmonic Balance for Rotor Blade in StarCCM+



Activate:

- Harmonic Balance
- Turbulent
- Spalart-Allmaras Turbulence

By « Auto-select recommended models »:

- HB Standard Spalart-Allmaras
- All y+ Wall Treatment
- Exact Wall Distance

Click « Close »



Harmonic Balance for Rotor Blade in StarCCM+

The screenshot displays the StarCCM+ interface for a simulation named "HarmonicBalanceSingleRow_RotorBlade". The main window shows a tree view of the simulation setup under "Physics 1".

Simulation Tree:

- Physics 1
 - Models
 - All y+ Wall Treatment
 - Exact Wall Distance
 - Gas
 - Gradients
 - Harmonic Balance
 - Harmonic Balance Flow and Energy
 - HB Standard Spalart-Allmaras
 - Ideal Gas
 - Reynolds-Averaged Navier-Stokes
 - Spalart-Allmaras Turbulence
 - Three Dimensional
 - Turbulent
 - Reference Values
 - Initial Conditions
 - Regions

Physics 1 - Properties:

Properties	
Regions	[Turbo Blade Row 1]
Interfaces	[In-place 1, Periodic 1]
Point Sets	[]
Tags	[]
Expert	
Active	<input checked="" type="checkbox"/>

Output - HarmonicBalanceSingleRow_RotorBlade:

```
Reading material property database C:\Program Files\CD-adapco\13.06.012-RS\Star-CCM+13.06.012-RS\data\props.mdb ...
Saving: C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim
Object state saved to C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim (57.779MB in 0.277s).
Loading module: HarmonicBalanceModel
Loading module: SaTurbModel
Loading module: HbSaTurbModel
```

Physics 1
A Physics Continuum



Harmonic Balance for Rotor Blade in StarCCM+

The screenshot displays the StarCCM+ software interface for a simulation named "HarmonicBalanceSingleRow_RotorBlade". The left sidebar shows the simulation hierarchy: Simulation > Geometry > Continua > Physics 1 > Models. Under "Models", "Harmonic Balance" is selected, and a context menu is open with "Blade Rows" highlighted. A purple arrow points to "Blade Rows" with the text "Right click on « Blade Rows »". Below the hierarchy, the "Blade Rows - Properties" panel is visible, showing settings for "Expert", "Frequency Compute Option" (Consider Only Neighbors), "Modes Table Filter Option" (Cut-Off), and "Fictitious Rotation Rate Factor" (0.001). The bottom right corner shows the "Output - HarmonicBalanceSingleRow_RotorBlade" window with the following text:

```
reading material property database C:\Program Files\CD-adapco\13.06.012-64\Star-CCM+13.06.012-64\data\props.mdb ...
Saving: C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim
Object state saved to C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim (57.779MB in 0.277s).
Loading module: HarmonicBalanceModel
Loading module: SaTurbModel
Loading module: HbSaTurbModel
```



Harmonic Balance for Rotor Blade in StarCCM+

The screenshot displays the StarCCM+ interface for a Harmonic Balance simulation of a rotor blade. The main window shows a tree view of the simulation setup, including Geometry, Continua, Physics 1, Models, and Blade Rows. The Harmonic Balance model is selected, and the Blade Rows section shows Blade Row 1 with a Blades Per Pitch of 36. The Properties panel for Blades Per Pitch shows the Number of Blades set to 36 and the Pitch set to 6.283185307179586 radian. The Output window shows the simulation progress, including the loading of material property database, saving the object state, and loading the HarmonicBalanceModel, SaTurbModel, and HbSaTurbModel.

HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+

File Edit Mesh Solution Tools Window Help

HarmonicBalanceSingleRow_RotorBlade

Simulation

HarmonicBalanceSingleRow_RotorBlade

Geometry

Continua

Physics 1

Models

All y+ Wall Treatment

Exact Wall Distance

Gas

Gradients

Harmonic Balance

Harmonic Balance Flow and Energy

Blade Rows

Blade Row 1

Blades Per Pitch

Unique Frequency Table

Filtered Modes Table

Cut-Off Filter

Blades Per Pitch - Properties

Properties

Number of Blades 36

Pitch 6.283185307179586 radian

Number of Blades

Specify the number of blades in the given pitch

Output - HarmonicBalanceSingleRow_RotorBlade

Reading material property database "C:\Program Files\CD-adapco\13.06.012-rc\Star-CCM+13.06.012-rc\data\props.mdb ...

Saving: C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim

Object state saved to C:\Users\Francesco\Desktop\CourseTurbulence\HarmonicBalanceSingleRow_RotorBlade.sim (57.779MB in 0.277s).

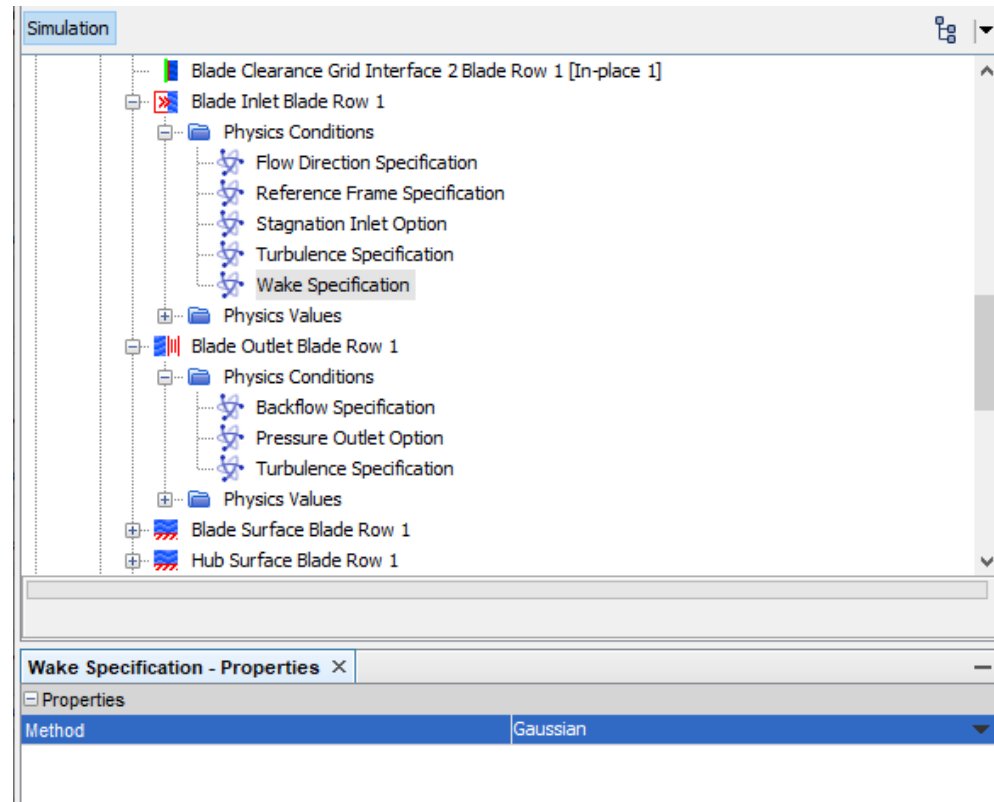
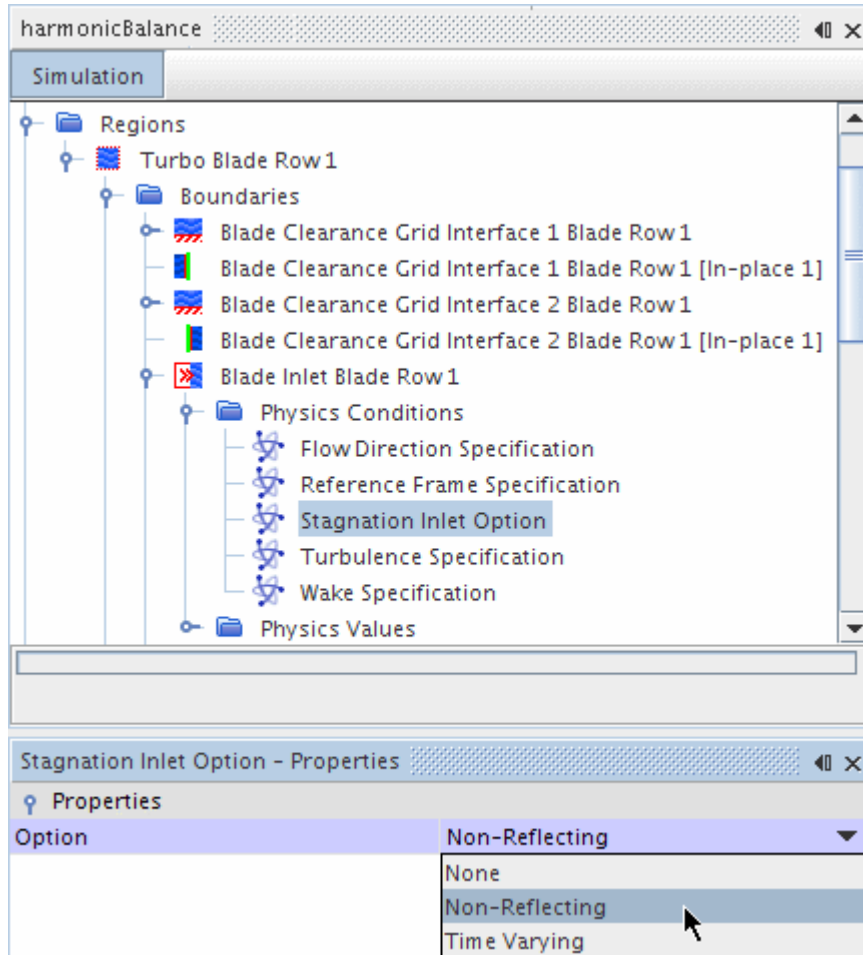
Loading module: HarmonicBalanceModel

Loading module: SaTurbModel

Loading module: HbSaTurbModel



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+

Simulation

- Blade Clearance Grid Interface 2 Blade Row 1 [In-place 1]
- Blade Inlet Blade Row 1
 - Physics Conditions
 - Flow Direction Specification
 - Reference Frame Specification
 - Stagnation Inlet Option
 - Turbulence Specification
 - Wake Specification
 - Physics Values
 - Gaussian Wake
 - Blades Per Pitch
 - Non-Reflecting Mode Specification
 - Supersonic Static Pressure
 - Total Pressure
 - Total Temperature
 - Turbulent Viscosity Ratio
- Blade Outlet Blade Row 1

Gaussian Wake - Properties

Properties	
Rotation Rate	0.0 radian/s
Modes	3
Defect	0.2
Width	0.15

Simulation

- Blade Clearance Grid Interface 2 Blade Row 1 [In-place 1]
- Blade Inlet Blade Row 1
 - Physics Conditions
 - Flow Direction Specification
 - Reference Frame Specification
 - Stagnation Inlet Option
 - Turbulence Specification
 - Wake Specification
 - Physics Values
 - Gaussian Wake
 - Blades Per Pitch
 - Non-Reflecting Mode Specification
 - Supersonic Static Pressure
 - Total Pressure
 - Total Temperature
 - Turbulent Viscosity Ratio
- Blade Outlet Blade Row 1

Blades Per Pitch - Properties

Properties	
Number of Blades	48
Pitch	6.283185307179586 radian



Harmonic Balance for Rotor Blade in StarCCM+

The image displays the StarCCM+ interface for setting up a Harmonic Balance simulation for a rotor blade. The main tree view on the left shows the hierarchy: **Regions** > **Turbo Blade Row 1** > **Boundaries**. Under **Boundaries**, the following items are listed: **Blade Clearance Grid Interface 1 Blade Row 1**, **Blade Clearance Grid Interface 1 Blade Row 1 [In-place 1]**, **Blade Clearance Grid Interface 2 Blade Row 1**, **Blade Clearance Grid Interface 2 Blade Row 1 [In-place 1]**, **Blade Inlet Blade Row 1**, **Blade Outlet Blade Row 1**, **Physics Conditions**, **Physics Values**, **Gaussian Wake**, **Non-Reflecting Mode Specification** (highlighted), and **Supersonic Static Pressure**.

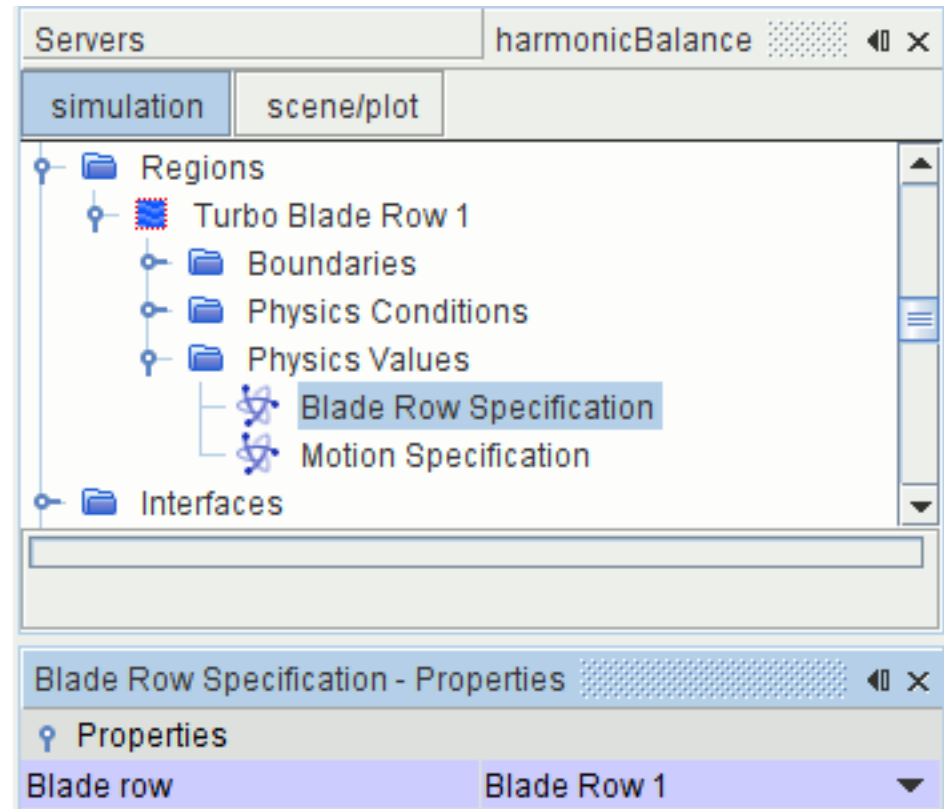
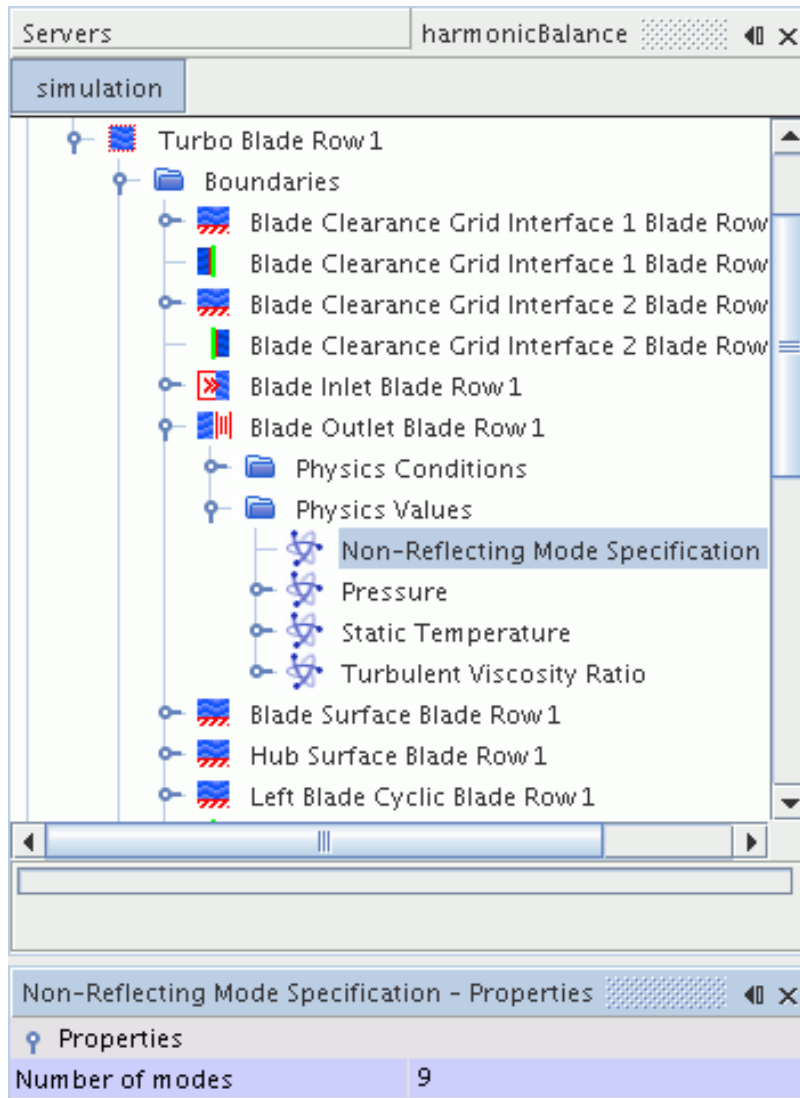
The **Non-Reflecting Mode Specification - Properties** panel at the bottom left shows the **Number of modes** set to **9**.

The **Simulation** panel on the right shows the **Physics Conditions** for **Blade Outlet Blade Row 1**, with **Pressure Outlet Option** selected. The **Pressure Outlet Option - Properties** panel at the bottom right shows the **Option** set to **Non-Reflecting**.

Option	Non-Reflecting
None	
Non-Reflecting	
Target Mass Flow	
Time Varying	



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+

Servers harmonicBalance

simulation scene/plot

- Solvers
 - Wall Distance
 - Implicit Harmonic Balance
 - Spalart-Allmaras Turbulence
- Stopping Criteria

Implicit Harmonic Balance - Properties

Properties

Courant Number 2.0

Expert

Maximum Steps - Properties

Properties

Enabled	<input checked="" type="checkbox"/>
Maximum Steps	6000
Logical Rule	Or
Criterion Satisfied	<input checked="" type="checkbox"/>



Harmonic Balance for Rotor Blade in StarCCM+

Tools

- Annotations
- Colormaps
- Coordinate Systems
- Data Mappers
- Data Set Functions
- Field Functions
- Layouts
- Material Databases
- Motions
- Reference Frames
- Tables
- Transforms**
- Units

Right click on « Transforms »

Run twice « Simple Transform »

Simple Transform Down - Properties

Properties	
Coordinate System	Laboratory
Rotation Angle	-10.0 deg
Rotation Origin	[0.0, 0.0, 0.0] m,m,m
Rotation Axis	[0.0, 0.0, 1.0] m,m,m
Translation	[0.0, 0.0, 0.0] m,m,m
Scale	[1.0, 1.0, 1.0]

Simple Transform Up - Properties

Properties	
Coordinate System	Laboratory
Rotation Angle	10.0 deg
Rotation Origin	[0.0, 0.0, 0.0] m,m,m
Rotation Axis	[0.0, 0.0, 1.0] m,m,m
Translation	[0.0, 0.0, 0.0] m,m,m
Scale	[1.0, 1.0, 1.0]



Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation

Reports
Monitors
Plots
Scenes
Surfaces
Results
Tools

Right click on « Scenes »

- New Scene
- Open All Scenes
- Apply Representation
- Test Graphics
- Paste Ctrl+V
- Edit...
- Refresh
- New Group
- UnGroup

- Geometry
- Mesh
- Scalar
- Vector
- Empty

Outline 1 - Properties

Properties

Opacity	0.2
Mesh	<input type="checkbox"/>
Outline	<input checked="" type="checkbox"/>
Feature Lines	<input type="checkbox"/>
Surface	<input checked="" type="checkbox"/>
Element Shrink	1.0
Color Mode	Type (Default)

Expert

Scenes - Properties

Expert

Output Verbosity ☒

Scenes

Scene manager

Output - HarmonicBalanceSingleRow_RotorBlade

STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial

Loading into:

STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial

Object database load completed.

Started default macro:

C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star599994073886812102.java

Loading/configuring connectivity (old/new partitions: 1/1)



Harmonic Balance for Rotor Blade in StarCCM+

The screenshot displays the StarCCM+ software interface for a simulation titled "HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+". The interface includes a menu bar (File, Edit, Mesh, Solution, Tools, Window, Help), a toolbar, and several panels:

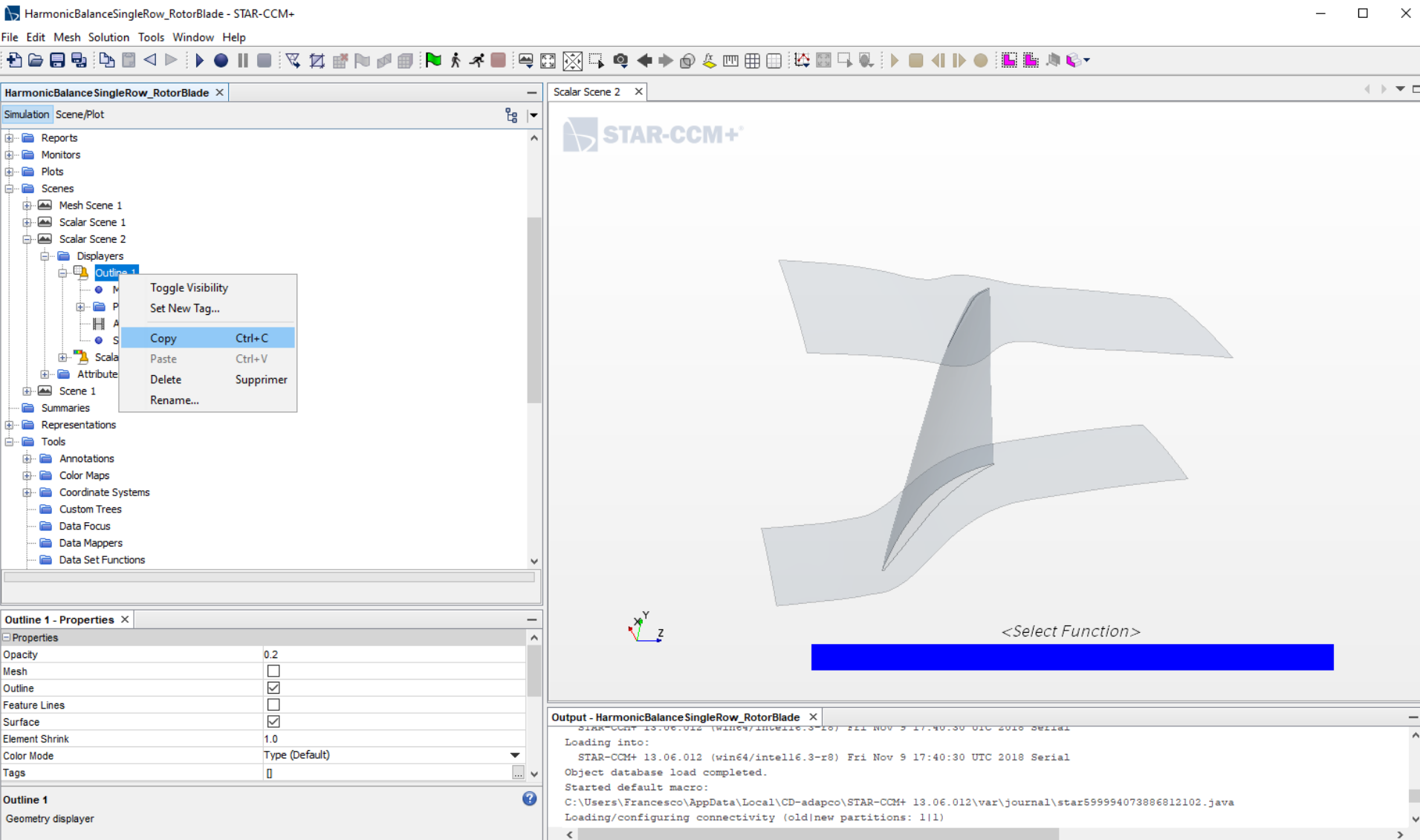
- Simulation Scene/Plot:** A tree view on the left showing the simulation hierarchy, including Reports, Monitors, Plots, Scenes, Mesh Scene 1, Scalar Scene 1, Scalar Scene 2, Displayers, Outline 1, Mesh Color, Parts, Animations, Shading Angle, Scalar 1, Attributes, Scene 1, Summaries, Representations, and Tools.
- Parts - Properties:** A panel at the bottom left showing the properties of the selected part, "Turbo Blade Row 1: Blade Inlet Blade Row 1, Turbo Blade Row 1".
- Parts - Parts:** A panel on the right showing the list of parts and regions. The "Regions" section is expanded, showing "Turbo Blade Row 1" and its sub-regions: "Blade Clearance Grid Interface 1 Blade", "Blade Clearance Grid Interface 1 Blade", "Blade Clearance Grid Interface 2 Blade", "Blade Clearance Grid Interface 2 Blade", "Blade Inlet Blade Row 1", "Blade Outlet Blade Row 1", "Blade Surface Blade Row 1", "Hub Surface Blade Row 1", "Left Blade Cyclic Blade Row 1", "Left Blade Cyclic Blade Row 1 [Periodic]", "Right Blade Cyclic Blade Row 1", "Right Blade Cyclic Blade Row 1 [Periodic]", and "Shroud Surface Blade Row 1".
- Output - HarmonicBalanceSingleRow_RotorBlade:** A panel at the bottom right showing the output log, which includes the following text:

```
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Loading into:
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Object database load completed.
Started default macro:
C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star599994073886812102.java
Loading/configuring connectivity (old/new partitions: 1/1)
```

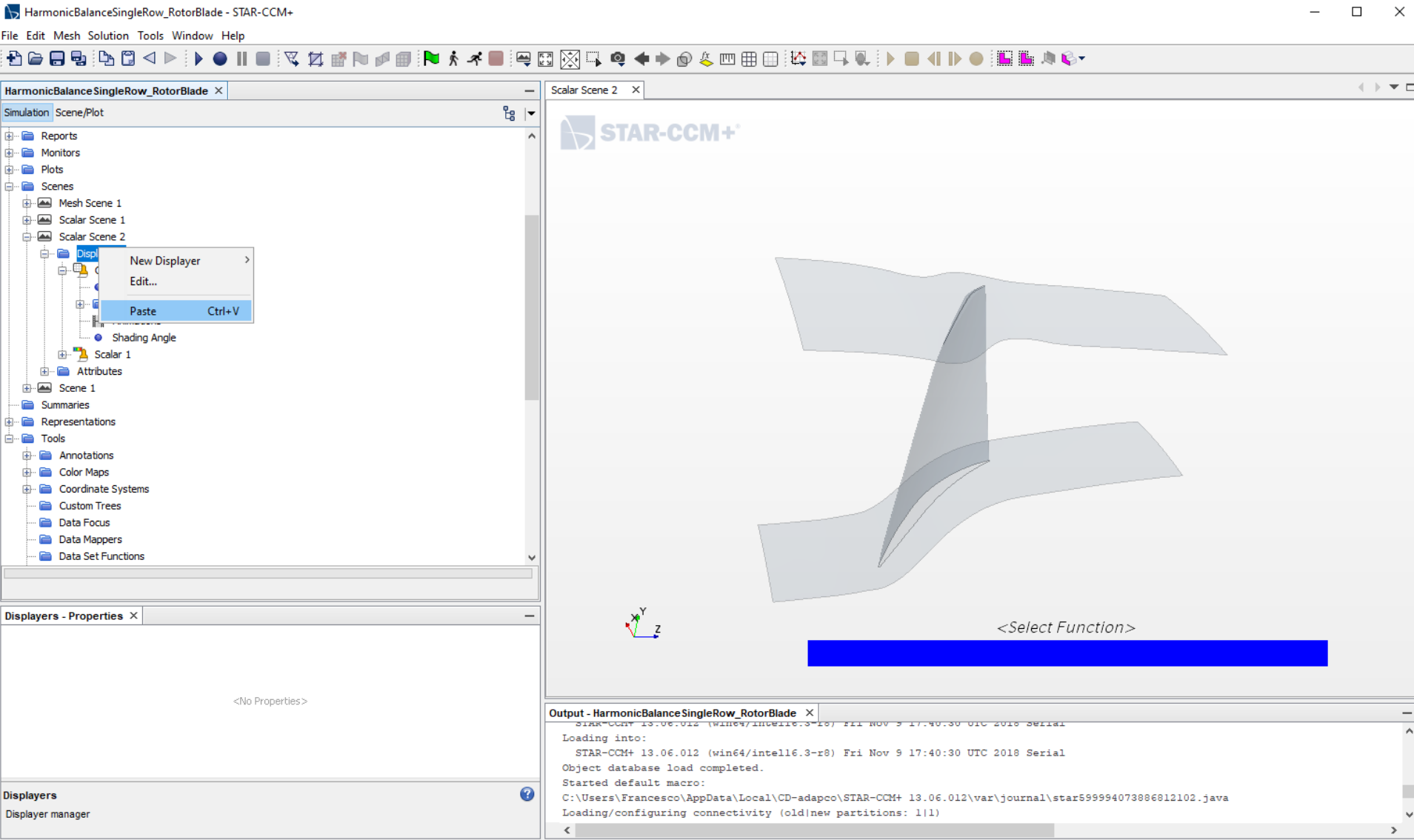
A red arrow points to the "Parts" panel, and a blue arrow points to the "Parts - Properties" panel. A text box at the bottom of the arrow points to the "Parts" panel, stating: "Click, or select and press CTRL-SPACE to open custom editor; right click for menu".



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+

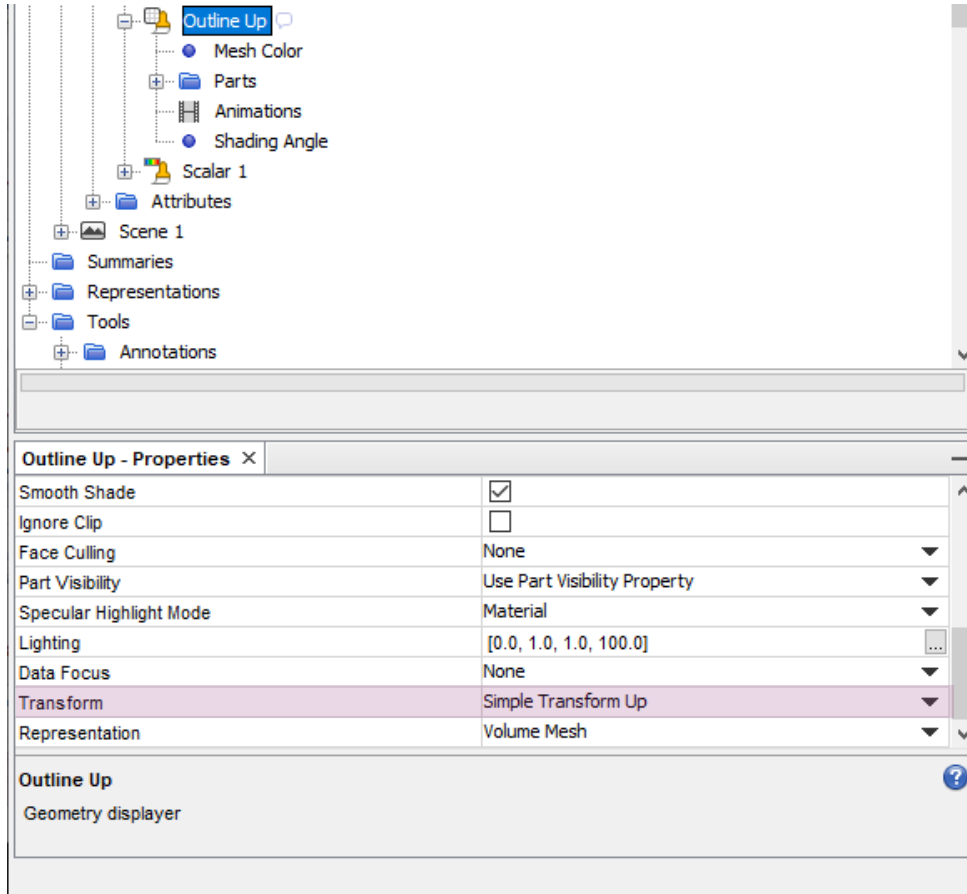


Repeat the copy-paste operation twice such to have 3 outlines

CFD applied to Turbomachinery



Harmonic Balance for Rotor Blade in StarCCM+



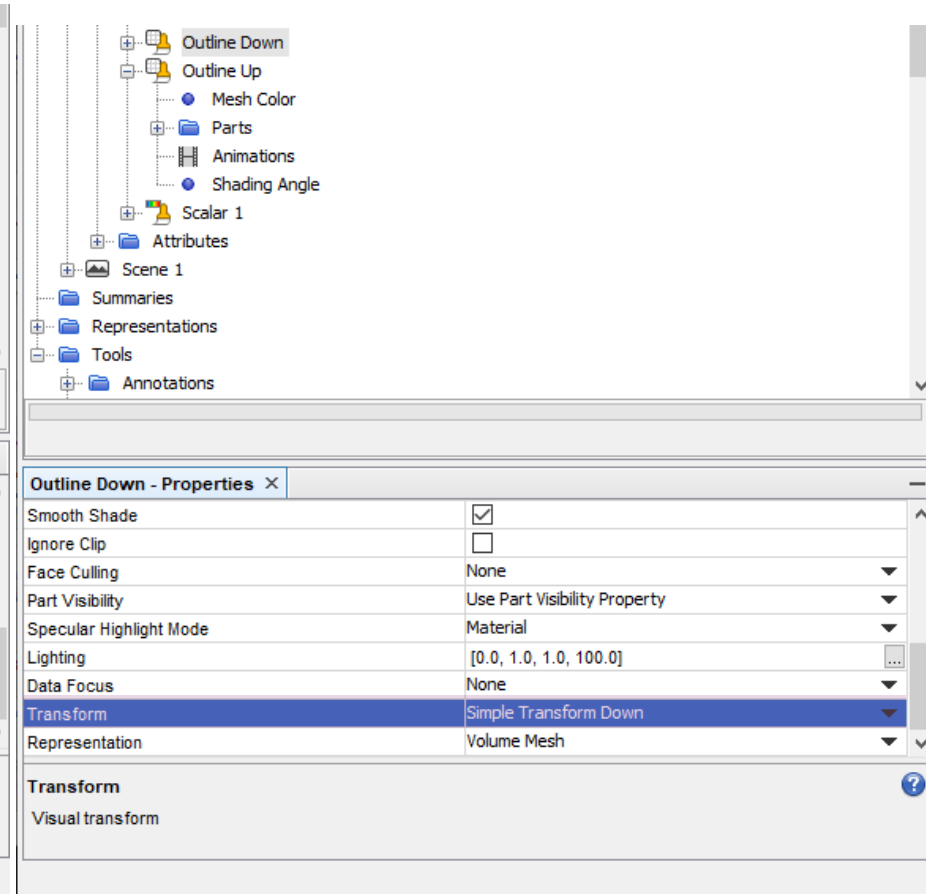
The left panel shows the 'Outline Up' tree with the following structure:

- Outline Up
 - Mesh Color
 - Parts
 - Animations
 - Shading Angle
 - Scalar 1
 - Attributes
 - Scene 1
 - Summaries
 - Representations
 - Tools
 - Annotations

The 'Outline Up - Properties' panel is open, showing the following settings:

Property	Value
Smooth Shade	<input checked="" type="checkbox"/>
Ignore Clip	<input type="checkbox"/>
Face Culling	None
Part Visibility	Use Part Visibility Property
Specular Highlight Mode	Material
Lighting	[0.0, 1.0, 1.0, 100.0]
Data Focus	None
Transform	Simple Transform Up
Representation	Volume Mesh

The 'Outline Up' section is labeled 'Geometry displayer'.



The right panel shows the 'Outline Down' tree with the following structure:

- Outline Down
 - Outline Up
 - Mesh Color
 - Parts
 - Animations
 - Shading Angle
 - Scalar 1
 - Attributes
 - Scene 1
 - Summaries
 - Representations
 - Tools
 - Annotations

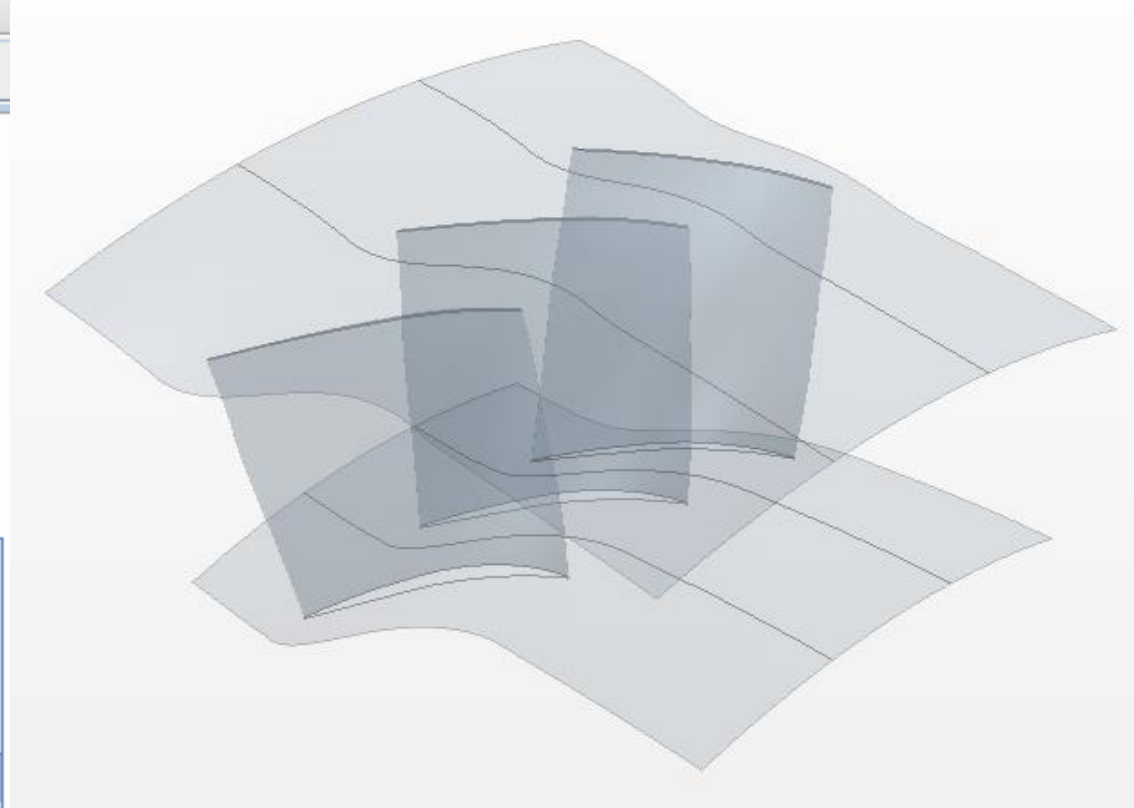
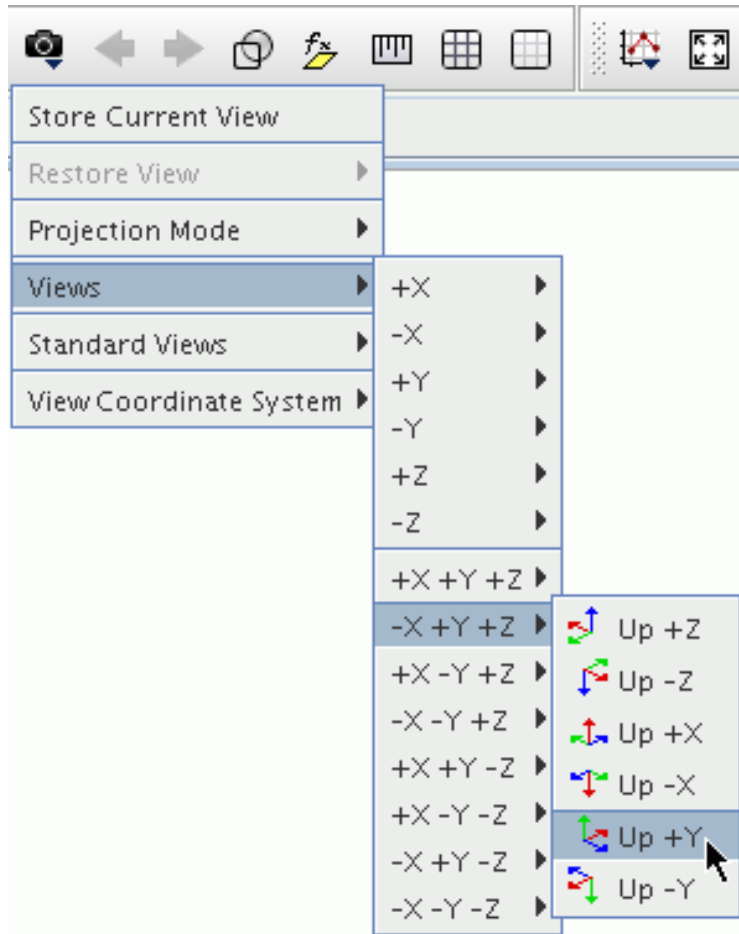
The 'Outline Down - Properties' panel is open, showing the following settings:

Property	Value
Smooth Shade	<input checked="" type="checkbox"/>
Ignore Clip	<input type="checkbox"/>
Face Culling	None
Part Visibility	Use Part Visibility Property
Specular Highlight Mode	Material
Lighting	[0.0, 1.0, 1.0, 100.0]
Data Focus	None
Transform	Simple Transform Down
Representation	Volume Mesh

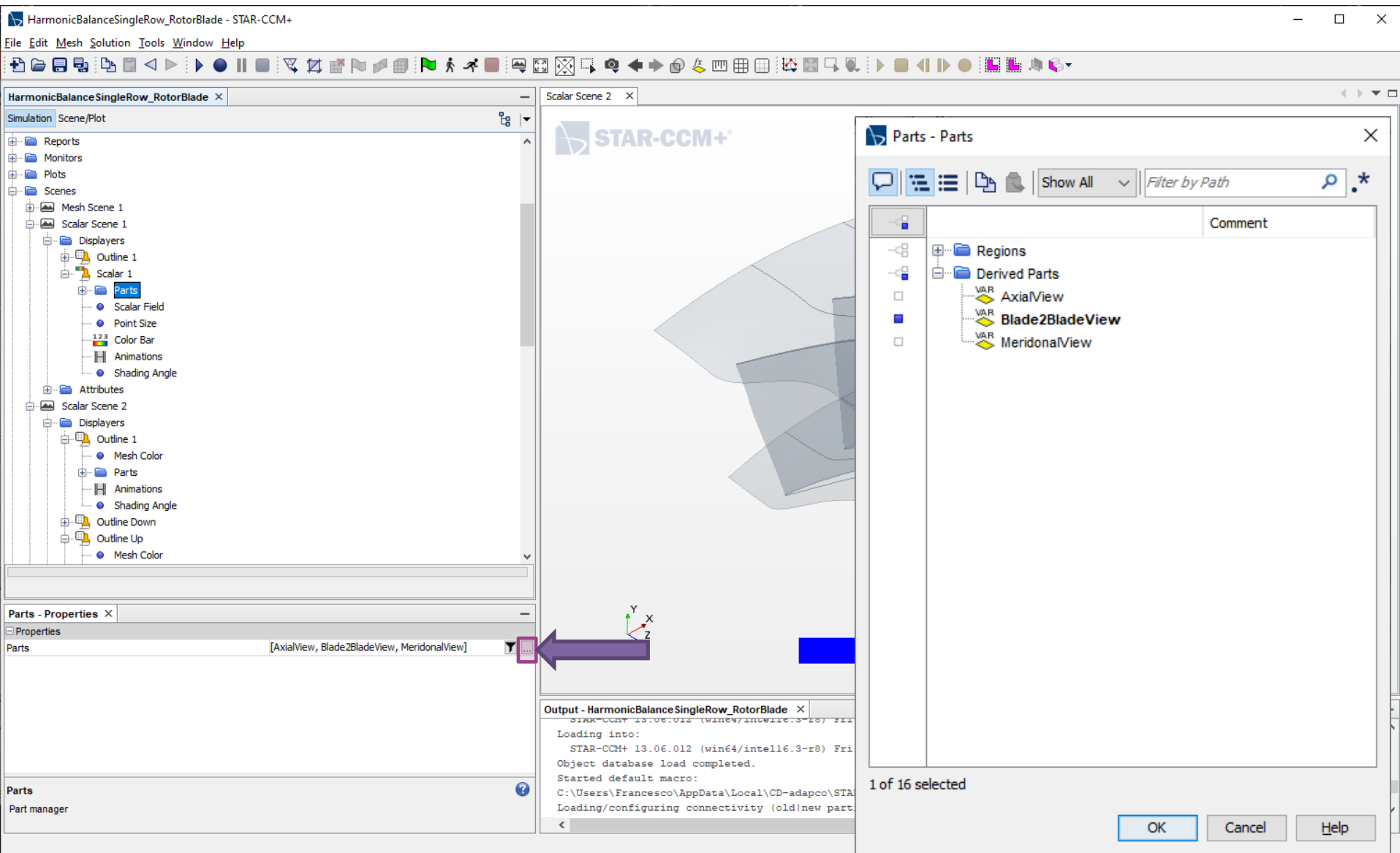
The 'Transform' section is labeled 'Visual transform'.



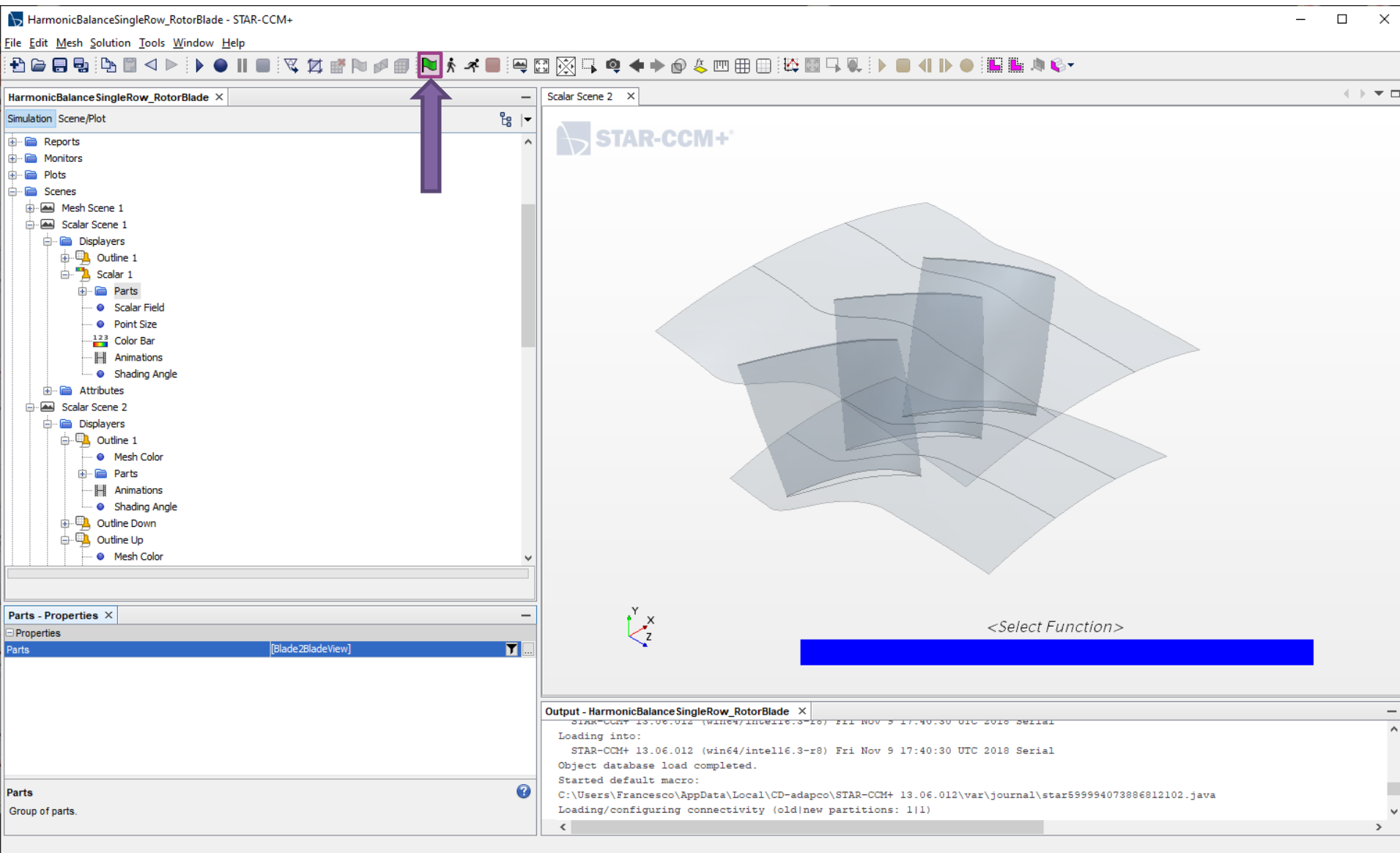
Harmonic Balance for Rotor Blade in StarCCM+



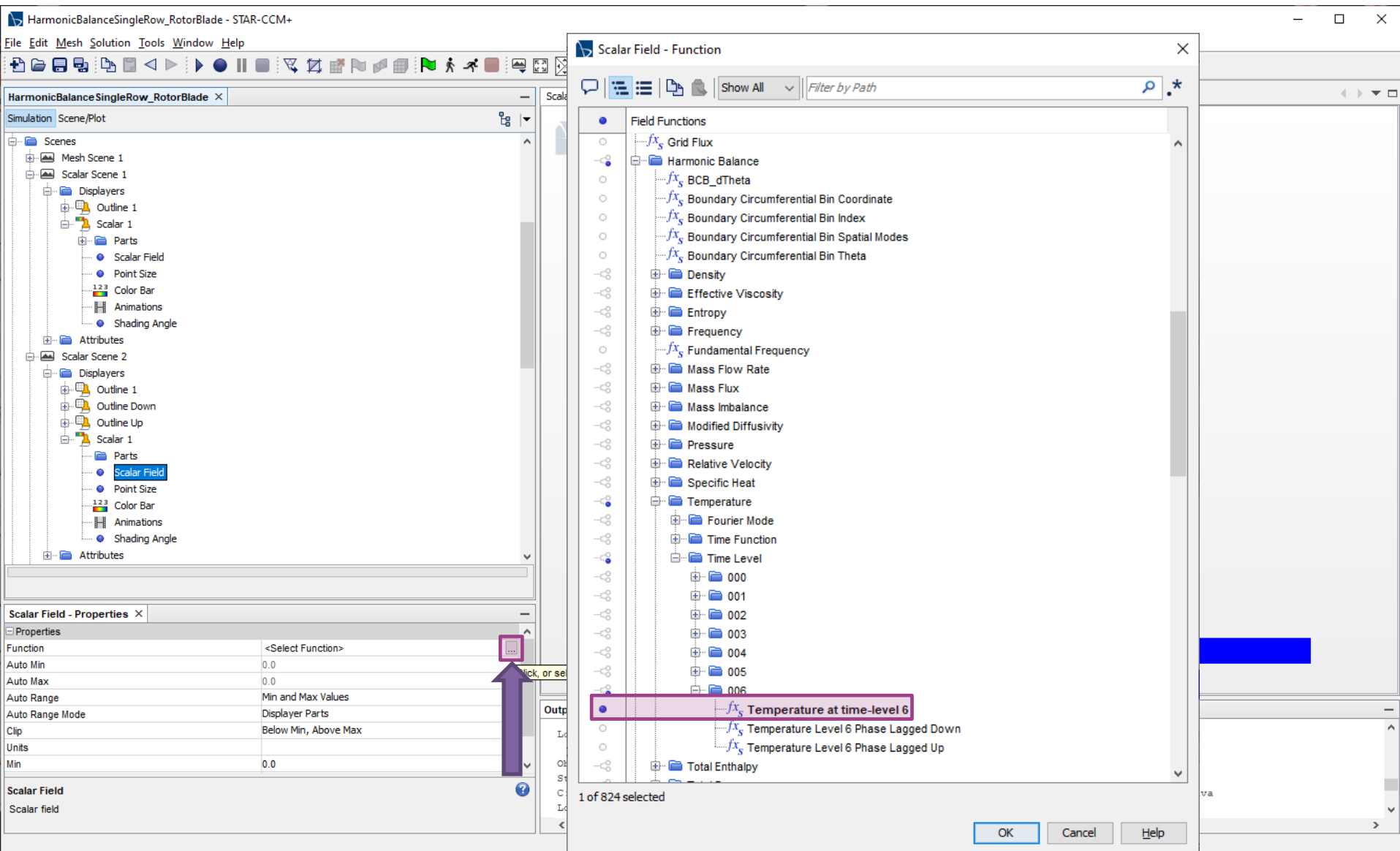
Harmonic Balance for Rotor Blade in StarCCM+



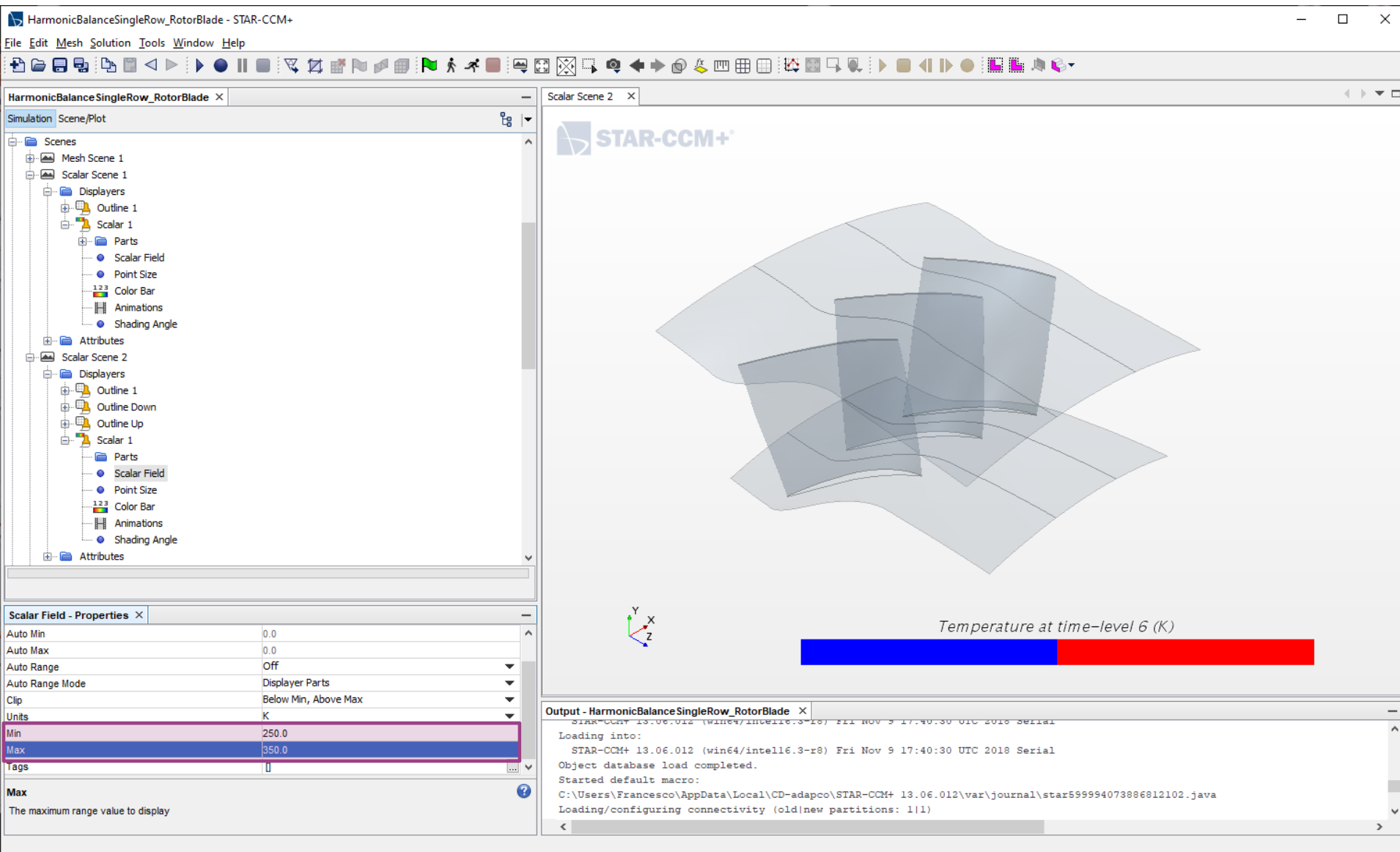
Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+



HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation Scene/Plot

Scenes

- Mesh Scene 1
- Scalar Scene 1
 - Displayers
 - Outline 1
 - Scalar 1
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle
- Scalar Scene 2
 - Displayers
 - Outline 1
 - Outline Down
 - Outline Up
 - Scalar 1
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle

- Attributes

Scalar Field - Properties

Auto Min	0.0
Auto Max	0.0
Auto Range	Off
Auto Range Mode	▼
Clip	▼
Units	K
Min	250.0
Max	350.0
Tags	0

Max
The maximum range value to display

STAR-CCM+

Temperature at time-level 6 (K)

Output - HarmonicBalanceSingleRow_RotorBlade

```
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Loading into:
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Object database load completed.
Started default macro:
C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star599994073886812102.java
Loading/configuring connectivity (old/new partitions: 1|1)
```

Copy-paste « Scalar 1 » twice as done for the Outline Displayers

CFD applied to Turbomachinery

Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation Scene/Plot

Displayers

- Outline 1
- Outline Down
- Outline Up
- Scalar 1
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle
- Scalar Down
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle
- Scalar Up
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle

Attributes

Scalar Field - Properties

Properties

Function	Temperature at time-level 6
Auto Min	0.0
Auto Max	0.0
Auto Range	Off
Auto Range Mode	Displayer Parts
Clip	Below Min, Above Max
Units	K
Min	250.0

Output - HarmonicBalance

STAR-CCM+ 13.0.0

Loading into:

STAR-CCM+ 13.0.0

Object database:

Started default:

C:\Users\France

Loading/configu

Field Functions

- Harmonic Balance
 - BCB_dTheta
 - Boundary Circumferential Bin Coordinate
 - Boundary Circumferential Bin Index
 - Boundary Circumferential Bin Spatial Modes
 - Boundary Circumferential Bin Theta
 - Density
 - Effective Viscosity
 - Entropy
 - Frequency
 - Fundamental Frequency
 - Mass Flow Rate
 - Mass Flux
 - Mass Imbalance
 - Modified Diffusivity
 - Pressure
 - Relative Velocity
 - Specific Heat
 - Temperature
 - Fourier Mode
 - Time Function
 - Time Level
 - 000
 - 001
 - 002
 - 003
 - 004
 - 005
 - 006
 - Temperature at time-level 6
 - Temperature Level 6 Phase Lagged Down
 - Temperature Level 6 Phase Lagged Up
 - Total Enthalpy
 - Total Pressure

Harmonic Balance > Temperature > Time Level > 006 > Temperature Level 6 Phase Lagged Up

OK Cancel Help

Change the Scalar Function of « Scalar Down » to « Temperature Level 6 Phase Lagged Down »

CFD applied to Turbomachinery

Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation Scene/Plot

Displayers

- Outline 1
- Outline Down
- Outline Up
- Scalar 1
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle
- Scalar Down
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle
- Scalar Up
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle

Attributes

Color Bar - Properties

Title Height	0.0275
Label Height	0.024
Orientation	Horizontal
Position	[0.3, 0.05]
Visible	<input checked="" type="checkbox"/>
Scale Mode	Linear
Text Color	Black
Expert	<input type="checkbox"/>
Opacity	

Visible

Display color bar in scene

STAR-CCM+

Temperature Levels Scalar Field Lagged Down (K)

Output - HarmonicBalanceSingleRow_RotorBlade

```
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Loading into:
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Object database load completed.
Started default macro:
C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star599994073886812102.java
Loading/configuring connectivity (old/new partitions: 1/1)
```

Deselect « Visible » for « Scalar Down » and « Scalar Up »

CFD applied to Turbomachinery

Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleRow_RotorBlade - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation Scene/Plot

Displayers

- Outline 1
- Outline Down
- Outline Up
- Scalar 1
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle
- Scalar Down
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle
- Scalar Up
 - Parts
 - Scalar Field
 - Point Size
 - Color Bar
 - Animations
 - Shading Angle

Attributes

Color Bar - Properties

Title Height	0.0275
Label Height	0.024
Orientation	Horizontal
Position	[0.3, 0.05]
Visible	<input type="checkbox"/>
Scale Mode	Linear
Text Color	Black
Expert	
Opacity	1.0

Visible

Display color bar in scene

Scalar Scene 2

STAR-CCM+

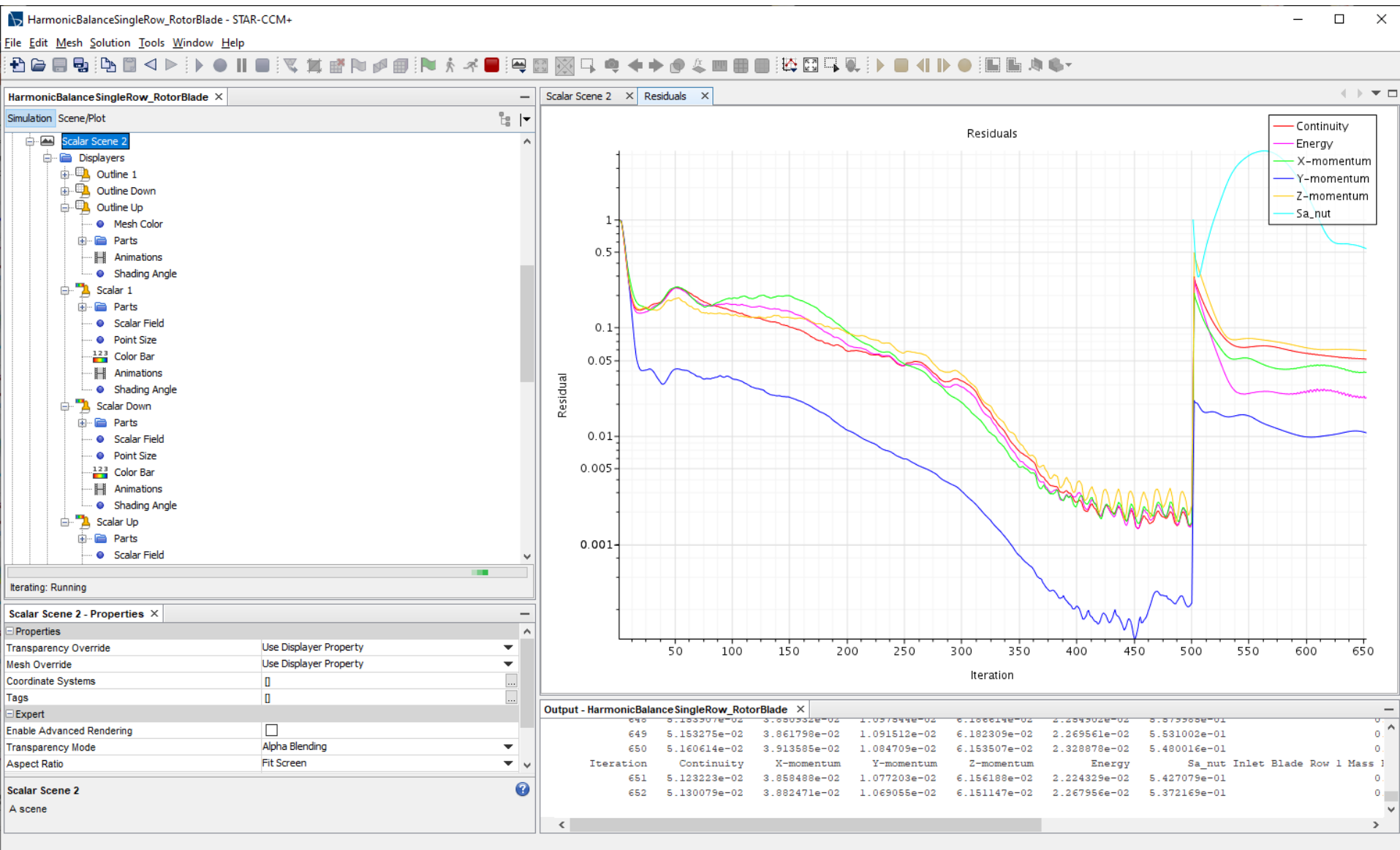
Temperature at time-level 6 (K)

Output - HarmonicBalanceSingleRow_RotorBlade

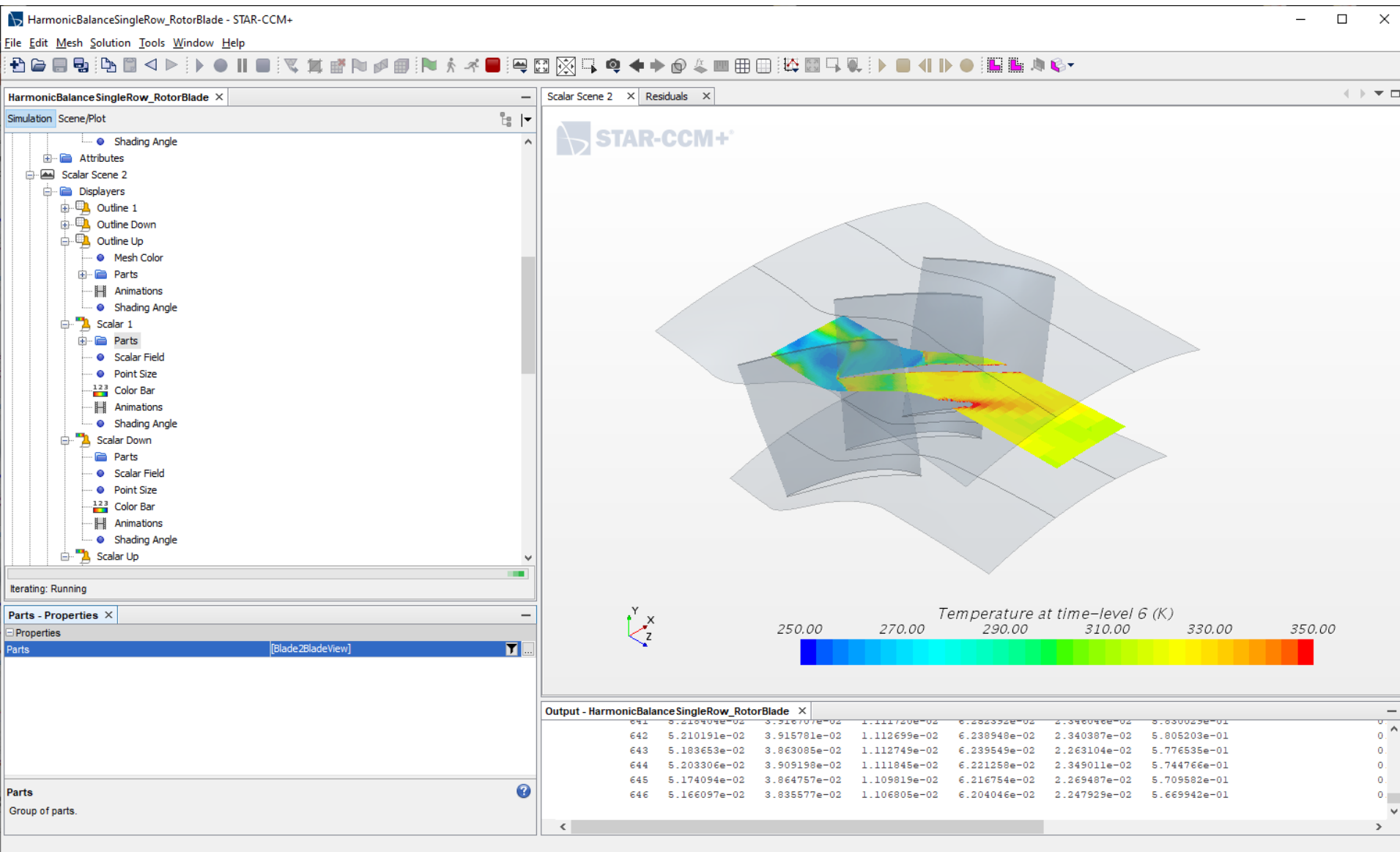
```
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Loading into:
STAR-CCM+ 13.06.012 (win64/intel16.3-r8) Fri Nov 9 17:40:30 UTC 2018 Serial
Object database load completed.
Started default macro:
C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star599994073886812102.java
Loading/configuring connectivity (old/new partitions: 1/1)
```



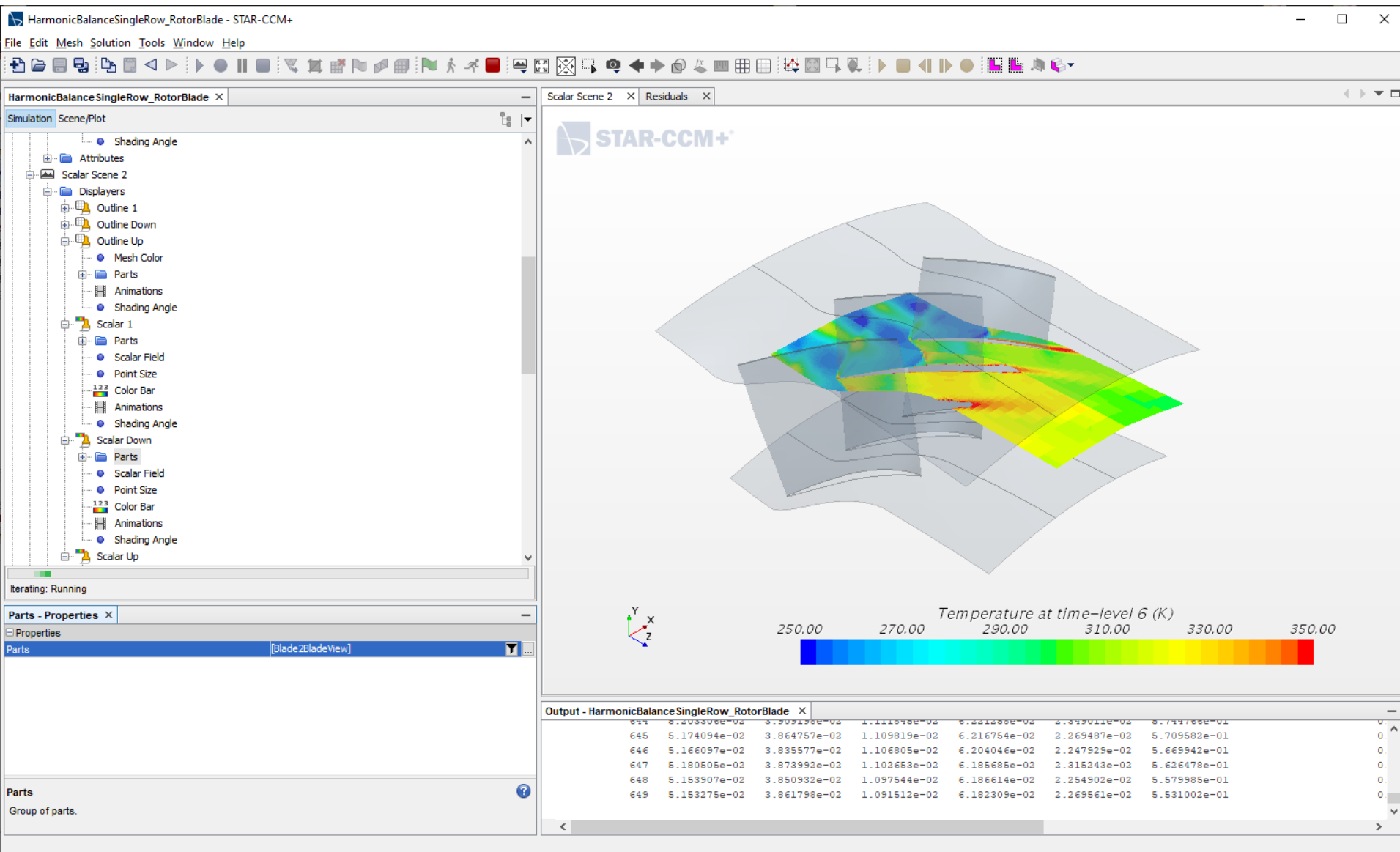
Harmonic Balance for Rotor Blade in StarCCM+



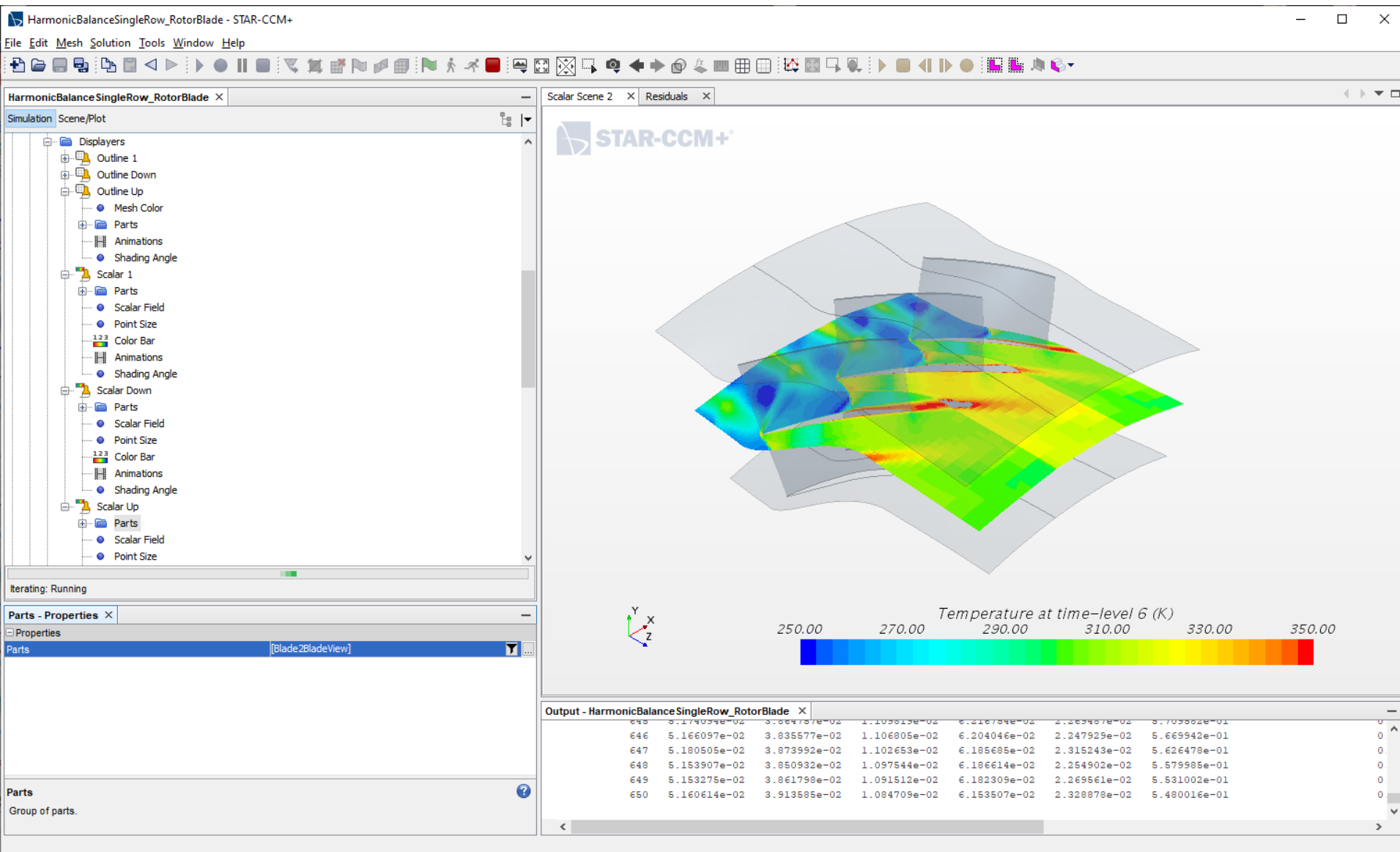
Harmonic Balance for Rotor Blade in StarCCM+



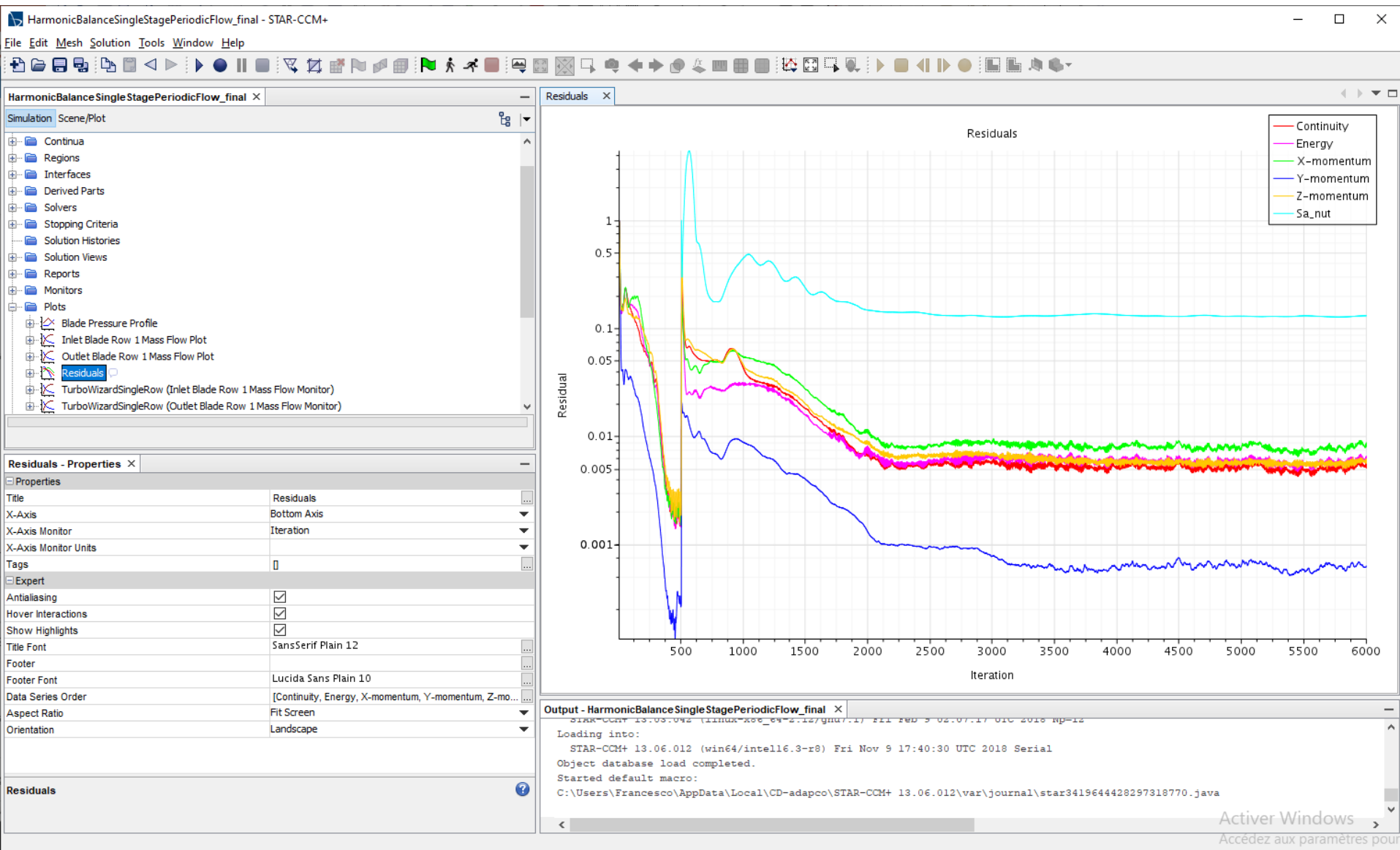
Harmonic Balance for Rotor Blade in StarCCM+



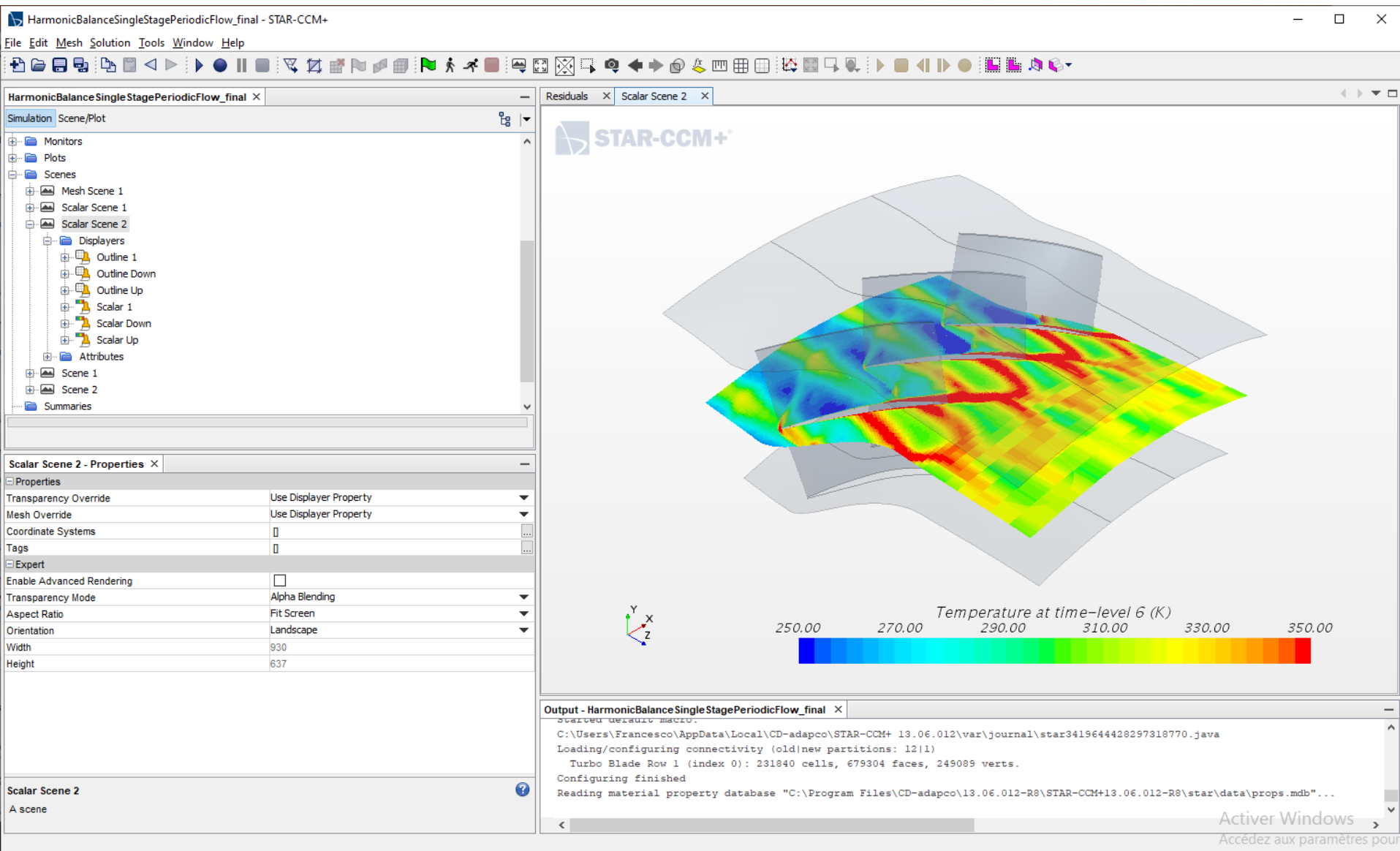
Harmonic Balance for Rotor Blade in StarCCM+



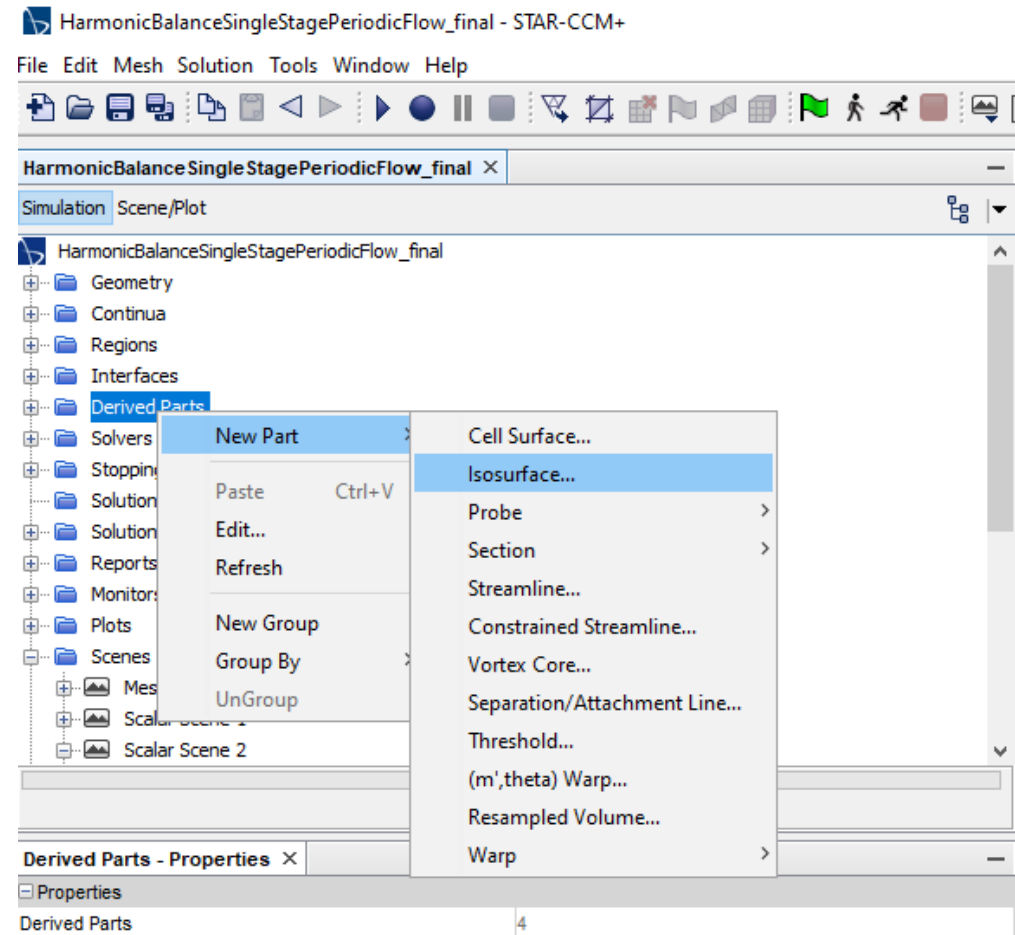
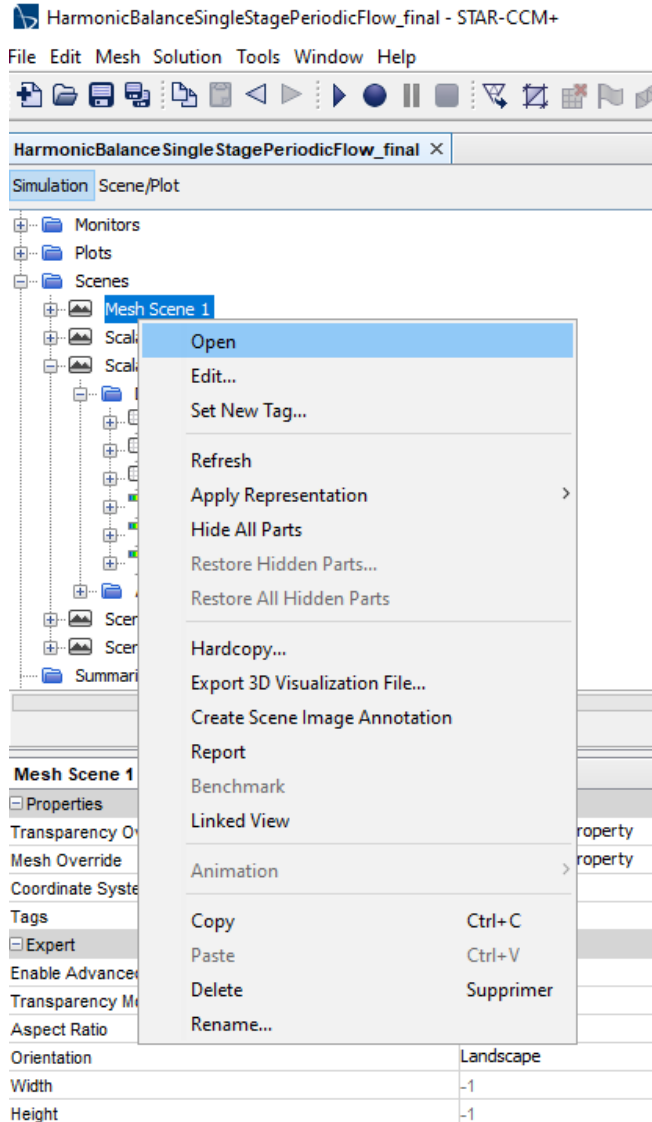
Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+

The screenshot displays the StarCCM+ interface for setting up a Harmonic Balance simulation. The main window is titled "HarmonicBalanceSingleStagePeriodicFlow_final - STAR-CCM+". The left sidebar shows the "Create Isosurface" panel with the "Input Parts" field set to "[Turbo Blade Row 1]". A purple arrow points to the "Select..." button next to this field. The "Scalar" field is empty, and the "Scalar Range" is set to "[0.0, 0.0]". The "Extraction Mode" is set to "Single Value" and the "Isovalue" is "0.0 m". The "Display" section shows "New Geometry Displayer" selected. The bottom of the left sidebar has "Create", "Close", and "Help" buttons.

The right sidebar shows the "Select Objects" panel with a tree view of the simulation hierarchy. The "Regions" folder is expanded, showing "Turbo Blade Row 1" and its "Boundaries". The "Boundaries" folder is also expanded, showing various interfaces and surfaces. The "Blade Clearance Grid Interface 1 Blade Row 1 [In-place 1]" is selected. The bottom of the right sidebar has "OK", "Cancel", and "Help" buttons.

The bottom panel shows the "Output - HarmonicBalanceSingleStagePeriodicFlow_final" window with the following text:

```
Started default macro.  
C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star3419644428297318770.java  
Loading/configuring connectivity (old/new partitions: 12/1)  
Turbo Blade Row 1 (index 0): 231840 cells, 679304 faces, 249089 verts.  
Configuring finished  
Reading material property database "C:\Program Files\CD-adapco\13.06.012-R8\STAR-CCM+13.06.012-R8\star\data\props.mdb"...
```



Harmonic Balance for Rotor Blade in StarCCM+

The screenshot displays the StarCCM+ interface for setting up a Harmonic Balance simulation. The main window is titled "HarmonicBalanceSingleStagePeriodicFlow_final - STAR-CCM+". The left sidebar shows the "Simulation" tab with the "Edit" sub-tab active. Under "Create Isosurface", the "Input Parts" field is set to "[Turbo Blade Row 1]". The "Scalar" field is highlighted with a red box and a red arrow pointing to it. The "Scalar Range" is set to "[0.0, 0.0]". The "Extraction Mode" is set to "Single Value". The "Isovalue" is set to "0.0 m". The "Display" section shows "New Geometry Display" selected. The "Output" window at the bottom shows the simulation setup details, including the file path and the number of cells, faces, and vertices.

HarmonicBalanceSingleStagePeriodicFlow_final - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation Scene/Plot Edit

Create Isosurface

Input Parts

[Turbo Blade Row 1] Select...

Scalar

Select...

Scalar Range

[0.0, 0.0]

Extraction Mode Single Value

Isovalue 0.0 m

Display

☐ No Displayer

☒ New Geometry Displayer

☐ New Scalar Displayer

☐ New Vector Displayer

☐ Existing Displayer

Mesh 1

Create Close Help

Select Object

Field Functions

- ☒ f_{x_s} Area
- ☐ f_{x_s} Block-Mapped 1: Umin to Umax
- ☒ f_{x_s} Block-Mapped 1: Vmin to Vmax
- ☐ f_{x_s} Block-Mapped 1: Wmin to Wmax
- ☐ f_{x_s} Boundary Advection Heat Flux
- ☐ f_{x_s} Boundary Advection Heat Transfer
- ☐ f_{x_s} Boundary Circumferential Bin Pitch
- ☐ f_{x_s} Boundary Conduction Heat Flux
- ☐ f_{x_s} Boundary Conduction Heat Transfer
- ☐ f_{x_s} Boundary Heat Flux
- ☐ f_{x_s} Boundary Heat Transfer
- ☐ f_{x_s} Boundary Index
- ☐ f_{x_s} Boundary Sliver Cell Indicator
- ☐ f_{x_s} Cell Aspect Ratio
- ☐ f_{x_s} Cell Index
- ☐ f_{x_s} Cell Part Index
- ☐ f_{x_s} Cell Quality

Boundary Heat Transfer

OK Cancel Help

Output - HarmonicBalanceSingleStagePeriodicFlow_final

Started default macro.

C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star3419644428297318770.java

Loading/configuring connectivity (old/new partitions: 12/1)

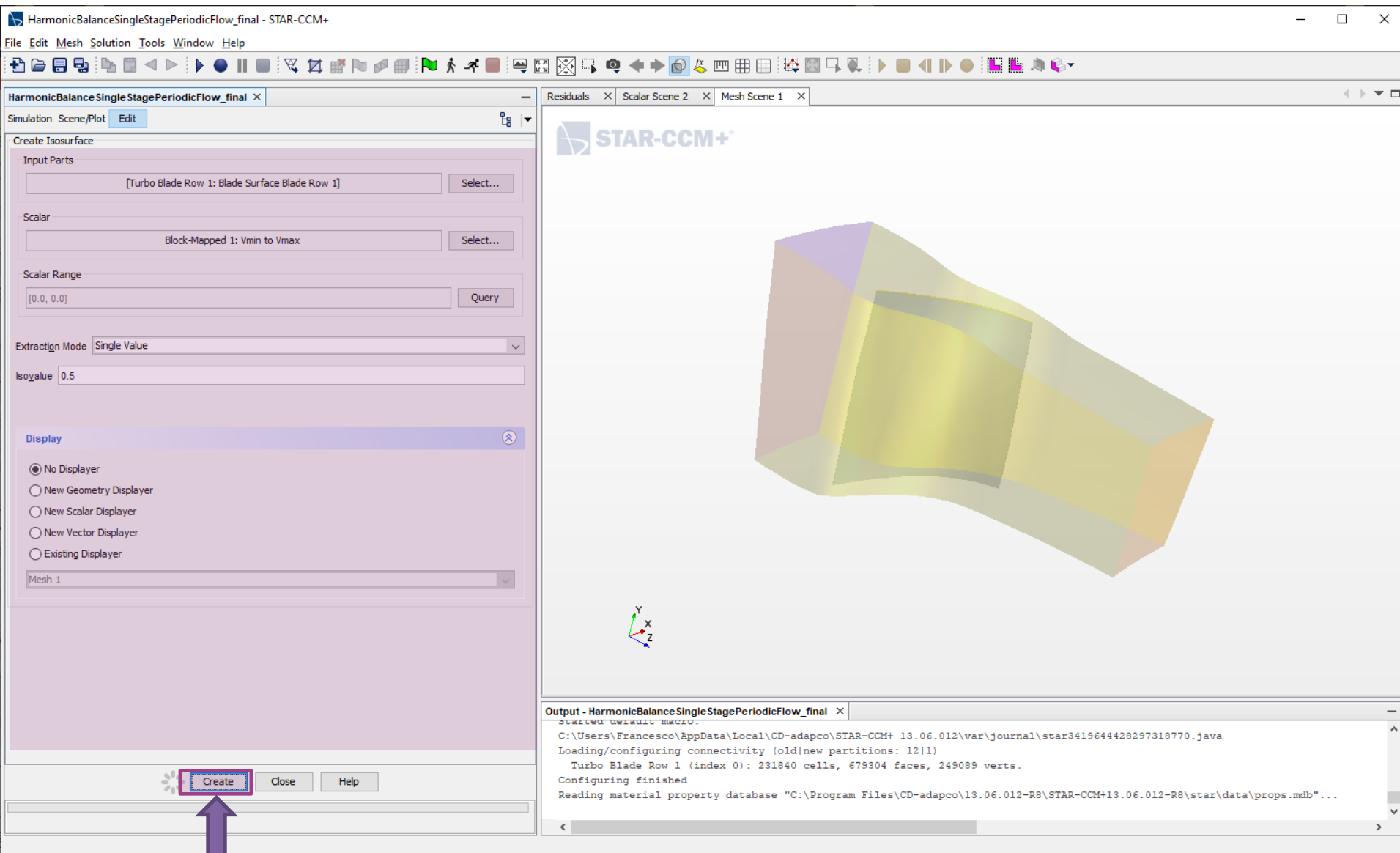
Turbo Blade Row 1 (index 0): 231840 cells, 679304 faces, 249089 verts.

Configuring finished

Reading material property database "C:\Program Files\CD-adapco\13.06.012-R8\STAR-CCM+13.06.012-R8\star\data\props.mdb"...



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleStagePeriodicFlow_final - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation Scene/Plot

- HarmonicBalanceSingleStagePeriodicFlow_final
 - Geometry
 - Continua
 - Regions
 - Interfaces
 - Derived Parts
 - VAR AxialView
 - VAR Blade2BladeView
 - VAR Blade 50% Section
 - VAR MeridionalView
 - Solvers
 - Stopping Criteria
 - Solution Histories
 - Solution Views
 - Reports
 - Monitors
 - Plots

Blade 50% Section - Properties

Properties

Parts	[Turbo Blade Row 1: Blade Surface Blade Row 1]
Scalar Field	Block-Mapped 1: Vmin to Vmax
Mode	Single
Tags	

Blade 50% Section
Isosurface Part

STAR-CCM+

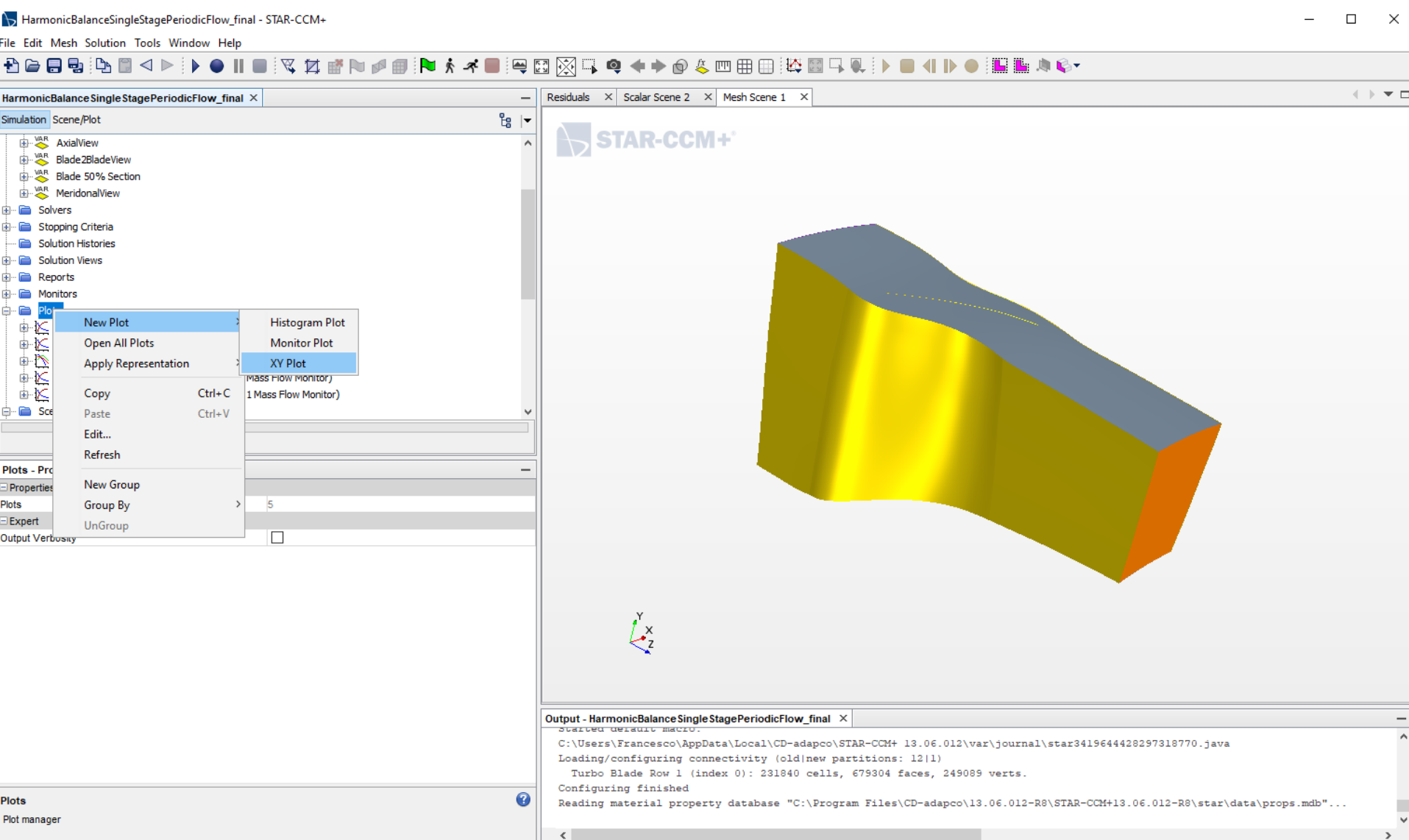
Blade 50% Section

Output - HarmonicBalanceSingleStagePeriodicFlow_final

```
Started default macro.  
C:\Users\Francesco\AppData\Local\CD-adapco\STAR-CCM+ 13.06.012\var\journal\star3419644428297318770.java  
Loading/configuring connectivity (old/new partitions: 12/1)  
Turbo Blade Row 1 (index 0): 231840 cells, 679304 faces, 249089 verts.  
Configuring finished  
Reading material property database "C:\Program Files\CD-adapco\13.06.012-R8\STAR-CCM+13.06.012-R8\star\data\props.mdb"...
```



Harmonic Balance for Rotor Blade in StarCCM+



Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleStagePeriodicFlow_final - STAR-CCM+

File Edit Mesh Solution Tools Window Help

Simulation Scene/Plot

- Solution Histories
- Solution Views
- Reports
- Monitors
- Plots
 - Blade Pressure Profile
 - X Type
 - Y Types
 - Data Series
 - Axes
 - Legend
 - Update
 - Inlet Blade Row 1 Mass Flow Plot
 - Outlet Blade Row 1 Mass Flow Plot
 - Residuals
 - TurboWizardSingleRow (Inlet Blade Row 1 Mass Flow Monitor)
 - TurboWizardSingleRow (Outlet Blade Row 1 Mass Flow Monitor)

Blade Pressure Profile - Properties

Properties	
Title	XY Plot
Parts	
Representation	Volume Mesh
Tags	
Expert	
Antialiasing	<input checked="" type="checkbox"/>
Hover Interactions	<input checked="" type="checkbox"/>
Show Highlights	<input checked="" type="checkbox"/>
Title Font	Lucida Sans Plain 14
Footer	
Footer Font	Lucida Sans Plain 10
Data Series Order	
Aspect Ratio	Fit Screen
Orientation	Landscape

Blade Pressure Profile

An XY plot

Residuals x Scalar Scene 2 x Mesh Scene 1 x Blade Pressure Profile x

Blade Pressure Profile - Parts

- Regions
- Derived Parts
 - AxialView
 - Blade2BladeView
 - Blade 50% Section
 - MeridionalView

Output - HarmonicBalanceSingleStagePeriodicFlow_final

started default macro.
C:\Users\Francesco\AppData
Loading/configuring conn
Turbo Blade Row 1 (inde
Configuring finished
Reading material property

Derived Parts > Blade 50% Section

OK Cancel Help



Harmonic Balance for Rotor Blade in StarCCM+

HarmonicBalanceSingleStagePeriodicFlow_final - STAR-CCM+

File Edit Mesh Solution Tools Window Help

HarmonicBalanceSingleStagePeriodicFlow_final x Residuals x Scalar Scene 2 x Mesh Scene 1 x Blade Pressure Profile x

Simulation Scene/Plot

- Solution Histories
- Solution Views
- Reports
- Monitors
- Plots
 - Blade Pressure Profile
 - X Type
 - Y Types
 - Y Type 1
 - Scalar Function
 - Data Series
 - Axes
 - Legend
 - Update
 - Inlet Blade Row 1 Mass Flow Plot
 - Outlet Blade Row 1 Mass Flow Plot

Scalar Function - Properties x

Properties

Field Function	<Select Function>
Units	
Tags	

Click, or select and press CTRL-SPACE to open the selection dialog

Output - HarmonicBalanceSingleStagePeriodicFlow_final

started default macro.
C:\Users\Francesco\AppData\Local\Temp\StarCCM+2023.02.01\HarmonicBalanceSingleStagePeriodicFlow_final
Loading/configuring connection
Turbo Blade Row 1 (index 1)
Configuring finished
Reading material property

Scalar Function
Simulation object

Scalar Function - Field Function

Show All Filter by Path

Field Functions

- Face Part Surface Index
- Face Type
- Face Validity
- FaceQuality
- FreeEdges
- Gas Constant
- Gauss/LSQ gradient blending factor
- Grid Flux
- Harmonic Balance
 - BCB_dTheta
 - Boundary Circumferential Bin Coordinate
 - Boundary Circumferential Bin Index
 - Boundary Circumferential Bin Spatial Modes
 - Boundary Circumferential Bin Theta
- Density
- Effective Viscosity
- Entropy
- Frequency
- Fundamental Frequency
- Mass Flow Rate
- Mass Flux
- Mass Imbalance
- Modified Diffusivity
- Pressure
 - Fourier Mode
 - Time Function
 - Time Level
 - 000
 - Pressure at time-level 0
 - Pressure Level 0 Phase Lagged Down
 - Pressure Level 0 Phase Lagged Up
 - 001
 - 002
 - 003

1 of 824 selected

OK Cancel Help



Harmonic Balance for Rotor Blade in StarCCM+

