SCORG™ – Tutorial for Thermodynamic module

SCORG is a tool for the design and CFD pre-processing of rotary twin screw machines. It includes modules for grid generation; importing and editing rotor profiles; and multi-domain thermodynamic chamber module. For more information on the product please visit the website: www.pdmanalysis.co.uk or refer to documentation help.

This tutorial lists the steps for setting up and performing Thermodynamic calculation which could be used for performance prediction of oil free and oil injected screw compressors as a preliminary setup of CFD simulation for Twin Screw Compressor. The user is expected to be familiar with screw machines. It is highly recommended that the users who attempt this tutorial study the books on the performance prediction methods for screw compressors[1,2]. This Tutorial should be studied alongside the SCORG™ User Manual.

The steps explained in this tutorial are demonstrated for Windows 7, x64 bit OS. Refer to SCORG™ Installation Guide V5.8 for the system and hardware requirements.

Table of Contents

[1] N. Stosic, I.K. Smith, A. Kovacevic Screw Compressor Mathematical Modelling and Performance Calculation, Springer, UK 2005, ISBN-10 3-540-24275-9

[2] A. Kovacevic. N. Stosic, I.K. Smith, Screw Compressor Three Dimensional Computational Fluid Dynamics and Fluid Solid Interaction, Springer, 2006, ISBN 3-540-36302-5

1 Introduction

Screw Compressors are rotary positive displacement machines. They can be oil free or oil injected. Oil free compressors require rotors to be synchronised by additional timing gears on rotor shaft in order to maintain the contact free operation. In the oil injected compressor one rotor drives the other through direct contact, Figure 1.1.

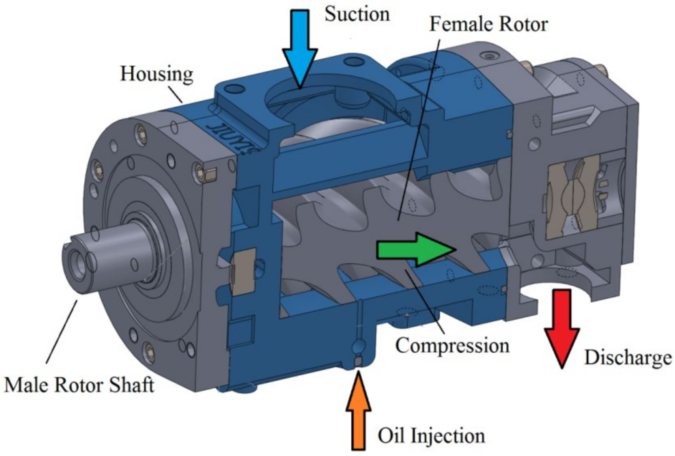


Figure 1.1 Oil injected twin screw compressor cross section

The screw compressor rotors are helically lobed gears with special rotor profile. Together with the casing they form a closed interlobe space called the working chamber which changes the size and shape during the operation of the machine. The working chamber itself is periodically connected to the suction and discharge chambers through flow areas which vary with time both in shape and size. The schematic view of a screw machine (compressor, pump or a motor) is shown in Figure **1.2**.

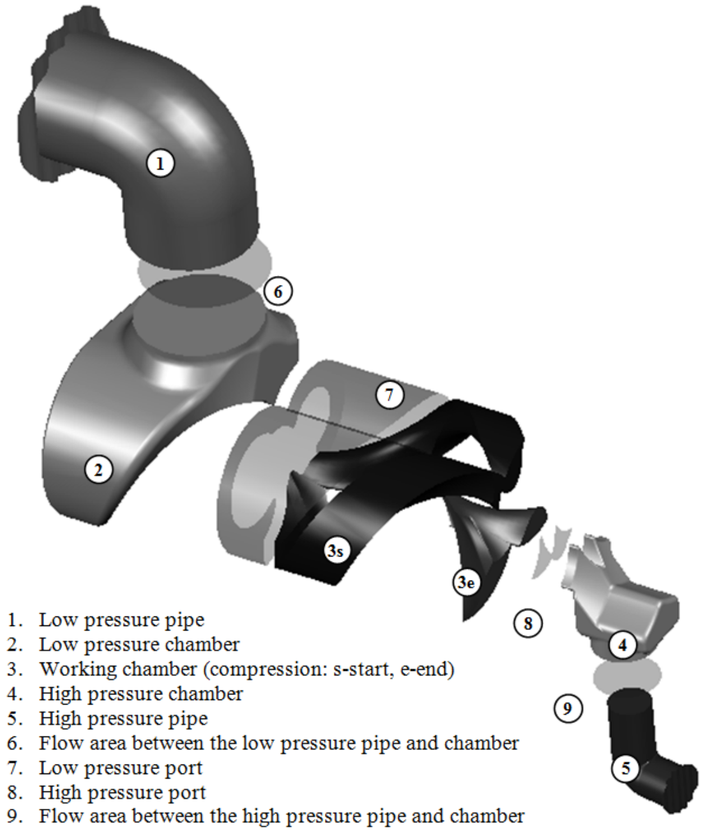


Figure 1.2 Configuration of a screw compressor

In the chamber model it is assumed that all thermodynamic values, such as the pressure, temperature, density etc. are uniform within the respective control volume. Any of the control volumes can be considered as open thermodynamic systems, which exchange fluid mass and energy with the environment, as shown in Figure 1.3. The mass and energy flows, in and out of the control volume affect the quantity of mass and internal energy of the fluid inside the working chamber. The rate of change of the mass and energy within the working chamber are defined by the conservation laws of mass and energy respectively expressed in terms of differential equations. Other phenomena within the control volume and at its boundaries are modelled by a number of algebraic equations which describe leakage, inlet and outlet fluid velocities, oil injection and heat exchange with environment and oil. The model is closed by the equation of state of the working fluid which can be defined as ideal or real gas.

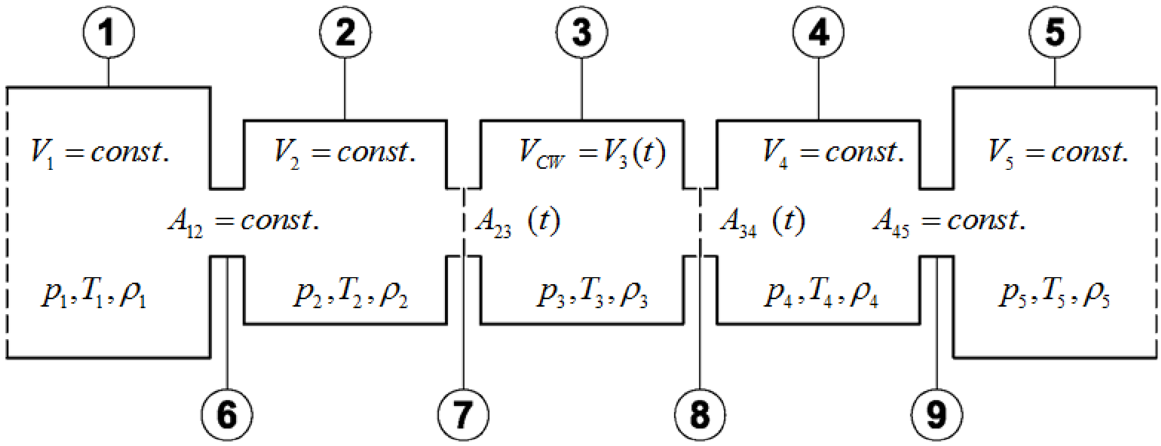
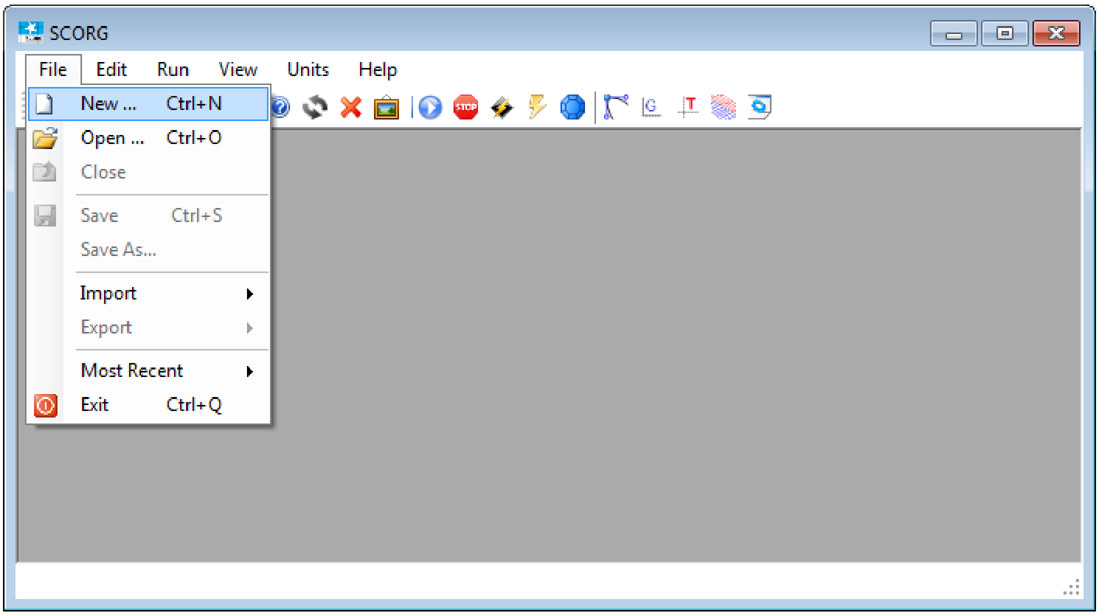


Figure 1.3 Schematic view of a screw machine chamber configuration

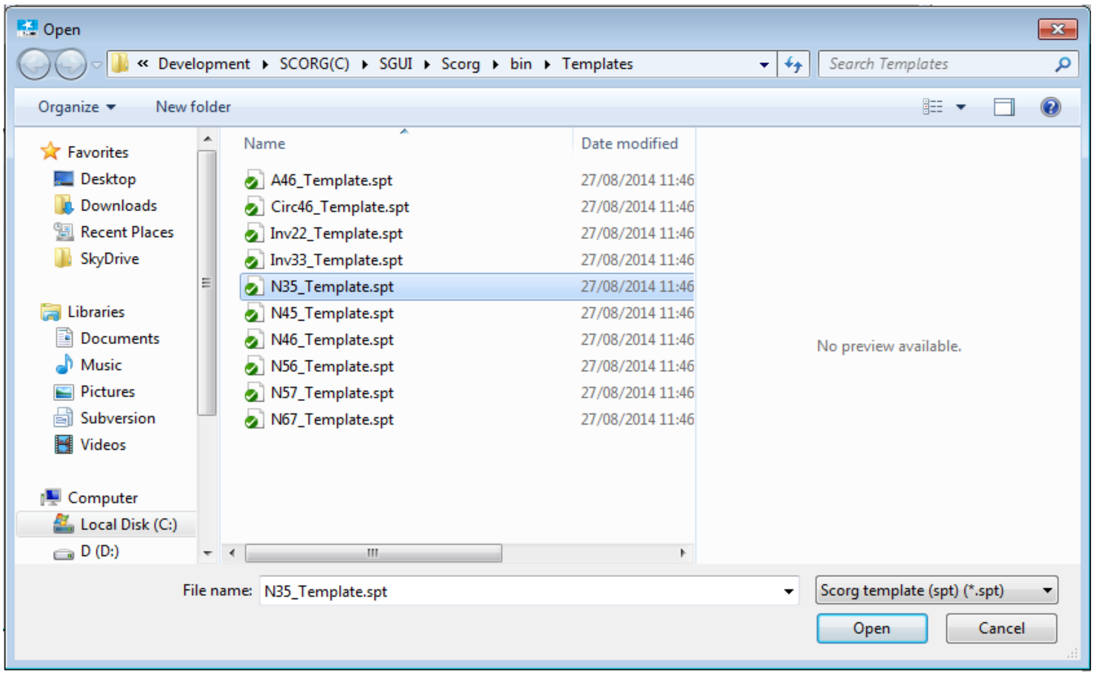
This Tutorial will provide a step by step guide to setup and execute thermodynamic simulation of a typical twin screw compressor. An example of a dry air compressor with 3/5 lobe combination, L/D ratio of 1.6 and wrap angle 285° is used in the tutorial. The effect of oil injection will also be demonstrated.

Start SCORG™ Project

- Launch SCORG™ on the Desktop.
- Select File → New

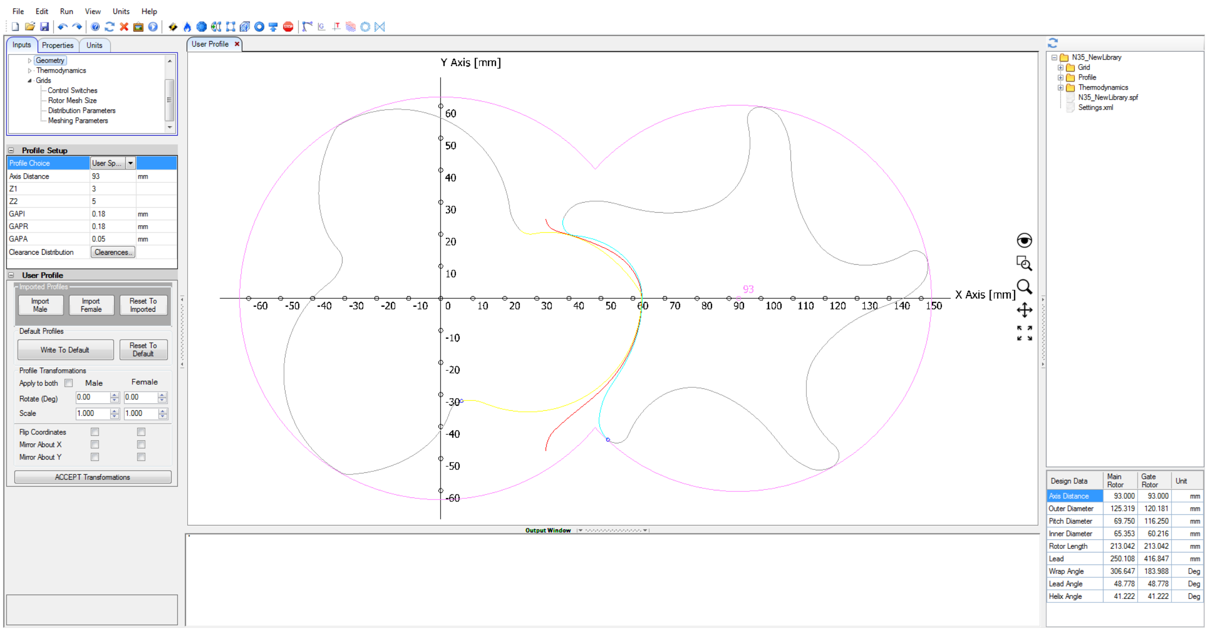


- Select N35_Template.spt → Open

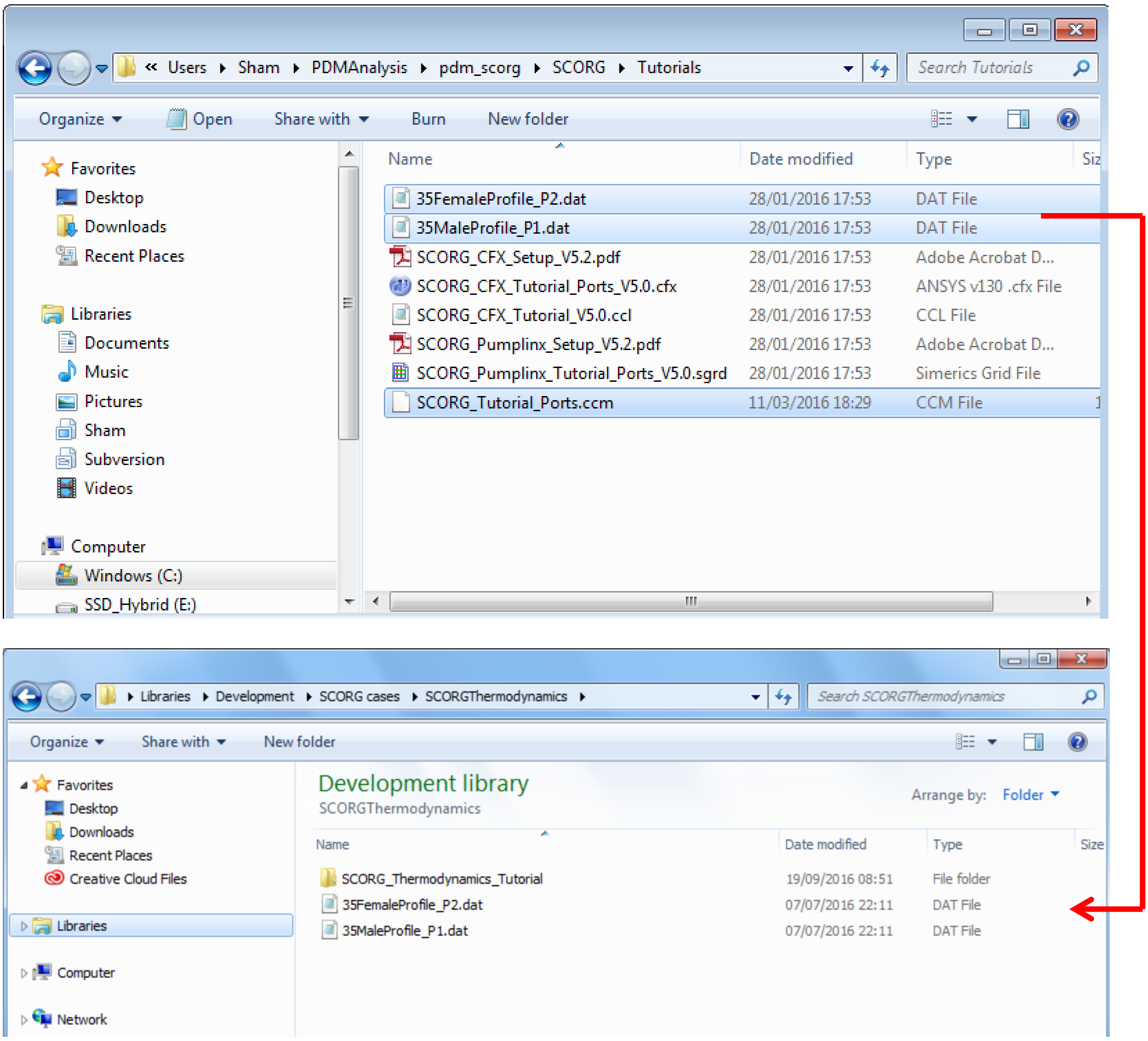


- Save the project in a new folder named SCORG_Thermodynamics→ SCORG_Thermodynamics_Tutorial.spf

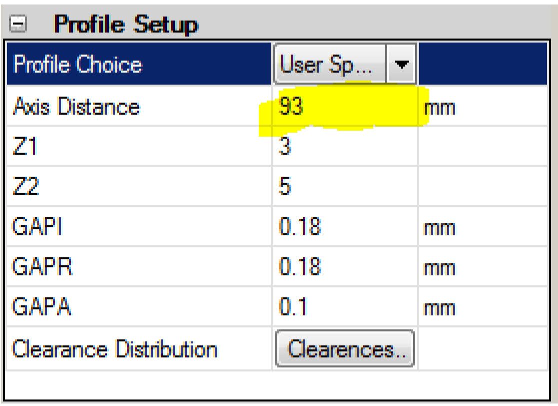
- The GUI of SCORG™ in the figure bellow shows the mains items of the front panel.



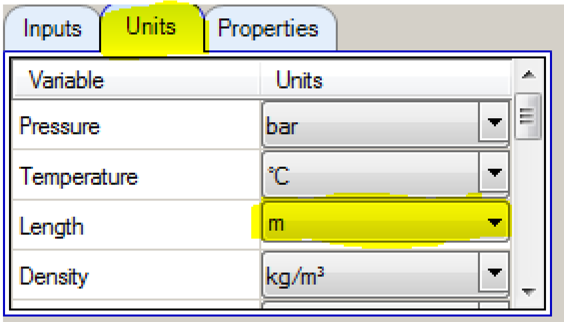
- Go to Help → Tutorials → Folder opens
- Copy the compressor rotor profile files → [*35MaleProfile_P1.dat* and *35FemaleProfile_P2.dat*]
- Paste these files in the working directory → SCORG_Thermodynamics



- In profile setup adjust Axis Distance to 93 mm

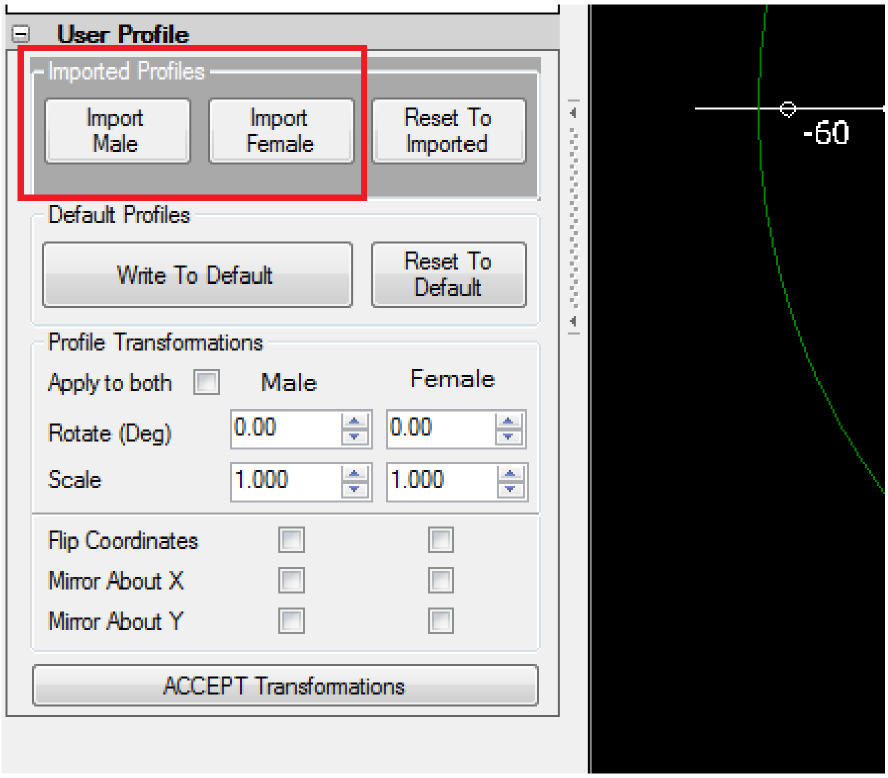


- Set Length Units to meters

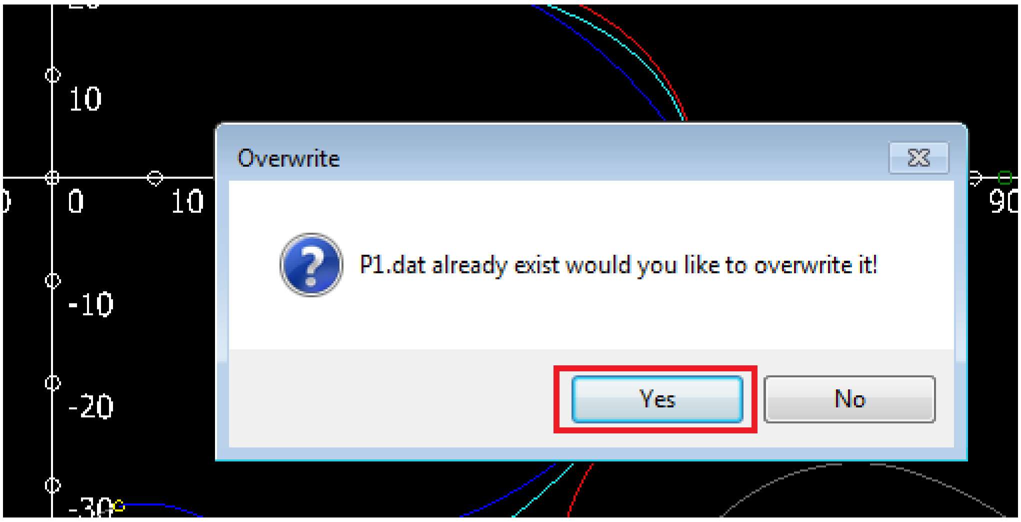


- Go to User Profile → Browse and Select the Male Rotor Profile from working directory.

  35MaleProfile_P1.dat



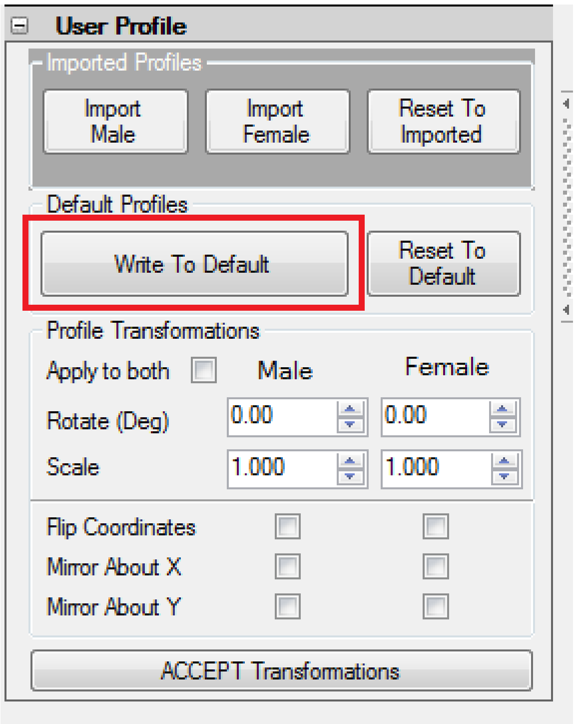
- Click 'Yes' to overwrite P1.dat.



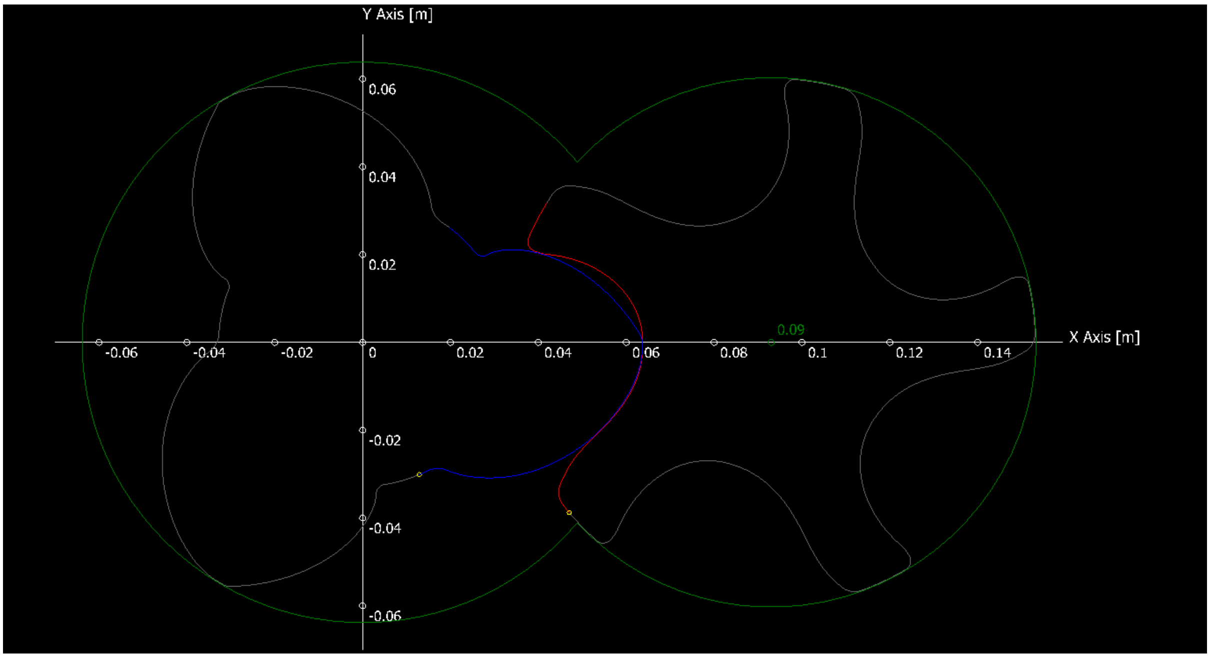
- Similarly Select the Female Rotor Profile.

  35FemaleProfile_P2.dat

- Click Write To Default.



- Click Right button and select Refresh to view new profiles.



- Inspect the Rotor Profile in the GUI for gaps in the tips, starting points of the profile indicated by the small yellow circles. For more information please see Section 6.4 in the SCORG^{TM} User manual.

2 Set Geometrical Clearances

- Set the following Profile Parameters to get desired clearance size:

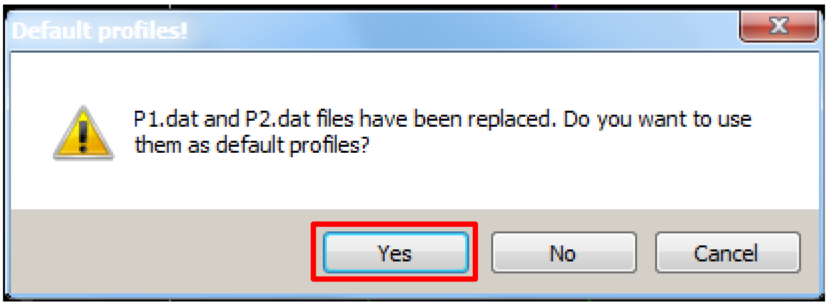
Profile Setup

Profile Choice	User Sp...	
Axis Distance	93	mm
Z1	3	
Z2	5	
GAPI	0.18	mm
GAPR	0.18	mm
GAPA	0.1	mm
NL	5	
NR	0	

- Run Geometry calculation through the shortcut highlighted in the figure below

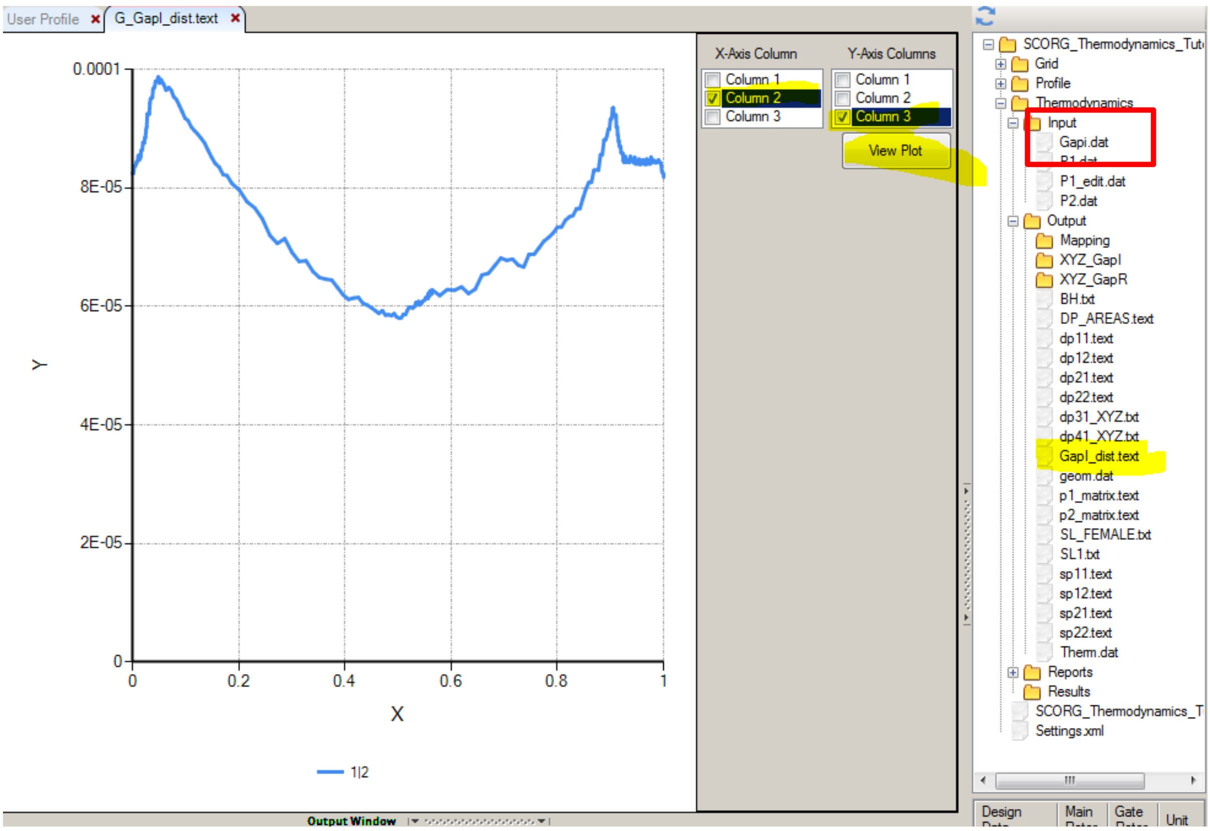
- Run Rack generation procedure by clicking on Numerical rack shortcut button.

This is required to inspect the profile and make any required corrections of the imported rotor profiles.
You will receive the following message



- Click on Yes to accept correction of the profiles.

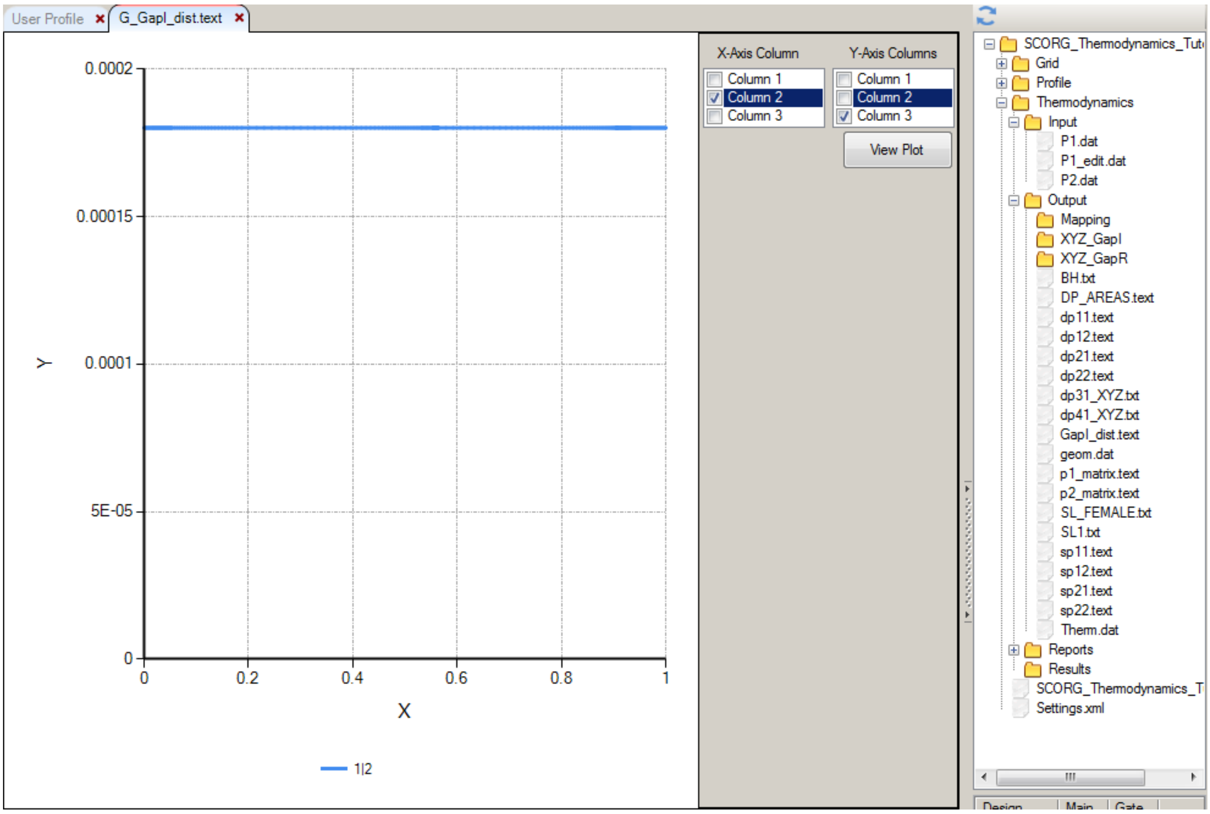
- Now you can inspect the Interlobe clearances which the imported profile will have with the given axis distance. To do that, Click with the right mouse button on file Case->Thermodynamics->Output->GapI_dist.text, select Graphical view and select columns 2 and 3 for X and Y axis respectively. The normal clearance distribution along the sealing line represented in the relative position from the beginning to the end of the profile is shown. In the diagram below it is visible that the normal clearance varies from 0.060mm to 0.1 mm in the given profile.



If you want to use this clearance for calculation of thermodynamic performance then set the GAPI value to 0.

- If you want to set Interlobe Clearance in thermodynamic through the Input value GAPI, then setup the GAPI to desired clearance value.

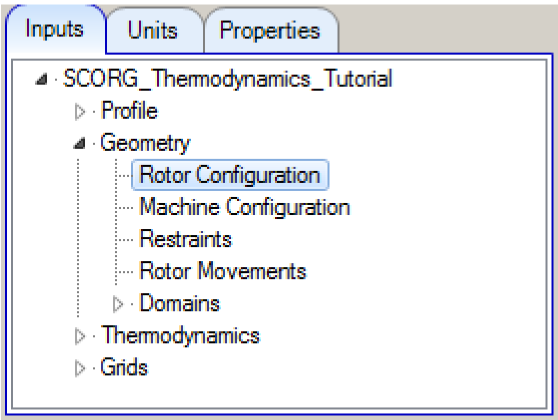
If you want to completely remove the clearance from the imported profile, then delete the file Case->Thermodynamics->Input->GapI.dat (shown in the red box abover). Then recalculate Geometry and refresh the diagram. You should see the diagram below.



- Save the Project.

3 Set and calculate Geometry

In order to perform thermodynamic calculation and to obtain expected results, it is important to set up all geometry and operational inputs correctly. This will be adjusted through Input window for Geometry



- Set values for Rotor Configuration and Machine Configuration as indicated below

Rotor Configuration

Relative Length	1.6	
Rotor Length	203.718	mm
Wrap Angle	285	Deg
Pitch Low Pressure Port	0	mm
Pitch High Pressure Port	0	mm
Rotor Pitch	Uniform	
Rotor Profile	Constant	
Main Rotor Centre X	0	mm
Main Rotor Centre Y	0	mm
Main Rotor Centre Z	0	mm
Main Rotor Start Angle	0	Deg
Rotor Stage Number	0	
Main Rotor Helix	Right	
Gate Rotor Position	Right	

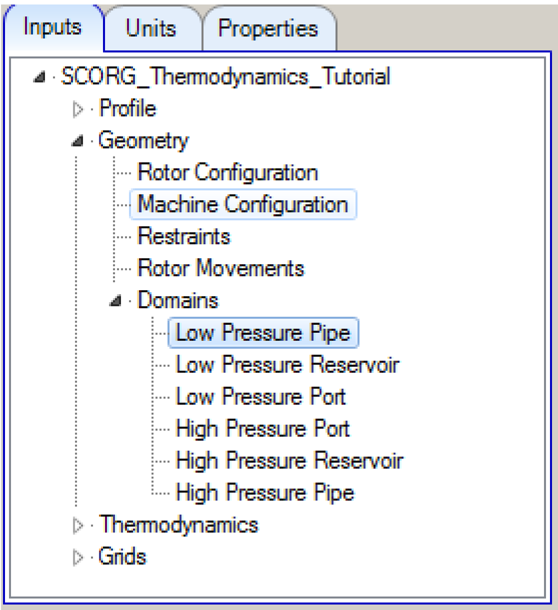
Machine Configuration
Restraints
Rotor Movements

Rotor Configuration
Machine Configuration

Machine Type	Screw ...	
N Gate	1	
Compression Start	0	Deg
Compression End	161.792	Deg
Volume Index	1.8	
Angle of Radial Dischar...	0	Deg
E Rotor	211	GPa
αL Rotor	1E-05	m/m/°C
E Casing	211	GPa
αL Casing	1E-05	m/m/°C
Wall Roughness	0	mm

Restraints

- The next geometry setup is related to setting size of flow domains and passages shown in Figure 1.2 and Figure 1.3.



The volumes of these domains and flow areas between them are set through the menu shown in the figure on the left.

The domains in the Inputs are also shown in Figure 1.2 with following numbers:

- Low pressure Pipe — Domain 1
- Low Pressure Reservoir — Domain 2
- High Pressure Reservoirs — Domain 4
- High Pressure Pipe — Domain 5

All these volumes are set by the equivalent diameter and length of each of these domains.

Flow areas between these domains in reference to Figure 1.2 are defined in the following way:

- The Area 6 between the Low pressure pipe (1) and Low pressure Reservoir (2) is defined by the Diameter of the Low Pressure Pipe
- The Area 9 between the High Pressure Reservoir (4) and High Pressure Pipe (5) is defined by the Diameter of the High Pressure Pipe
- Area between the Low Pressure Reservoir (2) and the Working Chamber (3) is called Low pressure Port. It is calculated by the Geom program as described in the User Manual while in the Inputs it is only selected if the port is Axial, Radial or both. The size of the port is defined by the Compression Start Angle in Machine Configuration.
- Area between the Working Chamber (3) and the Low Pressure Reservoir (4) is called High Pressure Port. It is calculated by the Geom program as described in the User Manual. In Inputs it is only selected as the Axial, Radial port or both. The size of the port is defined by the Compression End Angle in Machine Configuration which directly depends on the Volume Index.

- Set values of the flow domains as shown below

Low Pressure Pipe		
Diameter	100	mm
Length	200	mm

Low Pressure Reservoir		
Diameter	100	mm
Length	100	mm

High Pressure Reservoir		
Diameter	75	mm
Length	75	mm

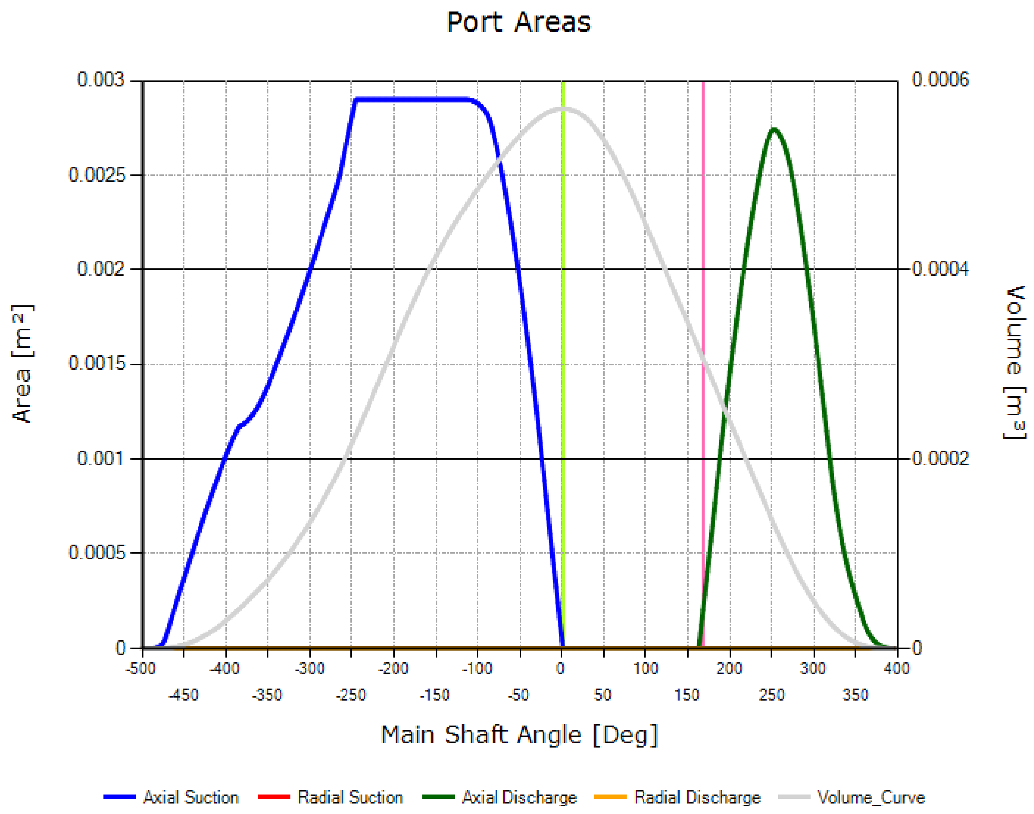
High Pressure Pipe		
Diameter	50	mm
Length	200	mm

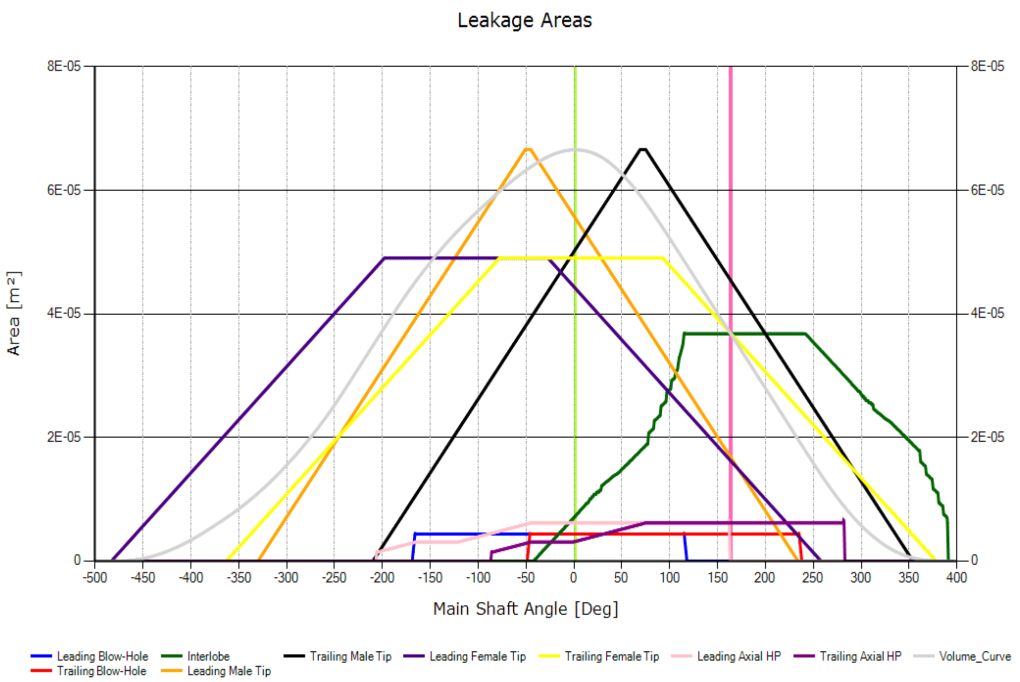
Low Pressure Port		
Port Type	Axial	
Depth Radial	8	mm
Circular Divisions	100	
Radial Divisions	8	
Depth Axial	9	mm
Angle Radial End Face	45	Deg
Length Radial	21	mm
Axial Clearance	0.2	mm
Orthogonalisation Factor	1	

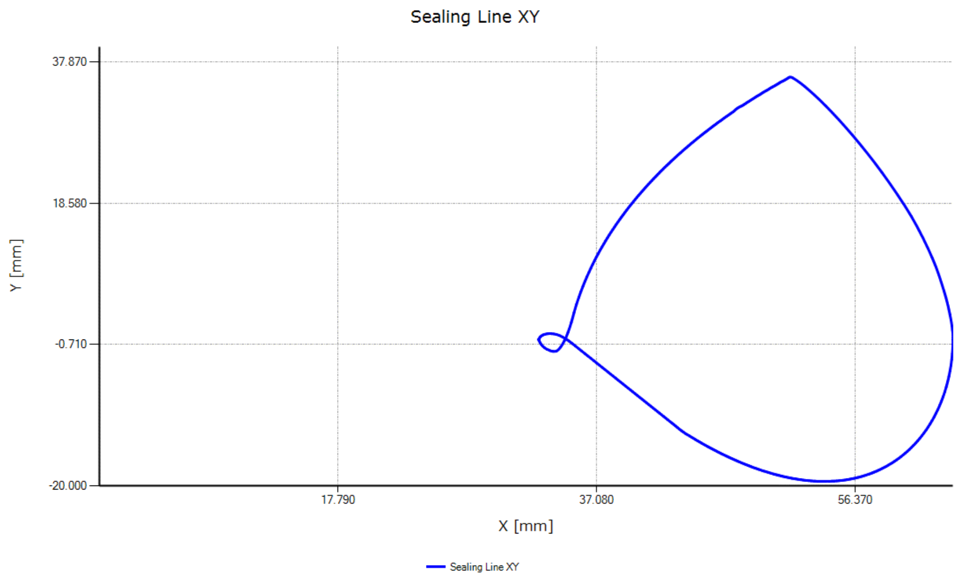
High Pressure Port		
Port Type	Axial	
Inner Circle Diameter	1	
Circular Divisions	20	
Radial Divisions	20	
Z Divisions	5	
Length	16	mm
Axial Clearance	0.13	mm
Orthogonalisation Factor	0.6	

- Calculate Geometry by clicking on the shortcut button for geometry calculation

- Inspect geometry diagrams


Port Areas
Area [m²]
Volume [m³]
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.0006
0.0004
0.0002
0
-500 -450 -400 -350 -300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400
Main Shaft Angle [Deg]
Axial Suction
Radial Suction
Axial Discharge
Radial Discharge
Volume_Curve


Leakage Areas
Area [m²]
Volume [m³]
8E-05
6E-05
4E-05
2E-05
0
-500 -450 -400 -350 -300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400
Main Shaft Angle [Deg]
Leading Blow-Hole
Trailing Blow-Hole
Interlobe
Leading Male Tip
Trailing Male Tip
Leading Female Tip
Trailing Female Tip
Leading Axial HP
Trailing Axial HP
Volume_Curve



Port Areas – The diagram shows the area of the Suction and Discharge Ports as function of the rotation angle as well as any other ports if they exist, such as oil injection port or economiser port. The diagram also shows the Volume curve and two vertical lines demonstrate start and end of the compression process.

Leakage Areas – The diagram shows the flow area through leakage paths as function of the main shaft angle. These include leakage areas of the inflow and outflow leakages.

The inflow leakage paths are these through which fluid leaks in the working chamber:

- Leading blow hole area, Leading male and female tip leakage area (radial leakage) and leading axial gap area

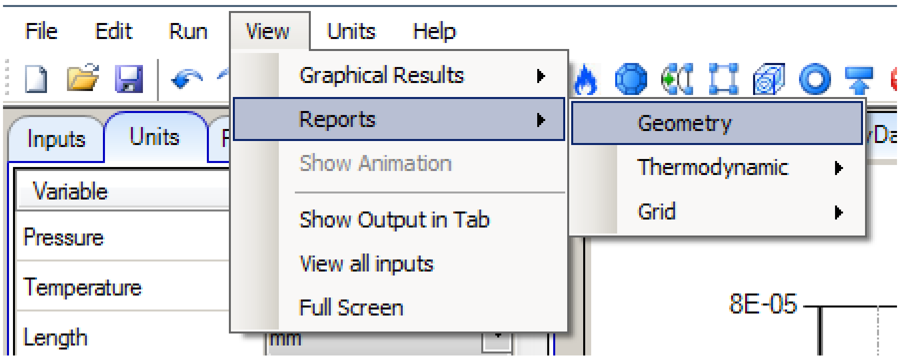
The outflow leakage paths through which fluid leaks from the working domain are:

- Trailing blow hole area, Trailing male and female tip leakage area (radial leakage), interlobe gap area and trailing axial gap area.

Sealing line – The diagram shows the sealing line in three coordinate planes, XY, YZ and ZX.

The influence of the change in clearances on the performance of the machine will be evaluated in the next Section.

► Inspect geometry report



User Profile Geometry Geometry.txt

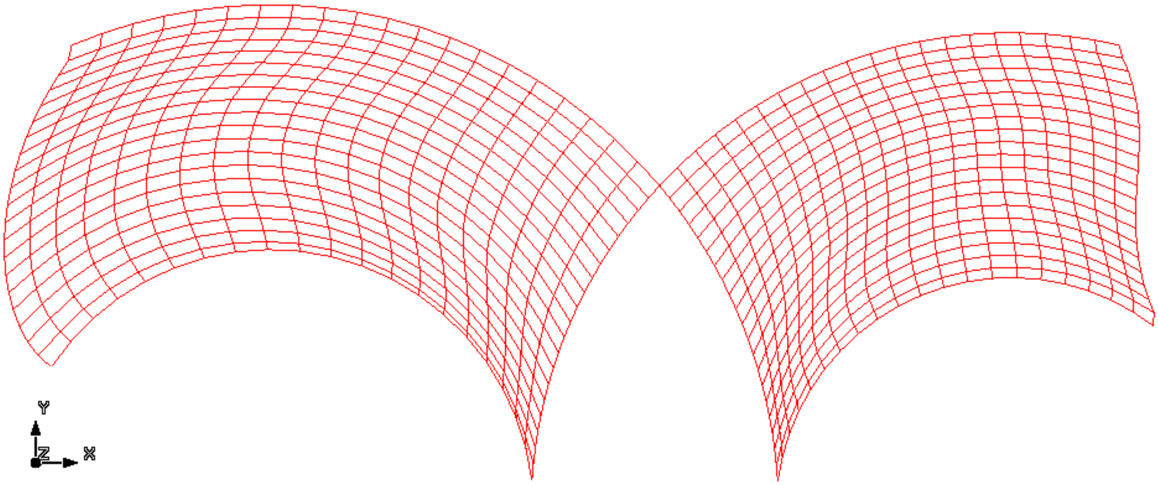
```
==========================================================
#########    Screw compressor geometry data    ##########
==========================================================

          Date: 30-Sep-2020   Time: 22:28:19


     Rotor centre distance:         93.000  mm

           Number of lobes:      3         5
    Pitch circle diameters:   69.750    116.250  mm
     Outer rotor diameters:  127.324    120.262  mm
     Inner rotor diameters:   65.535     58.473  mm
     Diameters difference :   30.895     30.895  mm
                Wrap angle:  285.000    171.000  deg
                Rotor lead:  257.328    428.880  mm

               Helix angle:         40.416  deg
                Lead angle:         49.584  deg
              Rotor length:        203.718  mm

           Rotor lobe area:     1739.      1161.   mm2

        Cross section area:          8700.  mm2
       Max. chamber volume:        570426.  mm3
              Displacement:       1711277.  mm3/rev
                                    1.711     l/rev

    Ports
       Axial  LP port area:          2900.  mm2
       Radial LP port area:             0.  mm2
       Axial  HP port area:          2742.  mm2
       Radial HP port area:             0.  mm2

    Leakage gaps
       Interlobe SL length:        203.462  mm
         Interlobe SL area:         36.589  mm2
            Blow-hole area:          4.375  mm2
           Radial gap area:   66.583     49.041  mm2
            Axial gap area:    4.634      4.634  mm2
==========================================================
```

The values shown in two columns relate to Male (left) and Female rotor (right)

- View the axial discharge port

The shape and the size of the discharge port is defined by the Compression End angle which is in turn defined by the Volume Index Vi. In order to inspect the shape and size of the discharge port please calculate grid for the discharge port using highlighted shortcut button below and then display the port mesh using the shortcut button shown in the rectangle.

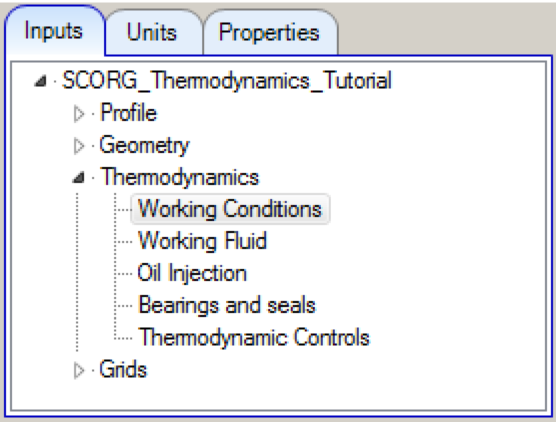
The shape and size of the port is displayed below. It will be later shown how it changes with the change in Vi.


Y
Z
X

4 Set and calculate Thermodynamics

Once the geometry of the compressor is correctly defined, it is possible to perform thermodynamic calculation. The objective of this calculation is to determine flow rate and power of the specified compressor operating at certain operating conditions and with the certain working fluid. The performance prediction will be obtained using multi domain chamber thermodynamic model. The basis of this model is explained in Stosic et al, 2005. More detail available through the SCORG™ user manual.

4.1 Single thermodynamic calculation of Oil free air compressor

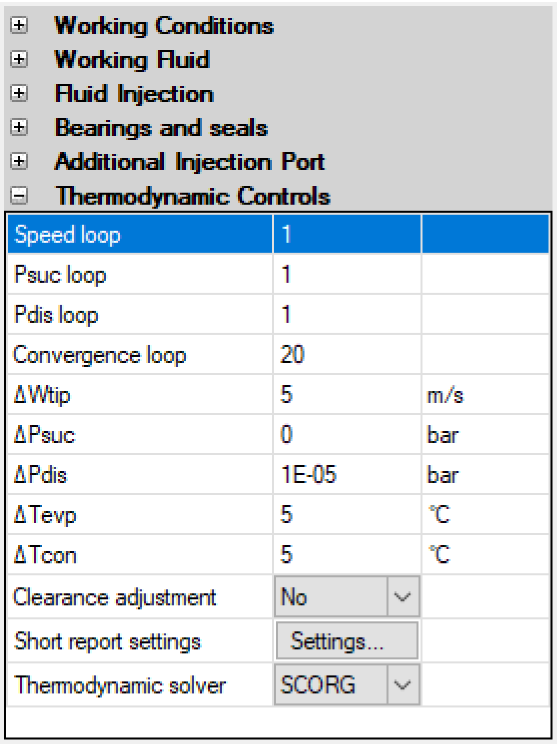


The setup for Thermodynamic calculation is performed through the Input controls shown in the control window on the left.

The controls are divided in 5 categories:

- Thermodynamic controls
- Working Fluid
- Working conditions
- Injection of liquid
- Bearing and seal setup

▶ Thermodynamic controls



For a single calculation of thermodynamic performance at one operating condition set the parameters in thermodynamic controls as listed below.

Set as low as possible number of convergence loops to get fast but accurate calculation. Usually 3-4 loops are sufficient to achieve good accuracy. The method on how to check if it is sufficient will be explained through temperature diagrams.

Please set values in your case to match the values in this window

▶ Working Fluid

Working Fluid		
Fluid	Ideal Gas	
Gamma	1.4	
RGas	287	J/(kg.K)
Z	1	

The working fluid can be ideal or real gas. In this example ideal gas will be used. The values in the window on the left are values for air.

- Working Conditions

Working Conditions		
Wtip	80	m/s
Rotor Speed	12000	RPM
P0	1	bar
Pr	3	bar
T0	19.85	℃
Tr	76.85	℃
Tevp	-5.15	℃
Tcond	39.85	℃
T Ambient	19.85	℃
Include heat transfer	No	
X	1	

The rotational speed can be defined by the tip speed or by the Rotor speed. Whichever value is set, the other will automatically adjust according to the size of the rotor.
The values required to be set for this calculation are
P0 – Suction pressure (absolute)
T0 – Suction Temperature
Pr – Discharge Pressure.
TAmbient – Ambient temperature used for calculation of conductive heat transfer from the compressor body.

- Liquid injection

Fluid Injection		
Fluid Injection	Off	
P	3	bar
T	36.85	℃
Injection Angle	63.025	Deg
Axial Position	100	mm
Port Diameter	5	mm
Doil	0.01	mm
CpOil	2000	J/(kg.K)
ρ	845	kg/m³
Viscosity of Oil	5E-05	m²/s

For oil free screw compressor the Oil injection control button should be off. In such case it is irrelevant what are the other values in this input window as these are not used in calculation.

- Bearings and seals

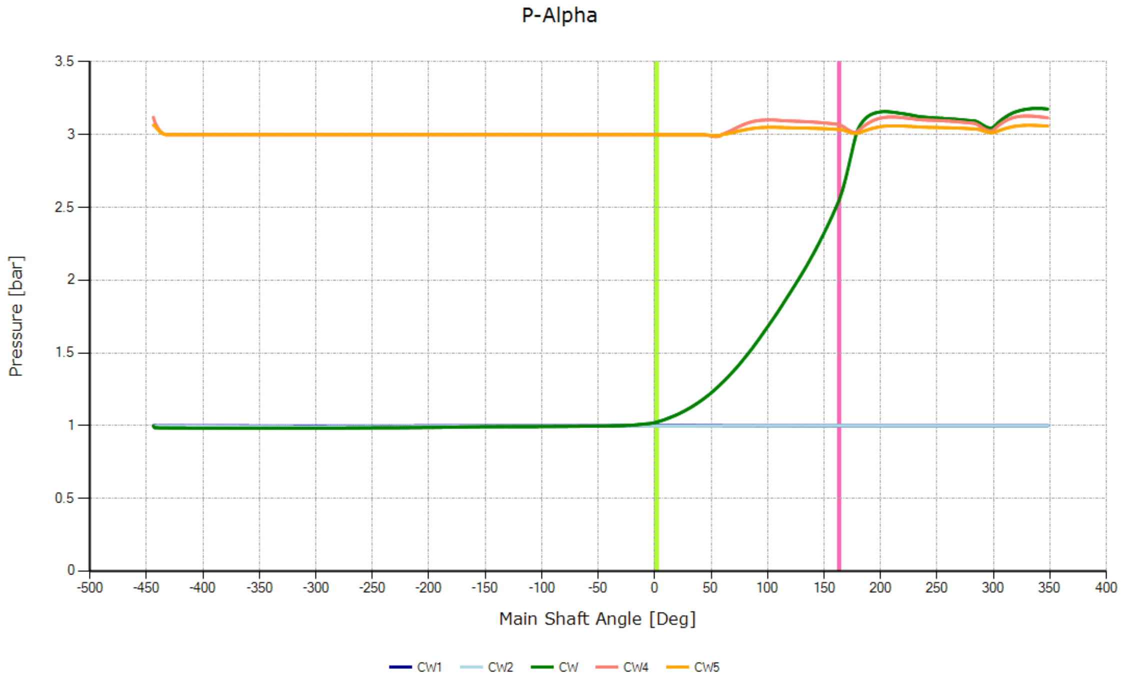
Bearings and seals		
Bearing Type	Rolling ...	
N Shaft	1	
Seal Ploss	300	W/1000...
Diameter Factor	0.023	
Speed Factor	0.001	

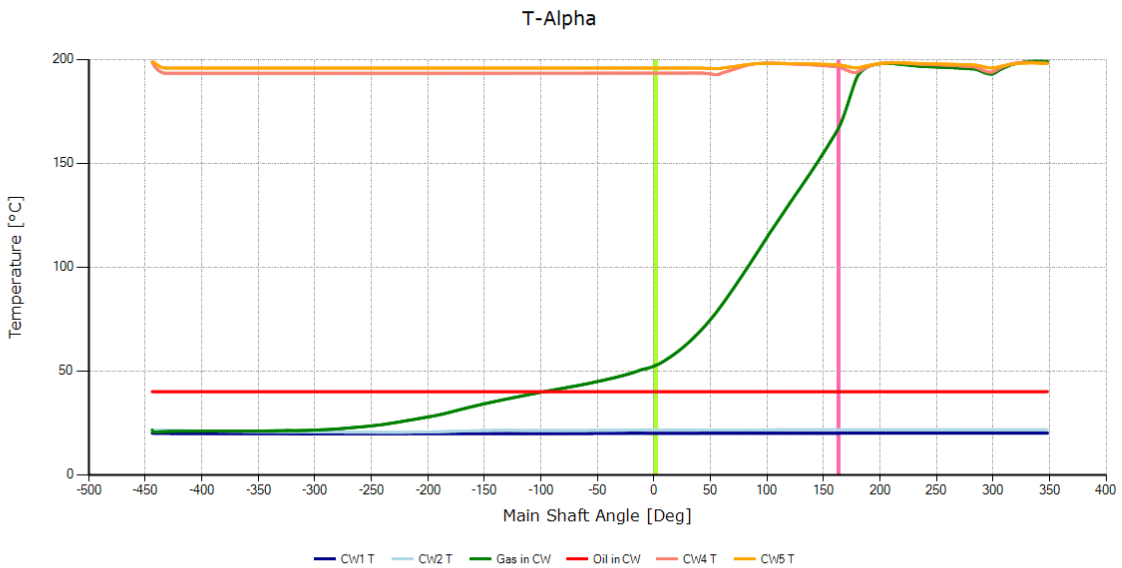
Oil free air compressors usually have rolling element bearings and their four mechanical seals are designed to prevent mixing of air and oil in the working chamber.
Seal Power losses are defined per 1000 rpm and are specified by manufacturers.

For this calculation, please set values as indicated in the input windows.

- Calculate Thermodynamics by selecting thermodynamics shortcut

- Inspect thermodynamic diagrams





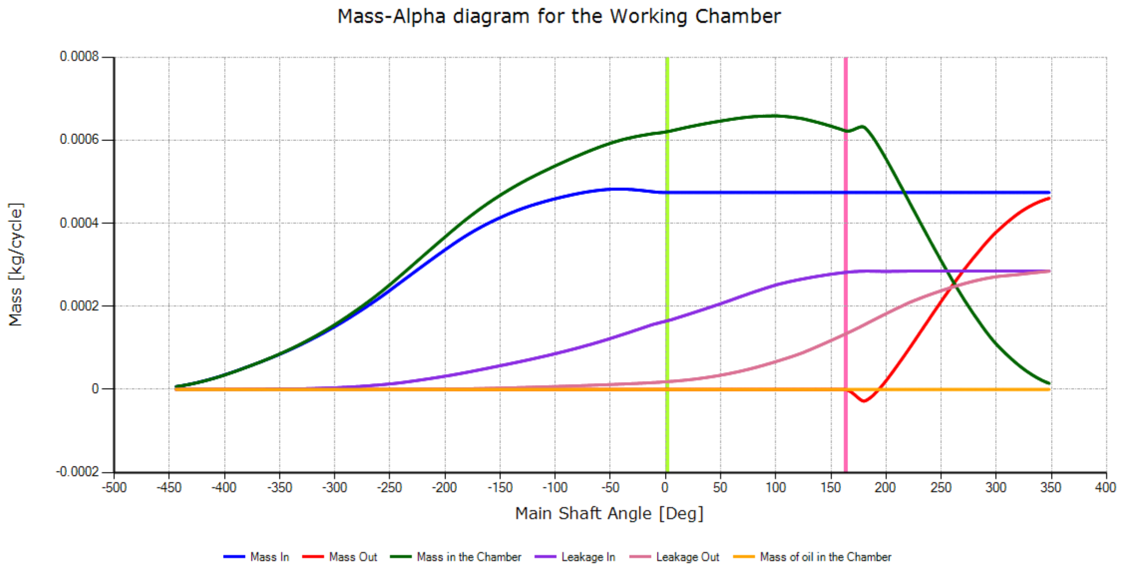
The above two diagrams show Pressure change with the angle of rotation and the temperature change with the angle of rotation respectively. The green line marked with CW represents the main working chamber.

The blue (CW1) and green (CW2) lines are low pressure pipe and reservoir respectively.

The red (CW4) and orange (CW5) lines are high pressure reservoir and pipe respectively.

The pulsations in the main chamber and in the pipes and reservoirs are visible on the above charts.

The chart below show the integrated mass flows in and out of the chamber through compressor ports, blue and red line respectively, actual mass in the chamber, green line, and the integrated leakage flows in and out of the chamber. These are all shown as the function of rotational angle.



- Results presented on the screen show calculated integral parameters and breakdown of Powers. IN case of oil free machine the oil drag power is equal to 0.

```
=== PROGRAM THERMODYNAMICS ===


RPM      Flow[m3/min]   Pow[kW]      P1[b]      P2[b]       T2[oC]      oil flow[kg/s]
12000   14.2083       55.8      1        3       196.09       0
Indicated Power     [kW]:49.86155
Shaft Seal Power    [kW]:3.6
Bearing Power       [kW]:2.33825
Oil Drag Power      [kW]:0
---------------------------------------------------
Total Shaft Power [kW]:55.7998
Number of conv. loops :10

Time elapsed:   00:00:21.0901734

=== PROGRAM THERMODYNAMICS END ===
```

▶ View Thermodynamic Report

```
SCORG - Thermodynamic Performance Calculation

          Date: 20/03/2021 22:35:52


Gas properties
     M   = 28.97 kmol/kg        Cp/Cv = 1.4
     R   = 287   J/kgK          Z     = 1

Machine: Oil Free Compressor
     Lobe combination   : 3/5
     Size               : 127/160 18
     Mechanical seals   : 1

==============================================

Tinl = 19.86 degC      Tout = 196.09 degC
Pinl = 1     bar       Pout = 3      bar
Moil = 0     kg/s      Toil = 40.01  degC
                       Poil = 7      bar

Volume Index Vi        = 1.8
Pressure Ratio Pi      = 2.28
Speed                  = 12000 rpm
Tip speed              = 80    m/s

Volume flow rate       = 14.21   m3/min
                       = 852.6   m3/h
Mass flow rate         = 1013.78 kg/h
Volumetric efficiency  = 69.19   %

Power (excl. gearbox)  = 55.8    kW
                       = 74.83   HP
Specific power         = 3.93    kW/m3/min
Adiabatic efficiency   = 54.77   %

Theoretical mass flow  = 1465.22 kg/h
Discharge mass flow    = 1013.78 kg/h
```

4.2 Changing compressor geometry and operating parameters

The thermodynamic multi-chamber model allows variation of parameters and evaluation of their influence on the performance of the compressor. As an example the following changes will be introduced:

- Radial clearance will be changed to 50 micrometers,
- Volume Index will be increased to 2.2
- Discharge pressure will be reduced to 2.5 bar
- Change the size of the discharge pipe (flange) to 70 mm

To introduce these changes please alter windows below:

Profile

⊟ **Profile Setup**

Profile Choice	User Sp...	
Axis Distance	93	mm
Z1	3	
Z2	5	
GAPI	0.18	mm
GAPR	0.05	mm
GAPA	0.05	mm
Clearance Distribution	Clearences..	

⊞ **User Profile**

Geometry

⊞ **Rotor Configuration**

⊟ **Machine Configuration**

Machine Type	Screw ...	
N Gate	1	
Compression Start	0	Deg
Compression End	189.49	Deg
Volume Index	2.2	
Angle of Radial Dischar...	0	Deg
E Rotor	211	GPa
αL Rotor	1E-05	m/m/℃
E Casing	211	GPa
αL Casing	1E-05	m/m/℃
Wall Roughness	0	mm

⊞ **Restraints**

Thermodynamics

⊟ **Working Conditions**

Wtip	80	m/s
Rotor Speed	12000	RPM
P0	1	bar
Pr	2.5	bar
T0	19.85	℃
Tr	76.85	℃
Tevp	-5.15	℃
Tcond	39.85	℃
T Ambient	19.85	℃
Ts	-273.15	℃
X	1	

⊞ **Working Fluid**

⊞ **Oil Injection**

⊞ **Bearings and seals**

⊞ **Thermodynamic Controls**

Domains

⊞ **Low Pressure Pipe**

⊞ **Low Pressure Reservoir**

⊞ **Low Pressure Port**

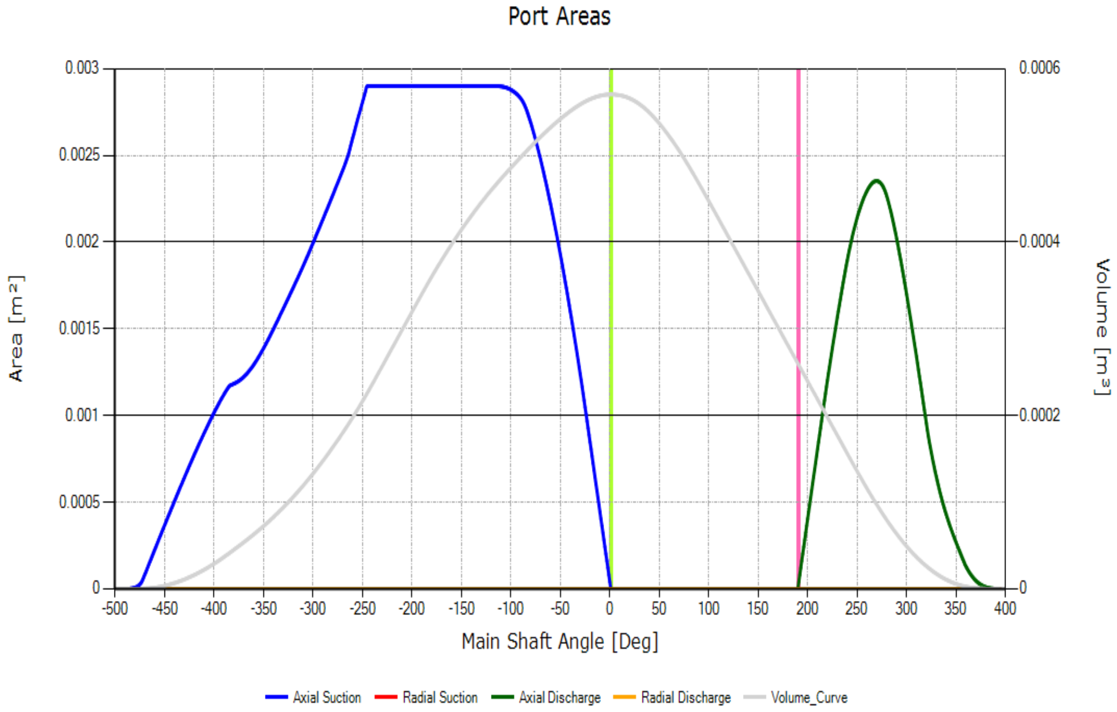
⊞ **High Pressure Port**

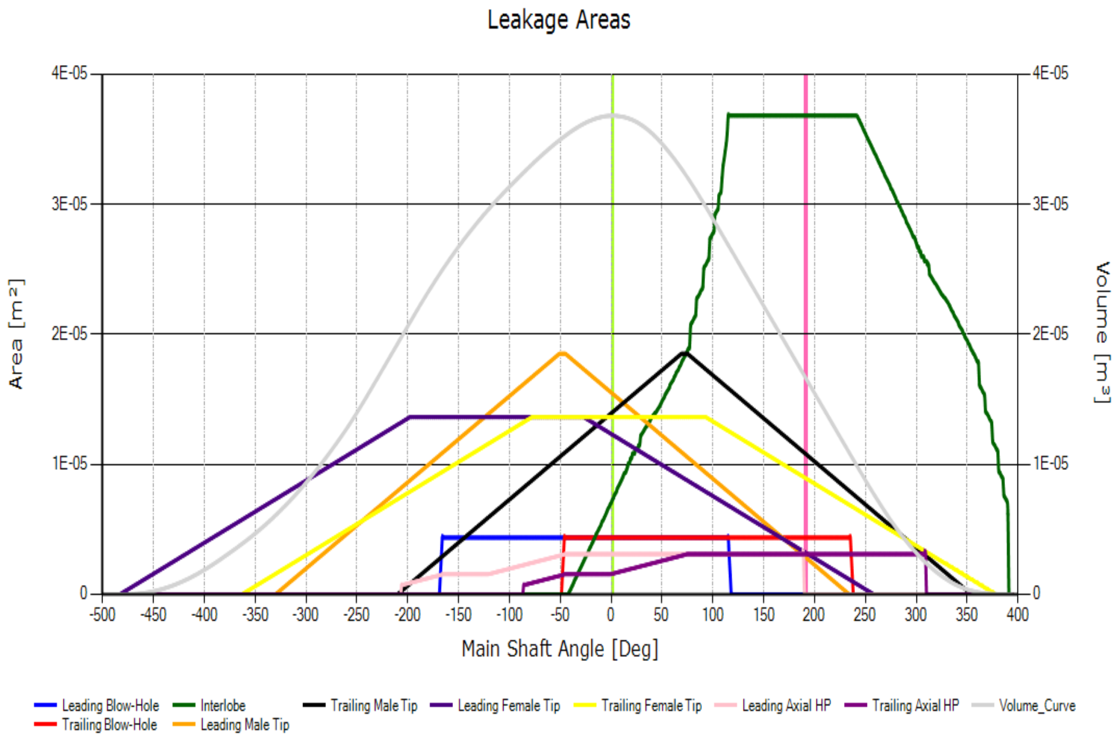
⊞ **High Pressure Reservoir**

⊟ **High Pressure Pipe**

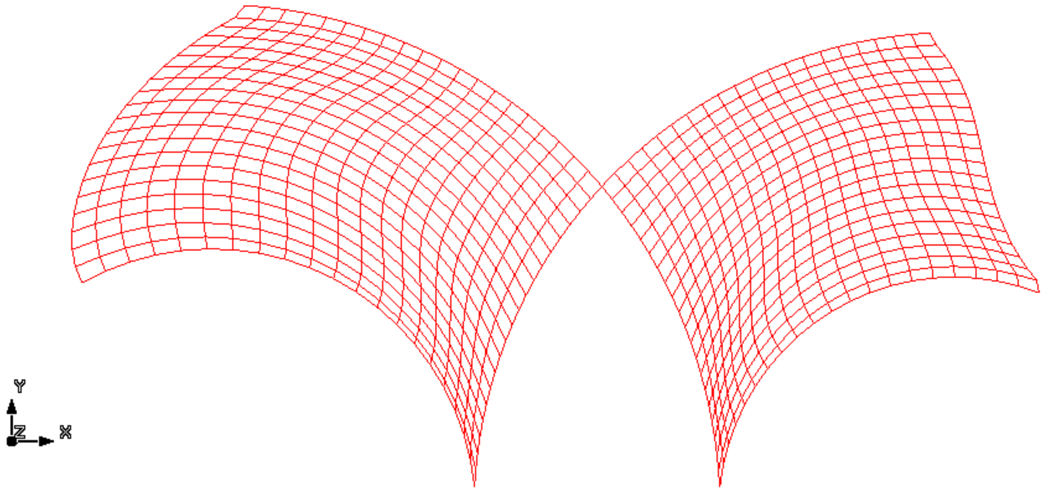
Diameter	70	mm
Length	200	mm

- Run Geometry calculation; Run Thermodynamics and Run Port Generation
- Inspect the results and compare with the results obtained previously
  a) Geometry Diagrams - Note the difference in the size of the discharge port, Compression angle and the size of radial gaps

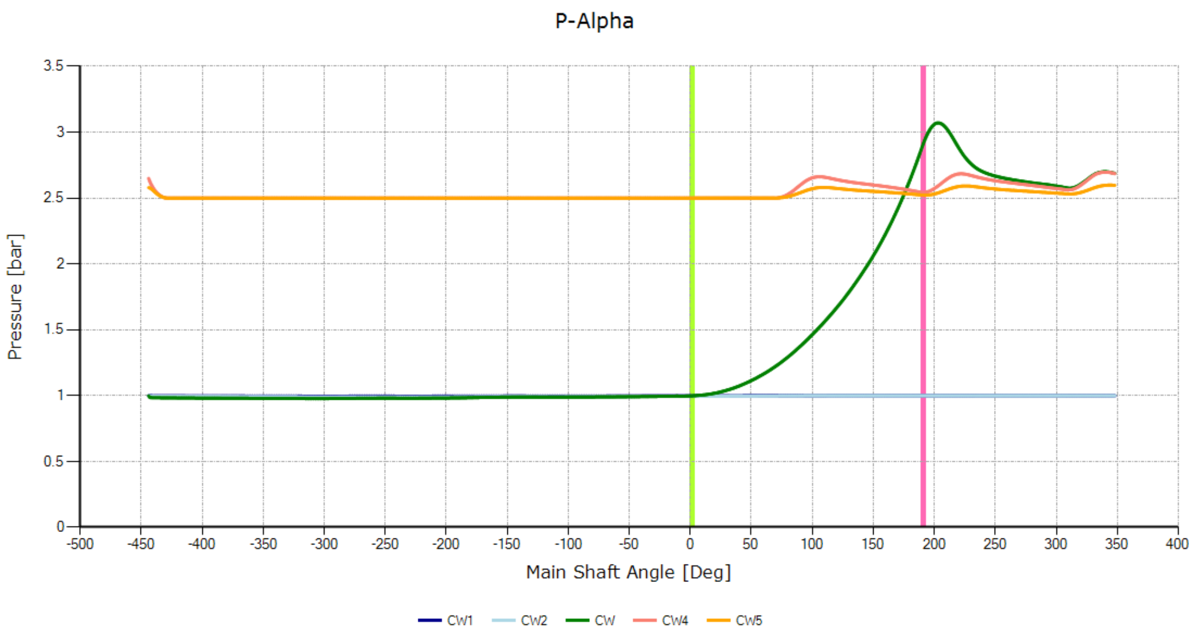

Port Areas
Area [m²]
Volume [m³]
Main Shaft Angle [Deg]
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.0006
0.0004
0.0002
0
-500 -450 -400 -350 -300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400
Axial Suction
Radial Suction
Axial Discharge
Radial Discharge
Volume_Curve


Leakage Areas
Area [m²]
Volume [m³]
Main Shaft Angle [Deg]
4E-05
3E-05
2E-05
1E-05
0
-500 -450 -400 -350 -300 -250 -200 -150 -100 -50 0 50 100 150 200 250 300 350 400
Leading Blow-Hole
Trailing Blow-Hole
Interlobe
Leading Male Tip
Trailing Male Tip
Leading Female Tip
Trailing Female Tip
Leading Axial HP
Trailing Axial HP
Volume_Curve

b) Note the difference in the size and shape of the discharge port



c) Note the difference in the thermodynamic performance
The compressor now over compresses but due to larger flow area behind the compressor introduces lower losses in the discharge reservoir and pipes and therefore lower pressure.



d) Inspect Thermodynamic report

```
SCORG - Thermodynamic Performance Calculation

          Date: 20/03/2021 22:38:23


Gas properties
     M   = 28.97 kmol/kg        Cp/Cv = 1.4
     R   = 287   J/kgK          Z     = 1

Machine: Oil Free Compressor
     Lobe combination   : 3/5
     Size               : 127/160 22
     Mechanical seals   : 1

==============================================

Tinl = 19.86 degC      Tout = 143.76 degC
Pinl = 1     bar       Pout = 2.5    bar
Moil = 0     kg/s      Toil = 40.01  degC
                       Poil = 7      bar

Volume Index Vi        = 2.2
Pressure Ratio Pi      = 3.02
Speed                  = 12000 rpm
Tip speed              = 80    m/s

Volume flow rate       = 16.32   m3/min
                       = 979.2   m3/h
Mass flow rate         = 1164.48 kg/h
Volumetric efficiency  = 79.47   %

Power (excl. gearbox)  = 46.52   kW
                       = 62.38   HP
Specific power         = 2.85    kW/m3/min
Adiabatic efficiency   = 61.24   %

Theoretical mass flow  = 1465.22 kg/h
Discharge mass flow    = 1164.48 kg/h
```

4.3 Calculating oil free case for variety of operating conditions

To calculate multiple parameters thermodynamic case, please set following parameters

⊟ **Profile Setup**

Profile Choice	User Sp...	
Axis Distance	93	mm
Z1	3	
Z2	5	
GAPI	0.18	mm
GAPR	0.18	mm
GAPA	0.05	mm
Clearance Distribution	Clearences..	

⊞ **User Profile**

⊞ **Rotor Configuration**

⊟ **Machine Configuration**

Machine Type	Compre...	
N Gate	1	
Compression Start	0	Deg
Compression End	162	Deg
Volume Index	1.8	
E Rotor	211	GPa
αL Rotor	1E-05	m/m/℃
E Casing	211	GPa
αL Casing	1E-05	m/m/℃

⊞ **Restraints**

⊞ **Rotor Movements**

The results will be obtained for speeds from 9000 to 15750 rpm and pressures from 1.5 to 2.5 bar.

⊟ **Working Conditions**

Wtip	60	m/s
Rotor Speed	9000	RPM
P0	1	bar
Pr	1.5	bar
T0	20	℃
Tr	76.85	℃
Tevp	-5.15	℃
Tcond	39.85	℃
T Ambient	19.85	℃
Include heat transfer	No	
X	1	

⊞ **Working Fluid**

⊞ **Fluid Injection**

⊞ **Bearings and seals**

⊞ **Additional Injection Port**

⊟ **Thermodynamic Controls**

⊞ **Working Conditions**

⊞ **Working Fluid**

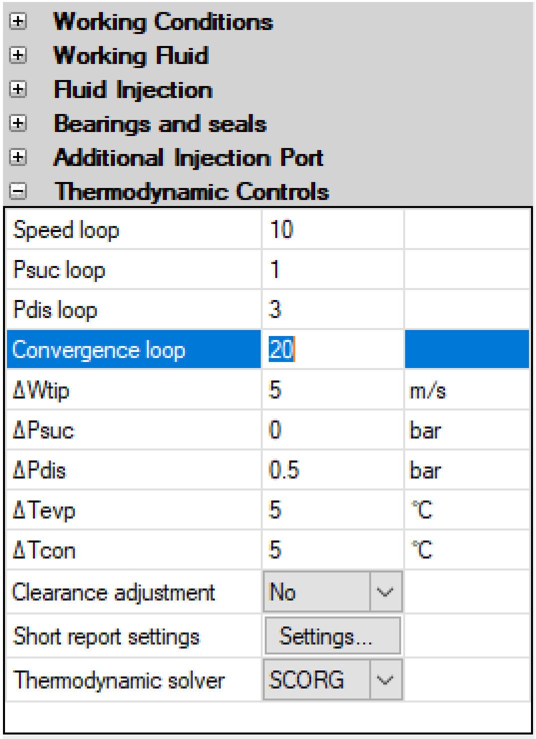
⊟ **Oil Injection**

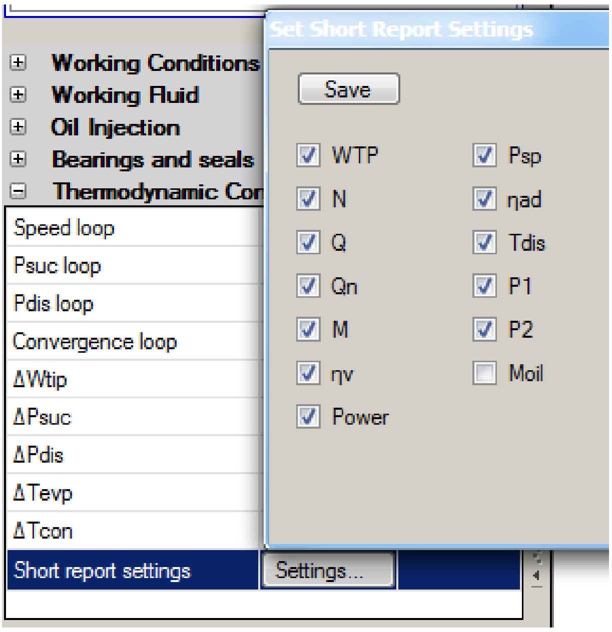
Oil Injection	Off	
P	7	bar
T	40	℃
Injection Angle	60	Deg
Axial Position	100	mm
Port Diameter	5	mm
Doil	0.01	mm
CpOil	2000	J/(kg.K)
ρ	845	kg/m³
Viscosity of Oil	5E-05	m²/s

⊟ **Bearings and seals**

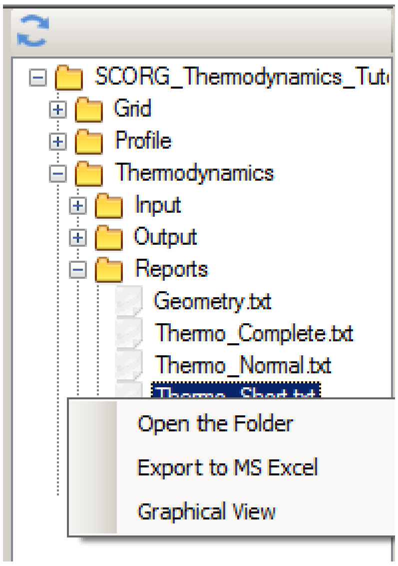
Bearing Type	Rolling ...	
N Shaft	4	
Seal Ploss	300	W/1000...
Diameter Factor	0.023	
Speed Factor	0.001	

⊞ **Thermodynamic Controls**





Once the results are calculated, these can be viewed in the report as presented before or exported to excel where these could be used for preparing diagrams etc. To export in excel select the Thermo_Short.txt report from the Case tree, click on the right mouse button and select ‘Export to excel’ as shown in the figure



The results will be in the form shown below.

4.4 Calculating Oil injected case

Majority of screw compressors today are oil injected. Oil is injected to seal, cool and lubricate the rotors. Rotors are in direct contact. Oil injected compressors achieve higher pressure ratios and lower discharge temperatures, rotate at lower speeds than oil free compressors and allow clearances to be much lower than in oil free machines.

The same compressor will be used for oil injection calculation.

The profile will be set with nominal clearance of 50 micrometers, Volume index will be set to 5, tip speed to 40m/s, discharge pressure to 8 bar. Oil injection will be switched on, Oil injection pressure set to 7 bar through oil injection port positioned at 60 degrees of the rotation of the male rotor from closing of the suction port and oil will be injected at 40 degC.

Please set the values as indicated in the figure below

Profile

Profile Setup		
Profile Choice	User Sp...	
Axis Distance	93	mm
Z1	3	
Z2	5	
GAPI	0.05	mm
GAPR	0.05	mm
GAPA	0.05	mm
NL	5	
NR	0	

Geometry

Machine Configuration		
Machine Type	Screw ...	
N Gate	1	
Compression Start	0	Deg
Compression End	259.899	Deg
Volume Index	5	
Angle of Radial Dischar...	0	Deg
E Rotor	211	GPa
αL Rotor	1E-05	m/m/°C
E Casing	211	GPa
αL Casing	1E-05	m/m/°C
Wall Roughness	0	mm

Domains

Low Pressure Pipe

Low Pressure Reservoir

Low Pressure Port

High Pressure Port

High Pressure Reservoir		
Diameter	75	mm
Length	75	mm

High Pressure Pipe		
Diameter	35	mm
Length	200	mm

Thermodynamics

⊟ **Working Conditions**

Wtip	40	m/s
Rotor Speed	6000	RPM
P0	1	bar
Pr	8	bar
T0	20	°C
Tr	76.85	°C
Tevp	-5.15	°C
Tcond	39.85	°C
T Ambient	19.85	°C
Include heat transfer	No	
X	1	

⊞ **Working Fluid**
⊞ **Fluid Injection**
⊞ **Bearings and seals**
⊞ **Additional Injection Port**
⊟ **Thermodynamic Controls**

⊞ **Working Conditions**
⊞ **Working Fluid**
⊟ **Fluid Injection**

Fluid Injection	Oil abs...	
P	7	bar
T	40	°C
Injection Angle	60	Deg
Axial Position	100	mm
Port Diameter	5	mm
Doil	0.01	mm
CpOil	2000	J/(kg.K)
ρ	845	kg/m³
Viscosity of Oil	1E-05	m²/s
Multiple injection holes	Setup	
Gas diluted in oil	0	%

⊞ **Bearings and seals**
⊞ **Additional Injection Port**
⊞ **Thermodynamic Controls**

⊞ **Working Conditions**
⊞ **Working Fluid**
⊞ **Fluid Injection**
⊟ **Bearings and seals**

Bearing Type	Rolling ...	
N Shaft	1	
Seal Ploss	300	W/1000...
Diameter Factor	0.023	
Speed Factor	0.001	

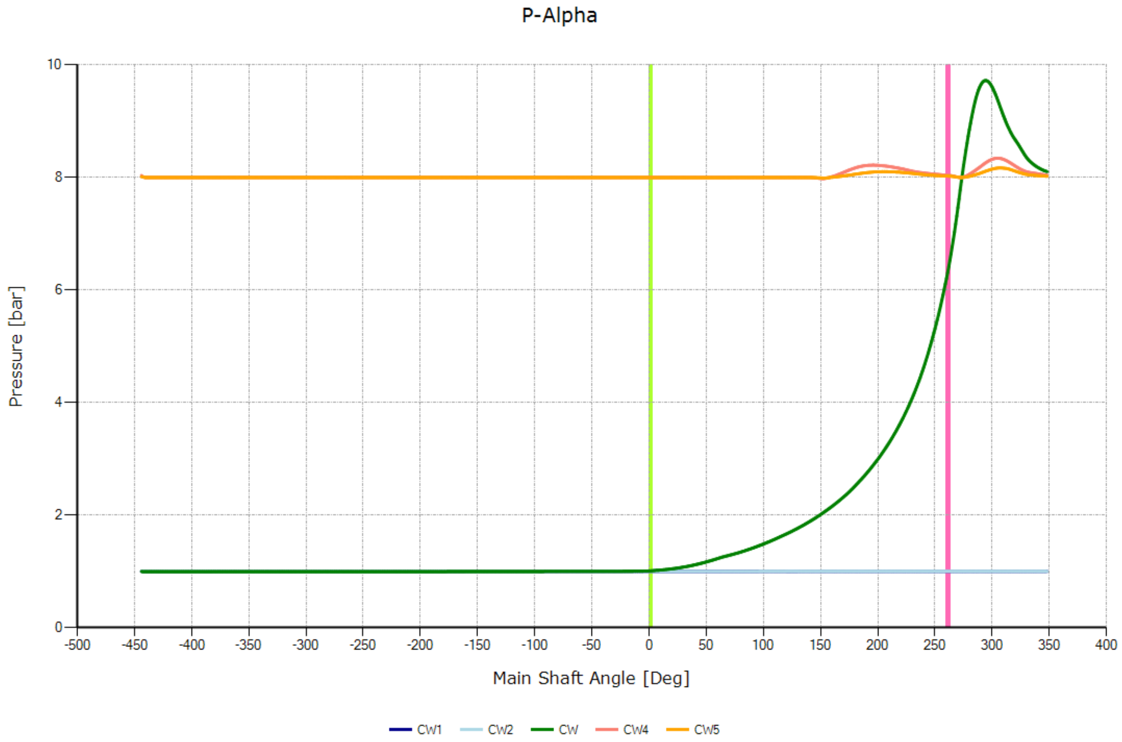
⊞ **Additional Injection Port**
⊞ **Thermodynamic Controls**

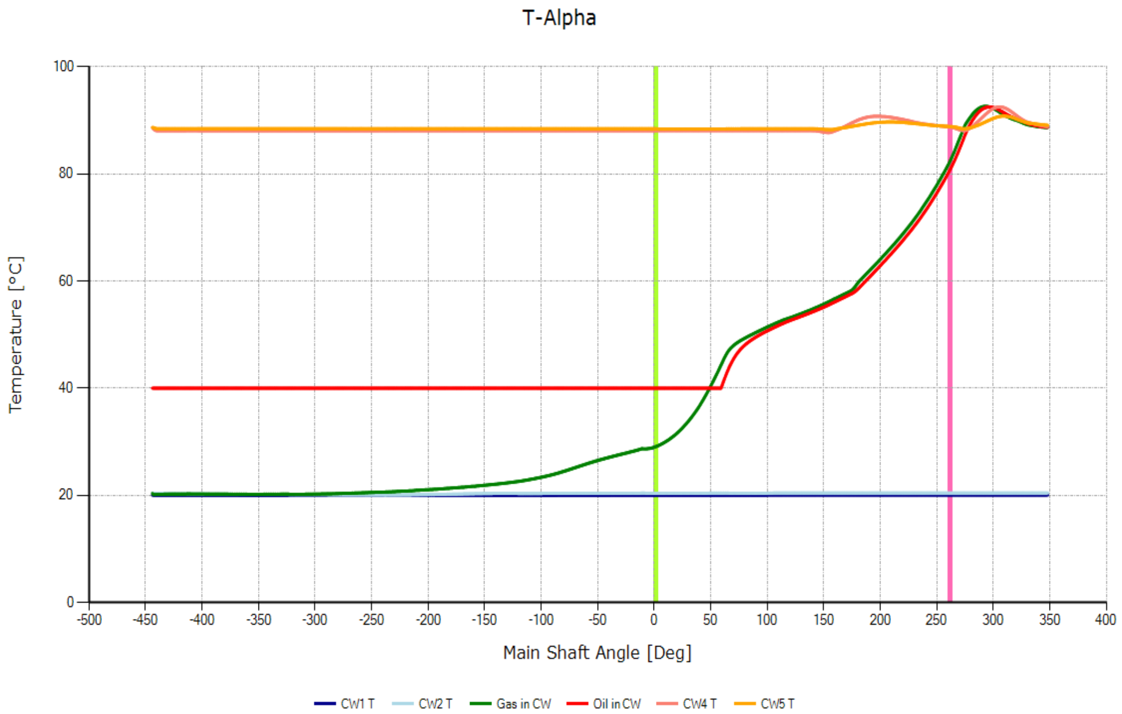
⊞ **Working Conditions**
⊞ **Working Fluid**
⊞ **Fluid Injection**
⊞ **Bearings and seals**
⊞ **Additional Injection Port**
⊟ **Thermodynamic Controls**

Speed loop	1	
Psuc loop	1	
Pdis loop	1	
Convergence loop	20	
ΔWtip	5	m/s
ΔPsuc	0	bar
ΔPdis	0.5	bar
ΔTevp	5	°C
ΔTcon	5	°C
Clearance adjustment	No	
Short report settings	Settings...	
Thermodynamic solver	SCORG	

- Calculate thermodynamics

View diagrams





Notice the red line which represents the oil in the working chamber. Oil is injected at 60 deg and is used to cool the air. Despite the discharge pressure reaching almost 9 bar, the discharge temperature is around 80 deg C.

The results displayed in the results window:

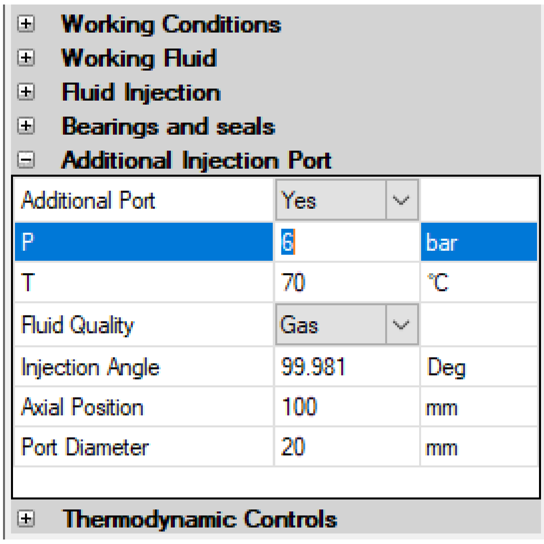
```
RPM       Flow[m3/min]    Pow[kW]      P1[b]      P2[b]       T2[oC]      Oil flow[kg/s]
6000    8.2763          54.68      1        8          85.75       0.3364
Indicated Power     [kW]:43.06776
Shaft Seal Power    [kW]:1.8
Bearing Power       [kW]:2.87728
Oil Drag Power      [kW]:6.93087
---------------------------------------------------
Total Shaft Power  [kW]:54.6759
Number of conv. loops :7

Time elapsed:   00:00:15.7901562
```

The report

```
SCORG - Thermodynamic Performance Calculation

          Date: 20/03/2021 22:57:02


Gas properties
     M   = 28.97 kmol/kg       Cp/Cv = 1.4
     R   = 287   J/kgK         Z     = 1

Machine: Oil Injected Compressor
     Lobe combination  : 3/5
     Size              : 127/160 50
     Mechanical seals  : 1

=============================================

Tinl = 20.01 degC      Tout = 85.75 degC
Pinl = 1     bar       Pout = 8     bar
Moil = 0.34  kg/s      Toil = 40.01 degC
                       Poil = 7     bar

Volume Index Vi        = 5
Pressure Ratio Pi      = 9.52
Speed                  = 6000 rpm
Tip speed              = 40   m/s

Volume flow rate       = 8.28   m3/min
                       = 496.8  m3/h
Mass flow rate         = 590.22 kg/h
Volumetric efficiency  = 80.61  %

Power (excl. gearbox)  = 54.68  kW
                       = 73.33  HP
Specific power         = 6.61   kW/m3/min
Adiabatic efficiency   = 71.65  %

Theoretical mass flow  = 732.24 kg/h
Discharge mass flow    = 590.22 kg/h
```

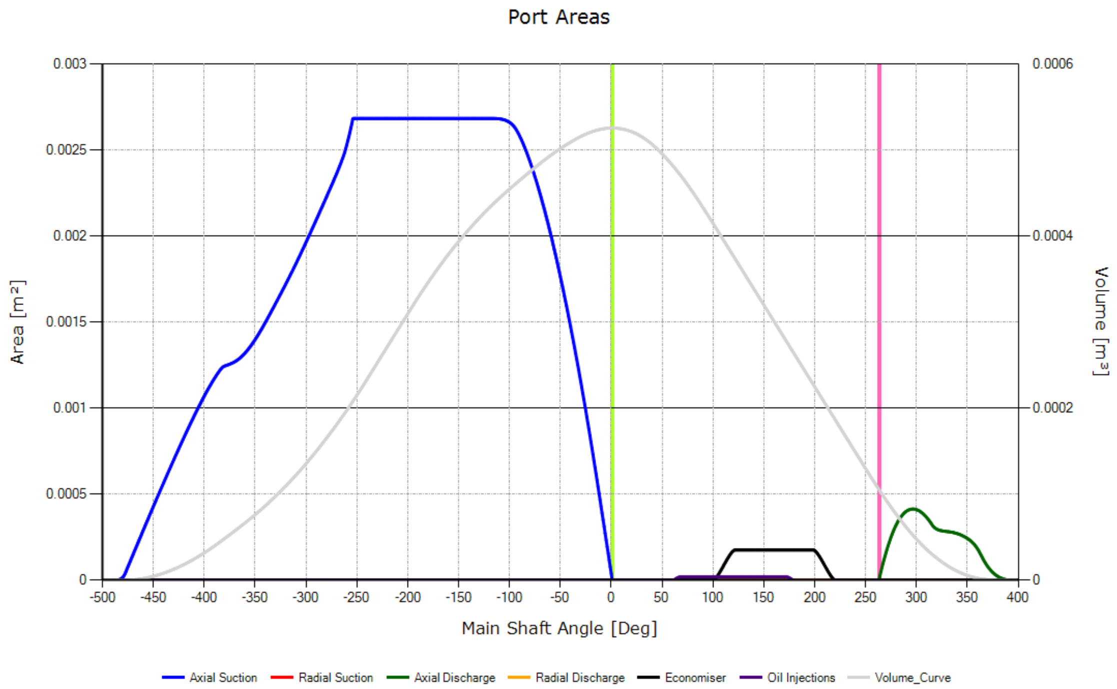
- Additional port

Often, oil injected screw compressor have additional injection port, which is in refrigeration called economizer port. IN SCORG, additional injection port is enabled through Thermodynamics->Additional Injection Port tab:



Additional Port	Yes	
P	6	bar
T	70	°C
Fluid Quality	Gas	
Injection Angle	99.981	Deg
Axial Position	100	mm
Port Diameter	20	mm

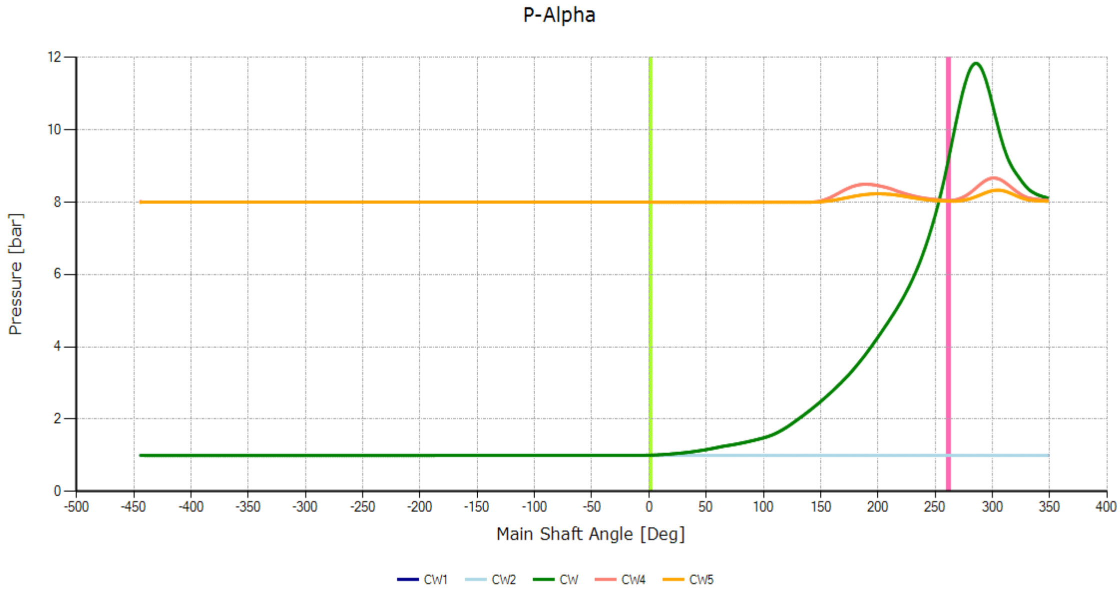
It is necessary to specify the position and size of the additional port as well as the pressure and temperature in the port. Before thermodynamics can be calculated, it is important to calculate geometry. The addional injection port is shown as exonomiser in the figure below

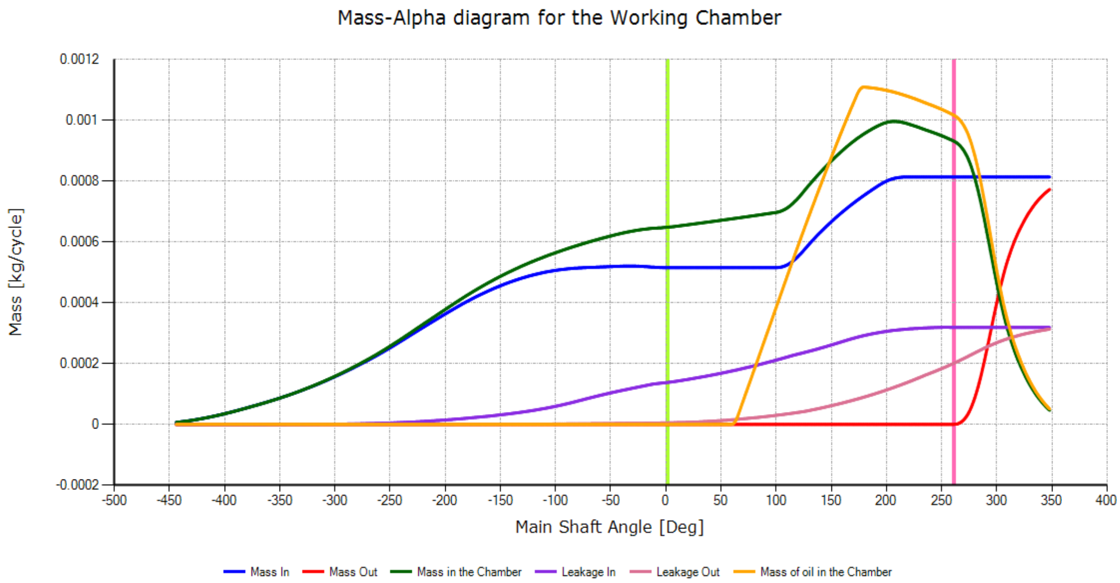


Once thermodynamics is calculated, it is possible to obeserve results trhough the thermodynamic diagrams below.

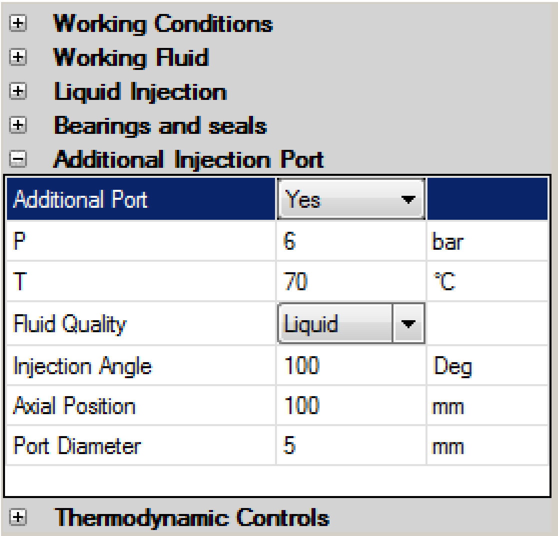
Notice the change in the pressure diagram where a sudden increase in the pressure can be observed from the angle of 100 deg.

The mass diagram below shows the increase of the mass in the working chamber.





The additional injection port can be also used for injection of additional liquid in the working domain. In oil injected compressors the liquid injected is oil. To enable oil injection instead gas/vapour injection through the additional injection port it is necessary to set Fluid quality to Liquid as shown in the figure below.



This same liquid selected in the Liquid injection input will be injected through the additional injection port. In this case it is oil. Since the injection liquid is much denser than the gas, the size of the port is normally smaller as shown in the figure.

The results of thermodynamics calculation without the additional oil injection are shown below>

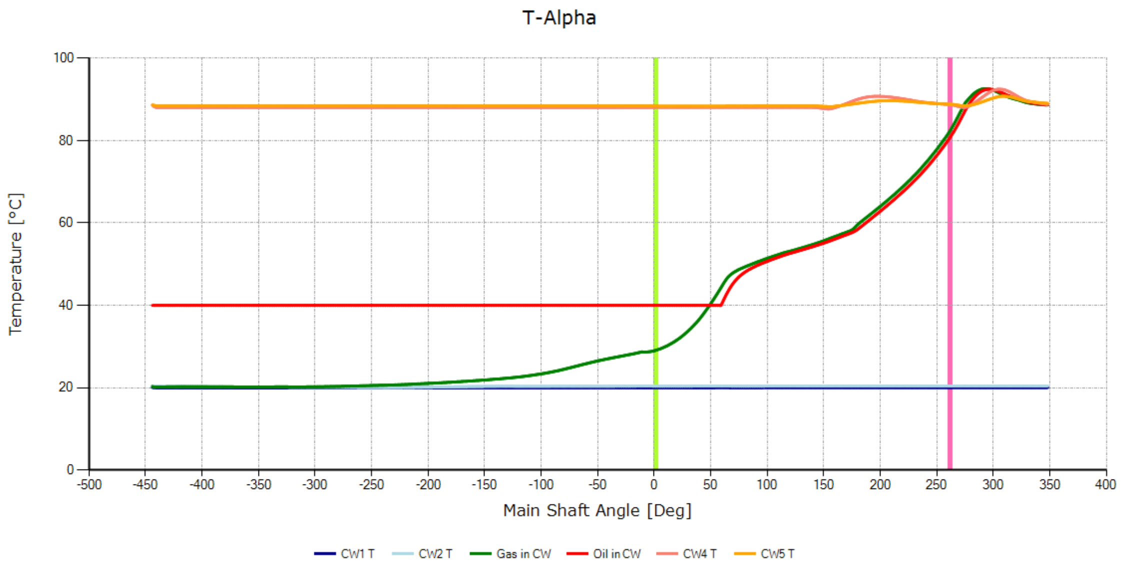
```
RPM      Flow[m3/min]    Pow[kW]        P1[b]       P2[b]         T2[oC]       Oil flow[kg/s]
6000    8.2763          54.68       1      8         85.75         0.3364
Indicated Power      [kW]:43.06776
Shaft Seal Power     [kW]:1.8
Bearing Power        [kW]:2.87728
Oil Drag Power       [kW]:6.93087
----------------------------------------------------
Total Shaft Power  [kW]:54.6759
Number of conv. loops :7

Time elapsed:   00:00:15.7901562
```

Once the additional oil injection is enabled, the quantity of oil and the performance will change dramatically:

```
RPM      Flow[m3/min]    Pow[kW]        P1[b]       P2[b]         T2[oC]       Oil flow[kg/s]
6000    7.6907          58.46       1      8         210.7         0.5898
Indicated Power      [kW]:53.04531
Shaft Seal Power     [kW]:1.8
Bearing Power        [kW]:3.54407
Oil Drag Power       [kW]:0.06858
----------------------------------------------------
Total Shaft Power  [kW]:58.45796
Number of conv. loops :6

Time elapsed:   00:00:09.7587221

=== PROGRAM THERMODYNAMICS END ===
```

Almost double amount of oil is injected which resulted in the smaller indicated power but the drag losses due to oil in the chamber increased leading to overall slightly higher power.

The discharge temperature also changed as shown in the figure below.

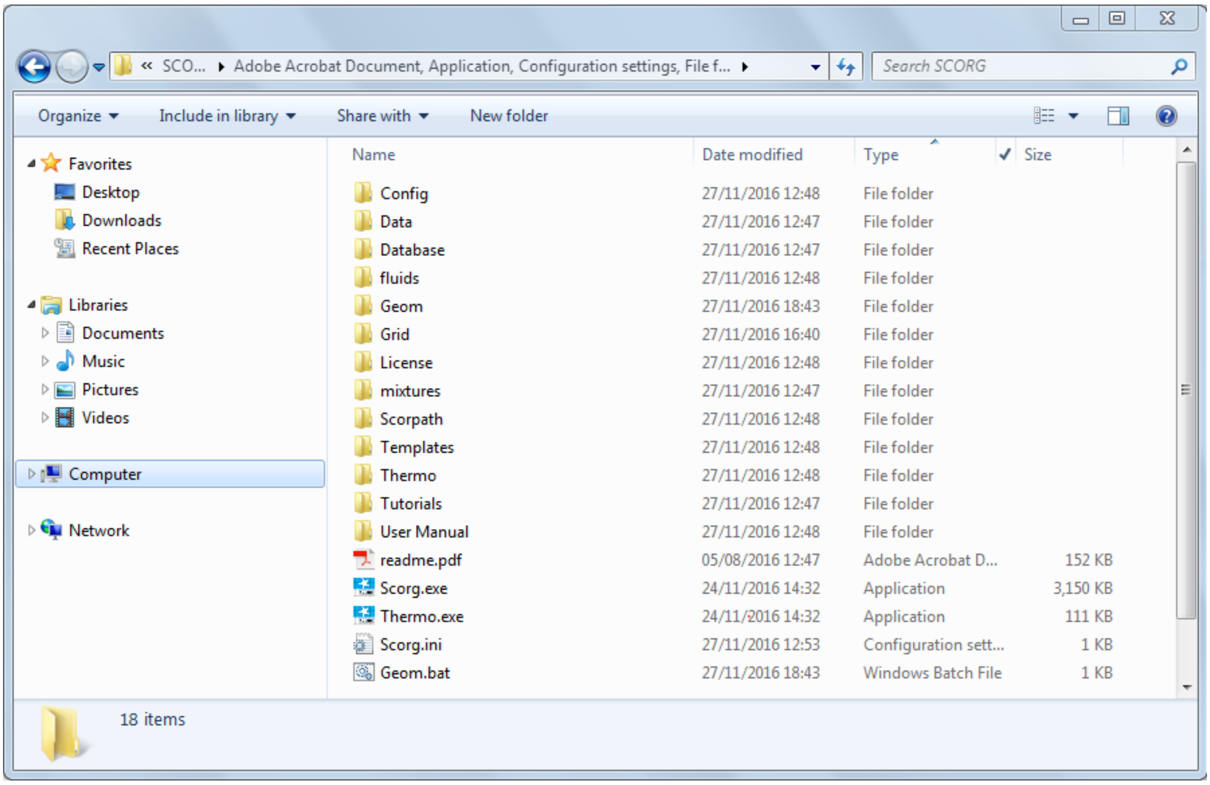


5 Thermodynamics in batch mode

Thermodynamic calculations can also be run in a batch mode. This means that calculations can be performed outside of SCORG Graphical User Interface for the convenience of automatic variation of parameters and in particular for optimization of screw compressors.

SCORG program operates in two folders, namely the Installation Folder and the Project Folder.

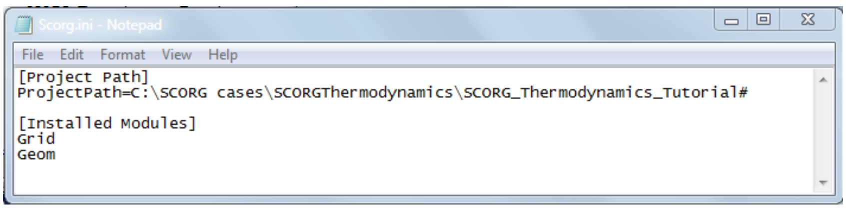
The Installation folder is the folder in which SCORG was originally installed. Usually that will be C:\SCORG or C:\Program Files\SCORG. The example of the SCORG Installation folder is shown in the figure below.



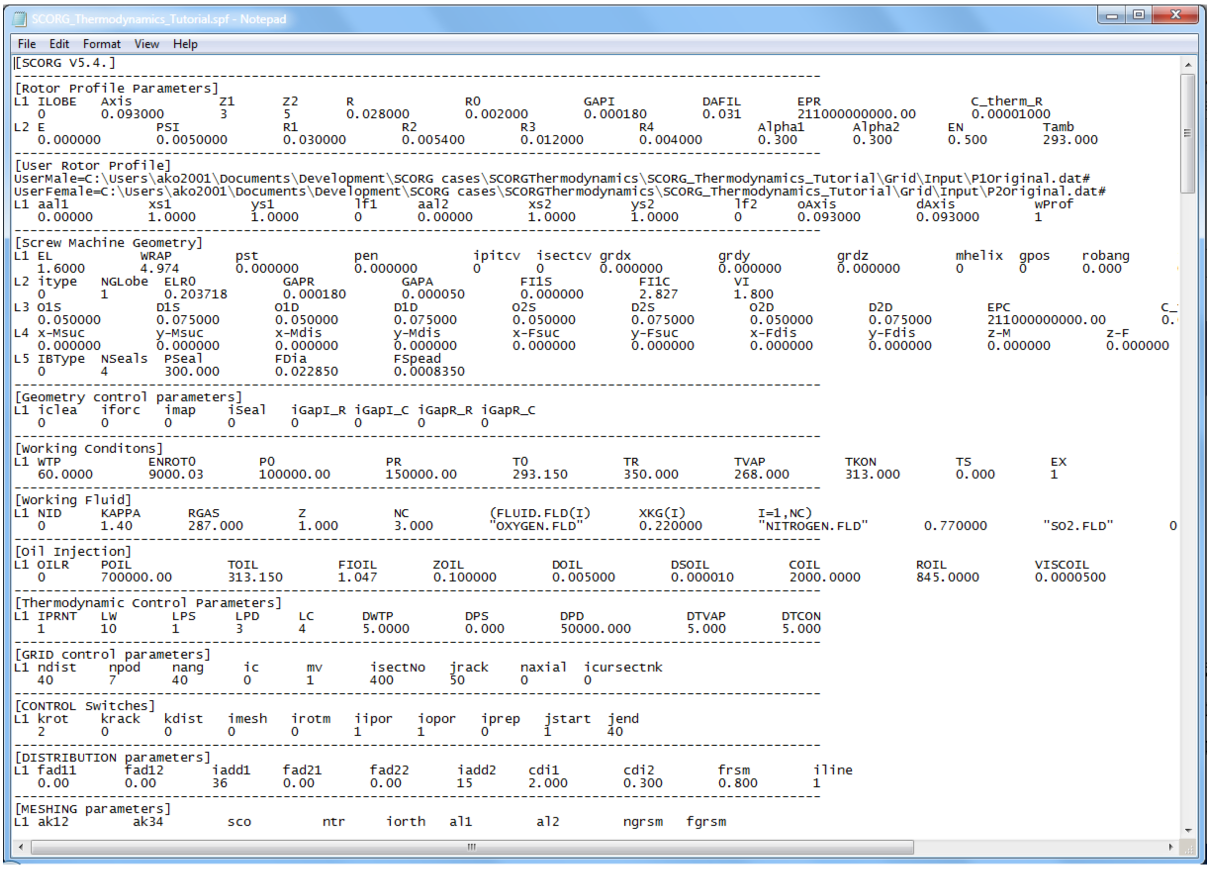
The files required to run thermodynamics in the batch mode from the Installation folder are:

- Thermo.exe
- Geom.bat

The project files are stored in the Project Folder. To identify or modify the active Project folder, please open Scorg.ini file from the Installation folder in any text editor, for example Notepad as shown in the figure below. The project Folder is shown as Project Path.



Open the Tutorial folder SCORG_Thermodynamics and identify file named: SCORG_Thermodynamics_Tutorial.spf. This file is textual file which contains all input parameters for the Project you are working on. Parameters are grouped in smaller set of parameters related to an activity, namely, profile definition, machine geometry, thermodynamics and grid.

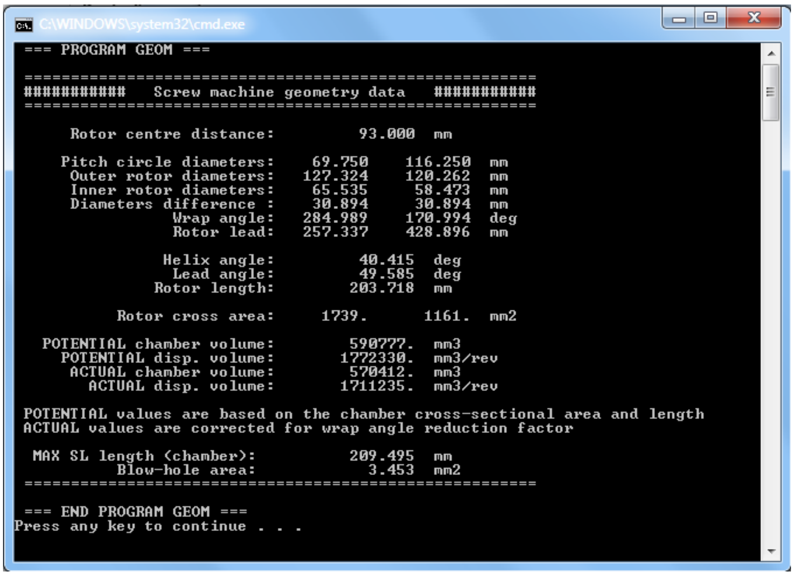


```
SCORG_Thermodynamics_Tutorial.spf - Notepad
File  Edit  Format  View  Help
[SCORG V5.4.]
--------------------------------------------------------------------------------
[Rotor Profile Parameters]
L1 ILOBE   Axis          Z1      Z2      R          R0         GAPI       DAFIL    EPR                C_therm_R
   0       0.093000      3       5       0.028000   0.002000   0.000180   0.031    211000000000.00    0.00001000
L2 E            PSI          R1           R2           R3           R4           Alpha1   Alpha2   EN      Tamb
   0.000000     0.0050000    0.030000     0.005400     0.012000     0.004000     0.300    0.300    0.500   293.000
--------------------------------------------------------------------------------
[User Rotor Profile]
UserMale=C:\Users\ako2001\Documents\Development\SCORG cases\SCORGThermodynamics\SCORG_Thermodynamics_Tutorial\Grid\Input\P1Original.dat#
UserFemale=C:\Users\ako2001\Documents\Development\SCORG cases\SCORGThermodynamics\SCORG_Thermodynamics_Tutorial\Grid\Input\P2Original.dat#
L1 aal1        xs1        ys1        lf1     aal2       xs2        ys2        lf2    oAxis        dAxis        wProf
   0.00000     1.0000     1.0000     0       0.00000    1.0000     1.0000     0      0.093000     0.093000     1
--------------------------------------------------------------------------------
[Screw Machine Geometry]
L1 EL         WRAP     pst         pen         ipitcv  isectcv grdx        grdy        grdz        mhelix  gpos  robang
   1.6000     4.974    0.000000    0.000000    0       0       0.000000    0.000000    0.000000    0       0     0.000
L2 itype   NGLobe  ELR0        GAPR        GAPA        FI1S        FI1C        VI
   0       1       0.203718    0.000180    0.000050    0.000000    2.827       1.800
L3 O1S         D1S         O1D         D1D         O2S         D2S         O2D         D2D         EPC                 C_
   0.050000    0.075000    0.050000    0.075000    0.050000    0.075000    0.050000    0.075000    211000000000.00     0.
L4 x-Msuc      y-Msuc      x-Mdis      y-Mdis      x-Fsuc      y-Fsuc      x-Fdis      y-Fdis      z-M         z-F
   0.000000    0.000000    0.000000    0.000000    0.000000    0.000000    0.000000    0.000000    0.000000    0.000000
L5 IBType  NSeals  PSeal       FDia        FSpead
   0       4       300.000     0.022850    0.0008350
--------------------------------------------------------------------------------
[Geometry control parameters]
L1 iclea   iforc   imap    iSeal   iGapI_R iGapI_C iGapR_R iGapR_C
   0       0       0       0       0       0       0       0
--------------------------------------------------------------------------------
[Working Conditons]
L1 WTP         ENROT0      P0           PR           T0          TR          TVAP        TKON        TS        EX
   60.0000     9000.03     100000.00    150000.00    293.150     350.000     268.000     313.000     0.000     1
--------------------------------------------------------------------------------
[Working Fluid]
L1 NID     KAPPA     RGAS        Z           NC          (FLUID.FLD(I)      XKG(I)         I=1,NC)
   0       1.40      287.000     1.000       3.000       "OXYGEN.FLD"       0.220000       "NITROGEN.FLD"      0.770000        "SO2.FLD"       0
--------------------------------------------------------------------------------
[Oil Injection]
L1 OILR    POIL          TOIL        FIOIL       ZOIL        DOIL        DSOIL       COIL          ROIL          VISCOIL
   0       700000.00     313.150     1.047       0.100000    0.005000    0.000010    2000.0000     845.0000      0.0000500
--------------------------------------------------------------------------------
[Thermodynamic Control Parameters]
L1 IPRNT   LW      LPS     LPD     LC      DWTP        DPS         DPD           DTVAP       DTCON
   1       10      1       3       4       5.0000      0.000       50000.000     5.000       5.000
--------------------------------------------------------------------------------
[GRID control parameters]
L1 ndist    npod    nang     ic       mv       isectNo  jrack    naxial  icursectnk
   40       7       40       0        1        400      50       0       0
--------------------------------------------------------------------------------
[CONTROL Switches]
L1 krot    krack   kdist   imesh   irotm   iipor   iopor   iprep   jstart  jend
   2       0       0       0       0       1       1       0       1       40
--------------------------------------------------------------------------------
[DISTRIBUTION parameters]
L1 fad11      fad12      iadd1    fad21      fad22      iadd2    cdi1       cdi2       frsm       iline
   0.00       0.00       36       0.00       0.00       15       2.000      0.300      0.800      1
--------------------------------------------------------------------------------
[MESHING parameters]
L1 ak12        ak34        sco        ntr      iorth   al1        al2        ngrsm   fgrsm
```

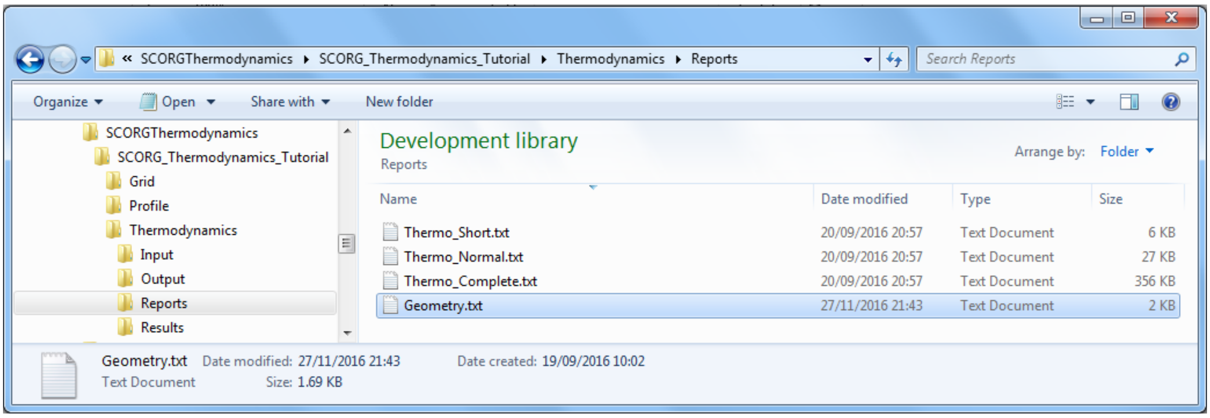
It is always recommended that a Project case is set up using SCORG GUI as explained throughout this tutorial first so that all parameters in input files are set properly. Then the parameters in the .spf file can be changed as required. Please do not forget to save file before thermodynamics is run.

Also, similarly to the case run through GUI, every time some of geometric inputs is changed, I is necessary to run geometry calculation.

To run geometry calculation use Geom.bat file form the Install Folder. The results of calculation will be shown on the screen in window similar to the one shown in the figure below.



The same results could be viewed any time by opening a report named Gemoetry.txt in the folder shown below.

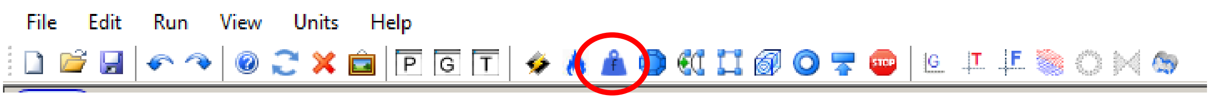


Equally, thermodynamics is run using the file Thermo.exe. Reports are stored in the same report folder in the Project Folder where geometry.txt was also located.

NOTE: Using geometry and thermodynamic calculation in batch mode requires good knowledge on the possible combination of input parameters. The inadequate combination of input parameters will lead to incorrect results.

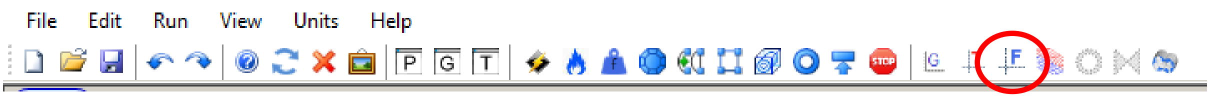
6 Calculation of bearing forces

Once Thermodynamic results are obtained, bearing forces may be calculated. Calculation of bearing forces is run using the button indicated below in red circle.

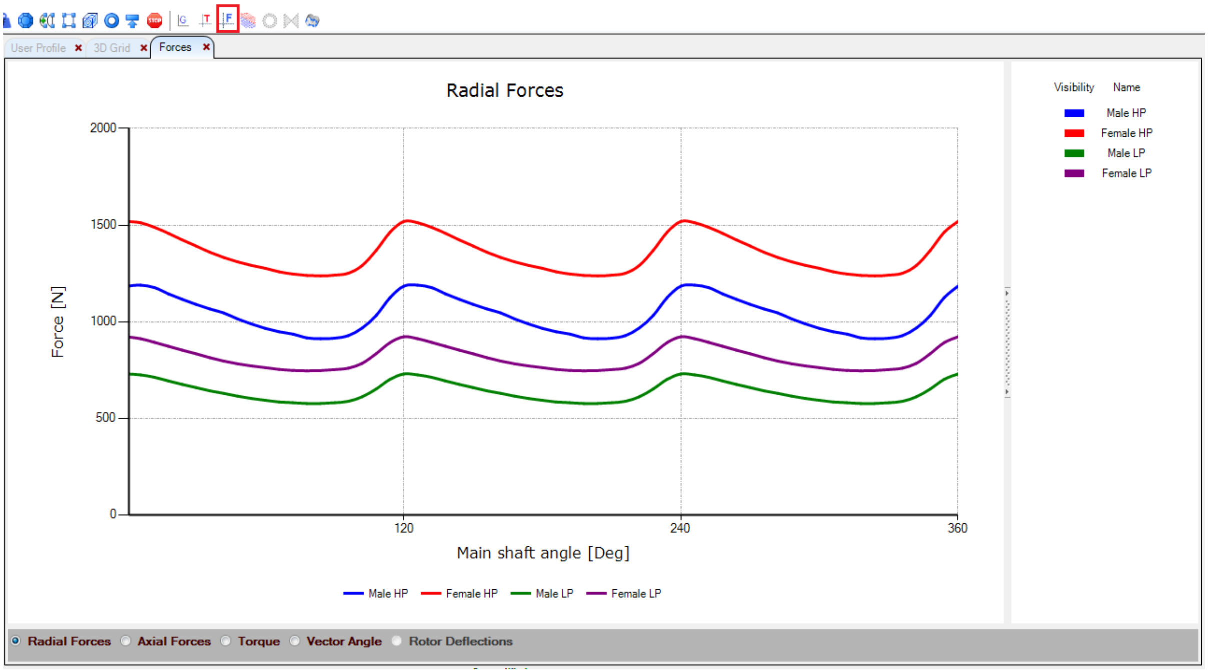


This command also initiates the boundary map generation which calculates distribution of pressure and temperature on the rotors and casing.

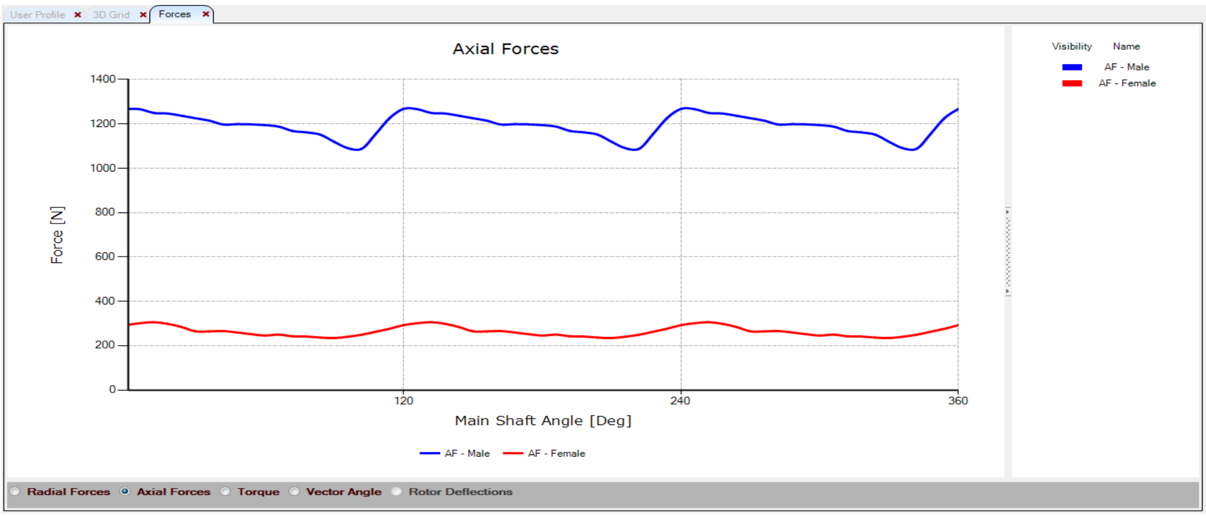
The force diagrams are activated using the icon circled below. Alternatively these could be initiated through the drop down view menu or by pressing F12 button.



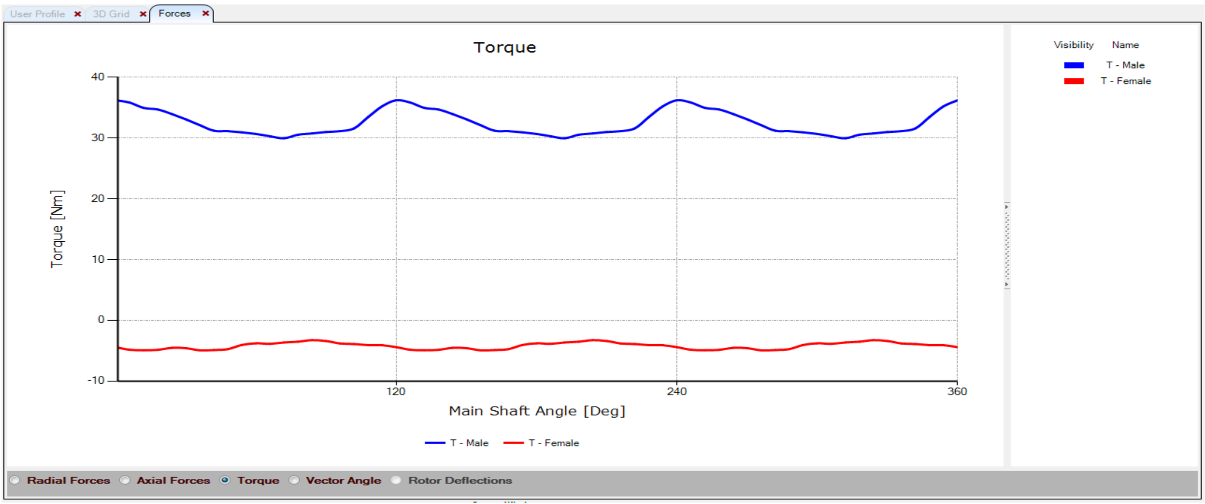
Radial forces on the rotors at Low pressure (LP) and high pressure (HP) end bearings:



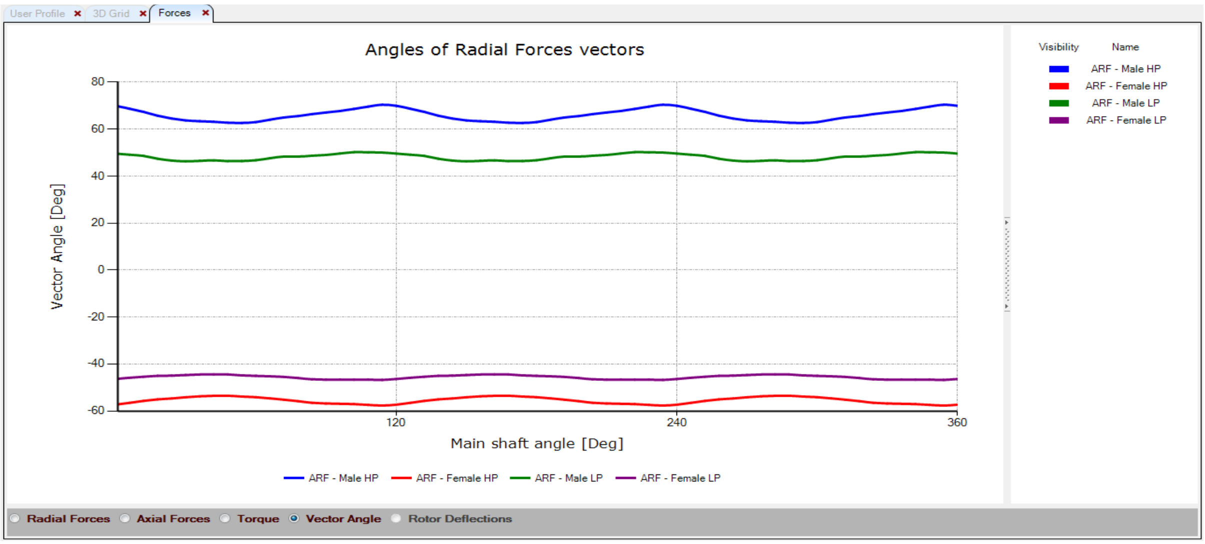
- forces on the rotors:



- Torque on the male and female rotors:



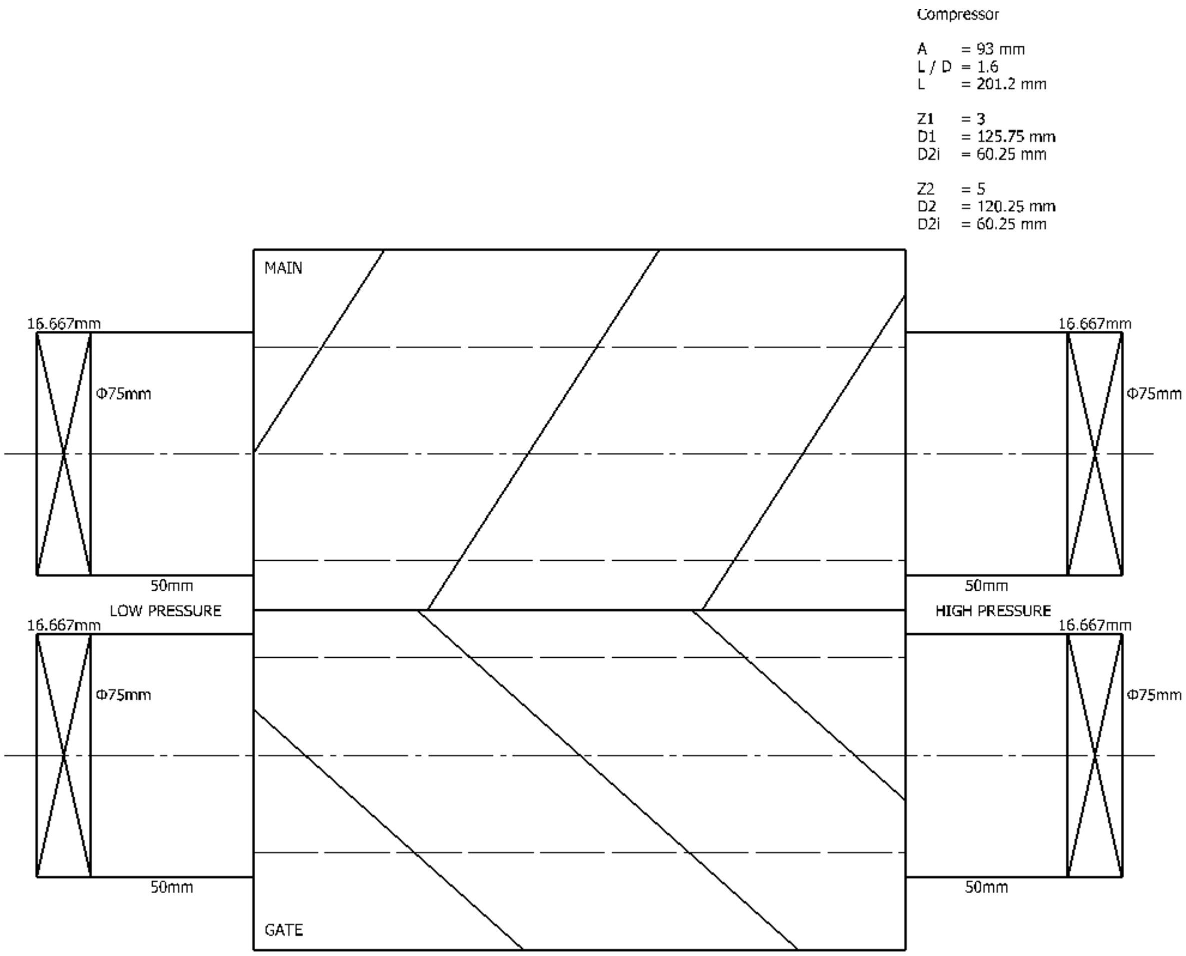
- Vector Angles for radial forces:



Please note that the forces on bearings depend on the relative position of bearings to the machine low and high pressure ends. The position of bearings is set using the Geometry->Restraints table below:

Restraints		
O1S	50	mm
D1S	75	mm
O1D	50	mm
D1D	75	mm
O2S	50	mm
D2S	75	mm
O2D	50	mm
D2D	75	mm

Graphical representation of bearing positions is shown in the Restraints Input window below. This window opens automatically when the Restraints command. For more details on how the forces are calculated please refer to the User Manual Chapter 8.11.



The report on calculation of forces is accessible through drop down View>Report menu in the form below. It reports on the configuration, thermodynamics and forces.

```
=======================================================
#########    Screw compressor geometry data    ##########
=======================================================
          Date: 25-Jun-2017   Time: 18:50:35

     Rotor centre distance:         93.000  mm
           Number of lobes:      3          5
     Pitch circle diameters:    69.750     116.250   mm
      Outer rotor diameters:   125.317     120.181   mm
      Inner rotor diameters:    65.353      60.216   mm
      Diameters difference :    29.982      29.983   mm
                 Wrap angle:   306.647     183.988   deg
                 Rotor lead:   250.106     416.843   mm
                Helix angle:         41.223  deg
                 Lead angle:         48.777  deg
               Rotor length:        213.039  mm
=======================================================
 Thermodynamic Results
    Gas properties
         M  = 28.97 kmol/kg       Cp/Cv = 1.4
         R  = 287   J/kgK         Z     = 1

    Machine: Oil Free Compressor
```

```
        Lobe combination  : 3/5
        Size              : 125/170 18
        Mechanical seals  : 4
   ==============================================
   Tinl = 19.86 degC      Tout = 199.73 degC
   Pinl = 1     bar       Pout = 4      bar
   Moil = 0     kg/s      Toil = 36.86  degC

   Volume Index Vi        = 1.8
   Pressure Ratio Pi      = 2.28
   Speed                  = 12344.5 rpm
   Tip speed              = 81      m/s

   Volume flow rate       = 15.66   m3/min
                          = 939.6   m3/h
   Mass flow rate         = 1117.44 kg/h
   Volumetric efficiency  = 77.04   %

   Power (excl. gearbox)  = 83.05   kW
                          = 111.37  HP
   Specific power         = 5.3     kW/m3/min
   Adiabatic efficiency   = 53.46   %

   Theoretical mass flow  = 1450.43 kg/h
   Discharge mass flow    = 1117.44 kg/h
   Suction mass flow      = 1347.96 kg/h
   Leakage mass flow      = 230.52  kg/h
=======================================================
########   Screw compressor bearing forces   ########
=======================================================
           Date: 25-Jun-2017   Time: 18:50:36

                        Male        Female
  Radial force HP:   1463.448    1857.830   N
  Radial force LP:    849.012    1061.457   N
  Vector angle HP:     60.652     -52.302   deg
  Vector angle LP:     44.619     -43.455   deg
  Axial  force   :   1641.678     375.738   N
  Torque         :     44.447      -6.355   Nm
 ======================================================
```

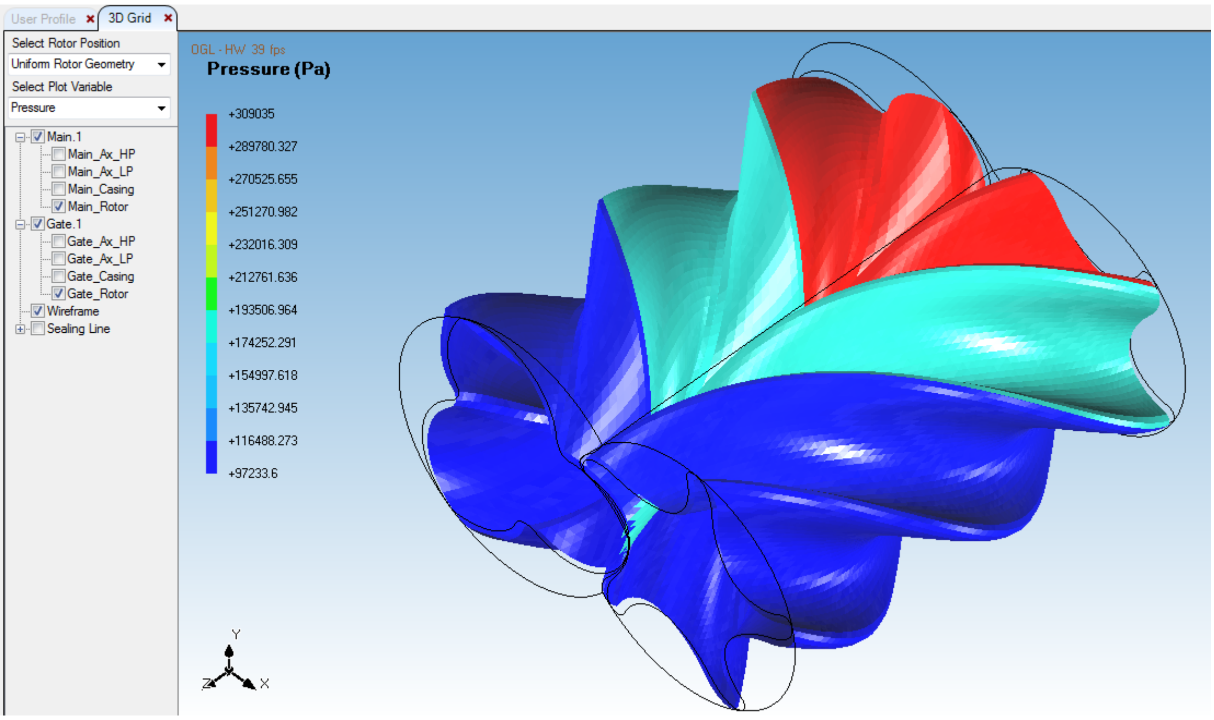
7 Thermodynamic 3D Results

The thermodynamic results od pressure and temperature distribution on the surface of rotors are used as initial and boundary conditions for CFD (Computational Fluid Dynamics) and structural analysis (FEA). These boundary pressures and temperatures can be graphically shown in 3D view on the surface of rotors and casing. To obtain results for both boundary conditions and 3D thermodynamic results, it is necessary to perform calculation of boundary distribution which is in detail explained in 10.15. Details about principles of calculation of boundary conditions are given in Paper Buckney et all, 2016. Boundary conditions are calculated together with the force calculation as described in Chapter 6.

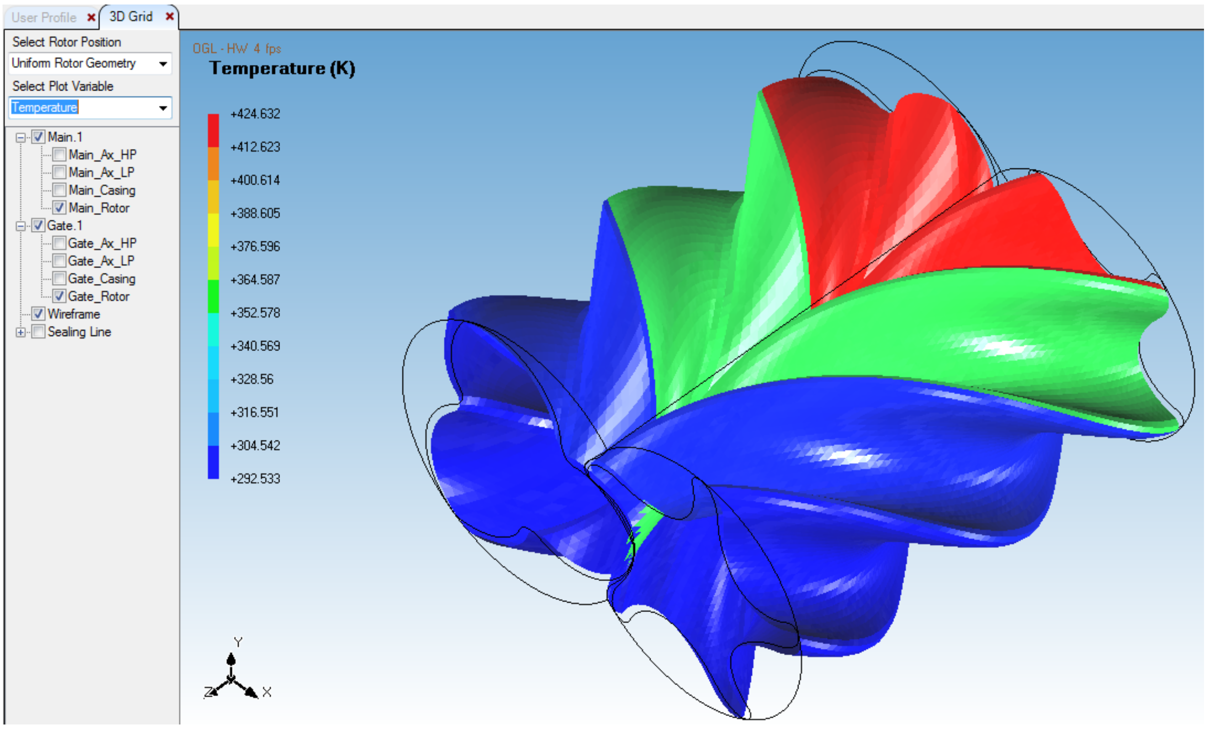
Once calculated, the 3D thermodynamic view icon shown in green above will activate. Position the mouse pointer to that icon and click on the left mouse button to activate 3D display.

Next three screenshots show the available diagrams:

- Example of pressure distribution on the surface of rotors and in the working domain:



- Example of temperature distribution on the surface of rotors



Pressure and temperature in the working domain shown above are suitable for initial condition for Computational Fluid dynamics. These could be imported in any CFD software from ASCII files based on which these diagrams are made. These are:

- Test Case>Thermodynamics>Output>Mapping>Surf_p_R1_HOME.txt for pressure distribution on the male rotor,
- Test Case>Thermodynamics>Output>Mapping>Surf_p_R2_HOME.txt for pressure distribution on the female rotor,
- Test Case>Thermodynamics>Output>Mapping>Surf_T_R1_HOME.txt for temperature distribution on the male rotor,
- Test Case>Thermodynamics>Output>Mapping>Surf_T_R2_HOME.txt for Temperature distribution on the female rotor,

The above files are in ASCI format containing X, Y and Z coordinate on the respective rotor and a value of the property displayed in SI Units. Pressures are given in Pa while temperatures are in deg C.

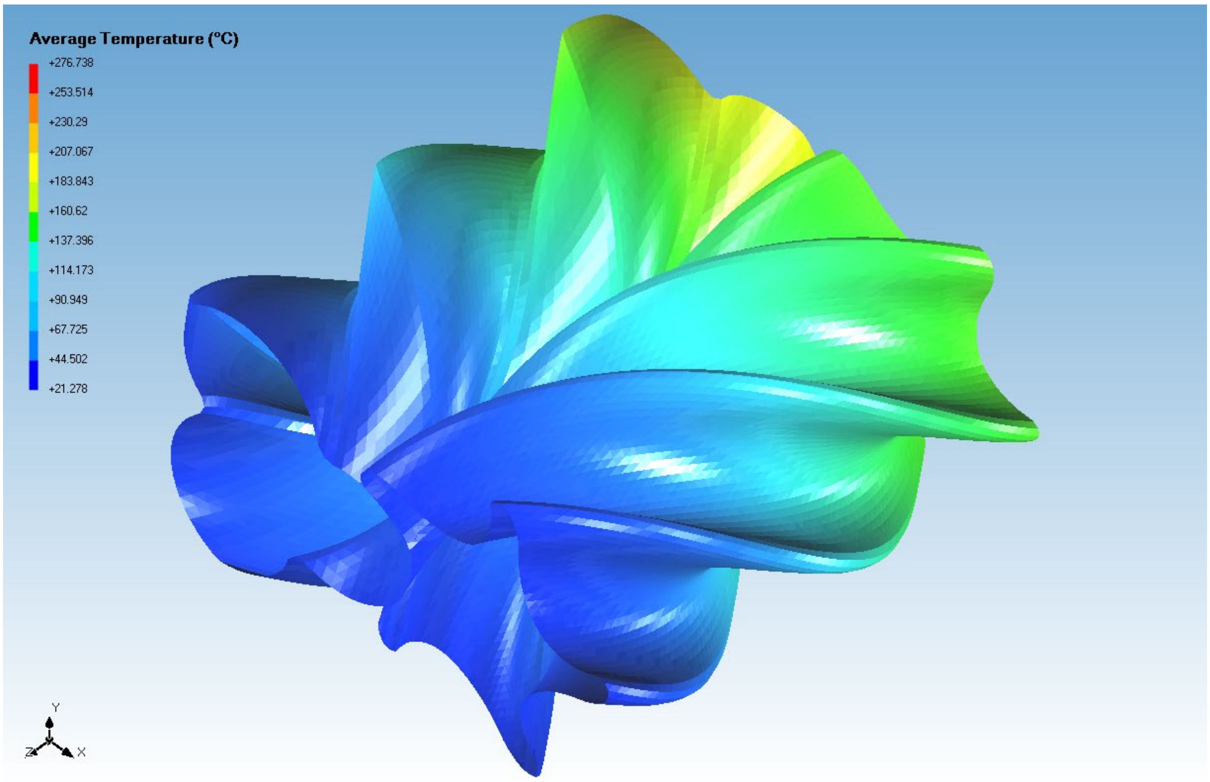
Surf_p_R1_HOME.txt - Notepad

File Edit Format View Help

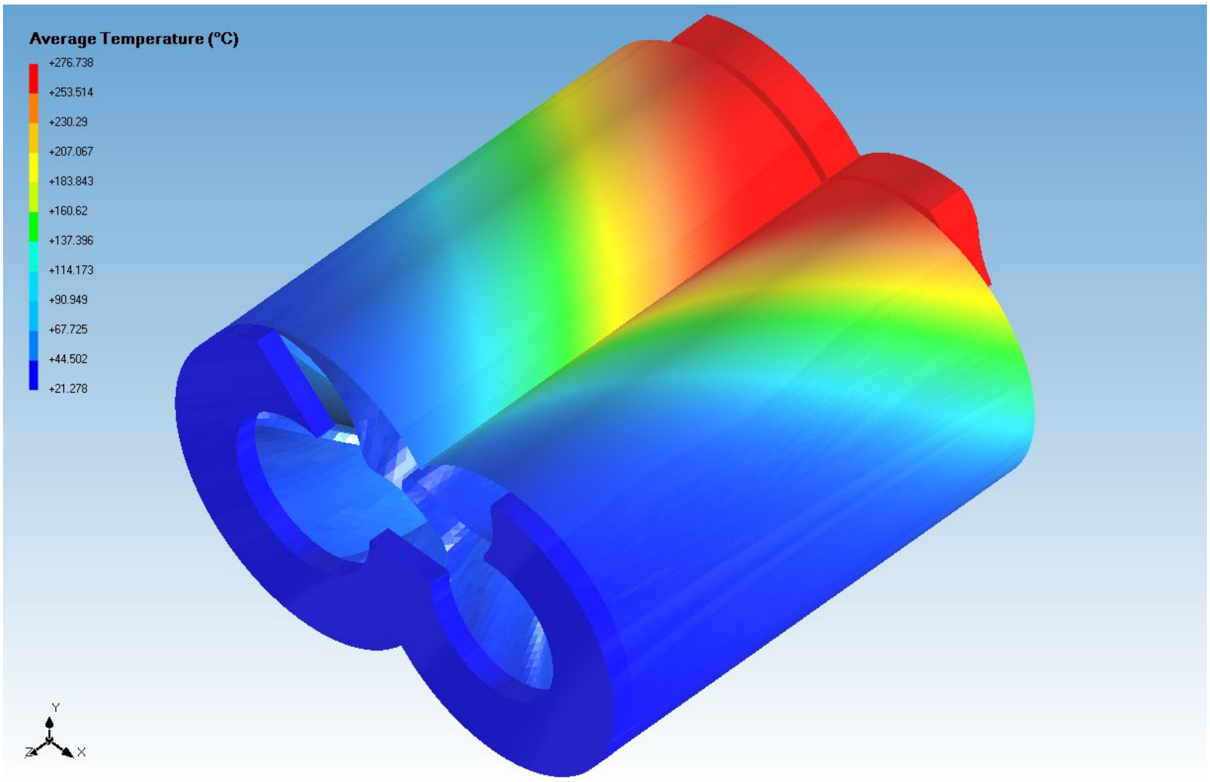
```
 8.7512229E-03 -3.1482939E-02  0.2130394      97242.00
 1.2842098E-02 -3.1084282E-02  0.2130394      97242.00
 1.6855568E-02 -3.1998899E-02  0.2130394      97242.00
 2.0868663E-02 -3.2962993E-02  0.2130394      97242.00
 2.4966480E-02 -3.3454698E-02  0.2130394      97242.00
 2.9093752E-02 -3.3467147E-02  0.2130394      97242.00
 3.3194508E-02 -3.3000283E-02  0.2130394      97242.00
 3.7213251E-02 -3.2060236E-02  0.2130394      97242.00
 4.1095741E-02 -3.0659964E-02  0.2130394      97242.00
 4.4789094E-02 -2.8817918E-02  0.2130394      97242.00
 4.8243582E-02 -2.6559474E-02  0.2130394      97242.00
 5.1412426E-02 -2.3915023E-02  0.2130394      97242.00
 5.4251753E-02 -2.0919723E-02  0.2130394      97242.00
 5.6723785E-02 -1.7614644E-02  0.2130394      97242.00
 5.8795128E-02 -1.4044832E-02  0.2130394      97242.00
 6.0437046E-02 -1.0258245E-02  0.2130394      97242.00
 6.1627034E-02 -6.3062636E-03  0.2130394      150545.0
 6.2348966E-02 -2.2426613E-03  0.2130394      150545.0
 6.2592700E-02  1.8773753E-03  0.2130394      150545.0
 6.2127169E-02  5.9528435E-03  0.2130394      97683.20
 5.9692409E-02  9.2703570E-03  0.2130394      97683.20
 5.6866486E-02  1.2279746E-02  0.2130394      97683.20
 5.3780600E-02  1.5021699E-02  0.2130394      97683.20
 5.0445303E-02  1.7453844E-02  0.2130394      97683.20
 4.6876255E-02  1.9527148E-02  0.2130394      97683.20
 4.3096047E-02  2.1183416E-02  0.2130394      97683.20
 3.9138038E-02  2.2350593E-02  0.2130394      99148.90
```

In the above example the pressure distribution on the male rotor is shown from file Surf_p_R1_HOME.txt. In order for this to be used for CFD or FEA the file can be directly imported into any commercial CFD or FEM software through their initial and boundary condition setting routines.

- Example of the thermodynamic cyclically time averaged Temperature result on rotors:



- Example of thermodynamic cyclically time averaged Temperature result on the casing



Cycle averaged temperatures on rotors and casing shown in the above graphs are suitable for boundary conditions for finite element analysis. These could be imported in any FAE software from ASCII files based on which these diagrams are made. These are:

- Test Case>Thermodynamics>Output>Mapping>Surf_T_R1_average2.txt for the average temperature on the male rotor,
- Test Case>Thermodynamics>Output>Mapping>Surf_T_R2_average2.txt for the average temperature on the female rotor,
- Test Case>Thermodynamics>Output>Mapping>Surf_T_B1.txt for the average temperature on the male rotor casing bore,
- Test Case>Thermodynamics>Output>Mapping>Surf_T_B2.txt for the average temperature on the female rotor casing bore,

The format of the above files is same as for the files shown earlier. The example below is for the cycle averaged temperature of the casing on the male rotor. For principles of cycle averaging, please refer to Buckney, Kovacevic, Stosic, 2016.

Surf_T_B1.txt - Notepad

File Edit Format View Help

4.8694912E-02	-3.9432354E-02	0.2130394	19.37861
4.7999304E-02	-4.0276192E-02	0.2130394	19.37628
4.7289077E-02	-4.1107763E-02	0.2130394	19.37420
4.6564445E-02	-4.1926805E-02	0.2130394	19.37242
4.5825630E-02	-4.2733084E-02	0.2130394	19.37091
4.5072854E-02	-4.3526344E-02	0.2130394	19.36965
4.4306349E-02	-4.4306342E-02	0.2130394	19.36858
4.3526348E-02	-4.5072846E-02	0.2130394	19.36767
4.2733092E-02	-4.5825623E-02	0.2130394	19.36691
4.1926816E-02	-4.6564437E-02	0.2130394	19.36625
4.1107770E-02	-4.7289073E-02	0.2130394	19.36572
4.0276200E-02	-4.7999296E-02	0.2130394	19.36530
3.9432362E-02	-4.8694905E-02	0.2130394	19.36497
3.8576514E-02	-4.9375676E-02	0.2130394	19.36475
3.7708916E-02	-5.0041407E-02	0.2130394	19.36462
3.6829825E-02	-5.0691899E-02	0.2130394	19.36458
3.5939526E-02	-5.1326949E-02	0.2130394	19.36462
3.5038274E-02	-5.1946361E-02	0.2130394	19.36475
3.4126345E-02	-5.2549951E-02	0.2130394	19.36495
3.3204027E-02	-5.3137533E-02	0.2130394	19.36522
3.2271590E-02	-5.3708933E-02	0.2130394	19.36551
3.1329323E-02	-5.4263972E-02	0.2130394	19.36580
3.0377513E-02	-5.4802477E-02	0.2130394	19.36613
2.9416459E-02	-5.5324286E-02	0.2130394	19.36651
2.8446434E-02	-5.5829253E-02	0.2130394	19.36694
2.7467746E-02	-5.6317206E-02	0.2130394	19.36743
2.6480692E-02	-5.6788009E-02	0.2130394	19.36799
2.5485570E-02	-5.7241511E-02	0.2130394	19.36862
2.4482692E-02	-5.7677578E-02	0.2130394	19.36930

8 Summary

This document describes the steps to setup and calculation of thermodynamic performance predictions using multi chamber thermodynamics. More detailed information on using SCORG can be found in user guide (SCORG, 2018). Thermodynamic calculations are used as the preliminary performance predictions which could be utilised for design of screw machines, initial conditions for CFD and FEM.

9 Bibliography

Buckney D, Kovacevic A, Stosic N, *Design and evaluation of rotor clearances for oil-injected screw compressors,* Proceedings of the IMechE, Part E: Journal of Process Mechanical Engineering, 2016 doi:10.1177/0954408916660342

CD Adapco Star CCM+ V10.06, 2016. *User Guide,* London: CD Adapco.

DISCO, 2007. *DISCO, User Help Manual,* London: City University.

Kovacevic, A., Stosic, N. & Smith, I. K., 2007. *Screw compressors - Three dimensional computational fluid dynamics and solid fluid interaction, ISBN 3-540-36302-5.* 1 ed. New York: Springer-Verlag Berlin Heidelberg.

Rane, S., 2015. *Grid Generation and CFD analysis of Variable Geometry Screw Machines,* London: City University London.

SCORG, 2018. *SCORG, User Help Manual,* London: City University.

Stosic, N., Smith, I. K. & Kovacevic, A., 2005. *Screw compressors: Mathematical modeling and performance calculation, ISBN 3540242759.* 1 ed. London: Springer.

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