

# **COMPR Program**

## **User Guide**

**January 2016**

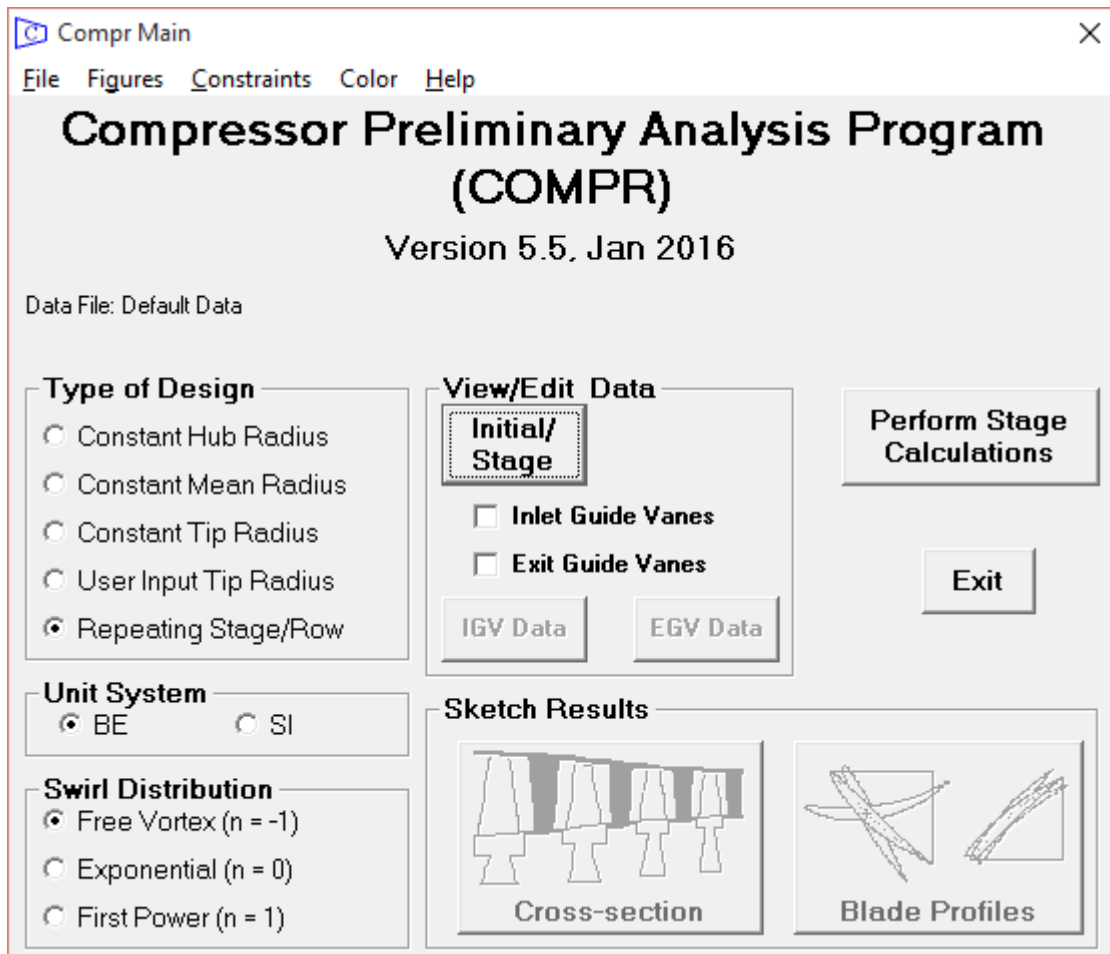
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# 1. MAIN Window

When the COMPR program is run, the default input data is loaded from within the program and the Main window is displayed as shown below.



The compressor mean-line design program COMPR is based on the equations developed in *Elements of Gas Turbine Propulsion* and *Aircraft Engine Design, Second Edition*. It can analyze the following five different types of mean-line design:

1. Constant hub radius.
2. Constant mean radius.
3. Constant tip radius.
4. User input tip radius.
5. Repeating stage/repeating row.

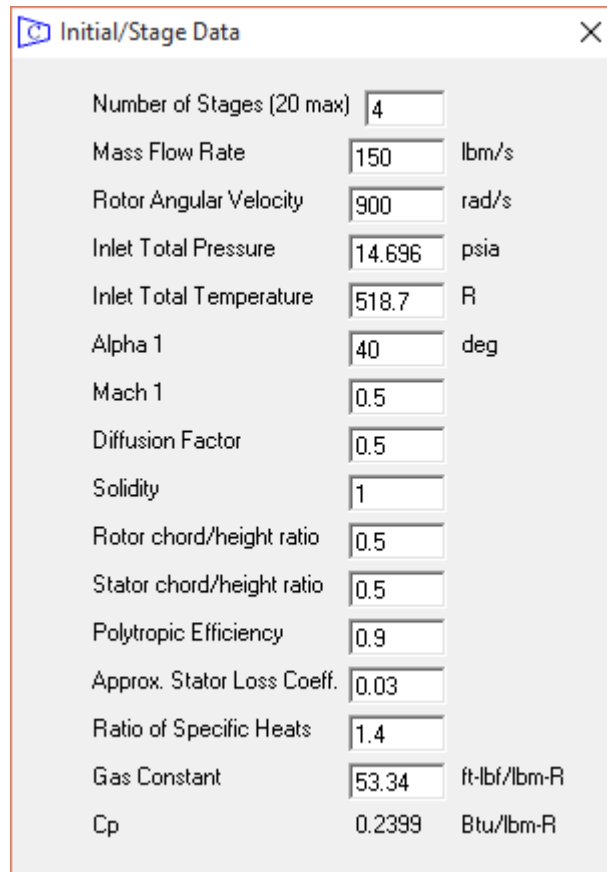
Each of these designs can be analyzed using the user-selected unit system (English or SI) and swirl velocity distribution (three choices: free vortex, exponential, and first power).

This program is designed to be user-friendly and multiple windows are used for program control and data input. COMPR input data files may be saved on disk for later use (the file extension "cmp" is used for these files). Also, saved input data files may be read from disk for current use. Program output is directed to an output window and may be sent to a printer.

It is recommended that a multi-stage compressor design begin with the Repeating Stage/Row type of design. Starting from the results of this design, each stage can be custom designed using the User Input Tip Radius or another type of design.

## 2. VIEW/EDIT DATA Windows

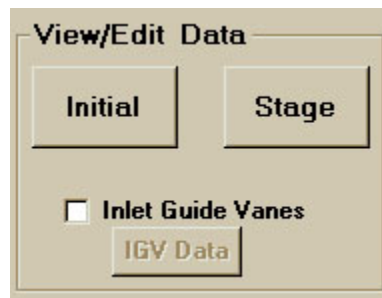
For the **Repeating Stage/Row** design, pressing the **Initial/Stage** button on the Main window opens the Initial/Stage Data window for that design as shown below.



Parameter	Value	Units
Number of Stages (20 max)	4	
Mass Flow Rate	150	lbm/s
Rotor Angular Velocity	900	rad/s
Inlet Total Pressure	14.696	psia
Inlet Total Temperature	518.7	R
Alpha 1	40	deg
Mach 1	0.5	
Diffusion Factor	0.5	
Solidity	1	
Rotor chord/height ratio	0.5	
Stator chord/height ratio	0.5	
Polytropic Efficiency	0.9	
Approx. Stator Loss Coeff.	0.03	
Ratio of Specific Heats	1.4	
Gas Constant	53.34	ft-lbf/lbm-R
Cp	0.2399	Btu/lbm-R

The approximate stator loss coefficient ( $\phi_s = \Delta P_t / \{\rho V_2^2 / [2g_c]\}$ ) allocates the stage total pressure loss (calculated using the polytropic efficiency) between the stator and rotor.

For the other four designs, two buttons for data entry are displayed on the Main window: **Initial** button and **Stage** button (see below).



**View/Edit Data**

**Initial**      **Stage**

**Inlet Guide Vanes**

**IGV Data**

When the **Initial** data button is pressed, the following Initial Data window is displayed:

The Initial Data dialog box contains the following parameters and values:

- Number of Stages (20 max): 4
- Mass Flow Rate: 150 lbm/s
- Rotor Angular Velocity: 900 rad/s
- Inlet Total Pressure: 14.696 psia
- Inlet Total Temperature: 518.7 R
- Solidity: 1
- Alpha 3 for Last Stage ( $\geq 0$ ): 40 deg
- Mach 3 for Last Stage ( $> 0$ ): 0.5
- Ratio of Specific Heats: 1.4
- Gas Constant: 53.34 ft-lbf/lbm-R
- Cp: 0.2399 Btu/lbm-R

When the **Stage** data button is pressed, the following data window is displayed:

The Stage Data dialog box displays a table with the following data:

	1	2	3	4
Alpha @1	40.0	40.0	40.0	40.0
Mach @1	0.5	0.47669	0.45447	0.43329
Tt Rise (R)	51.959	51.959	51.959	51.959
Phic rotor	0.10059	0.0978	0.09551	0.09361
Phic stator	0.03	0.03	0.03	0.03
c/h rotor	0.5	0.5	0.5	0.5
c/h stator	0.5	0.5	0.5	0.5
u2/u1	1.0	1.0	1.0	1.0

A "Close" button is located at the bottom of the dialog box.

Data is edited in this window by moving to the desired data cell, double-click on the cell to open an edit window as shown below.

	1	2	3	4
Alpha @1	30.0	40.0	40.0	40.0
Mach @1	0.5	0.47669	0.45447	0.43329
Tt Rise (R)	51.959	51.959	51.959	51.959
Phic rotor	0.10059	0.0978	0.09551	0.09361
Phic stator	0.03	0.03	0.03	0.03
c/h rotor	0.5	0.5	0.5	0.5
c/h stator	0.5	0.5	0.5	0.5
u2/u1	1.0	1.0	1.0	1.0

Close

Make the changes and then press either the Enter key or Tab key and the updated window is displayed as shown below.

	1	2	3	4
Alpha @1	30.0	40.0	40.0	40.0
Mach @1	0.5	0.47669	0.45447	0.43329
Tt Rise (R)	51.959	51.959	51.959	51.959
Phic rotor	0.10059	0.0978	0.09551	0.09361
Phic stator	0.03	0.03	0.03	0.03
c/h rotor	0.5	0.5	0.5	0.5
c/h stator	0.5	0.5	0.5	0.5
u2/u1	1.0	1.0	1.0	1.0

Close

If the Inlet Guide Vane **IGV** check box is marked on the Main window, the **IGV** button becomes active. Pressing the **IGV** button opens the Inlet Guide Vane Data window shown here.

If the Exit Guide Vane **EGV** check box is marked on the Main window, the **EGV** button becomes active. Pressing the **EGV** button opens the Exit Guide Vane Data window which is similar to that of the IGV.

Solidity	0.8
Chord/height ratio	0.35
Loss Coeff., phi	0.02
Inlet flow angle (deg)	0
Inlet Mach	0.35

### 3. RESULTS Window – Perform Calculations

Pressing the **Perform Calculations** button on the Main window causes the Results window to be opened and the input data and results displayed for the first stage (or IGV) as shown below for the first of a four-stage repeating stage/row design using the default data.

Results
×

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```

COMPR V5.50 - COMPRESSOR INITIAL DATA, Design: 5, Swirl: 1
Date - 1/20/2016 Time - 9:16:55 AM
Data File: Default Data
Corr Flow = 150.00 lbm/s Mass Flow = 150.00 lbm/s Rotor Speed = 0900 rad/s
Inlet Pt = 014.70 psia Inlet Tt = 0518.7 R Solidity = 1.0000
Gamma = 1.4000 Gas Constant =53.34ft-lbf/lbm-R Poly Eff = 0.900 Phis = 0.0300

COMPRESSOR STAGE: 1 u2/u1 = 1.0000 Rotor c/h = 0.5000 Stator c/h = 0.5000
RESULT: Tt3/Tt1 = 1.1002 Pt3/Pt1 = 1.3508 DTt =051.96 R AN^2=5.099E+10
Hub R = 0.0100 Dr = 0.1962 Ds = 0.5421 Phis = 0.0300 Eff = 0.8956
Mean R = 0.5000 Dr = 0.5000 Ds = 0.5000 Phir = 0.1006 r m = 13.459 in
Tip R = 0.7083 Dr = 0.3761 Ds = 0.4663 M1R = 1.0634 U m = 1009.5 fps
Flow Area 1 = 0764.55 Area 2 = 0690.31 Area 3 = 0615.65 in^2
Rotor - # of Blades = 21 Chord = 4.301 in
Stator - # of Blades = 23 Chord = 3.861 in
Coefficients: Stage Loading = 0.3063 Flow = 0.4134

  Station  1h   1m   1t   1Rm  2Rm  2h   2m   2t   3h   3m   3t
Prop:
Tt      R | 518.7 518.7 518.7 544.7 544.7 570.7 570.7 570.7 570.7 570.7 570.7
T       R | 481.1 494.0 498.5 494.0 520.0 481.6 520.0 534.9 537.0 546.0 549.8
Pt    psia | 14.70 14.70 14.70 17.44 16.99 20.00 20.00 20.00 19.85 19.85 19.85
P     psia | 11.29 12.39 12.79 12.39 14.44 11.05 14.44 15.94 16.05 17.00 17.43
M      | 0.625 0.500 0.450 0.716 0.487 0.961 0.698 0.579 0.560 0.476 0.435
Vel ft/s | 672.4 544.7 492.8 780.3 544.7 1034.2 780.3 655.8 636.0 544.7 500.1
u   ft/s | 417.3 417.3 417.3 417.3 417.3 417.3 417.3 417.3 417.3 417.3 417.3
v   ft/s | 527.2 350.1 262.1 659.3 350.1 946.3 659.3 505.9 479.9 350.1 275.6
alpha deg | 51.64 40.00 32.13                66.20 57.67 50.48 48.99 40.00 33.44
beta deg  |                57.67 40.00
radius in | 08.94 13.46 17.98 13.46 13.46 09.38 13.46 17.54 09.82 13.46 17.10
          
```

Print
Stage Nomenclature
Next Stage
Done

If the computer has a default printer, the **Print** button is visible and the user can use it to have the results printed. The **Next Stage** button is active for advancement to the next stage calculations.

The fourth stage results of the four-stage design is shown below.

**Results** x

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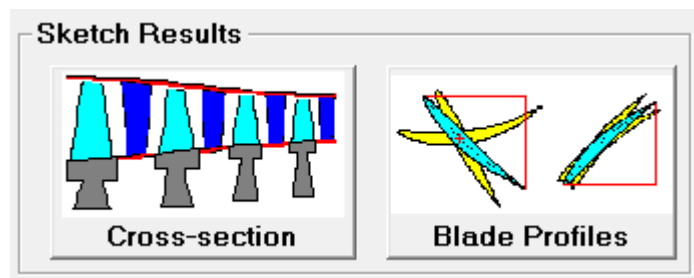
COMPR V5.50 - COMPRESSOR INITIAL DATA, Design: 5, Swirl: 1
Date - 1/20/2016 Time - 9:17:19 AM
Data File: Default Data
Corr Flow = 150.00 lbm/s Mass Flow = 150.00 lbm/s Rotor Speed = 0900 rad/s
Inlet Pt = 014.70 psia Inlet Tt = 0518.7 R Solidity = 1.0000
Gamma = 1.4000 Gas Constant =53.34ft-lbf/lbm-R Poly Eff = 0.900 Phis = 0.0300

COMPRESSOR STAGE: 4 u2/u1 = 1.0000 Rotor c/h = 0.5000 Stator c/h = 0.5000
RESULT: Tt3/Tt1 = 1.0770 Pt3/Pt1 = 1.2633 DTt =051.96 R AN^2=2.884E+10
Hub R = 0.2760 Dr = 0.5182 Ds = 0.5202 Phis = 0.0300 Eff = 0.8966
Mean R = 0.5000 Dr = 0.5000 Ds = 0.5000 Phir = 0.0936 r m = 13.459 in
Tip R = 0.6368 Dr = 0.4157 Ds = 0.4818 M1R = 0.7931 U m = 1009.5 fps
Flow Area 1 = 0422.26 Area 2 = 0390.51 Area 3 = 0357.56 in^2
Rotor - # of Blades = 36 Chord = 2.403 in
Stator - # of Blades = 39 Chord = 2.211 in
Coefficients: Stage Loading = 0.3063 Flow = 0.4134
    
```

	Station	1h	1m	1t	1Rm	2Rm	2h	2m	2t	3h	3m	3t
Prop:												
Tt	R	674.6	674.6	674.6	700.6	700.6	726.5	726.5	726.5	726.5	726.5	726.5
T	R	644.7	649.9	652.8	649.9	675.9	659.3	675.9	685.7	697.7	701.8	704.4
Pt	psia	33.63	33.63	33.63	38.38	37.63	42.74	42.74	42.74	42.48	42.48	42.48
P	psia	28.70	29.51	29.98	29.51	33.18	30.43	33.18	34.90	36.86	37.64	38.12
M		0.481	0.436	0.408	0.624	0.427	0.714	0.612	0.546	0.455	0.419	0.396
Vel	ft/s	599.1	544.7	511.2	780.3	544.7	898.6	780.3	700.6	588.8	544.7	515.5
u	ft/s	417.3	417.3	417.3	417.3	417.3	417.3	417.3	417.3	417.3	417.3	417.3
v	ft/s	429.9	350.1	295.4	659.3	350.1	795.8	659.3	562.8	415.4	350.1	302.6
alpha	deg	45.85	40.00	35.29			62.33	57.67	53.44	44.87	40.00	35.95
beta	deg				57.67	40.00						
radius	in	10.96	13.46	15.96	13.46	13.46	11.15	13.46	15.77	11.35	13.46	15.57

Print
Stage Nomenclature
Next Stage
Done

Pressing the Done button displays the Main window with both Sketch Results buttons active as shown below.





## 4. SKETCH RESULTS Window

Pressing the **Cross-section** button on the Main window causes the Stage Sketch Data window to be opened and the input data displayed as shown below.

The screenshot shows a window titled "Stage Sketch Data" with a table of input parameters for four stages. The parameters include Stage, Tt1R (R), Wr/cx, hr/Wr, sigma b/r, sp str rim \*, sp str disc \*, Wdr/Wr, DSF \*\*, hr (in), and WS \*\*\*\*. The "Sketch" button is highlighted with a dashed border.

Stage	1	2	3	4
Tt1R (R)	544.7	596.6	648.6	700.6
Wr/cx	1.1	1.1	1.1	1.1
hr/Wr	0.5	1.0	1.0	1.0
sigma b/r	0.1	0.1	0.1	0.1
sp str rim *	4.0	4.0	4.0	4.0
sp str disc *	4.0	4.0	4.0	4.0
Wdr/Wr				
DSF **				
hr (in)				
WS ****				

Wr = width of rim, hr = height of rim, cx = axial chord of rotor blade at hub, Wdr = width of disk at rim  
 \*Specific Strength (ksi-ft<sup>3</sup>/slug) \*\* DSF = Disk Shape Factor \*\*\*\* WS = Wheel Speed at rim (ft/s)

Buttons: Close, Blade-Disk Structure, Calculate, Sketch

Pressing the **Calculate** button on the Stage Sketch Data window displays the results on an updated window as shown below. If the **Sketch** button is selected before the **Calculate** button, the results are calculated but not displayed

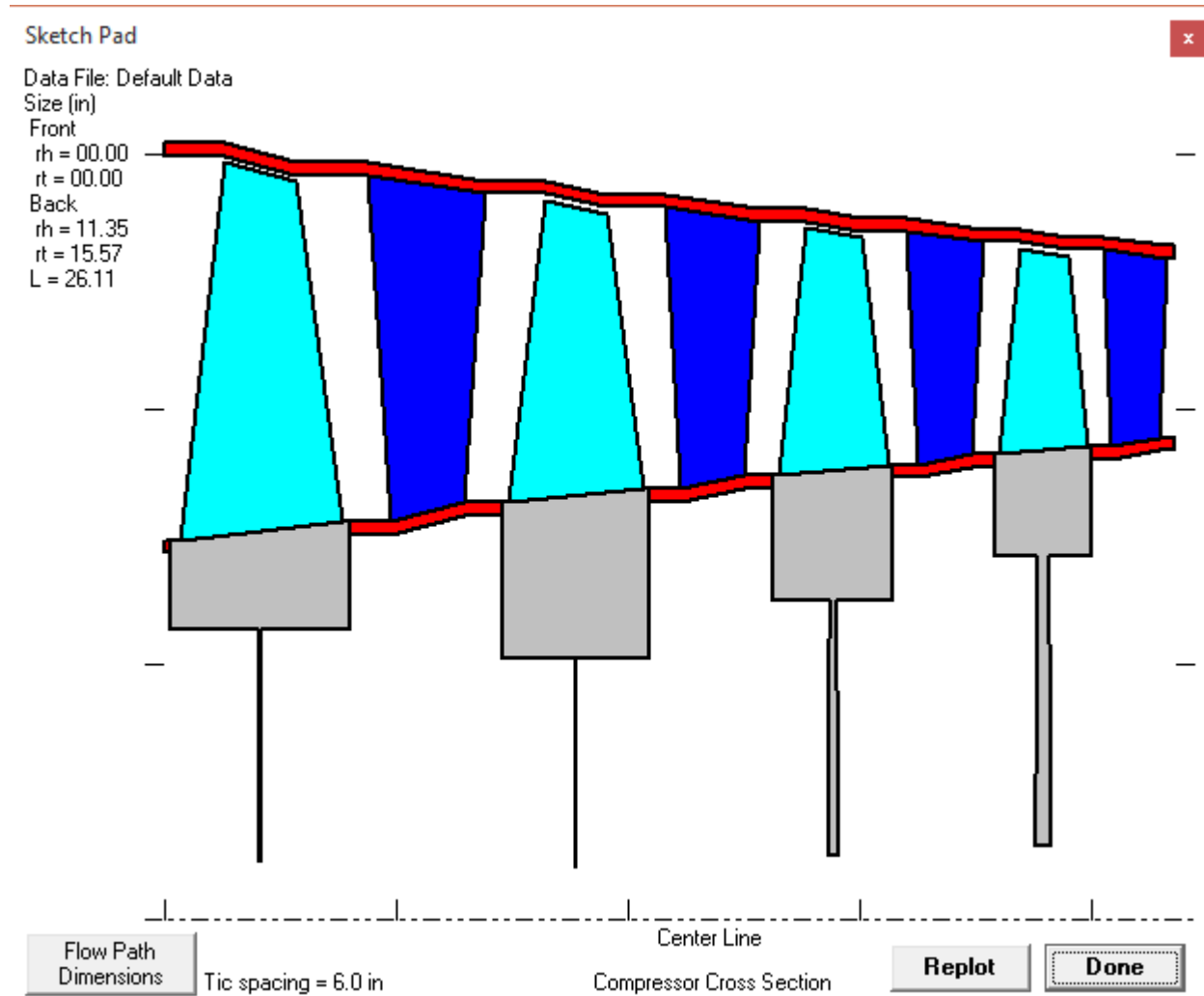
The screenshot shows the same "Stage Sketch Data" window, but now with calculated results for Wdr/Wr, DSF \*\*, hr (in), and WS \*\*\*\*. The "Calculate" button is highlighted with a dashed border.

Stage	1	2	3	4
Tt1R (R)	544.7	596.6	648.6	700.6
Wr/cx	1.1	1.1	1.1	1.1
hr/Wr	0.5	1.0	1.0	1.0
sigma b/r	0.1	0.1	0.1	0.1
sp str rim *	4.0	4.0	4.0	4.0
sp str disc *	4.0	4.0	4.0	4.0
Wdr/Wr	0.007	-0.064	0.058	0.111
DSF **	0.229	0.185	0.275	0.357
hr (in)	2.314	3.825	3.09	2.501
WS ****	513.4	461.7	562.6	641.7

Wr = width of rim, hr = height of rim, cx = axial chord of rotor blade at hub, Wdr = width of disk at rim  
 \*Specific Strength (ksi-ft<sup>3</sup>/slug) \*\* DSF = Disk Shape Factor \*\*\*\* WS = Wheel Speed at rim (ft/s)

Buttons: Close, Blade-Disk Structure, Calculate, Sketch

Pressing the **Sketch** button displays the Sketch Pad window with a cross-sectional sketch of the multi-stage axial flow compressor.



Pressing the **Blade Profiles** button on the Main window causes the Blade Description window to be opened and the input data displayed as shown below.

Blade Description
✕

Stage Number	<input style="width: 40px;" type="text" value="1"/>
Rotor Blade Thickness (%)	<input style="width: 40px;" type="text" value="10"/>
Stator Blade Thickness (%)	<input style="width: 40px;" type="text" value="10"/>
Rotor Stack @ % of Chord	<input style="width: 40px;" type="text" value="40"/>
Stator Stack @ % of Chord	<input style="width: 40px;" type="text" value="40"/>
Number of Blades per Row	<input style="width: 40px;" type="text" value="1"/>
Radial Location in % of hub/tip	<input style="width: 40px;" type="text" value="50"/>

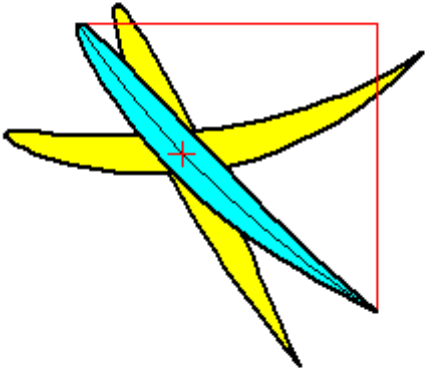
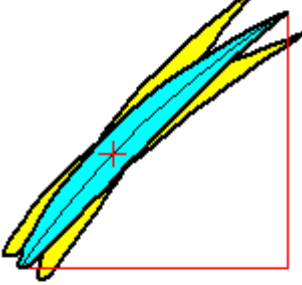
Pressing the **Plot** button for the data above displays the Sketch Pad window with a sketch of the blade shape. The hub and tip blade profiles are shown in yellow and the profile at the radius of interest is shown in light blue. The rotor airfoil is shown on the left and the stator airfoil is shown on the right.

Sketch Pad
✕

Data File: Default Data

Stage: 1	Rotor	Stator
Inlet	-57.7	57.7
Exit	-34.1	34.1
Thickness	10.0%	10.0%
Chord (in)	04.30	03.86
Stack@%c	40.0	40.0

Radial Position 50% hub/tip

▲ Tip

% Radius  
50

▼ Hub

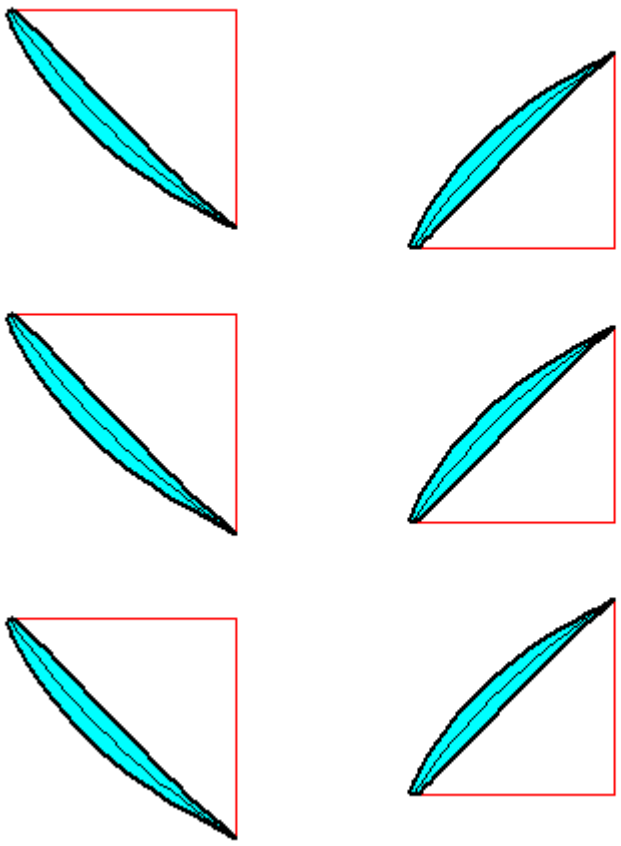
Pressing the **Plot** button for previous data with three blades per row displays the Sketch Pad window as shown below.

Sketch Pad ✕

Data File: Default Data

Stage: 1	Rotor	Stator
Inlet	-57.7	57.7
Exit	-34.1	34.1
Thickness	10.0%	10.0%
Chord (in)	04.30	03.86

Radial Position 50% hub/tip



Tip

% Radius

50

Hub

Replot Done