SCORG™ Setup for CFD Simulation of Twin Screw Machines with Simerics Inc. Simerics-MP+® Solver

SCORG™ is the CFD grid generation tool for rotary twin screw machines. The tool includes additional modules for designing and editing rotor profiles, executing a thermodynamic calculation based on quasi 1D chamber models and generating the deforming working chamber grids for selected commercial CFD solvers. For more information on the product please visit the website: www.pdmanalysis.co.uk or refer to documentation help.

This guide lists the steps for setting up a CFD simulation for Twin Screw Compressor with SCORG™ and Simerics MP+ Solver. The user is expected to be familiar with screw machines, CFD and Simerics MP+ in order to be able to use these procedures. It is highly recommended that books on that topic are studied[1][2]

Refer SCORG™ Installation Guide for 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. Although the working principle of these machines is simple, the geometry of rotors which are in the form of multi -lobe helical screws meshing with each other, is making analysis by use of Computational Fluid Dynamics (CFD) challenging. The process starts when the lobes are engaged at one end, which creates continuous increase of the volume between the rotors and the casing which reduces pressure in the suction domain and draws the working fluid in. Further rotation of the rotors makes this volume between the rotors and the casing enclosed when the compression of fluid begins. This increases the pressure within the chamber. Further rotation exposes the pressurized fluid to the outlet port and the fluid is delivered (Stosic, et al., 2005). Similar process is occurring in other helical screw machines such as pumps, vacuum pumps, gear pumps, expanders, extruders and motors. The CFD is equally challenging in such machines due to sliding and stretching

The main objectives of CFD simulations of a screw compressor are to:

a. Obtain the pressure field inside the rotor chamber and in the suction and discharge domains. Example shown in *Figure 1-1*.
b. Obtain the velocity fields in critical regions of the computational domain.
c. Obtain temperature fields in critical regions of the computational domain.
d. Obtain integral parameters of the machine such as power, mass flow rate, discharge temperature, torques on the rotor shafts, etc.
e. Obtain the loads and temperatures on boundaries with solid parts of the machine for further structural and thermal analysis.

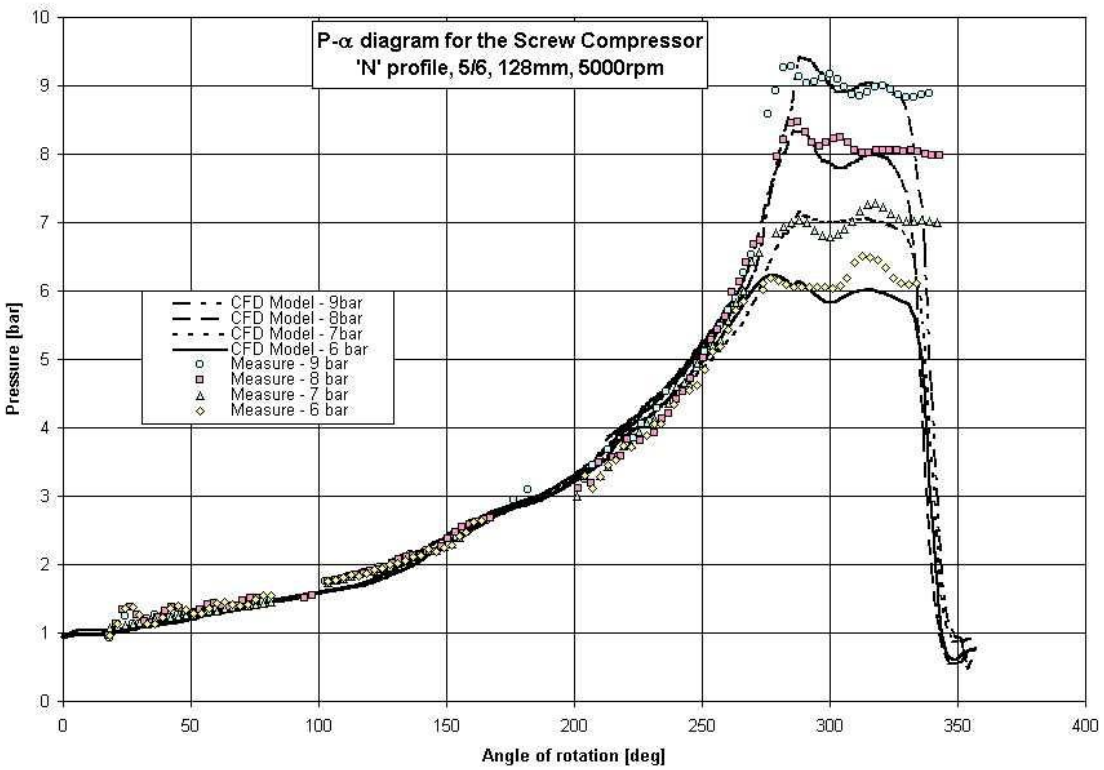
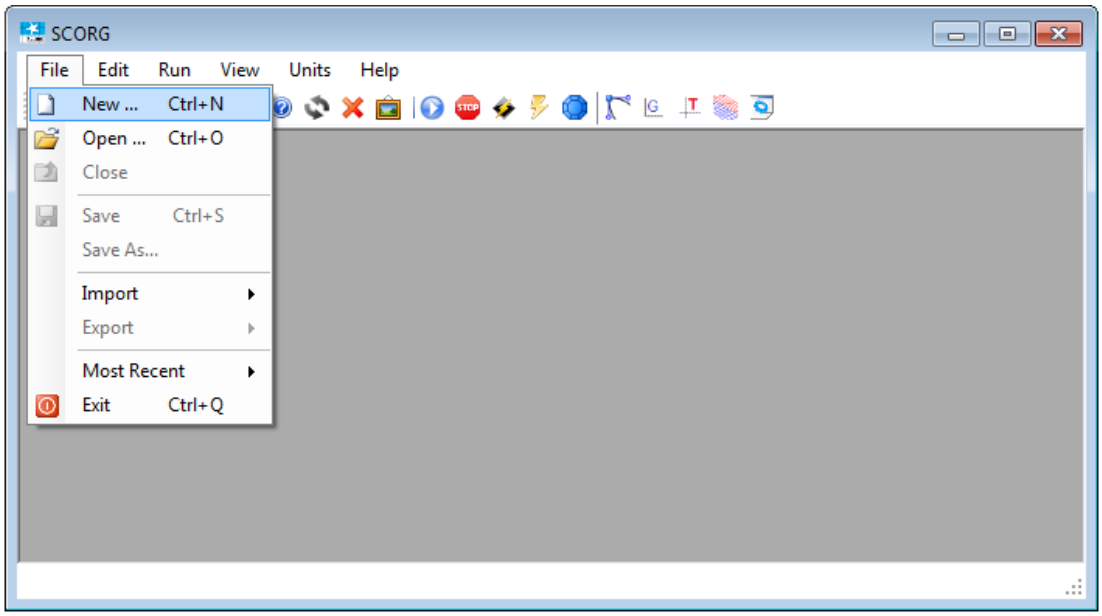


Figure 1-1 *Pressure Variation diagram of a Twin Screw Compressor* **(Kovacevic, et al., 2007)**

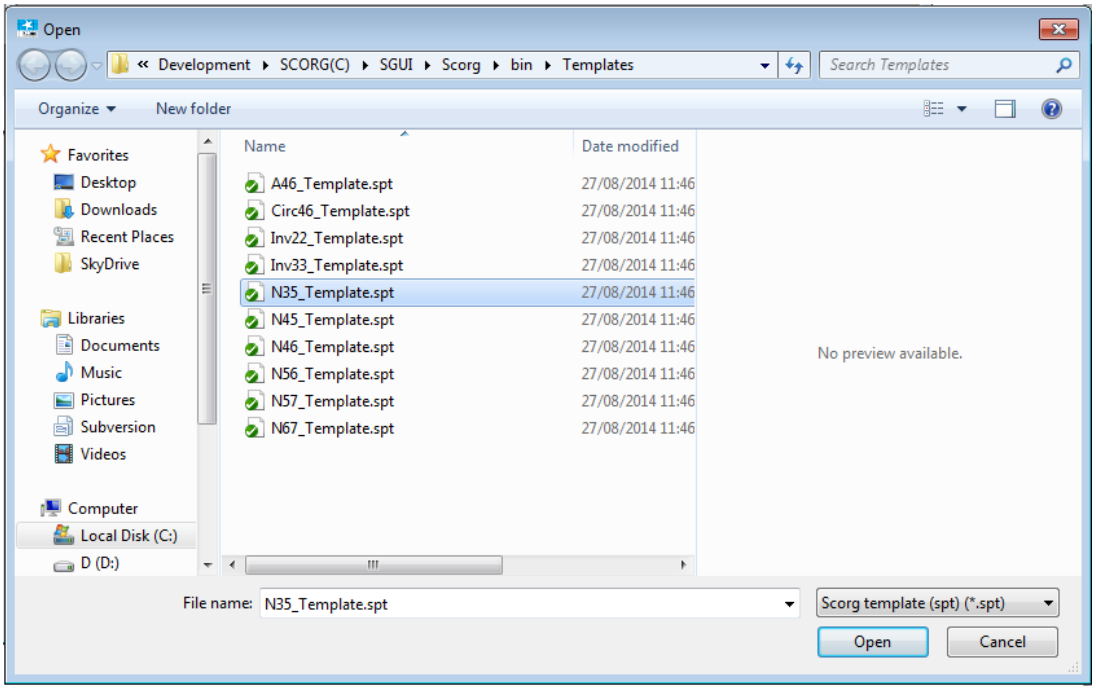
This Tutorial will provide a step by step guide for the procedure to setup and execute a typical twin screw compressor, pump or motor simulation. An example of a dry air compressor with 3/5 lobe combination, L/D ratio of 1.6 and wrap angle 285 deg has been considered.

2 SCORG™ Project

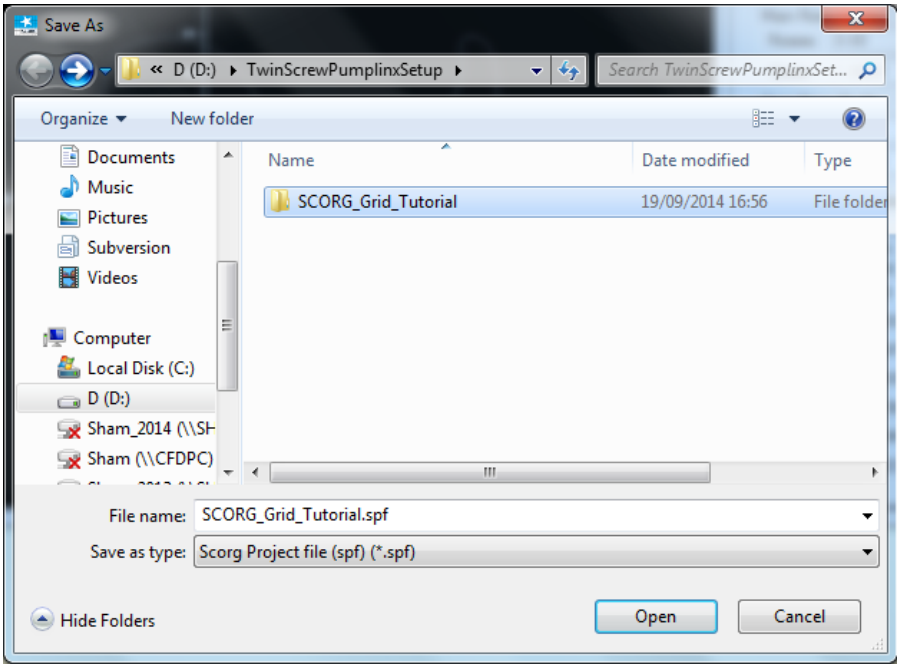
- Launch SCORG™ on the Desktop.
- Select File → New



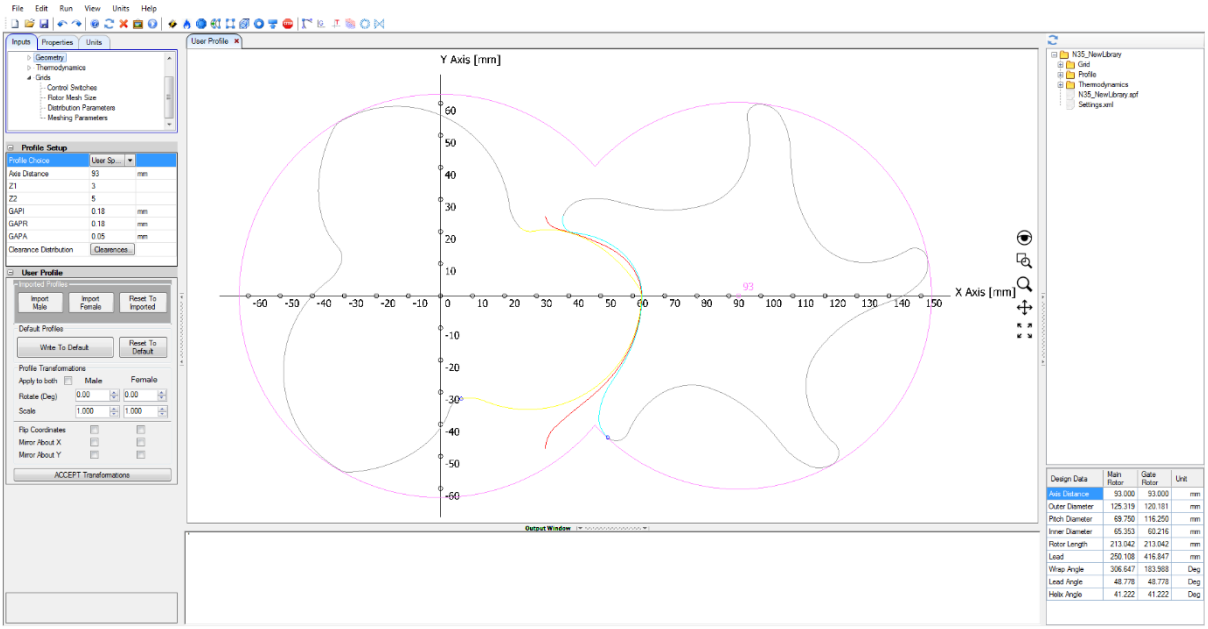
- Select N35_Template.spt → Open



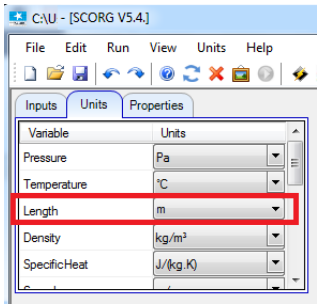
- Save the project in a new folder named TwinScrewSimericsSetup → SCORG_Grid_Tutorial.spf



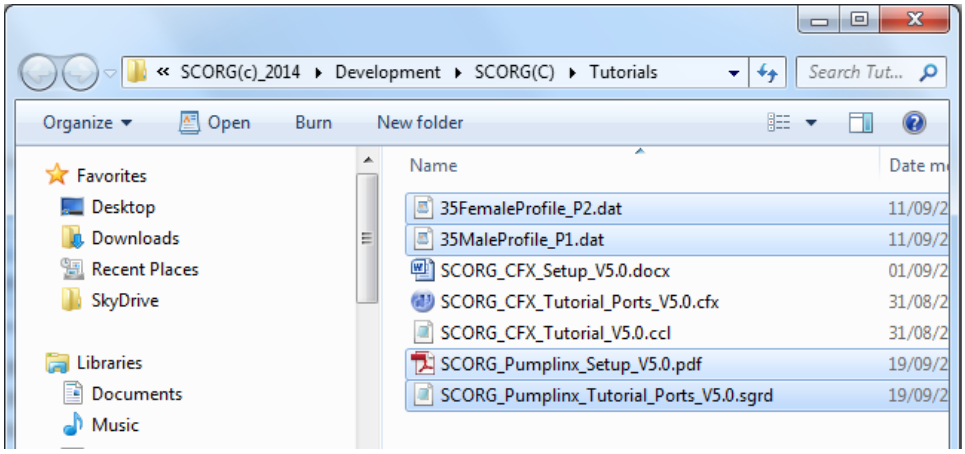
- The GUI of SCORG™ in the figure bellow shows the mains items of the front panel.

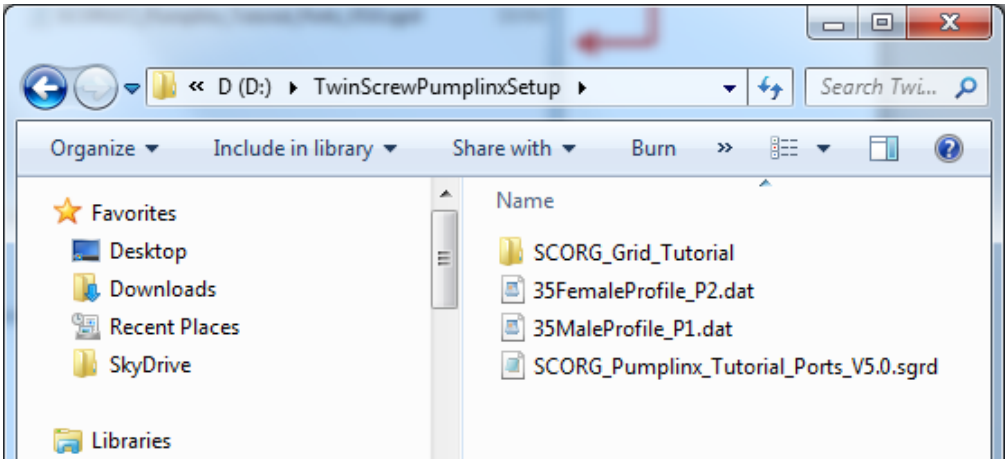


- In Units Tab, Select Length units as ‘m’. This selection has to be the same as the units in which input profile coordinates are available.



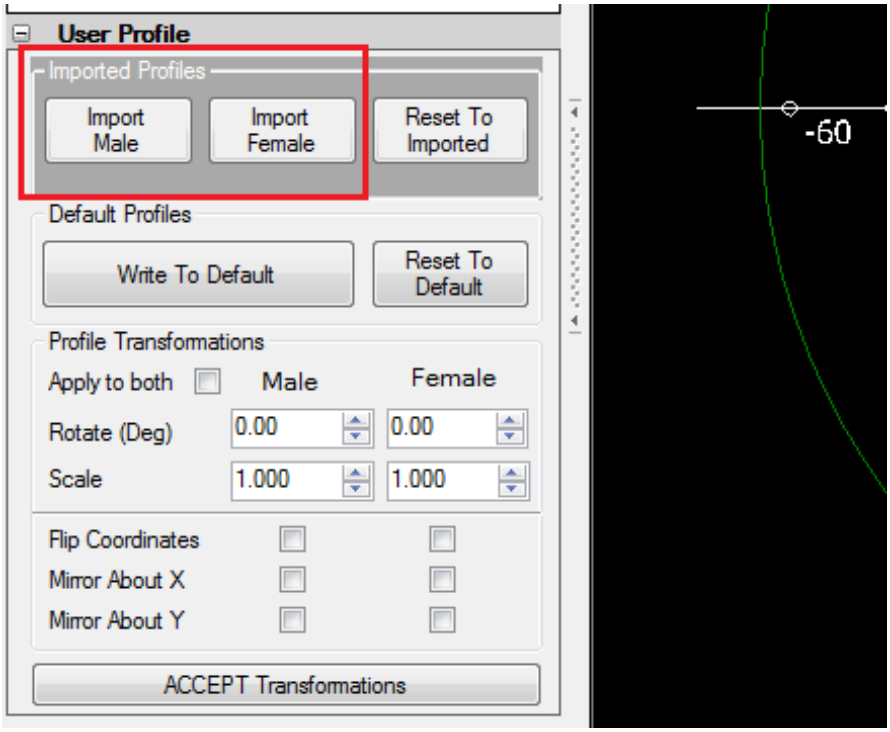
- Go to Help → Tutorials → Folder opens
- Copy the compressor rotor profile files → [*35MaleProfile_P1.dat* and *35FemaleProfile_P2.dat*]
- Copy the compressor suction and discharge port grids → [*SCORG_Simerics_Tutorial_Ports_V5.0.sgrd*]
- Copy the setup template → [*SCORG_Simerics_Tutorial_V5.9.spro*]
- Paste these files in the working directory → TwinScrewSimericsSetup



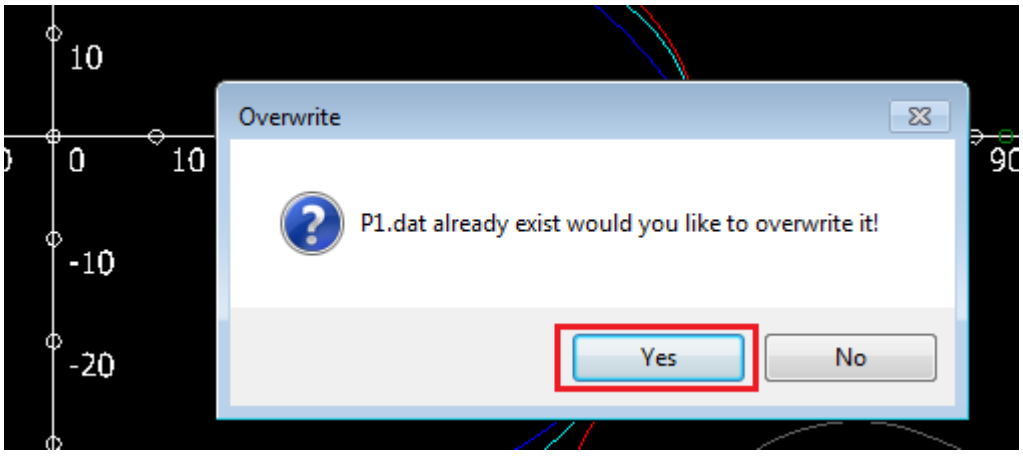


- Go to User Profile → Browse and Select the Male Rotor Profile from working directory.

  35MaleProfile_P1.dat



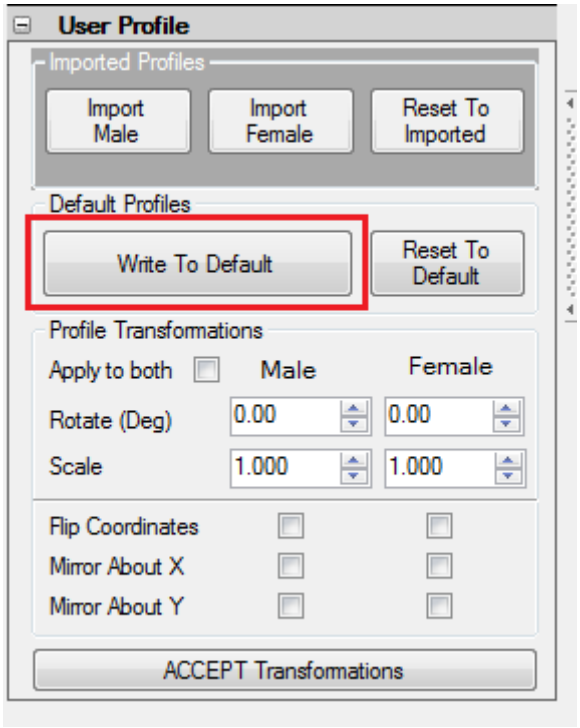
- Click 'Yes' to overwrite P1.dat.



- Similarly Select the Female Rotor Profile.

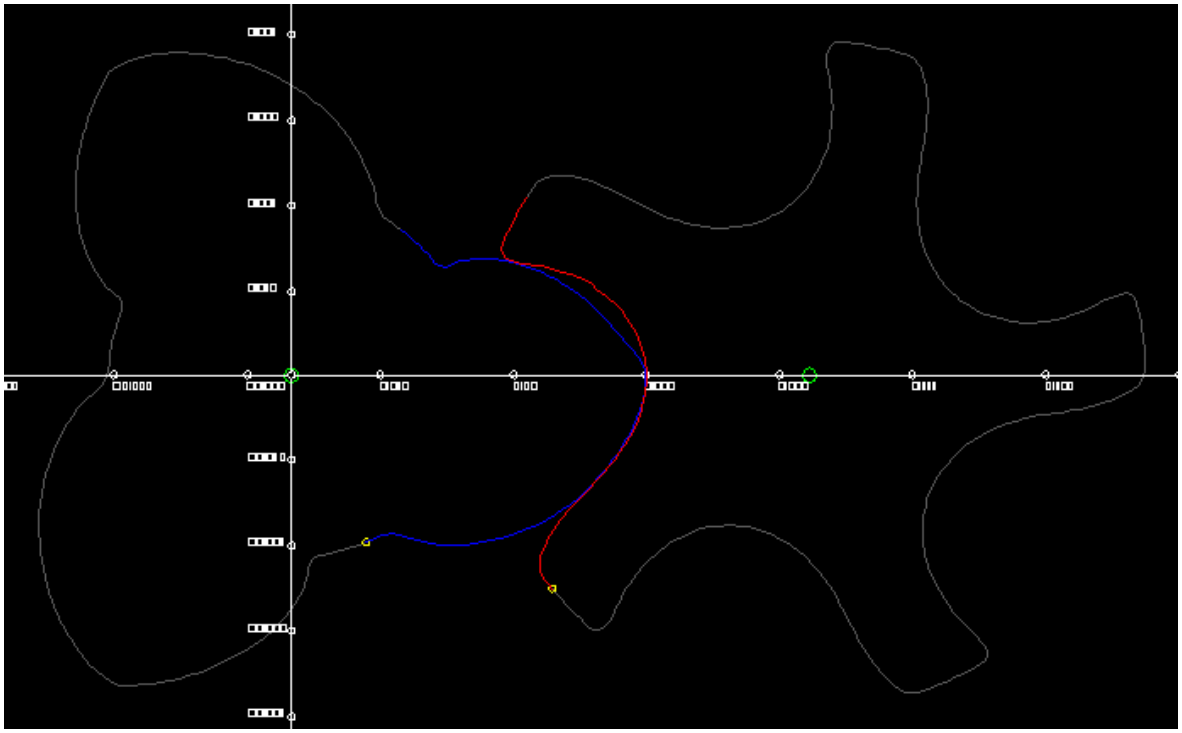
  35FemaleProfile_P2.dat

- Click Write To Default.

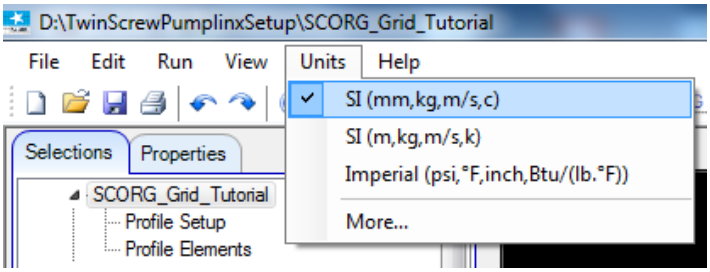


- Click Refresh to view new profiles.

- Inspect the Rotor Profile in the GUI for gaps in the tips, starting points of the profile indicated by the small yellow circles. Below is the required orientation.



- Set Project Units to SI



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

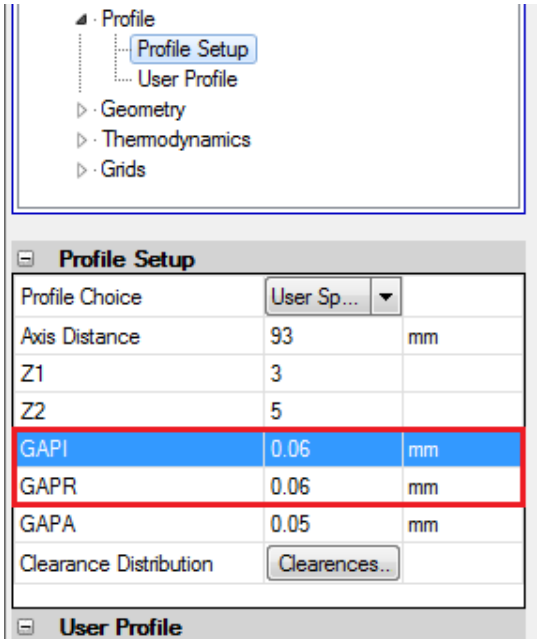
GAPI = 0.06mm

GAPR = 0.06mm

GAPA = 0.05mm

*Setting GAPI = 0.06 sets the minimum interlobe clearance as the GAPI.

- Go to Geometry → Set the following parameters:



Profile Setup

Profile Choice	User Sp...	
Axis Distance	93	mm
Z1	3	
Z2	5	
GAPI	0.06	mm
GAPR	0.06	mm
GAPA	0.05	mm
Clearance Distribution	Clearences..	

User Profile

Rotor Configuration

Relative Length	1.6	
Rotor Length	0	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

Machine Type	Compressor	
N Gate	1	
Compression Start	0	Deg
Compression End	161.001	Deg
Volume Index	1.8	
E Rotor	211	GPa
αL Rotor	1E-05	m/m/K
E Casing	211	GPa
αL Casing	1E-05	m/m/K

- Go to Thermodynamics → Set the following parameters:

Working Conditions

Wtip	66.6665	m/s
Rotor Speed	10000	RPM
P0	100000	Pa
Pr	300000	Pa
T0	293	K
Tr	350	K
Tevp	268	K
Tcond	313	K
T Ambient	293	K
Ts	0	K
X	1	

- Save the Project.

3 SCORG™ Mesh Generation

SCORG™ is stand-alone numerical CAD-CFD interface used to generate a numerical mesh of rotating parts of a screw machine and to transfer it to a general finite volume numerical solver. The program generates a block structured hexahedral numerical grid for rotor flow domains, solid rotor domains, inlet and outlet ports.

Inputs Required

In this step the rotor domain mesh is generated in SCORG™. The inputs required for this mesh generation are: (Kovacevic, et al., 2007).

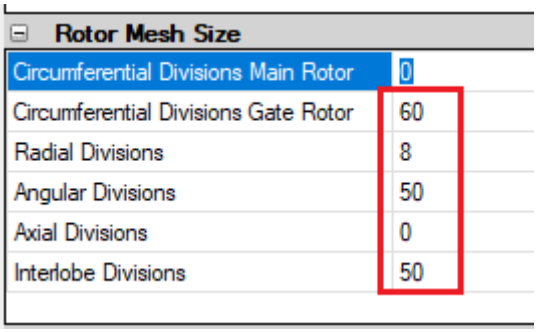
Control Parameters:

- Type of the machine.
- Number of mesh divisions along the lobe in circumferential direction.
- Number of mesh divisions in radial direction.
- Number of Angular divisions of the rotation.

Control Switches:

These Inputs are used to specify the method used for Rotor Profile Input and the required mesh calculation options.

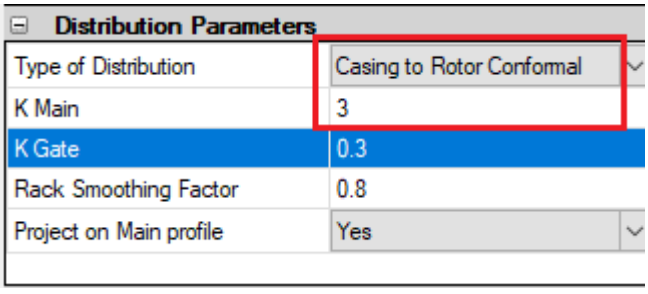
- Click Grid Module in the project tree
- In Mesh Type Size set:
  - Circumferential Main = 0
  - Circumferential Gate = 60
  - Radial = 8
  - Angular = 50
  - Interlobe Divisions = 50



- Distribution Parameters:

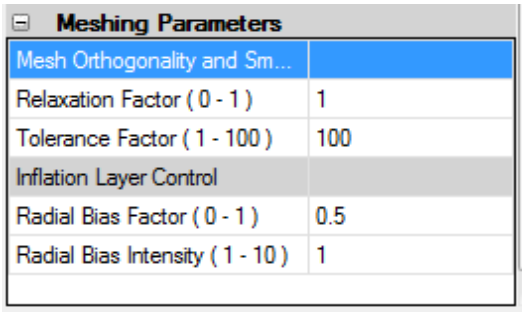
These inputs are used for adaptation and distribution of the grid points on the boundaries of the domain and for smoothing of rack (Rack is the curve representing a rotor with infinite radius which uniquely separates the flow domains of the male and female rotors).

  - Type of Distribution → Casing to Rotor Conformal



- Meshing Parameters:

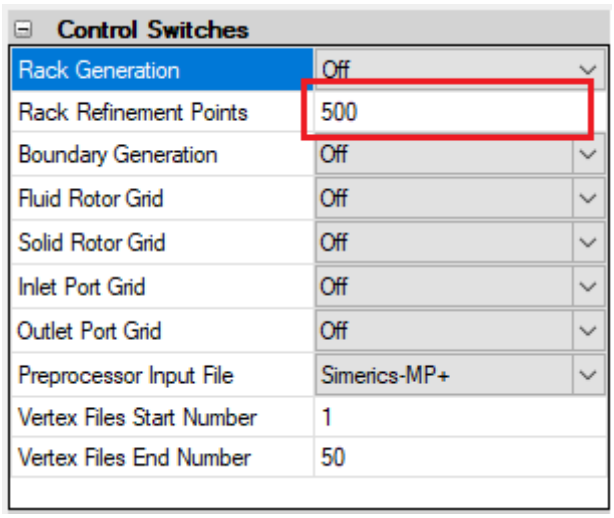
Meshing parameters provide control over the distribution of the internal mesh points in each cross section of the rotors.



  - both the distribution and meshing parameters can be changed later

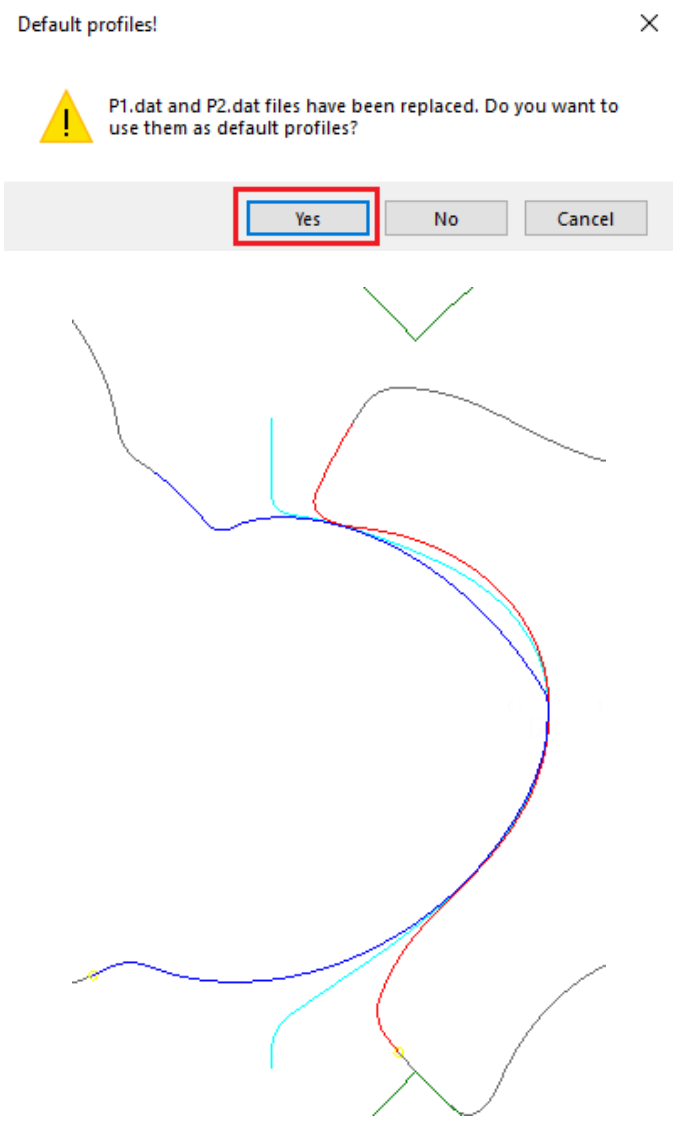
- Start Grid Generation through a three step process as below.

- Select Rack Refinement Points = 500



- Click Numerical Rack Generation

This operation produces the rack curve between the two profiles. It is required to be executed only once in the grid generation process.



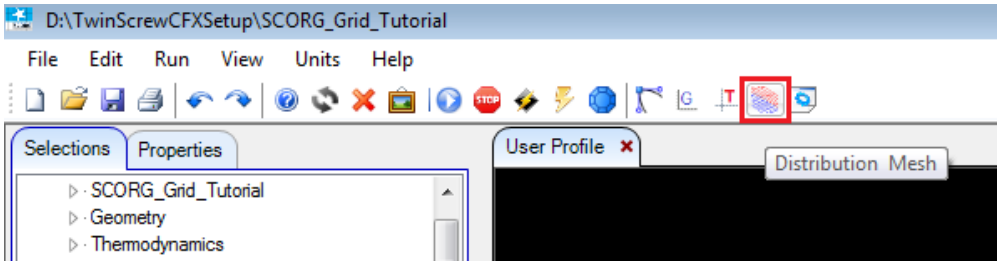
- Click Boundary Distribution Generation

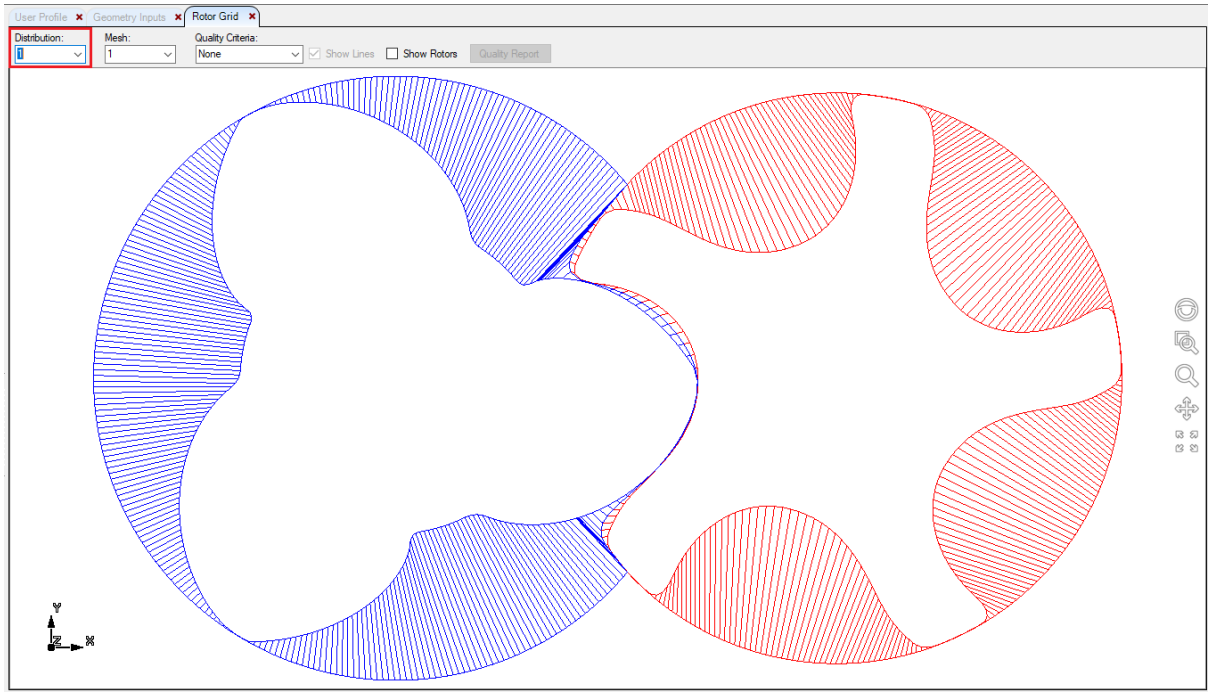
Information about the progress of the selected activities in the meshing procedure is displayed in the output window. Any warning or error and their locations are indicated. If errors occur, it is important to manually tune the input parameters which will produce a mesh without errors. Graphically the mesh distribution in each section can be visualized and checked for any deviation from requirements. The detailed description of methods used for distribution, adaptation and generation of numerical mesh is available through the Help in the drop down menu.

- Inspect report and check that there are no distribution warnings listed

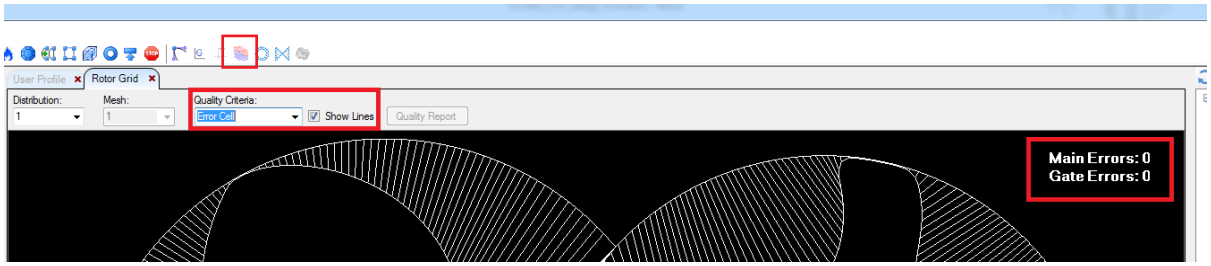
```
C:\SCORG\Grid>echo off

 ..................................................................
 InstallPath = C:\SCORG
 ProjectPath = D:\TwinScrewCFXSetup\SCORG_Grid_Tutorial
 ..................................................................

  SCORG - Screw COmpressor Rotor Geometry grid  generator V.5.9
 ..................................................... 3/ 3/2021...
 Screw compressor/p Wrap =  283.2   RPM=12344.    Vel=  82.3   Ncel= 566400
  Z1/Z2= 3/5  d1=127.38 [mm]  d2=120.32 [mm]  a= 93.00 [mm]  len=216.45 [mm]
 ..................................................................
  Nfi   Nr   Nz Nadd  Rot Rack Boun Mesh RotM InpP OutP Prep RaSm Line  Oil
   60    8  118   50    3    1    1    0    0    0    0    0    1    1    0
 ..................................................................
 Calculation:  ROTOR       1:  0.00 Dist  0.00 Cos   2: 0.00 Ang.  0.00 Sin
 Calculation:  RACK        Smoothing factor:  0.80   Smooth: ON
 Calculation:  BOUNDARY    Male =  300               Female =  300
 Initial Smoothing Distribution:Casing to Rotor Conformal
  TFI_Mesh routine - Rotor           1
  TFI_Mesh routine - Rotor           2
 Initial Smoothing GRID  RelaxFac, TolFac, RadBFac, RadBInt, InterlobeBInt
                           1.0     100     0.5     1.0       2
  PDE Interlobe mesh routine
  Distribution Type: Casing to Rotor Conformal
 ..................................................................
 Distribution: Casing to Rotor Conformal
 ..................................................................
 Cell statistics        Overall number of cells         0
 .Rotor fluid         0            .Inlet  port         0
 .Rotor solid         0            .Outlet port         0
 ..................................................................
  Start: 11:23:18    End: 11:24: 2    Running time: 0h: 0m:43s =    42 sec
 ..................................................... 3/ 3/2021...
  SCORG - Screw COmpressor Rotor Geometry grid generator - Ver. 5.9
```

- Click Distribution Mesh to visually inspect the distribution in each cross section





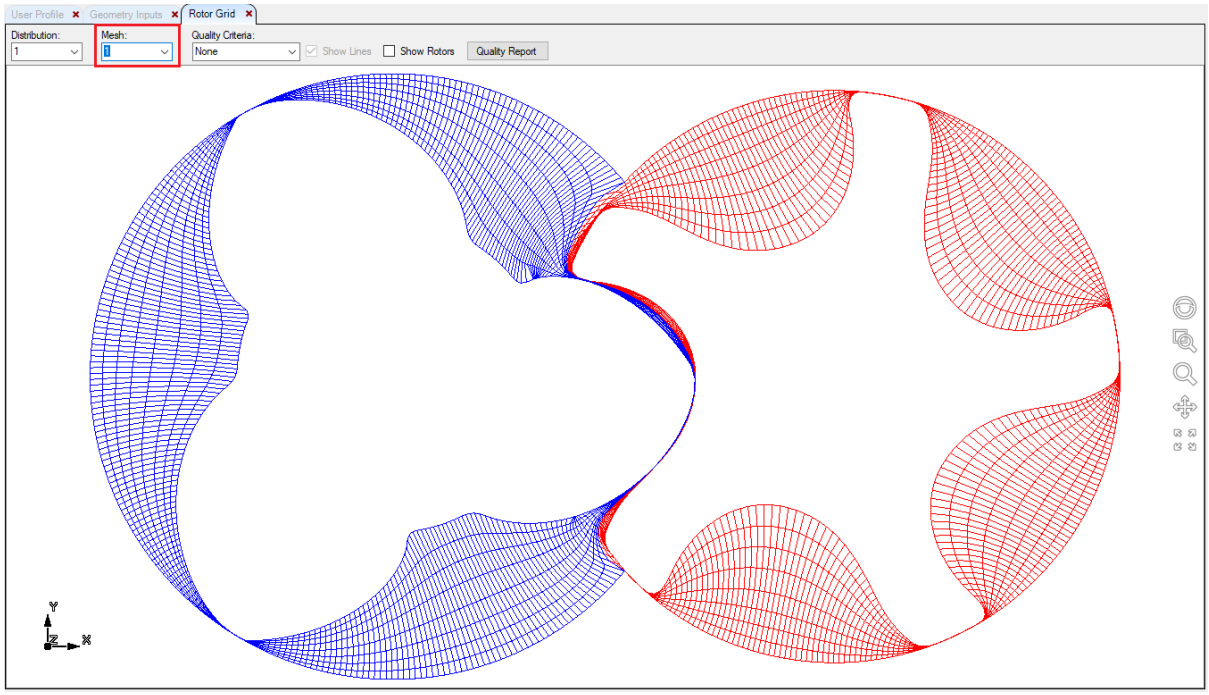
- In the Distribution Display → Select Quality Criteria = Error Cell



- Inspect all the distribution positions and ensure that 0 error are reported in each position.

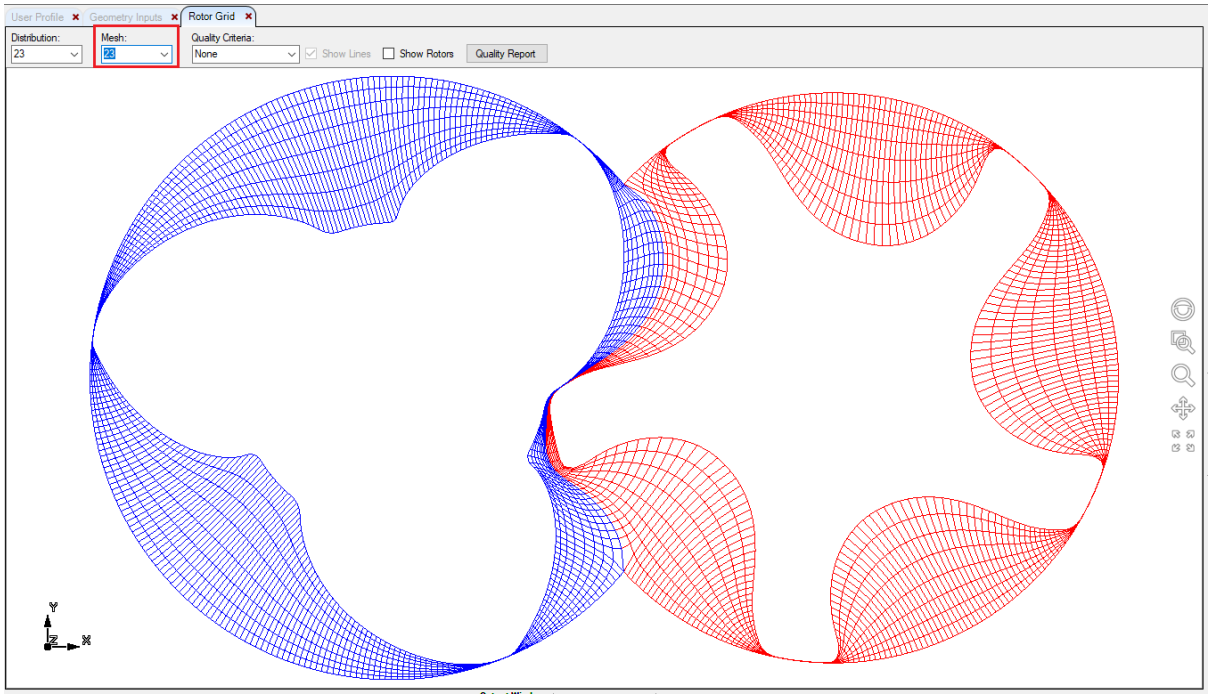
- Click Rotor Grid Generation

- Inspect report and check that there are no grid errors listed

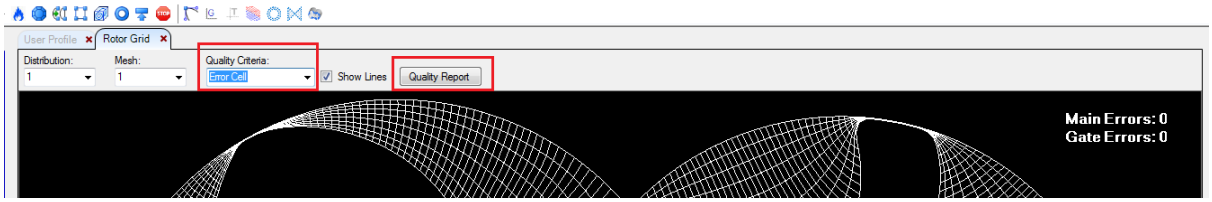



```
C:\SCORG\Grid>echo off

 ..................................................................
 InstallPath = C:\SCORG
 ProjectPath = D:\TwinScrewCFXSetup\SCORG_Grid_Tutorial
 ..................................................................

  SCORG - Screw COmpressor Rotor Geometry grid  generator V.5.9
 ..................................................... 3/ 3/2021...
 Screw compressor/p Wrap =  283.2   RPM=12344.    Vel=  82.3   Ncel= 566400
  Z1/Z2= 3/5  d1=127.38 [mm]  d2=120.32 [mm]  a= 93.00 [mm]  len=216.45 [mm]
 ..................................................................
  Nfi   Nr   Nz Nadd  Rot Rack Boun Mesh RotM InpP OutP Prep RaSm Line  Oil
   60    8  118   50    0    0    0    1    0    0    0    0    1    1    0
 ..................................................................
 Calculation:  FLUID GRID  RelaxFac, TolFac, RadBFac, RadBInt, InterlobeBInt
                              1.0     100     0.5     1.0       2
  TFI_Mesh routine - Rotor           1
  TFI_Mesh routine - Rotor           2
  PDE_mesh routine - Rotor           1
  PDE_mesh routine - Rotor           2
  PDE_Interlobe_mesh2 routine: Smooth Interlobe
 ..................................................................
  Check_Grid - Rotor:           1
  Check_Grid - Rotor:           2
  Write 2D Grid Data

  Grid Data Count:
   Male rotor domain, Vertices:  321300, Cells  283200
 Female rotor domain, Vertices:  321300, Cells  283200
 Written Control.dat
 ..................................................................
 Cell statistics       Overall number of cells         0
 .Rotor fluid        0           .Inlet  port         0
 .Rotor solid        0           .Outlet port         0
 ..................................................................
  Start: 11:29:31    End: 11:29:42    Running time: 0h: 0m:10s =     2 sec
 ..................................................... 3/ 3/2021...
  SCORG - Screw COmpressor Rotor Geometry grid generator - Ver. 5.9
```

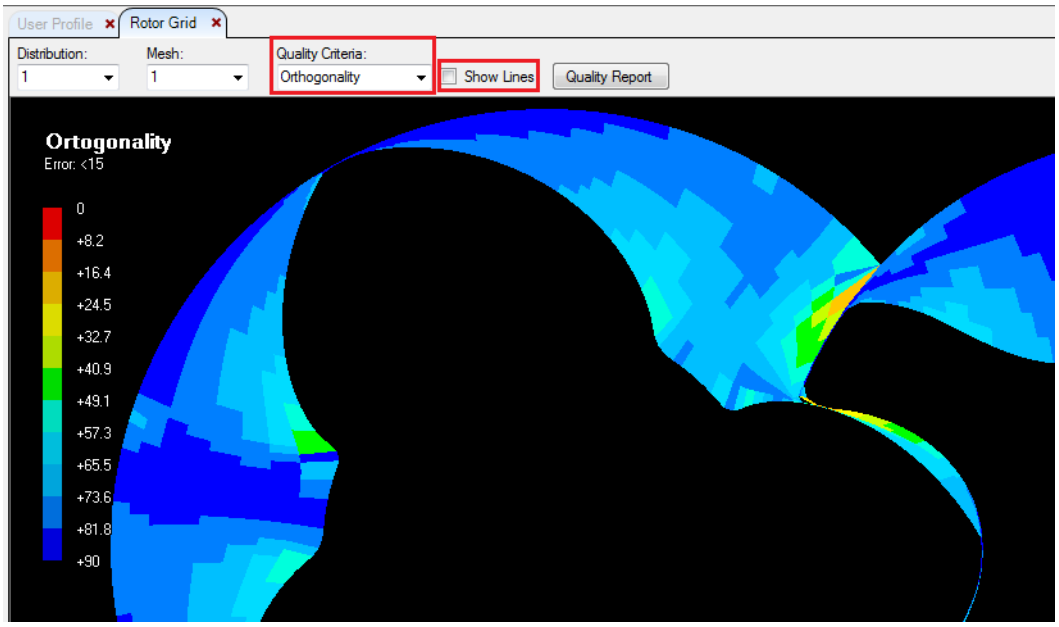
- Click Rotor Grid 2D Mesh to visually inspect the grid in each cross section



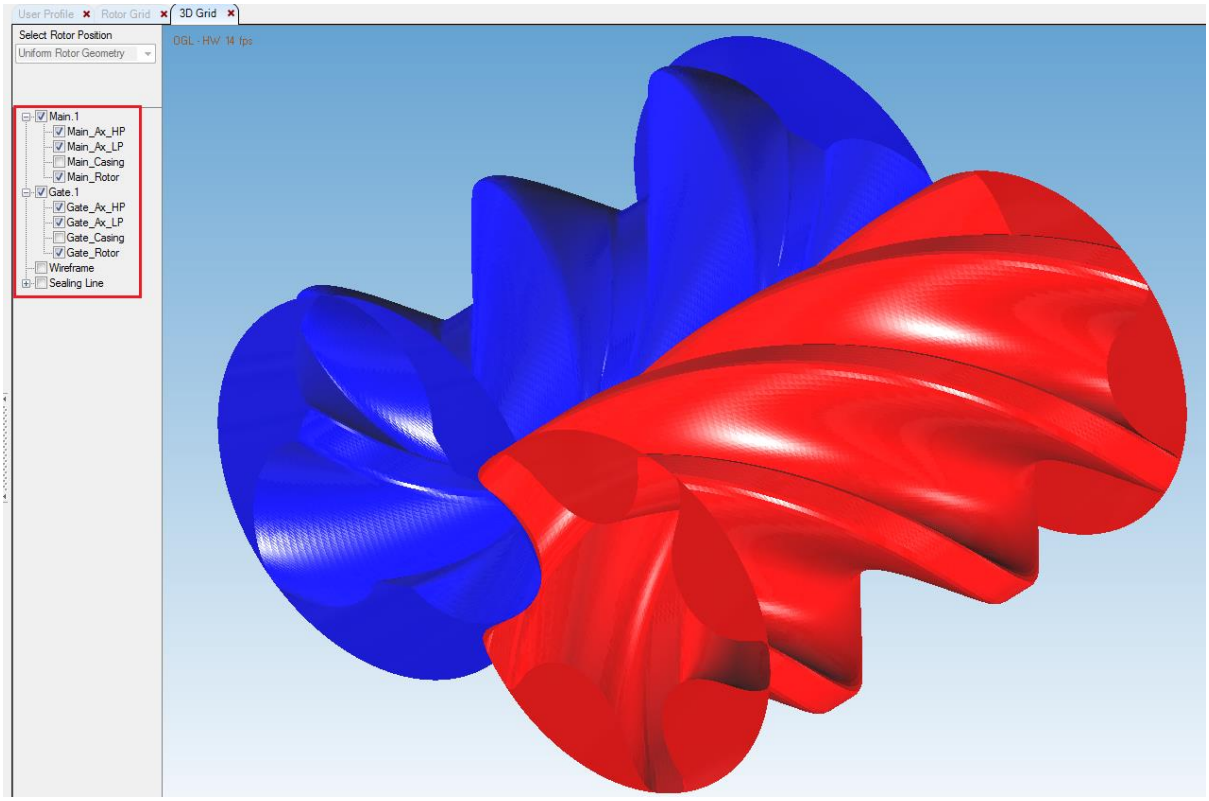
- Click Quality Critera → Error Cell and Inspect.



- Click Quality Critera → Orthogonality and Inspect.



- Inspect the 3D mesh



- In Control Switches → Preprocessor Input File select → Simerics-MP+
- Set Vertex Files Start = 1
- Set Vertex Files End = 50

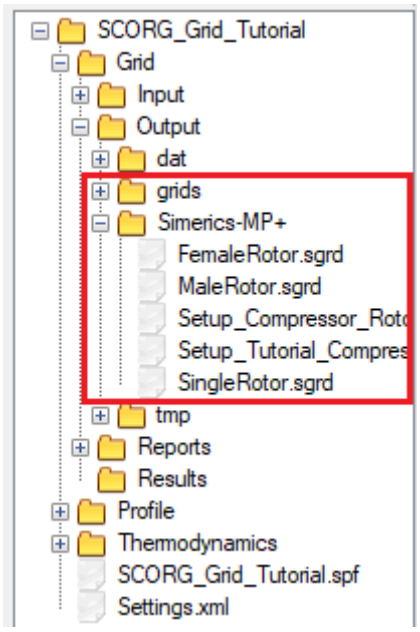
Control Switches

Rack Generation	Off
Rack Refinement Points	500
Boundary Generation	Off
Fluid Rotor Grid	Off
Solid Rotor Grid	Off
Inlet Port Grid	Off
Outlet Port Grid	Off
Preprocessor Input File	Simerics-MP+
Vertex Files Start Number	1
Vertex Files End Number	50

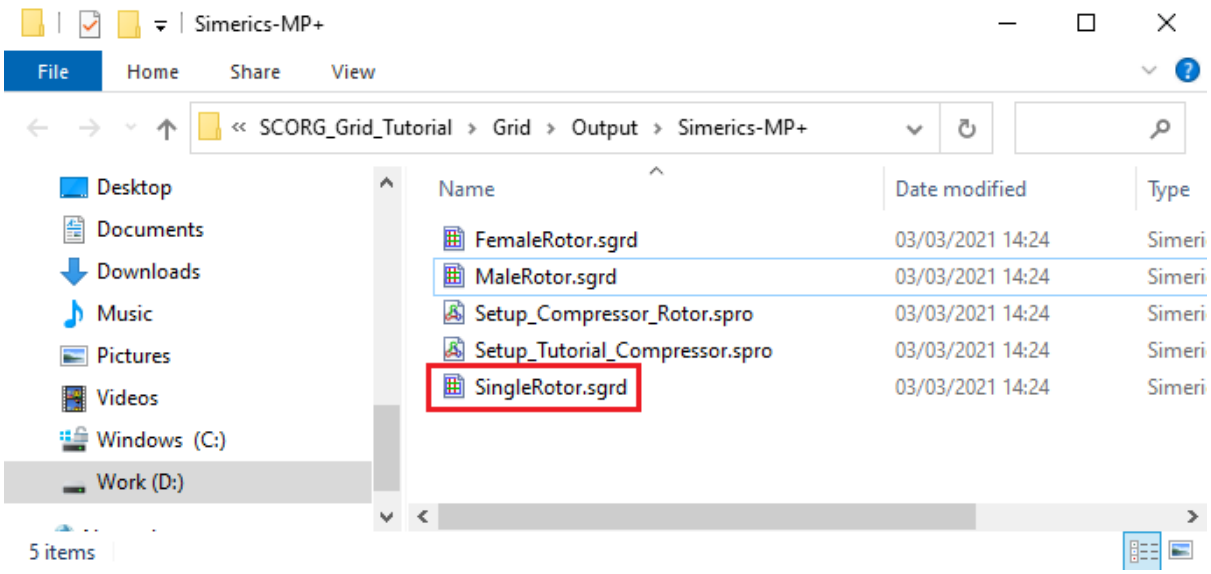
- Calculate Preprocessor Files Generation


```
 ----Generation of Rotor Pre Processor files
 Checking volumes in Male
 Min/Max Volume=  2.5494173E-11  2.4967806E-08
Boundaries:
Rotor_male
Casing_male
Axial1_male
Axial2_male
Zones:
Fluid_male
 Checking volumes in Female
 Min/Max Volume=  1.8902525E-11  3.7128007E-08
Boundaries:
Rotor_female
Casing_female
Axial1_female
Axial2_female
Zones:
Fluid_female
 Number of grids =             1
Boundaries:
Rotor1_rotor
Casing1_rotor
Axial1_rotor
Axial2_rotor
Rotor2_rotor
Casing2_rotor
Zones:
Fluid_rotor

 Simerics-MP+ SETUP Grids written

 Generation of time step grid files
   Start time step:           1
   End   time step:          50

Rotor     1,  Grid position     1
Rotor     1,  Grid position     2
```

- With this the SCORG Project is complete and the Simerics-MP+ setup can be started.
- In the directory structure of SCORG Project → Grid → Output consists of Simerics-MP+ folder.
- Copy files in this folders to the project working directory → TwinScrewSimericsSetup
- These are Rotor grids and the Simerics Template Setup



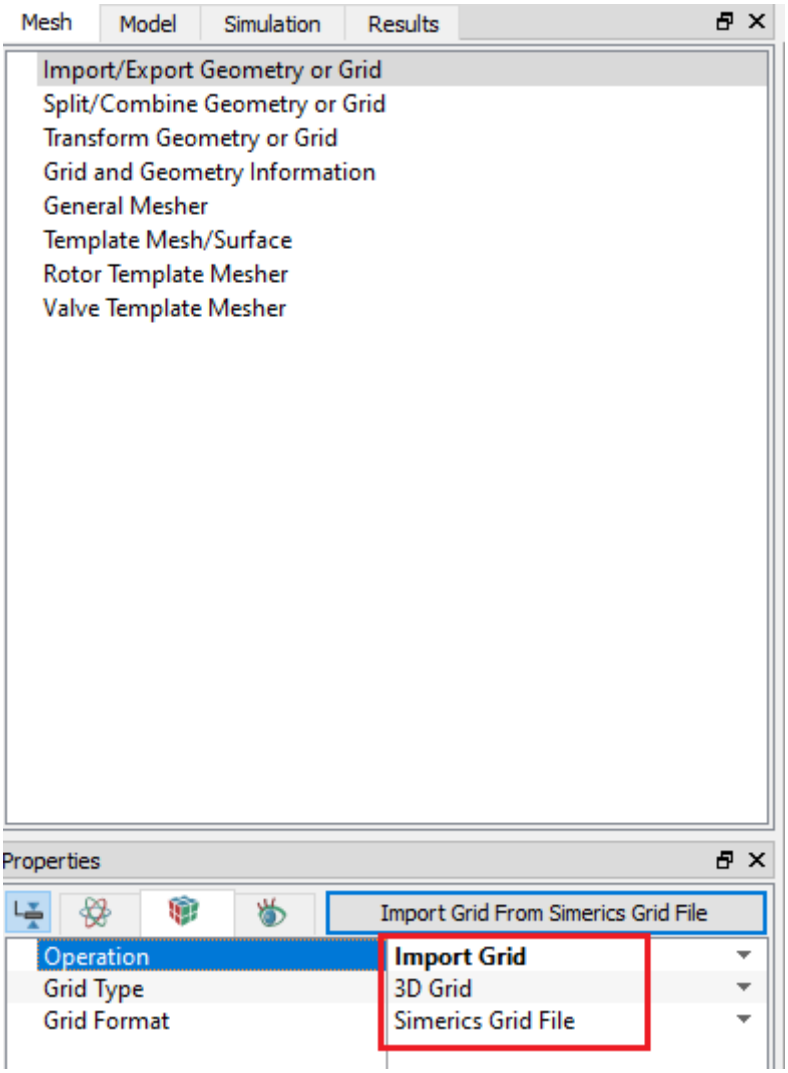
- The highlighted files are required for full setup.

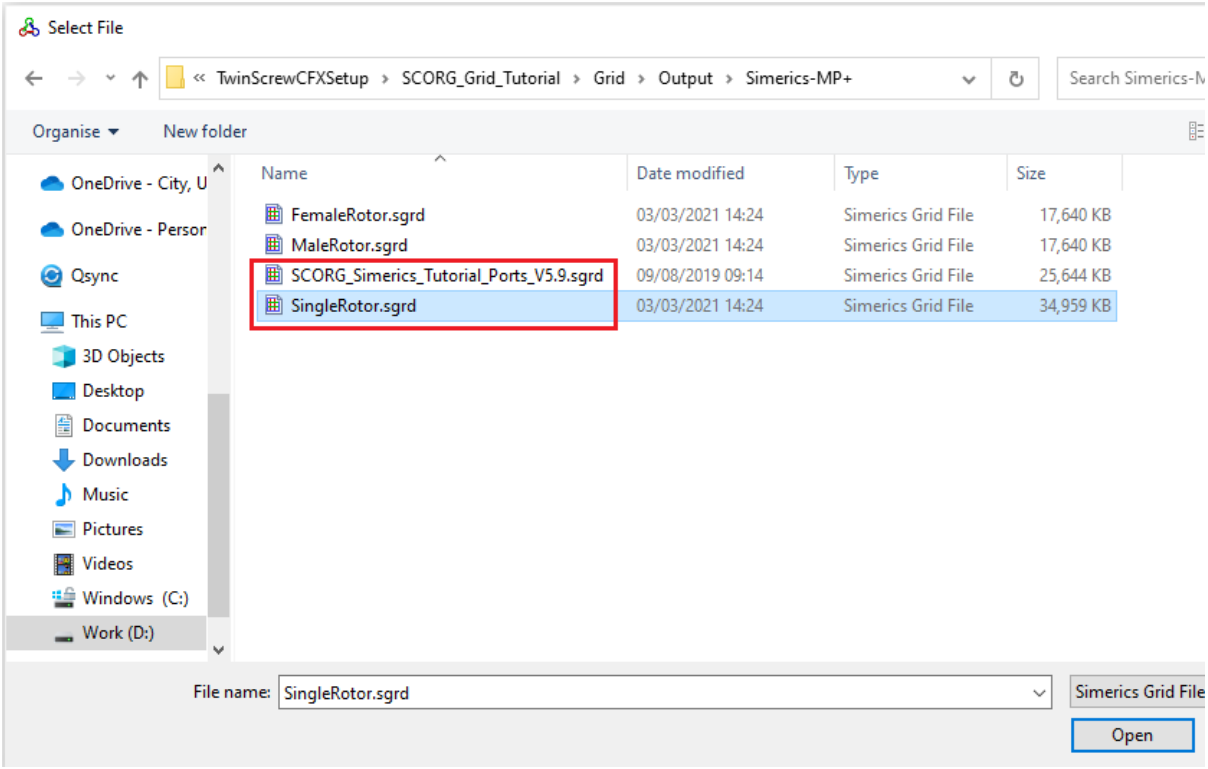


4 Simerics MP+ case setup

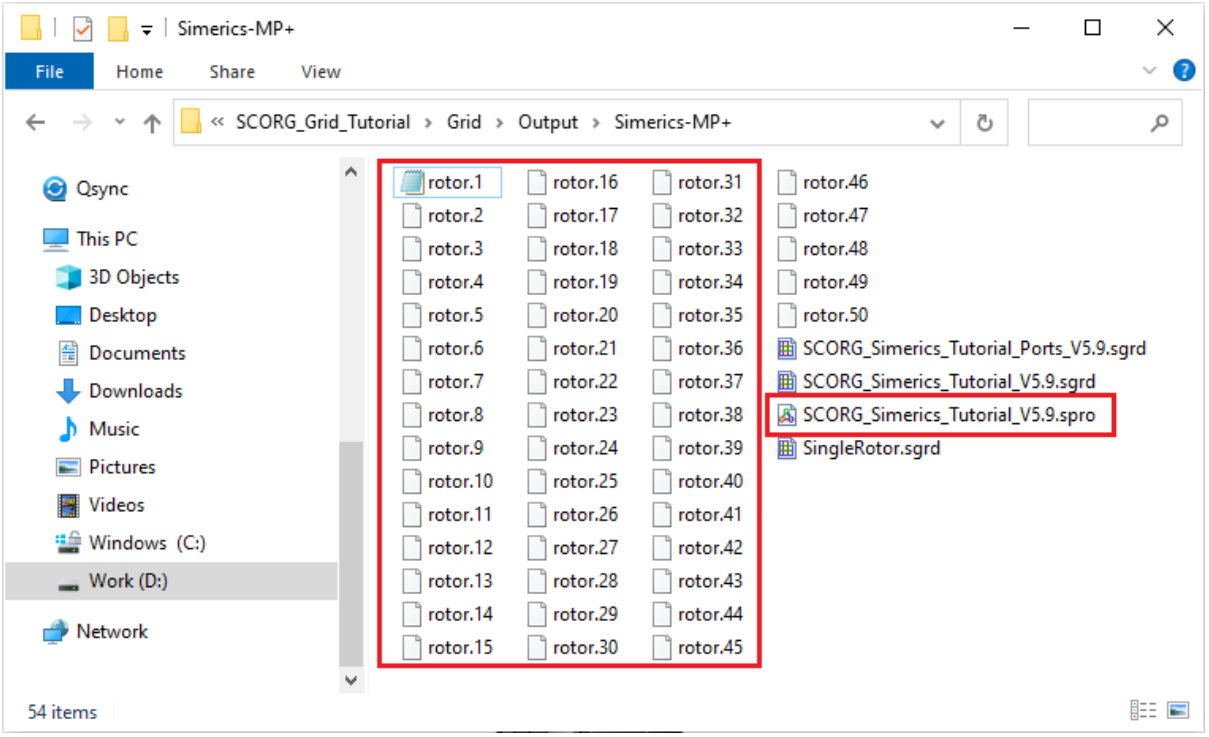
- Launch Simerics MP+
- Select Open → New → Import port and singlerotor grid

- Save as [*TwinScrew35_Compressor.spro*]


Mesh
Model
Simulation
Results
Import/Export Geometry or Grid
Split/Combine Geometry or Grid
Transform Geometry or Grid
Grid and Geometry Information
General Mesher
Template Mesh/Surface
Rotor Template Mesher
Valve Template Mesher
Properties
Import Grid From Simerics Grid File
Operation
Grid Type
Grid Format
Import Grid
3D Grid
Simerics Grid File

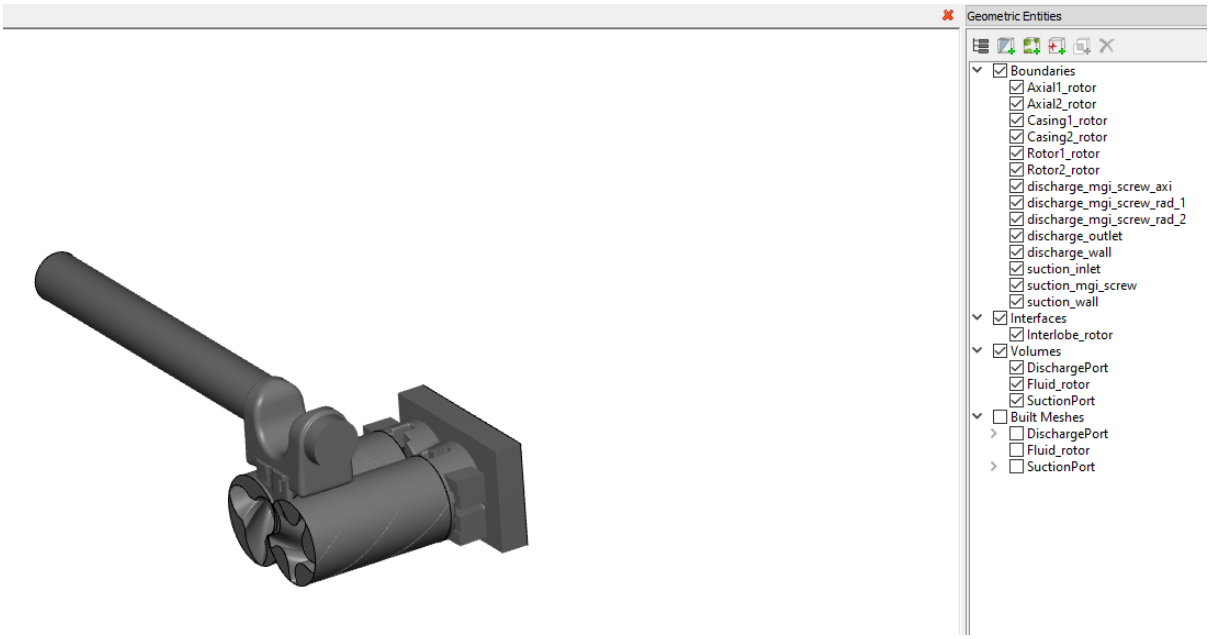


- Click Screw Module → Save As → SCORG_Simerics_Tutorial_V5.9.spro

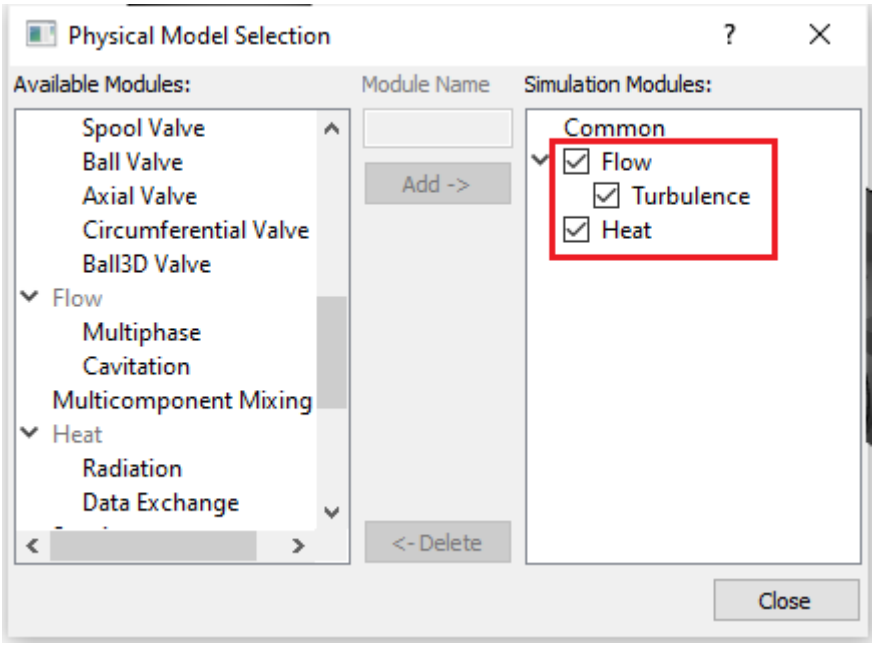


Copy rotor.1, rotor.2 etc files to the working directory.

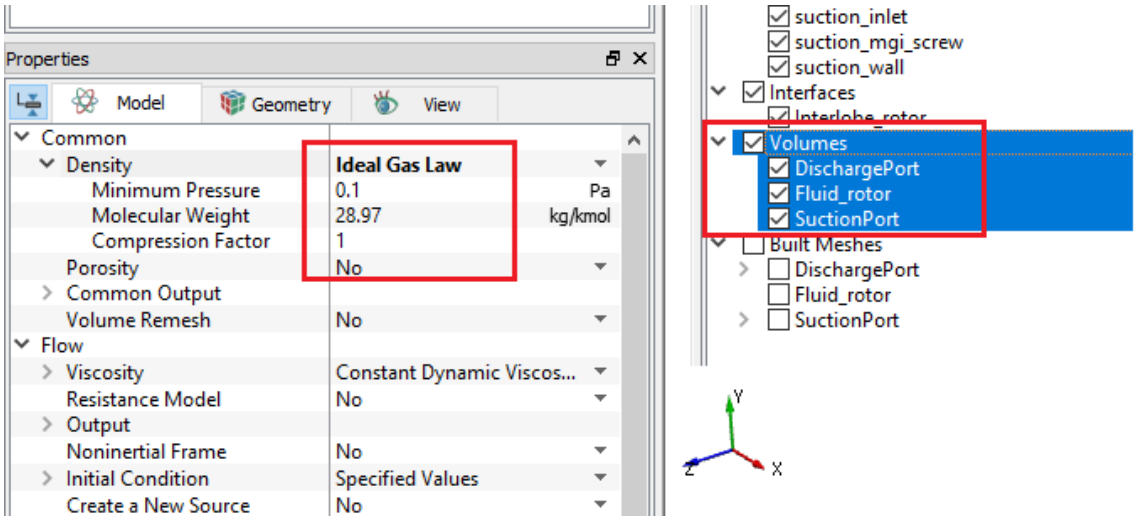
- View Geometric Entities by Type:



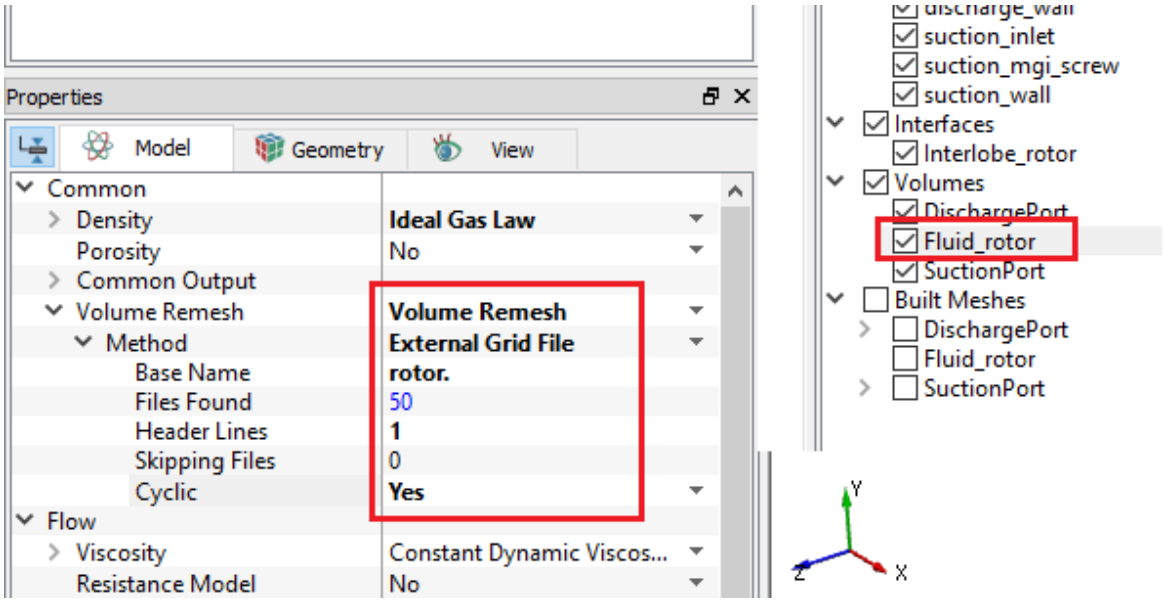
- Add Flow-Turbulence and Heat modules.



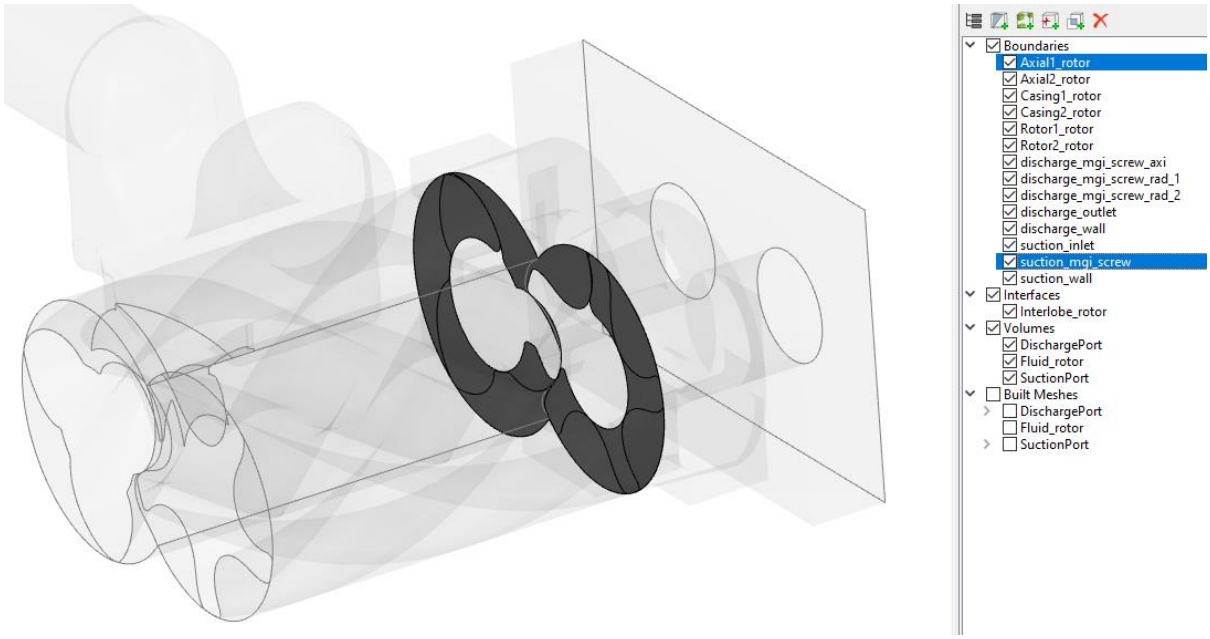
- Select all volumes and set Ideal Gas Law.



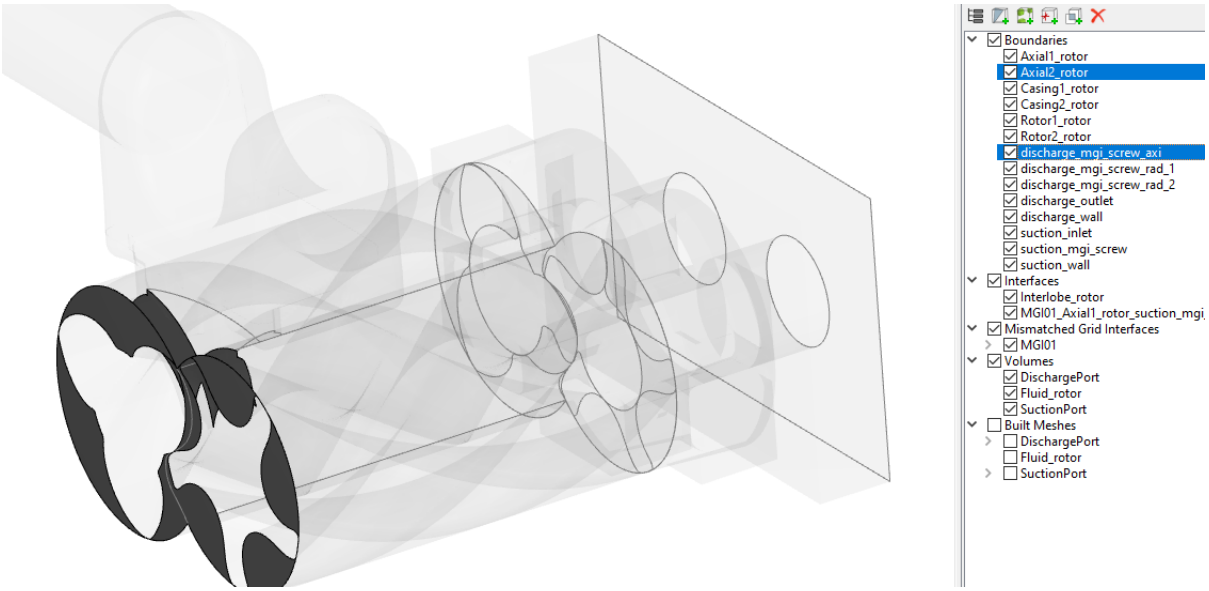
- Select Fluid_rotor and Set Volume Remesh



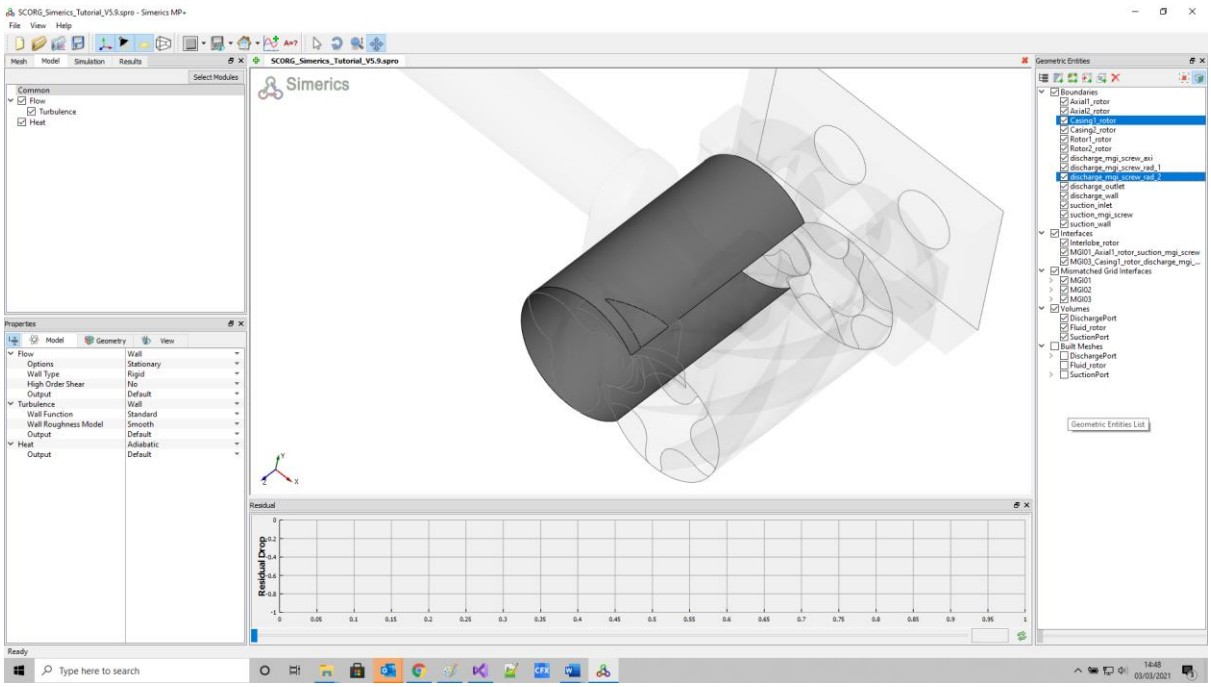
- Create Interfaces
- 1 – Axial Suction



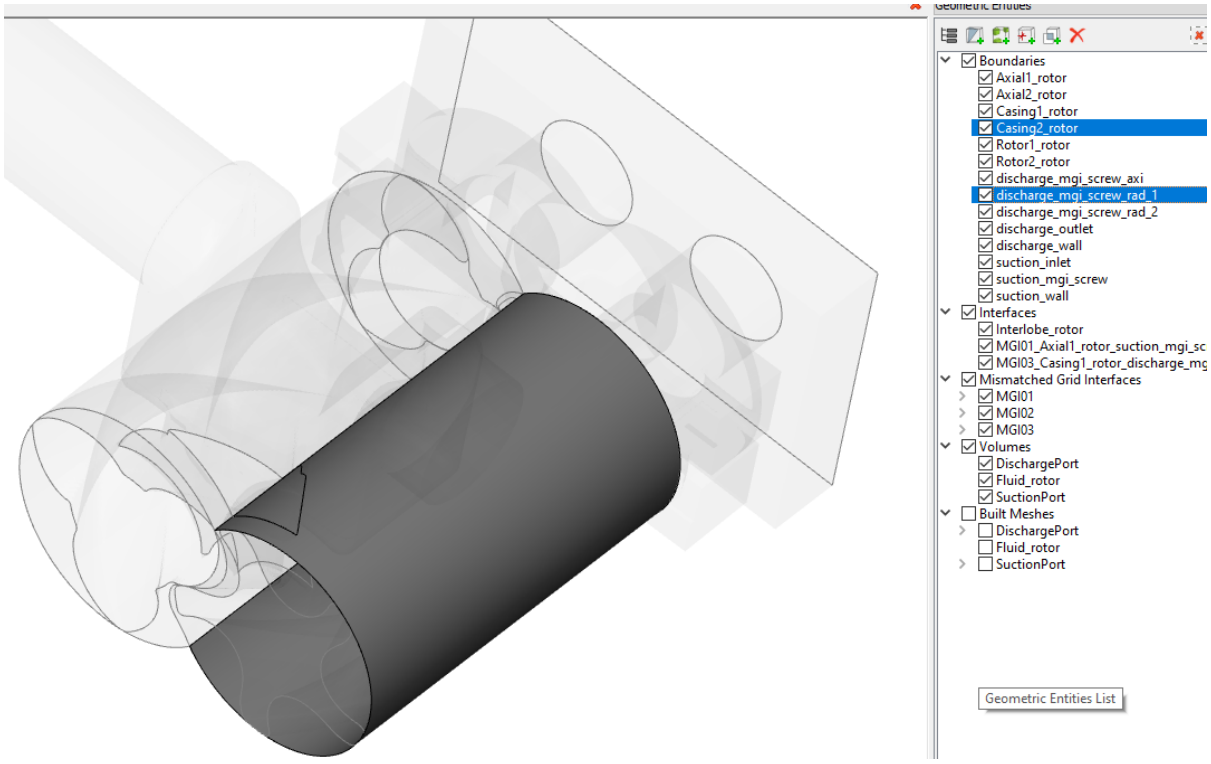
- 2- Axial Discharge



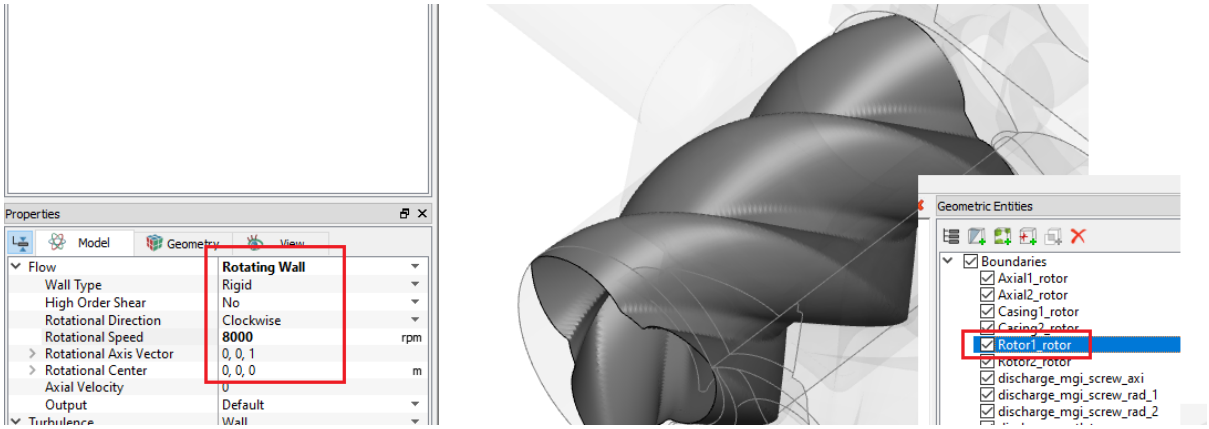
- 3 – Radial Discharge Main Rotor



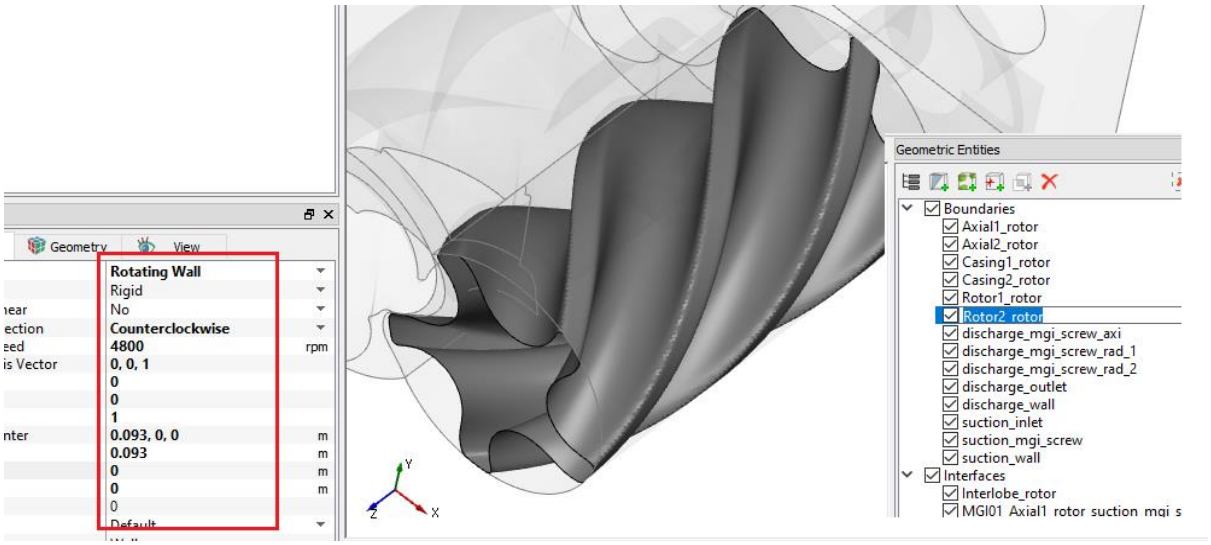
- 4 – Radial Discharge Gate Rotor



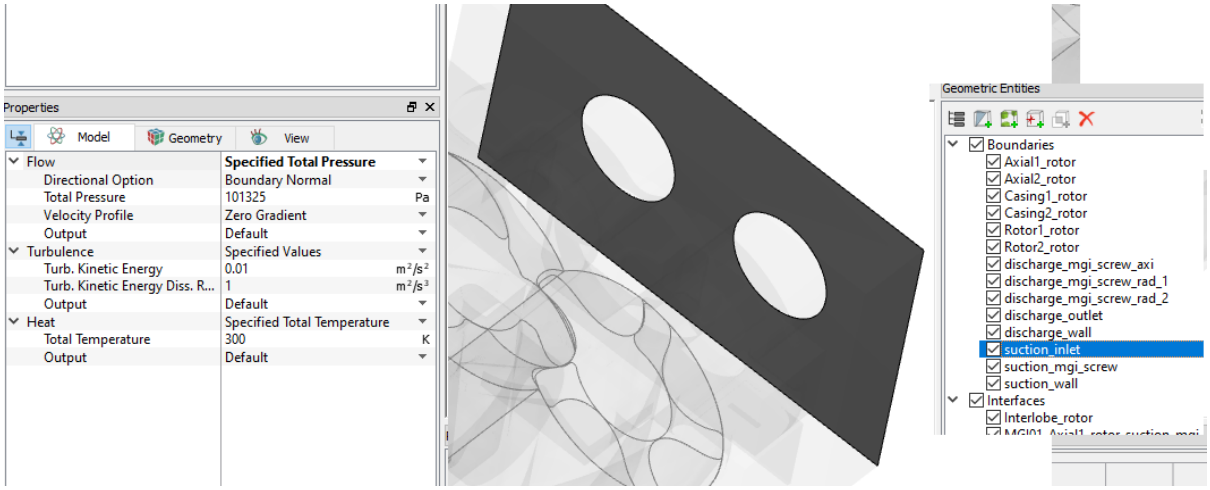
- ***Rotor1_rotor*** has following properties:



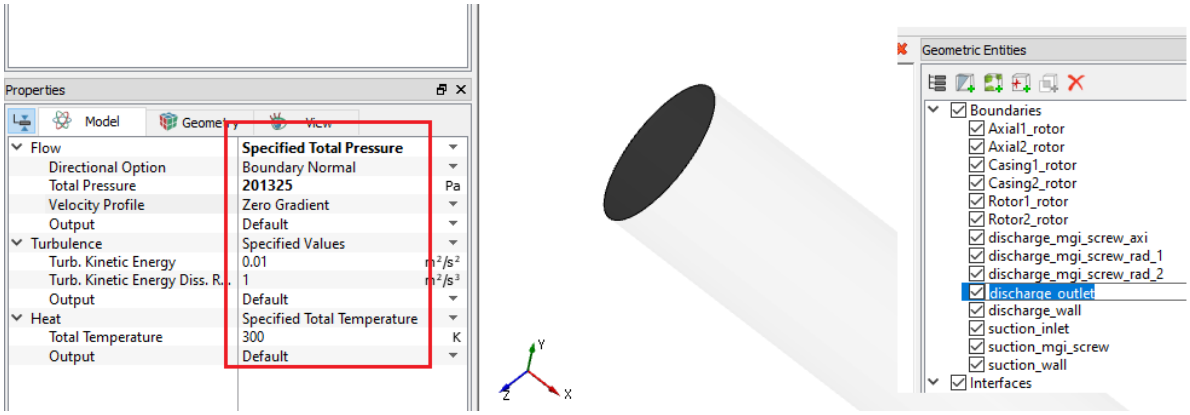
- ***Rotor2_rotor*** has following properties:



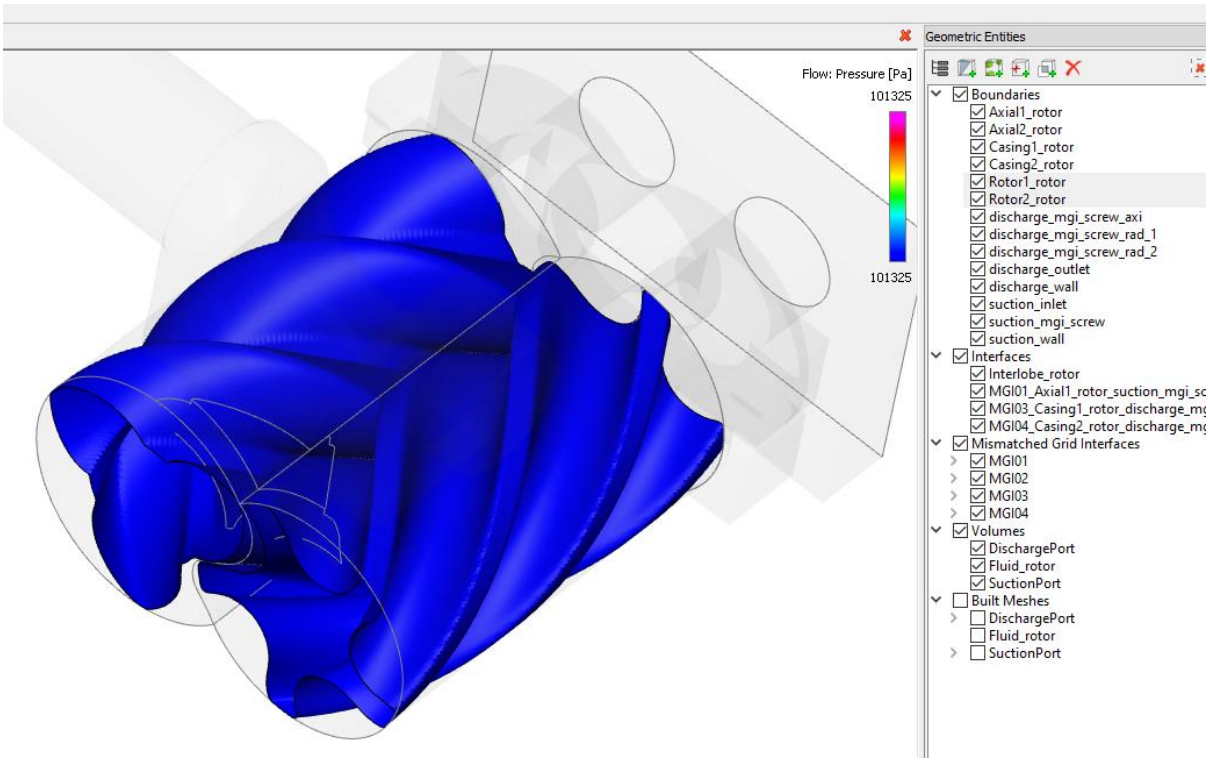
- ***Set Inlet***



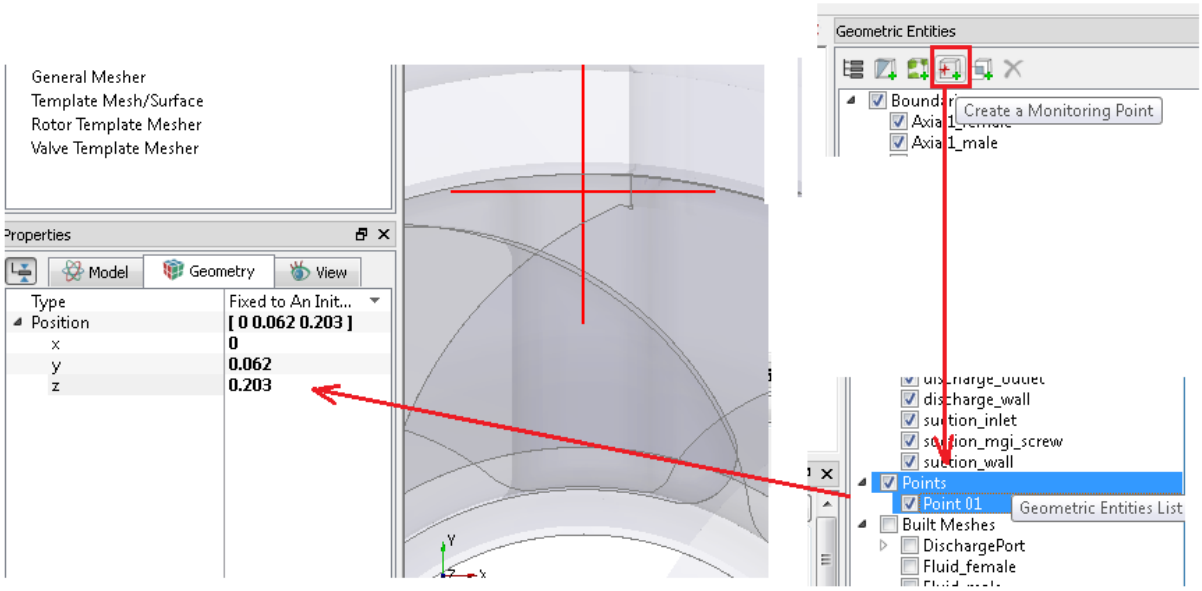
- ***Set Outlet***



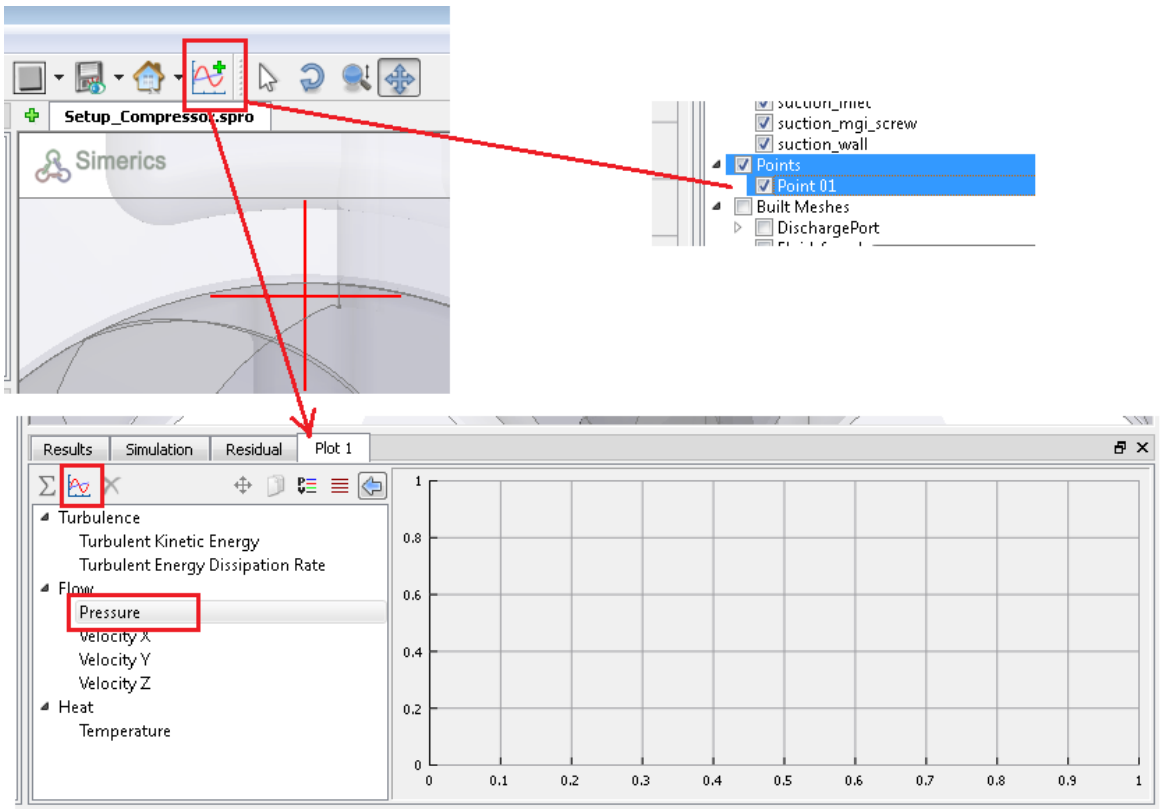
- Go to Geometry tree → Select ***Rotor1_rotor*** and ***Rotor2_rotor***
- Go to Results → Select Pressure



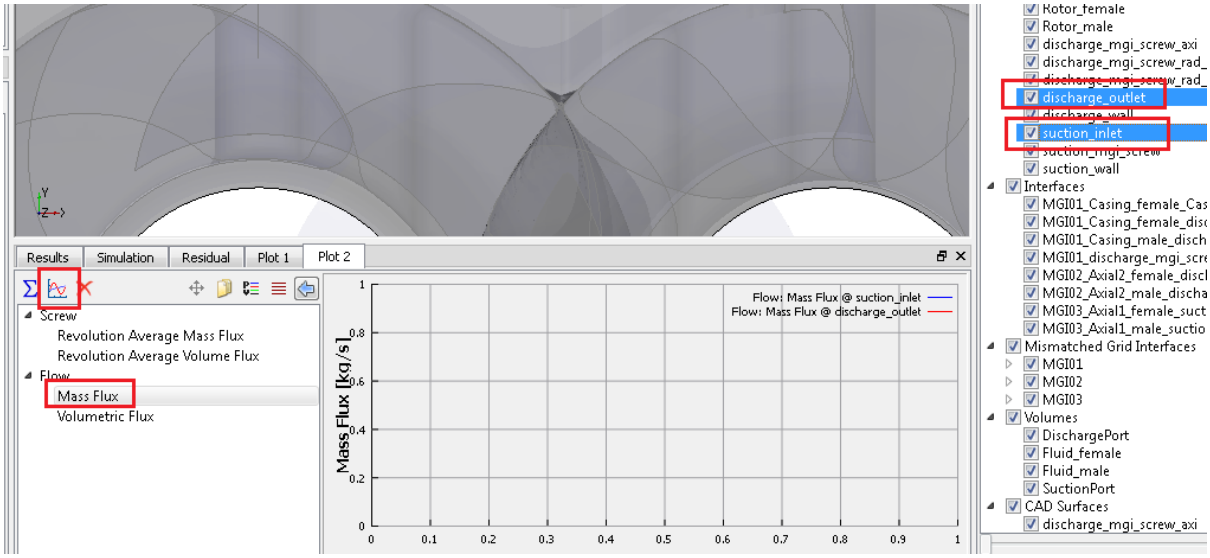
- Create a monitor point at (0.0, 0.062,0.203) for tracking Pressure history



- While Point01 is active in the selection, Click → Add XY Plot → Select Pressure → Plot



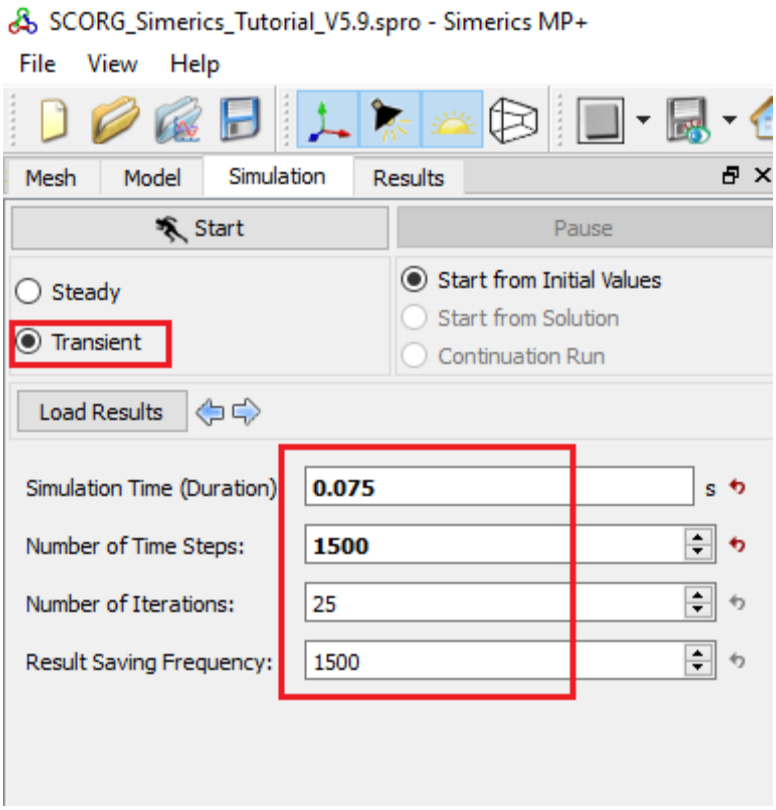
- Similarly create Plots for Mass Flux through the ***suction_inlet*** and ***discharge_outlet*** boundaries.



- Save the project

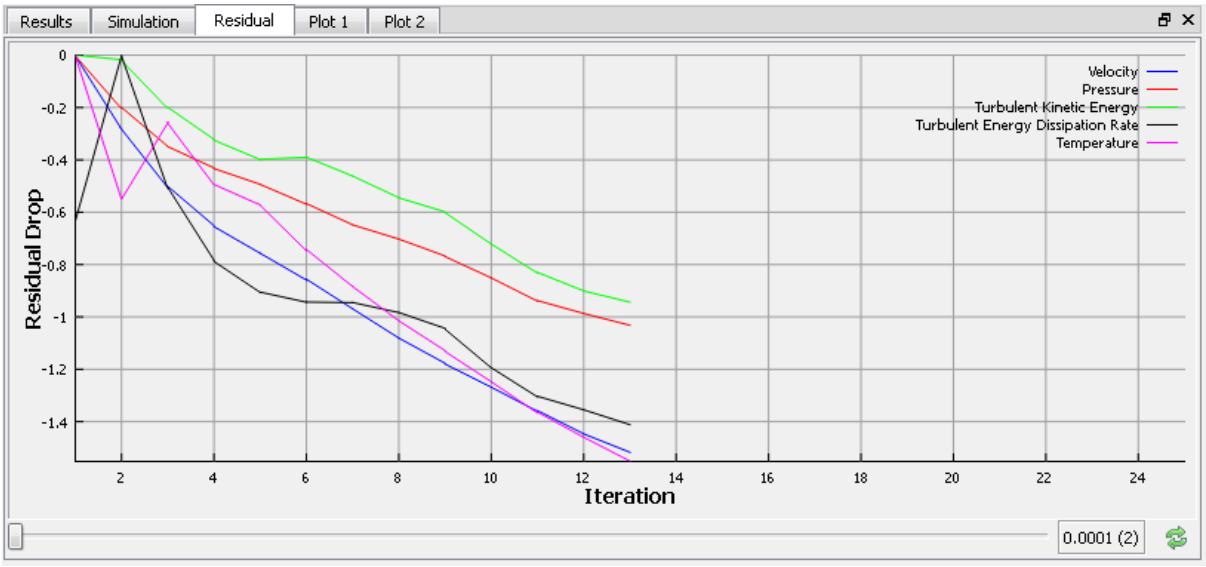
5 Simerics MP+ Solver Calculation

- Go to Simulation tab → Click Start

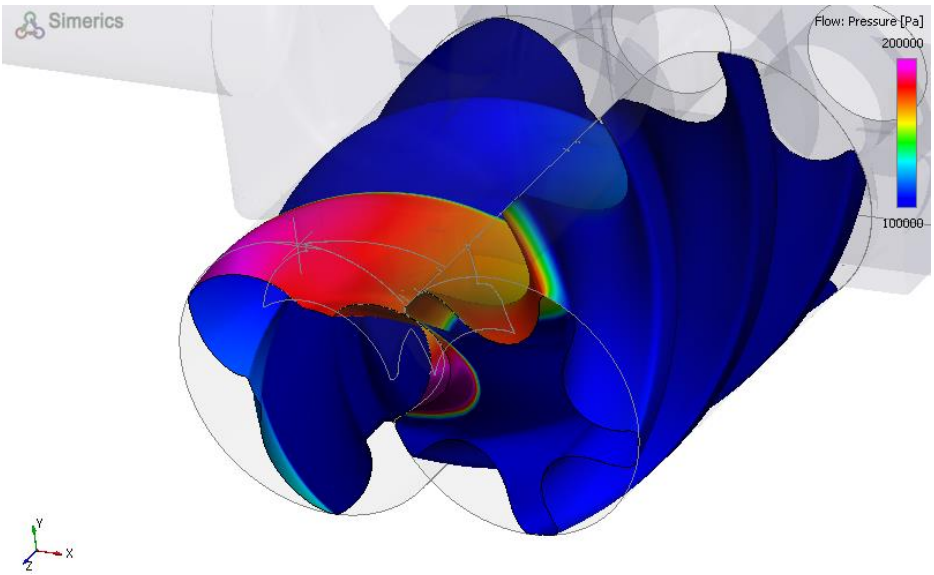


The time step size is controlled by the number of divisions used for angular discretization during grid generation in SCORG.

- Monitor the convergence in residuals:



- Pressure contours on the rotor profile can be seen updated by selecting the boundaries in geometric tree.



6 Summary

This document describes the steps to setup a Simerics MP+ model for Screw compressor CFD analysis starting from output data generated by SCORG™ Meshing tool. More detailed information on using SCORG and Screw compressor mesh generation can be found in user guide (SCORG, 2021). The Screw Module built in Simerics MP+ provides a very fast and user friendly setup procedure. It is possible to make quick changes in the grids and simply update the model by replacing the grid. The setup can be easily duplicated to users own port grids by

editing the ***.spro*** file in an ordinary text editor. More detailed information on using Simerics MP+, Transient simulations and Post-Processing can be found in user guide (Simerics, 2021)

7 Bibliography

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, 2021. *SCORG, User Help Manual,* London: City University.

Simerics, 2021. *Simerics MP+ User Guide, Simerics Inc.* s.l.:Simerics inc.

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

End of Document

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