



Model created in COMSOL Multiphysics 6.4

Transonic Flow over the ONERA M6 Wing



Introduction

The present example demonstrates how to set up the classical external-flow problem of solving for the high-speed, compressible, turbulent flow over the ONERA M6 wing. The example originates from experiments performed in the 1970s (Ref. 1), which were designed to be used in the validation of simulation codes. The problem involves finding a steady-state solution of the flow field around the 3D, swept wing geometry for different flow speeds and angles of attack. However, the present example looks at transonic flow speeds and a moderately high angle of attack, leading to the formation of weak shocks on the upper surface of the wing. The High Mach Number Flow, Spalart–Allmaras interface is set-up to solve for the flow of air, while assuming ideal gas conditions. The validation of the numerical solution is performed by the comparison of the computed surface values of the nondimensional coefficient of pressure, C_p , with the experimental values at various cross-sections along the span of the wing.

Model Definition

GEOMETRY

The geometry involves an enclosure around the wing large enough such that far-field conditions for the inlet and outlet boundaries may be imposed suitably. The enclosing boundary is placed at a distance of $10C_0$ from the wing, where C_0 is the chord length at the base of the wing; see Figure 1. The geometry of the wing, imported as a CAD file, is obtained from Ref. 2. In this case, a sharp trailing edge is created (as opposed to a blunt trailing edge used in the experiments), which is suitable for numerical simulations (see Ref. 3).

PHYSICS INTERFACE SETTINGS

The High Mach Number Flow interface and Spalart–Allmaras turbulence model with automatic wall treatment model the flow of air under ideal gas conditions. Additionally the Sutherland’s law accounts for the dependency of thermal conductivity k and dynamic viscosity μ on temperature.

INITIAL AND BOUNDARY CONDITIONS

The initial condition corresponds to a pressure of 1 atm. The inlet Mach number is incremented in stages using the auxiliary sweep functionality available in the Stationary study step. The Mach number is computed as $M_{\text{step}}M_{\infty}$, where, the value of the parameter M_{step} for the first auxiliary sweep is taken to be 0.25 and incremented up to a value of 1. Here, the desired far-field Mach number, M_{∞} , is taken to be 0.84. The no slip wall

condition and thermal insulation conditions are applied to the wing surface. The characteristics-based inflow condition is specified at the inlet boundary. The hybrid flow condition with a static pressure of 1 atm is applied at the outflow boundary. Also, a symmetry condition is applied to minimize the number of degrees of freedom of the problem.

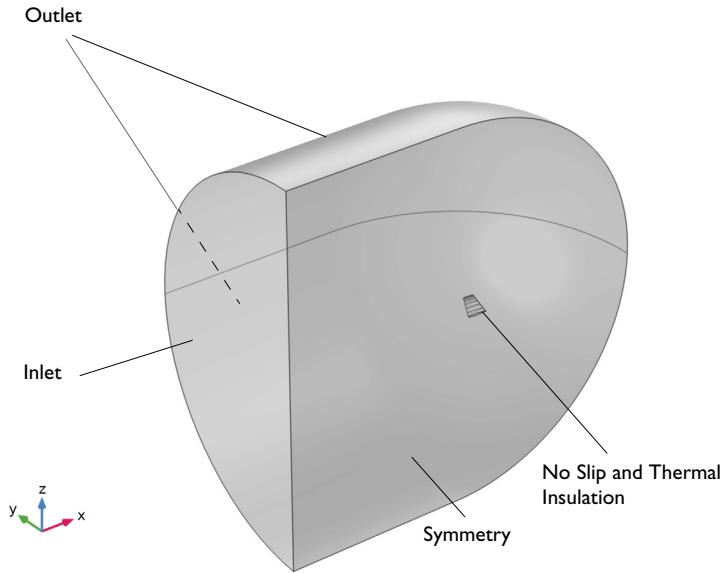


Figure 1: A schematic of the geometry and boundary conditions of the problem.

MESHING

The meshing process begins with a swept surface mesh on the wing from a suitable predefined distribution of mesh nodes on the wing's profile. A free triangular mesh is applied for the wing tip surface. As a final step, a volume mesh is populated in the domain with a suitable spatial resolution and element growth rate.

STUDY

The study contains a Wall Distance Initialization step followed by the Stationary step. The Stationary step involves an aforementioned auxiliary sweep of the parameter M_{step} in order to increment the far-field Mach number to the desired value.

Results and Discussion

The steady-state solution on the wing is visualized through the surface plot of the Mach number with contours of pressure as shown in [Figure 2](#). A merging of two weak shocks along the span of the wing is noticeable.

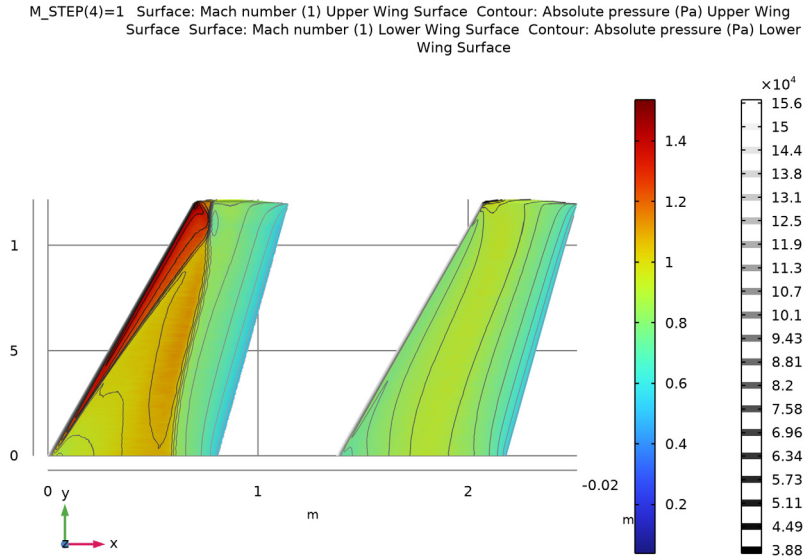


Figure 2: Surface plots of Mach number with contours of absolute pressure. The upper and lower surfaces of the wing are shown in the left and the right plots, respectively.

The vorticity generated as a consequence of pressure (and velocity) difference between the upper and the lower surfaces of the wing at the wing tip is clearly visible in [Figure 3](#) which plots an isosurface of the Q-criterion. All surfaces, including the aforementioned isosurface, plot the fluid velocity.

M_STEP(4)=1 Surface: Velocity magnitude (m/s) Isosurface: ((hmnf.rr²-hmnf.sr²)>0)*hmnf.U (m/s)

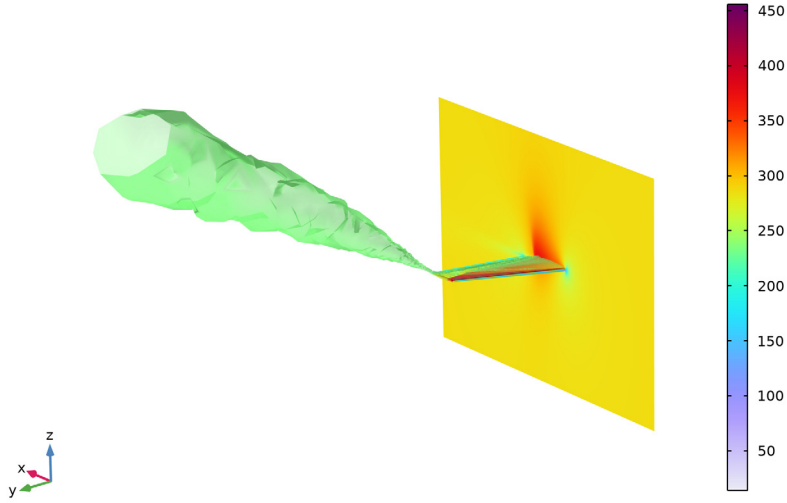


Figure 3: An isosurface of the Q -criterion shows the vortex emerging from the wing tip. All surfaces, including the aforementioned isosurface, plot the fluid velocity.

The validation of the simulations is provided by the comparison with the experiments of the coefficient of pressure, given by the expression

$$C_p = \frac{p - p_\infty}{\frac{1}{2}\gamma p_\infty M_\infty^2} \quad (1)$$

where p is the pressure, γ is the ratio of specific heats of the fluid, and the subscript ∞ signifies far-field values. [Figure 4](#), which shows the comparison at both the top and bottom edges of the wing and at several locations along its span, indicates a good correlation between the experiment and the simulation results. The location of the shocks and the magnitude of the jumps in the pressure coefficient are captured accurately.

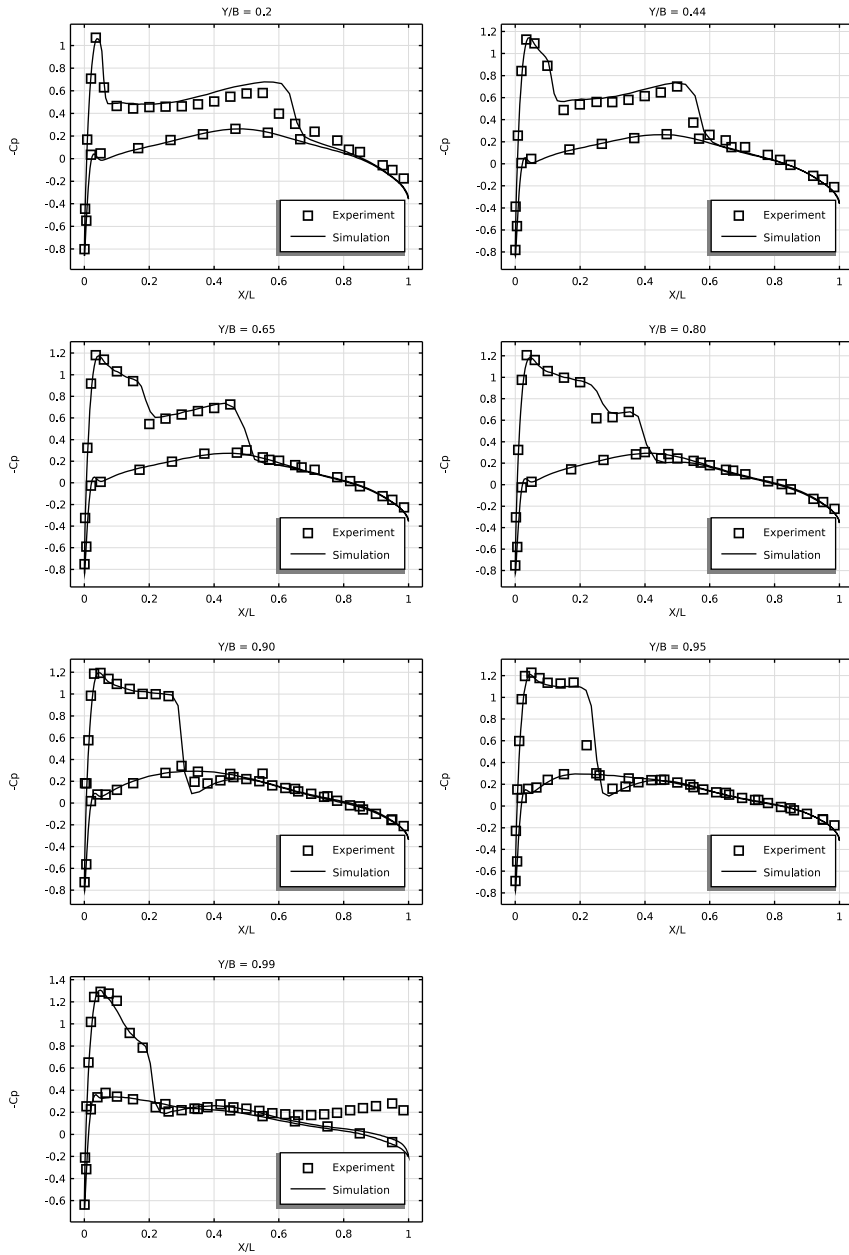


Figure 4: A comparison of C_p values at different locations along the wing span.

References


1. V. Schmitt and F. Charpin, “Pressure Distributions on the ONERA-M6-Wing at Transonic Mach Numbers,” *Experimental Data Base for Computer Program Assessment*, report of the Fluid Dynamics Panel Working Group 04, AGARD AR 138, May 1979.
2. NASA Langley Research Center Turbulence Modeling Resource, 3D ONERA M6 Wing Validation Case, turbmodels.larc.nasa.gov/onerawingnumerics_val.html.
3. J. Mayeur, A. Dumont, D. Destarac, and V. Gleize, “RANS simulations on TMR test cases and M6 wing with the Onera elsA flow solver,” *54th AIAA Aerospace Sciences Meeting*, pp. 2015–1745, 2015.

Application Library path: CFD_Module/High_Mach_Number_Flow/onera_m6_wing

Modeling Instructions

From the **File** menu, choose **New**.

NEW

In the **New** window, click  **Blank Model**.



ADD COMPONENT

In the **Home** toolbar, click  **Add Component** and choose **3D**.

GEOMETRY I


Set the geometry representation to use the CAD Kernel. Import the geometry from the prepared geometry sequence. Refer to the end of the documentation on instructions to create the geometry sequence.

- 1 In the **Settings** window for **Geometry**, locate the **Advanced** section.
- 2 From the **Geometry representation** list, choose **CAD kernel**.
- 3 In the **Geometry** toolbar, click **Insert Sequence** and choose **Insert Sequence**.
- 4 Browse to the model’s Application Libraries folder and double-click the file `onera_m6_wing_geom_sequence.mph`.

- 5 In the **Geometry** toolbar, click  **Build All**.
Disable the analysis of the geometry as the remaining small geometric details are needed.
- 6 Locate the **Cleanup** section. Clear the **Automatic detection of small details** checkbox.
- 7 Click the  **Zoom Extents** button in the **Graphics** toolbar.



GLOBAL DEFINITIONS

Parameters 2

- 1 In the **Home** toolbar, click  **Parameters** and choose **Add > Parameters**.
- 2 In the **Settings** window for **Parameters**, locate the **Parameters** section.
- 3 In the table, enter the following settings:

Name	Expression	Value	Description
M_INF	0.84	0.84	Far-field Mach Number
M_STEP	0.25	0.25	Multiplication factor for Mach Number



ADD MATERIAL

- 1 In the **Materials** toolbar, click  **Add Material** to open the **Add Material** window.
- 2 Go to the **Add Material** window.
- 3 In the tree, select **Built-in > Air**.
- 4 Right-click and choose **Add to Component 1 (comp1)**.
- 5 In the **Materials** toolbar, click  **Add Material** to close the **Add Material** window.

DEFINITIONS



Prepare explicit surface and edge selections to help in applying boundary conditions, generating the mesh and plotting the results.

Top and bottom surfaces of the wing



- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Top and bottom surfaces of the wing in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Boundary**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 5-20 in the **Selection** text field.

6 Click **OK**.



Trailing edge surfaces of the wing

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Trailing edge surfaces of the wing in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Boundary**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 25-40 in the **Selection** text field.
- 6 Click **OK**.


Tip surfaces of the wing


- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Tip surfaces of the wing in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Boundary**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 21-24, 41, 42 in the **Selection** text field.
- 6 Click **OK**.

All surfaces of the wing



- 1 In the **Definitions** toolbar, click  **Union**.
- 2 In the **Settings** window for **Union**, type All surfaces of the wing in the **Label** text field.
- 3 Locate the **Geometric Entity Level** section. From the **Level** list, choose **Boundary**.
- 4 Locate the **Input Entities** section. Under **Selections to add**, click  **Add**.
- 5 In the **Add** dialog, in the **Selections to add** list, choose **Top and bottom surfaces of the wing**, **Trailing edge surfaces of the wing**, and **Tip surfaces of the wing**.
- 6 Click **OK**.

Edges of the wing at $Y/B = 0.20$



- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Edges of the wing at $Y/B = 0.20$ in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Edge**.

- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 11, 12, 44, 46 in the **Selection** text field.
- 6 Click **OK**.



Edges of the wing at $Y/B = 0.44$

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Edges of the wing at $Y/B = 0.44$ in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Edge**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 14, 15, 49, 51 in the **Selection** text field.
- 6 Click **OK**.


Edges of the wing at $Y/B = 0.65$


- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Edges of the wing at $Y/B = 0.65$ in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Edge**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 17, 18, 54, 56 in the **Selection** text field.
- 6 Click **OK**.

Edges of the wing at $Y/B = 0.80$



- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Edges of the wing at $Y/B = 0.80$ in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Edge**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 20, 21, 59, 61 in the **Selection** text field.
- 6 Click **OK**.

Edges of the wing at $Y/B = 0.90$



- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Edges of the wing at $Y/B = 0.90$ in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Edge**.

- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 23, 24, 64, 66 in the **Selection** text field.
- 6 Click **OK**.

Edges of the wing at $Y/B = 0.95$

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Edges of the wing at $Y/B = 0.95$ in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Edge**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 26, 27, 69, 71 in the **Selection** text field.
- 6 Click **OK**.

Edges of the wing at $Y/B = 0.99$

- 1 In the **Definitions** toolbar, click  **Explicit**.
- 2 In the **Settings** window for **Explicit**, type Edges of the wing at $Y/B = 0.99$ in the **Label** text field.
- 3 Locate the **Input Entities** section. From the **Geometric entity level** list, choose **Edge**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 29, 30, 74, 76 in the **Selection** text field.
- 6 Click **OK**.



MESH 1

Generate a suitable surface mesh for the wing, followed by an appropriate volume mesh for the computational domain.

- 1 In the **Model Builder** window, under **Component 1 (comp1)** click **Mesh 1**.
- 2 In the **Settings** window for **Mesh**, locate the **Sequence Type** section.
- 3 From the list, choose **User-controlled mesh**.

Edge 1

Create an edge mesh with appropriate node distribution.

- 1 In the **Mesh** toolbar, click  **More Generators** and choose **Edge**.
- 2 In the **Settings** window for **Edge**, locate the **Edge Selection** section.
- 3 Click  **Paste Selection**.

4 In the **Paste Selection** dialog, type 8, 9, 11, 12, 14, 15, 17, 18, 20, 21, 23, 24, 26, 27, 29, 30 in the **Selection** text field.

5 Click **OK**.

Distribution 1

1 Right-click **Edge 1** and choose **Distribution**.

2 In the **Settings** window for **Distribution**, locate the **Distribution** section.

3 From the **Distribution type** list, choose **Predefined**.

4 In the **Number of elements** text field, type 100.

5 In the **Element ratio** text field, type 20.

6 From the **Growth rate** list, choose **Exponential**.

7 Select the **Symmetric distribution** checkbox.

Edge 2

1 In the **Mesh** toolbar, click  **More Generators** and choose **Edge**.

2 In the **Settings** window for **Edge**, locate the **Edge Selection** section.

3 Click  **Paste Selection**.

4 In the **Paste Selection** dialog, type 39, 41, 44, 46, 49, 51, 54, 56, 59, 61, 64, 66, 69, 71, 74, 76, 80, 82, 83 in the **Selection** text field.

5 Click **OK**.

Distribution 1

1 Right-click **Edge 2** and choose **Distribution**.

2 In the **Settings** window for **Distribution**, locate the **Distribution** section.

3 In the **Number of elements** text field, type 4.

Mapped 1

Create a surface mesh, which preserves the curvature of the wing profile, using the mapped mesh functionality.

1 In the **Mesh** toolbar, click  **More Generators** and choose **Mapped**.

2 In the **Settings** window for **Mapped**, locate the **Boundary Selection** section.

3 Click  **Paste Selection**.

4 In the **Paste Selection** dialog, type 5-18, 25-40 in the **Selection** text field.



5 Click **OK**.

Size 1



- 1 Right-click **Mapped 1** and choose **Size**.
- 2 In the **Settings** window for **Size**, locate the **Element Size** section.
- 3 From the **Calibrate for** list, choose **Fluid dynamics**.
- 4 From the **Predefined** list, choose **Extremely fine**.
- 5 Click the **Custom** button.
- 6 Locate the **Element Size Parameters** section.
- 7 Select the **Maximum element size** checkbox. In the associated text field, type $4e-3$.
- 8 Select the **Minimum element size** checkbox. In the associated text field, type $4e-3$.

Convert 1



Create a surface mesh with triangular elements at the wing tip and the trailing edge. This ensures good element quality in the volume mesh generated in the next step.

- 1 In the **Mesh** toolbar, click  **Modify** and choose **Convert**.
- 2 In the **Settings** window for **Convert**, locate the **Geometric Entity Selection** section.
- 3 From the **Geometric entity level** list, choose **Boundary**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 39, 40 in the **Selection** text field.
- 6 Click **OK**.
- 7 In the **Settings** window for **Convert**, locate the **Element Split Method** section.
- 8 From the **Element split method** list, choose **Insert centerpoints**.

Convert 2

- 1 In the **Mesh** toolbar, click  **Modify** and choose **Convert**.
- 2 In the **Settings** window for **Convert**, locate the **Geometric Entity Selection** section.
- 3 From the **Geometric entity level** list, choose **Boundary**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 25-38 in the **Selection** text field.
- 6 Click **OK**.

Free Triangular 1

- 1 In the **Mesh** toolbar, click  **More Generators** and choose **Free Triangular**.
- 2 In the **Settings** window for **Free Triangular**, locate the **Boundary Selection** section.
- 3 Click  **Paste Selection**.

- 4 In the **Paste Selection** dialog, type 19-24, 41, 42 in the **Selection** text field.
- 5 Click **OK**.

Size I

- 1 Right-click **Free Triangular I** and choose **Size**.
- 2 In the **Settings** window for **Size**, locate the **Element Size** section.
- 3 From the **Calibrate for** list, choose **Fluid dynamics**.
- 4 From the **Predefined** list, choose **Extremely fine**.
- 5 Click the **Custom** button.
- 6 Locate the **Element Size Parameters** section.
- 7 Select the **Maximum element size** checkbox. In the associated text field, type $4e-3$.
- 8 Select the **Minimum element size** checkbox. In the associated text field, type $1e-3$.

Size


As a final step in meshing, generate the volume mesh.


- 1 In the **Model Builder** window, under **Component 1 (comp1) > Mesh 1** click **Size**.
- 2 In the **Settings** window for **Size**, locate the **Element Size** section.
- 3 From the **Calibrate for** list, choose **Fluid dynamics**.
- 4 From the **Predefined** list, choose **Coarse**.
- 5 Click the **Custom** button.
- 6 Locate the **Element Size Parameters** section. In the **Maximum element size** text field, type 4.
- 7 In the **Minimum element size** text field, type $1e-3$.
- 8 In the **Maximum element growth rate** text field, type 1.1.

Free Tetrahedral I

- 1 In the **Model Builder** window, click **Free Tetrahedral I**.
- 2 Drag and drop below **Free Triangular I**.
- 3 In the **Model Builder** window, right-click **Mesh 1** and choose **Build All**.

ADD PHYSICS

- 1 In the **Home** toolbar, click  **Add Physics** to open the **Add Physics** window.
- 2 Go to the **Add Physics** window.
- 3 In the tree, select **Fluid Flow > High Mach Number Flow > Turbulent Flow > High Mach Number Flow, Spalart–Allmaras (hmnf)**.

- 4 Click the **Add to Component 1** button in the window toolbar.
- 5 In the **Home** toolbar, click  **Add Physics** to close the **Add Physics** window.



HIGH MACH NUMBER FLOW, SPALART–ALLMARAS (HMNF)

Initial Values 1



- 1 In the **Model Builder** window, under **Component 1 (comp1) > High Mach Number Flow, Spalart–Allmaras (hmnf)** click **Initial Values 1**.
- 2 In the **Settings** window for **Initial Values**, locate the **Initial Values** section.
- 3 Specify the **u** vector as

$M_INF * \sqrt{hmnf.gamma * hmnf.Rs * 293.15[K]} * M_STEP$	x
0	y
0	z



Symmetry 1

- 1 In the **Physics** toolbar, click  **Boundaries** and choose **Symmetry**.
- 2 In the **Settings** window for **Symmetry**, locate the **Boundary Selection** section.
- 3 Click  **Paste Selection**.
- 4 In the **Paste Selection** dialog, type 2 in the **Selection** text field.
- 5 Click **OK**.

Inlet 1



- 1 In the **Physics** toolbar, click  **Boundaries** and choose **Inlet**.
- 2 In the **Settings** window for **Inlet**, locate the **Boundary Selection** section.
- 3 Click  **Paste Selection**.
- 4 In the **Paste Selection** dialog, type 1 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Inlet**, locate the **Flow Properties** section.
- 7 In the $T_{0,stat}$ text field, type 293.15[K].
- 8 In the Ma_0 text field, type $M_INF * M_STEP$.

Outlet 1

- 1 In the **Physics** toolbar, click  **Boundaries** and choose **Outlet**.
- 2 In the **Settings** window for **Outlet**, locate the **Boundary Selection** section.
- 3 Click  **Paste Selection**.


- 4 In the **Paste Selection** dialog, type 3-4 in the **Selection** text field.
- 5 Click **OK**.

ADD STUDY

- 1 In the **Home** toolbar, click  **Add Study** to open the **Add Study** window.
- 2 Go to the **Add Study** window.
- 3 Find the **Studies** subsection. In the **Select Study** tree, select **Preset Studies for Selected Physics Interfaces > Stationary with Initialization**.
- 4 Click the **Add Study** button in the window toolbar.
- 5 In the **Home** toolbar, click  **Add Study** to close the **Add Study** window.


STUDY 1

Step 2: Stationary

- 1 In the **Model Builder** window, click **Step 2: Stationary**.
- 2 In the **Settings** window for **Stationary**, click to expand the **Study Extensions** section.
- 3 Select the **Auxiliary sweep** checkbox.
- 4 Click  **Add**.
- 5 In the table, enter the following settings:

Parameter name	Parameter value list	Parameter unit
M_STEP (Multiplication factor for Mach Number)	0.25 0.5 0.75 1	

The parameter M_STEP is used to sequentially increase the far-field Mach number values to the requisite transonic flow regime.

- 6 In the **Model Builder** window, click **Study 1**.
- 7 In the **Settings** window for **Study**, locate the **Study Settings** section.
- 8 Clear the **Generate default plots** checkbox.
- 9 In the **Study** toolbar, click  **Compute**.

RESULTS

Table 2

Import tabulated experimental results.

- 1 In the **Model Builder** window, expand the **Results** node.
- 2 Right-click **Results > Tables** and choose **Table**.

Experimental Cp values along the top edge of the wing at Y/B = 0.20



- 1 In the **Settings** window for **Table**, type Experimental Cp values along the top edge of the wing at $Y/B = 0.20$ in the **Label** text field.
- 2 Locate the **Data** section. Click  **Import**.
- 3 Browse to the model's Application Libraries folder and double-click the file onera_m6_wing_Cp_YbyB_1_up.txt.

Table 3

In the **Results** toolbar, click  **Table**.

Experimental Cp values along the bottom edge of the wing at Y/B = 0.20



- 1 In the **Model Builder** window, under **Results > Tables** click **Table 2**.
- 2 In the **Settings** window for **Table**, type Experimental Cp values along the bottom edge of the wing at $Y/B = 0.20$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file onera_m6_wing_Cp_YbyB_1_down.txt.

Table 4

In the **Results** toolbar, click  **Table**.

Experimental Cp values along the top edge of the wing at Y/B = 0.44


- 1 In the **Model Builder** window, under **Results > Tables** click **Table 3**.
- 2 In the **Settings** window for **Table**, type Experimental Cp values along the top edge of the wing at $Y/B = 0.44$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file onera_m6_wing_Cp_YbyB_2_up.txt.

Table 5

In the **Results** toolbar, click  **Table**.

Experimental Cp values along the bottom edge of the wing at Y/B = 0.44



- 1 In the **Model Builder** window, under **Results > Tables** click **Table 4**.
- 2 In the **Settings** window for **Table**, type Experimental Cp values along the bottom edge of the wing at $Y/B = 0.44$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file onera_m6_wing_Cp_YbyB_2_down.txt.

Table 6

In the **Results** toolbar, click  **Table**.

Experimental C_p values along the top edge of the wing at $Y/B = 0.65$


- 1 In the **Model Builder** window, under **Results > Tables** click **Table 5**.
- 2 In the **Settings** window for **Table**, type Experimental C_p values along the top edge of the wing at $Y/B = 0.65$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_3_up.txt`.

Table 7

In the **Results** toolbar, click  **Table**.

Experimental C_p values along the bottom edge of the wing at $Y/B = 0.65$



- 1 In the **Model Builder** window, under **Results > Tables** click **Table 6**.
- 2 In the **Settings** window for **Table**, type Experimental C_p values along the bottom edge of the wing at $Y/B = 0.65$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_3_down.txt`.

Table 8

In the **Results** toolbar, click  **Table**.

Experimental C_p values along the top edge of the wing at $Y/B = 0.80$



- 1 In the **Model Builder** window, under **Results > Tables** click **Table 7**.
- 2 In the **Settings** window for **Table**, type Experimental C_p values along the top edge of the wing at $Y/B = 0.80$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_4_up.txt`.

Table 9

In the **Results** toolbar, click  **Table**.

Experimental C_p values along the bottom edge of the wing at $Y/B = 0.80$

- 1 In the **Model Builder** window, under **Results > Tables** click **Table 8**.



- 2 In the **Settings** window for **Table**, type Experimental Cp values along the bottom edge of the wing at $Y/B = 0.80$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_4_down.txt`.

Table 10

In the **Results** toolbar, click  **Table**.

Experimental Cp values along the top edge of the wing at $Y/B = 0.90$



- 1 In the **Model Builder** window, under **Results > Tables** click **Table 9**.
- 2 In the **Settings** window for **Table**, type Experimental Cp values along the top edge of the wing at $Y/B = 0.90$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_5_up.txt`.

Table 11

In the **Results** toolbar, click  **Table**.

Experimental Cp values along the bottom edge of the wing at $Y/B = 0.90$


- 1 In the **Model Builder** window, under **Results > Tables** click **Table 10**.
- 2 In the **Settings** window for **Table**, type Experimental Cp values along the bottom edge of the wing at $Y/B = 0.90$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_5_down.txt`.

Table 12

In the **Results** toolbar, click  **Table**.

Experimental Cp values along the top edge of the wing at $Y/B = 0.95$



- 1 In the **Model Builder** window, under **Results > Tables** click **Table 11**.
- 2 In the **Settings** window for **Table**, type Experimental Cp values along the top edge of the wing at $Y/B = 0.95$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_6_up.txt`.

Table 13

In the **Results** toolbar, click  **Table**.

Experimental C_p values along the bottom edge of the wing at $Y/B = 0.95$


- 1 In the **Model Builder** window, under **Results > Tables** click **Table 12**.
- 2 In the **Settings** window for **Table**, type Experimental C_p values along the bottom edge of the wing at $Y/B = 0.95$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_6_down.txt`.

Table 14

In the **Results** toolbar, click  **Table**.

Experimental C_p values along the top edge of the wing at $Y/B = 0.99$




- 1 In the **Model Builder** window, under **Results > Tables** click **Table 13**.
- 2 In the **Settings** window for **Table**, type Experimental C_p values along the top edge of the wing at $Y/B = 0.99$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_7_up.txt`.

Table 15


In the **Results** toolbar, click  **Table**.

Experimental C_p values along the bottom edge of the wing at $Y/B = 0.99$

- 1 In the **Model Builder** window, under **Results > Tables** click **Table 14**.
- 2 In the **Settings** window for **Table**, type Experimental C_p values along the bottom edge of the wing at $Y/B = 0.99$ in the **Label** text field.
- 3 Locate the **Data** section. Click  **Import**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing_Cp_YbyB_7_down.txt`.

C_p values at $Y/B = 0.20$

Plot C_p values from experiment and simulation.

- 1 In the **Results** toolbar, click  **ID Plot Group**.
- 2 In the **Settings** window for **ID Plot Group**, type C_p values at $Y/B = 0.20$ in the **Label** text field.

- 3 Locate the **Data** section. From the **Parameter selection (M_STEP)** list, choose **Last**.
- 4 Click to expand the **Title** section. From the **Title type** list, choose **Manual**.
- 5 In the **Title** text area, type $Y/B = 0.2$.
- 6 Locate the **Plot Settings** section.
- 7 Select the **x-axis label** checkbox. In the associated text field, type X/L .
- 8 Select the **y-axis label** checkbox. In the associated text field, type $-C_p$.
- 9 Locate the **Legend** section. From the **Position** list, choose **Lower right**.

Table Graph 1

- 1 Right-click **Cp values at Y/B = 0.20** and choose **Table Graph**.
- 2 In the **Settings** window for **Table Graph**, locate the **Coloring and Style** section.
- 3 Find the **Line style** subsection. From the **Line** list, choose **None**.
- 4 From the **Color** list, choose **Black**.
- 5 Find the **Line markers** subsection. From the **Marker** list, choose **Square**.
- 6 Click to expand the **Legends** section. Select the **Show legends** checkbox.
- 7 From the **Legends** list, choose **Manual**.
- 8 In the table, enter the following settings:

Legends
Experiment

Table Graph 2

- 1 Right-click **Table Graph 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the bottom edge of the wing at Y/B = 0.20**.
- 4 Locate the **Coloring and Style** section. Find the **Line markers** subsection. From the **Marker** list, choose **Square**.
- 5 Locate the **Legends** section. Clear the **Show legends** checkbox.

Line Graph 1

- 1 In the **Model Builder** window, right-click **Cp values at Y/B = 0.20** and choose **Line Graph**.
- 2 In the **Settings** window for **Line Graph**, locate the **Selection** section.
- 3 From the **Selection** list, choose **Edges of the wing at Y/B = 0.20**.

- 4 Locate the **y-Axis Data** section. In the **Expression** text field, type $(1[\text{atm}] - \text{hmnf}.\text{pA}) / (0.5 * \text{hmnf}.\text{gamma} * M_INF^2 * 1[\text{atm}])$.
- 5 Locate the **x-Axis Data** section. From the **Parameter** list, choose **Expression**.
Normalize the position in the x direction with respect to the local chord length of the wing.
- 6 In the **Expression** text field, type $(x - 0.13793[\text{m}]) / (0.87646[\text{m}] - 0.13793[\text{m}])$.
- 7 Click to expand the **Coloring and Style** section. From the **Color** list, choose **Black**.
- 8 Click to expand the **Legends** section. Select the **Show legends** checkbox.
- 9 From the **Legends** list, choose **Manual**.
- 10 In the table, enter the following settings:

Legends

Simulation

C_p values at Y/B = 0.20

Similarly, reproduce the C_p plots at other sections along the wing span.

C_p values at Y/B = 0.44

- 1 In the **Model Builder** window, right-click **C_p values at Y/B = 0.20** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type C_p values at $Y/B = 0.44$ in the **Label** text field.
- 3 Locate the **Title** section. In the **Title** text area, type $Y/B = 0.44$.

Table Graph 1

- 1 In the **Model Builder** window, expand the **C_p values at Y/B = 0.44** node, then click **Table Graph 1**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental C_p values along the top edge of the wing at Y/B = 0.44**.

Table Graph 2

- 1 In the **Model Builder** window, click **Table Graph 2**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental C_p values along the bottom edge of the wing at Y/B = 0.44**.

Line Graph 1

- 1 In the **Model Builder** window, click **Line Graph 1**.

- 2 In the **Settings** window for **Line Graph**, locate the **Selection** section.
- 3 From the **Selection** list, choose **Edges of the wing at Y/B = 0.44**.
- 4 Locate the **x-Axis Data** section. In the **Expression** text field, type $(x-0.30346[m]) / (0.95700[m]-0.30346[m])$.

Cp values at Y/B = 0.65

- 1 In the **Model Builder** window, right-click **Cp values at Y/B = 0.44** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type **Cp values at Y/B = 0.65** in the **Label** text field.
- 3 Locate the **Title** section. In the **Title** text area, type **Y/B = 0.65**.

Table Graph 1

- 1 In the **Model Builder** window, expand the **Cp values at Y/B = 0.65** node, then click **Table Graph 1**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the top edge of the wing at Y/B = 0.65**.

Table Graph 2

- 1 In the **Model Builder** window, click **Table Graph 2**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the bottom edge of the wing at Y/B = 0.65**.

Line Graph 1

- 1 In the **Model Builder** window, click **Line Graph 1**.
- 2 In the **Settings** window for **Line Graph**, locate the **Selection** section.
- 3 From the **Selection** list, choose **Edges of the wing at Y/B = 0.65**.
- 4 Locate the **x-Axis Data** section. In the **Expression** text field, type $(x-0.44829[m]) / (1.0275[m]-0.44829[m])$.

Cp values at Y/B = 0.80

- 1 In the **Model Builder** window, right-click **Cp values at Y/B = 0.65** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type **Cp values at Y/B = 0.80** in the **Label** text field.
- 3 Locate the **Title** section. In the **Title** text area, type **Y/B = 0.80**.

Table Graph 1

- 1 In the **Model Builder** window, expand the **Cp values at Y/B = 0.80** node, then click **Table Graph 1**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the top edge of the wing at Y/B = 0.80**.

Table Graph 2

- 1 In the **Model Builder** window, click **Table Graph 2**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the bottom edge of the wing at Y/B = 0.80**.

Line Graph 1

- 1 In the **Model Builder** window, click **Line Graph 1**.
- 2 In the **Settings** window for **Line Graph**, locate the **Selection** section.
- 3 From the **Selection** list, choose **Edges of the wing at Y/B = 0.80**.
- 4 Locate the **x-Axis Data** section. In the **Expression** text field, type $(x-0.55174[m]) / (1.0778[m]-0.55174[m])$.

Cp values at Y/B = 0.90

- 1 In the **Model Builder** window, right-click **Cp values at Y/B = 0.80** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type Cp values at Y/B = 0.90 in the **Label** text field.
- 3 Locate the **Title** section. In the **Title** text area, type Y/B = 0.90.

Table Graph 1

- 1 In the **Model Builder** window, expand the **Cp values at Y/B = 0.90** node, then click **Table Graph 1**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the top edge of the wing at Y/B = 0.90**.

Table Graph 2

- 1 In the **Model Builder** window, click **Table Graph 2**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the bottom edge of the wing at Y/B = 0.90**.

Line Graph 1

- 1 In the **Model Builder** window, click **Line Graph 1**.
- 2 In the **Settings** window for **Line Graph**, locate the **Selection** section.
- 3 From the **Selection** list, choose **Edges of the wing at Y/B = 0.90**.
- 4 Locate the **x-Axis Data** section. In the **Expression** text field, type $(x-0.62070[m]) / (1.1114[m]-0.62070[m])$.

Cp values at Y/B = 0.95

- 1 In the **Model Builder** window, right-click **Cp values at Y/B = 0.90** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type **Cp values at Y/B = 0.95** in the **Label** text field.
- 3 Locate the **Title** section. In the **Title** text area, type **Y/B = 0.95**.

Table Graph 1

- 1 In the **Model Builder** window, expand the **Cp values at Y/B = 0.95** node, then click **Table Graph 1**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the top edge of the wing at Y/B = 0.95**.

Table Graph 2

- 1 In the **Model Builder** window, click **Table Graph 2**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the bottom edge of the wing at Y/B = 0.95**.

Line Graph 1

- 1 In the **Model Builder** window, click **Line Graph 1**.
- 2 In the **Settings** window for **Line Graph**, locate the **Selection** section.
- 3 From the **Selection** list, choose **Edges of the wing at Y/B = 0.95**.
- 4 Locate the **x-Axis Data** section. In the **Expression** text field, type $(x-0.65519[m]) / (1.1282[m]-0.65519[m])$.

Cp values at Y/B = 0.99

- 1 In the **Model Builder** window, right-click **Cp values at Y/B = 0.95** and choose **Duplicate**.
- 2 In the **Settings** window for **ID Plot Group**, type **Cp values at Y/B = 0.99** in the **Label** text field.

3 Locate the **Title** section. In the **Title** text area, type $Y/B = 0.99$.

Table Graph 1

- 1 In the **Model Builder** window, expand the **Cp values at Y/B = 0.99** node, then click **Table Graph 1**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the top edge of the wing at Y/B = 0.99**.



Table Graph 2

- 1 In the **Model Builder** window, click **Table Graph 2**.
- 2 In the **Settings** window for **Table Graph**, locate the **Data** section.
- 3 From the **Table** list, choose **Experimental Cp values along the bottom edge of the wing at Y/B = 0.99**.

Line Graph 1

- 1 In the **Model Builder** window, click **Line Graph 1**.
- 2 In the **Settings** window for **Line Graph**, locate the **Selection** section.
- 3 From the **Selection** list, choose **Edges of the wing at Y/B = 0.99**.
- 4 Locate the **x-Axis Data** section. In the **Expression** text field, type $(x - 0.68277[m]) / (1.1416[m] - 0.68277[m])$.

Mach Number and Pressure


- 1 In the **Results** toolbar, click  **3D Plot Group**.
- 2 In the **Settings** window for **3D Plot Group**, type Mach Number and Pressure in the **Label** text field.
- 3 Locate the **Plot Settings** section. From the **View** list, choose **New view**.
- 4 In the **Mach Number and Pressure** toolbar, click  **Plot**.

Surface 1

- 1 Right-click **Mach Number and Pressure** and choose **Surface**.
- 2 In the **Settings** window for **Surface**, locate the **Expression** section.
- 3 In the **Expression** text field, type $hmnf \cdot Ma$.
- 4 Click to expand the **Title** section. From the **Title type** list, choose **Custom**.
- 5 Find the **User** subsection. In the **Suffix** text field, type Upper Wing Surface.

Selection 1

- 1 Right-click **Surface 1** and choose **Selection**.

- 2 In the **Settings** window for **Selection**, locate the **Selection** section.
- 3 Click  **Paste Selection**.
- 4 In the **Paste Selection** dialog, type 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42 in the **Selection** text field.
- 5 Click **OK**.


Mach Number and Pressure

- 1 In the **Model Builder** window, under **Results** click **Mach Number and Pressure**.
- 2 In the **Settings** window for **3D Plot Group**, click to expand the **Plot Array** section.
- 3 From the **Array type** list, choose **Linear**.
- 4 In the **Relative padding** text field, type 0.2.
- 5 Locate the **Plot Settings** section. Clear the **Plot dataset edges** checkbox.




Contour 1

- 1 Right-click **Mach Number and Pressure** and choose **Contour**.
- 2 In the **Settings** window for **Contour**, locate the **Expression** section.
- 3 In the **Expression** text field, type `hmnf.pA`.
- 4 Click to expand the **Title** section. From the **Title type** list, choose **Custom**.
- 5 Find the **User** subsection. In the **Suffix** text field, type `Upper Wing Surface`.
- 6 Locate the **Coloring and Style** section. From the **Coloring** list, choose **Gradient**.
- 7 Click to expand the **Plot Array** section. Select the **Manual indexing** checkbox.

Selection 1

- 1 Right-click **Contour 1** and choose **Selection**.
- 2 In the **Settings** window for **Selection**, locate the **Selection** section.
- 3 Click  **Paste Selection**.
- 4 In the **Paste Selection** dialog, type 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42 in the **Selection** text field.
- 5 Click **OK**.



Mach Number and Pressure

- 1 In the **Model Builder** window, under **Results** click **Mach Number and Pressure**.
- 2 In the **Mach Number and Pressure** toolbar, click  **Plot**.
- 3 Click the  **Go to XY View** button in the **Graphics** toolbar.
- 4 Click the  **Orthographic Projection** button in the **Graphics** toolbar.

Surface 2

- 1 In the **Model Builder** window, under **Results > Mach Number and Pressure** right-click **Surface 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Surface**, locate the **Title** section.
- 3 Find the **User** subsection. In the **Suffix** text field, type Lower Wing Surface.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Surface 1**.
- 5 Click to expand the **Plot Array** section.



Selection 1

- 1 In the **Model Builder** window, expand the **Surface 2** node, then click **Selection 1**.
- 2 In the **Settings** window for **Selection**, locate the **Selection** section.
- 3 Click  **Clear Selection**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41 in the **Selection** text field.
- 6 Click **OK**.



Contour 2

- 1 In the **Model Builder** window, under **Results > Mach Number and Pressure** right-click **Contour 1** and choose **Duplicate**.
- 2 In the **Settings** window for **Contour**, locate the **Title** section.
- 3 Find the **User** subsection. In the **Suffix** text field, type Lower Wing Surface.
- 4 Click to expand the **Inherit Style** section. From the **Plot** list, choose **Contour 1**.
- 5 Locate the **Plot Array** section. In the **Index** text field, type 1.
- 6 Locate the **Coloring and Style** section. Clear the **Color legend** checkbox.


Selection 1

- 1 In the **Model Builder** window, expand the **Contour 2** node, then click **Selection 1**.
- 2 In the **Settings** window for **Selection**, locate the **Selection** section.
- 3 Click  **Clear Selection**.
- 4 Click  **Paste Selection**.
- 5 In the **Paste Selection** dialog, type 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41 in the **Selection** text field.
- 6 Click **OK**.

Mach Number and Pressure

- 1 In the **Model Builder** window, under **Results** click **Mach Number and Pressure**.
- 2 In the **Mach Number and Pressure** toolbar, click  **Plot**.
- 3 Click the  **Zoom Extents** button in the **Graphics** toolbar.

Wing Tip Vortex

- 1 In the **Results** toolbar, click  **3D Plot Group**.
- 2 In the **Settings** window for **3D Plot Group**, type Wing Tip Vortex in the **Label** text field.
- 3 Locate the **Plot Settings** section. Clear the **Plot dataset edges** checkbox.

Surface 1

- 1 Right-click **Wing Tip Vortex** and choose **Surface**.
- 2 In the **Settings** window for **Surface**, locate the **Coloring and Style** section.
- 3 From the **Color table** list, choose **Prism**.

Filter 1

- 1 Right-click **Surface 1** and choose **Filter**.
- 2 In the **Settings** window for **Filter**, locate the **Element Selection** section.
- 3 In the **Logical expression for inclusion** text field, type $(x > -2 * C0) \ \&\& \ (x < 3 * C0) \ \&\& \ (y < B + 2 * C0) \ \&\& \ (z > -2 * C0) \ \&\& \ (z < 2 * C0)$.

Isosurface 1


- 1 In the **Model Builder** window, right-click **Wing Tip Vortex** and choose **Isosurface**.
- 2 In the **Settings** window for **Isosurface**, locate the **Expression** section.
- 3 In the **Expression** text field, type $((hmnf.r^2 - hmnf.s^2) > 0) * hmnf.U$.
- 4 Locate the **Levels** section. In the **Total levels** text field, type 1.
- 5 Locate the **Coloring and Style** section. From the **Color table** list, choose **Prism**.
- 6 Clear the **Color legend** checkbox.

Transparency 1


- 1 Right-click **Isosurface 1** and choose **Transparency**.
- 2 In the **Settings** window for **Transparency**, locate the **Transparency** section.
- 3 Find the **Fresnel transmittance** subsection. In the **Fresnel transmittance** text field, type 0.5.

Material Appearance 1

- 1 In the **Model Builder** window, right-click **Isosurface 1** and choose **Material Appearance**.

- 2 In the **Settings** window for **Material Appearance**, locate the **Color** section.
- 3 Select the **Use the plot's color** checkbox.
- 4 Click the  **Zoom Extents** button in the **Graphics** toolbar.

Wing Tip Vortex


- 1 In the **Model Builder** window, under **Results** click **Wing Tip Vortex**.
- 2 In the **Settings** window for **3D Plot Group**, locate the **Plot Settings** section.
- 3 From the **View** list, choose **View 3D I4**.
- 4 In the **Wing Tip Vortex** toolbar, click  **Plot**.

Geometry Modeling Instructions



Follow these steps below to generate the geometry.

From the **File** menu, choose **New**.

NEW

In the **New** window, click  **Model Wizard**.

MODEL WIZARD

- 1 In the **Model Wizard** window, click  **3D**.
- 2 Click  **Done**.

GLOBAL DEFINITIONS

Parameters 1

- 1 In the **Model Builder** window, under **Global Definitions** click **Parameters 1**.
- 2 In the **Settings** window for **Parameters**, locate the **Parameters** section.
- 3 In the table, enter the following settings:



Name	Expression	Value	Description
C0	0.8059[m]	0.8059 m	Chord length at the wing base
B	1.1963[m]	1.1963 m	Span of the wing
D	10*C0	8.059 m	Distance to far-field boundaries
YbyB_1	0.20[1]	0.2	Wing section 1
YbyB_2	0.44[1]	0.44	Wing section 2

Name	Expression	Value	Description
YbyB_3	0.65[1]	0.65	Wing section 3
YbyB_4	0.80[1]	0.8	Wing section 4
YbyB_5	0.90[1]	0.9	Wing section 5
YbyB_6	0.95[1]	0.95	Wing section 6
YbyB_7	0.99[1]	0.99	Wing section 7
ALPHA	3.06[deg]	0.053407 rad	Angle of attack

GEOMETRY I

- 1 In the **Model Builder** window, under **Component 1 (comp1)** click **Geometry I**.
- 2 In the **Settings** window for **Geometry**, locate the **Advanced** section.
- 3 From the **Geometry representation** list, choose **CAD kernel**.


Work Plane 1 (wp1)

- 1 In the **Geometry** toolbar, click  **Work Plane**.
- 2 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 3 Locate the **Plane Definition** section. From the **Plane** list, choose **xz-plane**.

Work Plane 1 (wp1) > Plane Geometry

In the **Model Builder** window, click **Plane Geometry**.

Work Plane 1 (wp1) > Circle 1 (c1)



- 1 In the **Work Plane** toolbar, click  **Circle**.
- 2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.
- 3 In the **Radius** text field, type D.
- 4 In the **Sector angle** text field, type 180.
- 5 Locate the **Position** section. In the **xw** text field, type -C0/2.
- 6 Locate the **Rotation Angle** section. In the **Rotation** text field, type -90.

Revolve 1 (rev1)

- 1 In the **Model Builder** window, under **Component 1 (comp1)** > **Geometry I** right-click **Work Plane 1 (wp1)** and choose **Revolve**.
- 2 In the **Settings** window for **Revolve**, locate the **Revolution Angles** section.
- 3 Click the **Angles** button.
- 4 In the **End angle** text field, type 90.

- 5 Locate the **Revolution Axis** section. Find the **Point on the revolution axis** subsection. In the **xw** text field, type $-C0/2$.


Work Plane 2 (wp2)

- 1 In the **Geometry** toolbar, click  **Work Plane**.
- 2 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 3 Locate the **Plane Definition** section. From the **Plane** list, choose **yz-plane**.
- 4 In the **x-coordinate** text field, type $-D$.

Work Plane 2 (wp2) > Plane Geometry

In the **Model Builder** window, click **Plane Geometry**.

Work Plane 2 (wp2) > Circle 1 (c1)

- 1 In the **Work Plane** toolbar, click  **Circle**.
- 2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.
- 3 In the **Radius** text field, type D .
- 4 In the **Sector angle** text field, type 180 .
- 5 Locate the **Rotation Angle** section. In the **Rotation** text field, type -90 .

Extrude 1 (ext1)

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Geometry 1** right-click **Work Plane 2 (wp2)** and choose **Extrude**.
- 2 In the **Settings** window for **Extrude**, locate the **Distances** section.
- 3 In the table, enter the following settings:


Distances (m)
$D-C0/2$

Import 1 (imp1)

- 1 In the **Geometry** toolbar, click  **Import**.
- 2 In the **Settings** window for **Import**, locate the **Source** section.
- 3 Click  **Browse**.
- 4 Browse to the model's Application Libraries folder and double-click the file `onera_m6_wing.igs`.
- 5 Click  **null**.

Work Plane 3 (wp3)


- 1 In the **Geometry** toolbar, click  **Work Plane**.

- 2 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 3 Locate the **Plane Definition** section. From the **Plane** list, choose **xz-plane**.


Work Plane 3 (wp3) > Plane Geometry

In the **Model Builder** window, click **Plane Geometry**.



Work Plane 3 (wp3) > Circle 1 (c1)

- 1 In the **Work Plane** toolbar, click  **Circle**.
- 2 In the **Settings** window for **Circle**, locate the **Size and Shape** section.
- 3 In the **Radius** text field, type D.
- 4 In the **Sector angle** text field, type 180.
- 5 Locate the **Position** section. In the **xw** text field, type -C0/2.
- 6 Locate the **Rotation Angle** section. In the **Rotation** text field, type -90.



Convert to Solid 1 (csol1)


- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Conversions > Convert to Solid**.
- 2 In the **Settings** window for **Convert to Solid**, locate the **Input** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type imp1, wp3 in the **Selection** text field.
- 5 Click **OK**.

Rotate 1 (rot1)



- 1 In the **Geometry** toolbar, click  **Transforms** and choose **Rotate**.
- 2 In the **Settings** window for **Rotate**, locate the **Input** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type cs011 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Rotate**, locate the **Rotation** section.
- 7 From the **Axis type** list, choose **y-axis**.
- 8 In the **Angle** text field, type ALPHA.

Difference 1 (dif1)

- 1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Difference**.
- 2 In the **Settings** window for **Difference**, locate the **Difference** section.
- 3 Click the  **Paste Selection** button for **Objects to add**.

- 4 In the **Paste Selection** dialog, type rev1 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Difference**, locate the **Difference** section.
- 7 Click the  **Paste Selection** button for **Objects to subtract**.
- 8 In the **Paste Selection** dialog, type rot1 in the **Selection** text field.
- 9 Click **OK**.


Work Plane 4 (wp4)

- 1 In the **Geometry** toolbar, click  **Work Plane**.
- 2 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 3 Locate the **Plane Definition** section. From the **Plane** list, choose **xz-plane**.
- 4 In the **y-coordinate** text field, type YbyB_1*B.


Work Plane 4 (wp4) > Plane Geometry

In the **Model Builder** window, click **Plane Geometry**.

Work Plane 4 (wp4) > Rectangle 1 (r1)


- 1 In the **Work Plane** toolbar, click  **Rectangle**.
- 2 In the **Settings** window for **Rectangle**, locate the **Size and Shape** section.
- 3 In the **Width** text field, type 1.5.
- 4 In the **Height** text field, type 0.5.
- 5 Locate the **Position** section. In the **yw** text field, type -0.25.

Intersection 1 (int1)



- 1 In the **Model Builder** window, right-click **Geometry 1** and choose **Booleans and Partitions** > **Intersection**.
- 2 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type dif1, wp4 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 7 Select the **Keep input objects** checkbox.

Work Plane 5 (wp5)


- 1 In the **Model Builder** window, under **Component 1 (comp1)** > **Geometry 1** right-click **Work Plane 4 (wp4)** and choose **Duplicate**.

- 2 In the **Model Builder** window, click **Work Plane 5 (wp5)**.
- 3 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 4 Locate the **Plane Definition** section. In the **y-coordinate** text field, type $YbyB_2*B$.



Intersection 2 (int2)

- 1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Intersection**.
- 2 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type `dif1`, `wp5` in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 7 Select the **Keep input objects** checkbox.


Work Plane 6 (wp6)

- 1 In the **Model Builder** window, under **Component 1 (comp1)** > **Geometry 1** right-click **Work Plane 5 (wp5)** and choose **Duplicate**.
- 2 In the **Model Builder** window, click **Work Plane 6 (wp6)**.
- 3 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 4 Locate the **Plane Definition** section. In the **y-coordinate** text field, type $YbyB_3*B$.



Intersection 3 (int3)

- 1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Intersection**.
- 2 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type `dif1`, `wp6` in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 7 Select the **Keep input objects** checkbox.


Work Plane 7 (wp7)

- 1 In the **Model Builder** window, under **Component 1 (comp1)** > **Geometry 1** right-click **Work Plane 6 (wp6)** and choose **Duplicate**.
- 2 In the **Model Builder** window, click **Work Plane 7 (wp7)**.
- 3 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 4 Locate the **Plane Definition** section. In the **y-coordinate** text field, type $YbyB_4*B$.



Intersection 4 (int4)

- 1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Intersection**.
- 2 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type dif1, wp7 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 7 Select the **Keep input objects** checkbox.


Work Plane 8 (wp8)

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Geometry 1** right-click **Work Plane 7 (wp7)** and choose **Duplicate**.
- 2 In the **Model Builder** window, click **Work Plane 8 (wp8)**.
- 3 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 4 Locate the **Plane Definition** section. In the **y-coordinate** text field, type YbyB_5*B.



Intersection 5 (int5)

- 1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Intersection**.
- 2 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type dif1, wp8 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 7 Select the **Keep input objects** checkbox.

Work Plane 9 (wp9)


- 1 In the **Model Builder** window, under **Component 1 (comp1) > Geometry 1** right-click **Work Plane 8 (wp8)** and choose **Duplicate**.
- 2 In the **Model Builder** window, click **Work Plane 9 (wp9)**.
- 3 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 4 Locate the **Plane Definition** section. In the **y-coordinate** text field, type YbyB_6*B.

Intersection 6 (int6)



- 1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Intersection**.
- 2 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 3 Click the  **Paste Selection** button for **Input objects**.

- 4 In the **Paste Selection** dialog, type dif1, wp9 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 7 Select the **Keep input objects** checkbox.


Work Plane 10 (wp10)

- 1 In the **Model Builder** window, under **Component 1 (comp1) > Geometry 1** right-click **Work Plane 9 (wp9)** and choose **Duplicate**.
- 2 In the **Model Builder** window, click **Work Plane 10 (wp10)**.
- 3 In the **Settings** window for **Work Plane**, click  **Go to Plane Geometry**.
- 4 Locate the **Plane Definition** section. In the **y-coordinate** text field, type YbyB_7*B.



Intersection 7 (int7)

- 1 In the **Geometry** toolbar, click  **Booleans and Partitions** and choose **Intersection**.
- 2 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 3 Click the  **Paste Selection** button for **Input objects**.
- 4 In the **Paste Selection** dialog, type dif1, wp10 in the **Selection** text field.
- 5 Click **OK**.
- 6 In the **Settings** window for **Intersection**, locate the **Intersection** section.
- 7 Select the **Keep input objects** checkbox.



Form Union (fin)

- 1 In the **Model Builder** window, click **Form Union (fin)**.
- 2 In the **Settings** window for **Form Union/Assembly**, click  **Build Selected**.

Ignore Faces 1 (igf1)

- 1 In the **Geometry** toolbar, click  **Virtual Operations** and choose **Ignore Faces**.
- 2 In the **Settings** window for **Ignore Faces**, locate the **Input** section.
- 3 Click the  **Paste Selection** button for **Faces to ignore**.
- 4 In the **Paste Selection** dialog, type 6 in the **Selection** text field.
- 5 Click **OK**.

Ignore Faces 2 (igf2)

- 1 In the **Geometry** toolbar, click  **Virtual Operations** and choose **Ignore Faces**.
- 2 In the **Settings** window for **Ignore Faces**, locate the **Input** section.
- 3 Click the  **Paste Selection** button for **Faces to ignore**.

4 In the **Paste Selection** dialog, type 7-13 in the **Selection** text field.

5 Click **OK**.

Ignore Edges 1 (ige1)

1 In the **Geometry** toolbar, click  **Virtual Operations** and choose **Ignore Edges**.

2 In the **Settings** window for **Ignore Edges**, locate the **Input** section.

3 Click the  **Paste Selection** button for **Edges to ignore**.

4 In the **Paste Selection** dialog, type 5 in the **Selection** text field.

5 Click **OK**.

Ignore Faces 3 (igf3)

1 In the **Geometry** toolbar, click  **Virtual Operations** and choose **Ignore Faces**.

2 In the **Settings** window for **Ignore Faces**, locate the **Input** section.


3 Click the  **Paste Selection** button for **Faces to ignore**.

4 In the **Paste Selection** dialog, type 9, 12, 15, 18, 21, 24, 27 in the **Selection** text field.

5 Click **OK**.

6 In the **Settings** window for **Ignore Faces**, locate the **Input** section.

7 Clear the **Ignore adjacent edges and vertices** checkbox.

8 In the **Geometry** toolbar, click  **Build All**.