Project 2: ANSYS DOE

By: Cristian Herrera

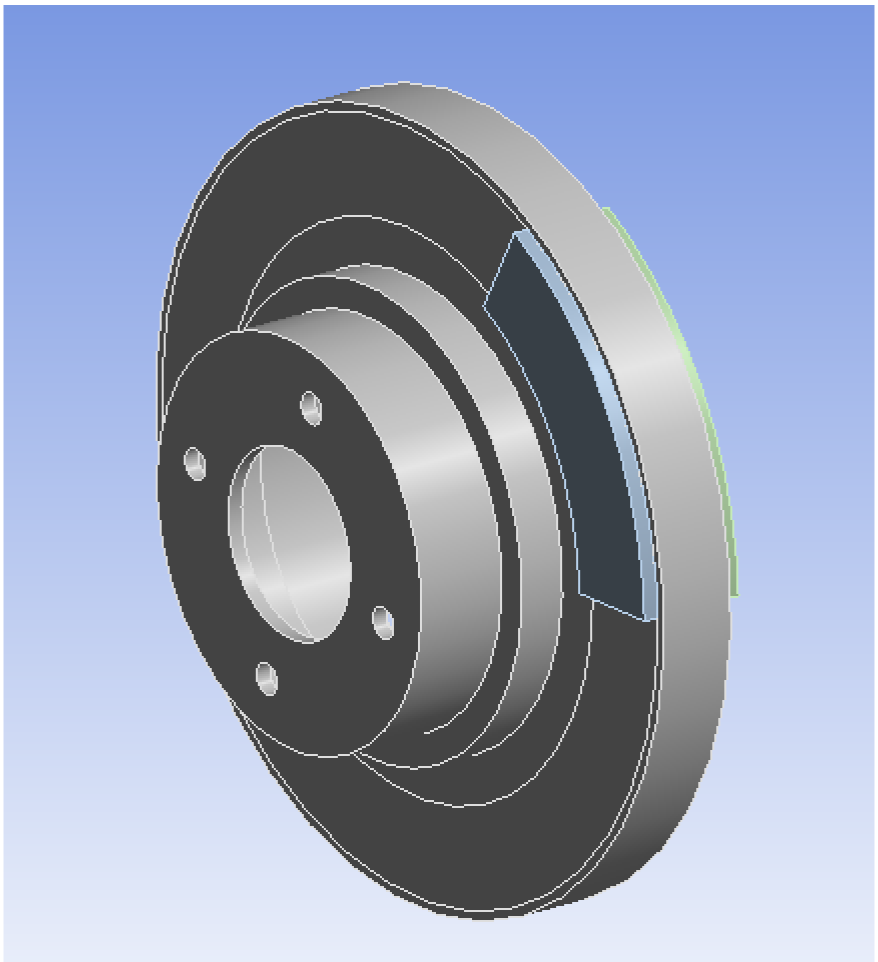
Design Optimization Fall 2021: Yi Ren

12/5/2021

Initial Setup

The following setup outlines the input and output parameters as well as the initial settings of the design experiment outlined for a brake disc and pads. Here the system was designed to minimize thermal loading as well as the maximum Von-Misses stress experienced by the system while simultaneously maximizing the first natural frequency experienced by the brake disk.

Geometry:



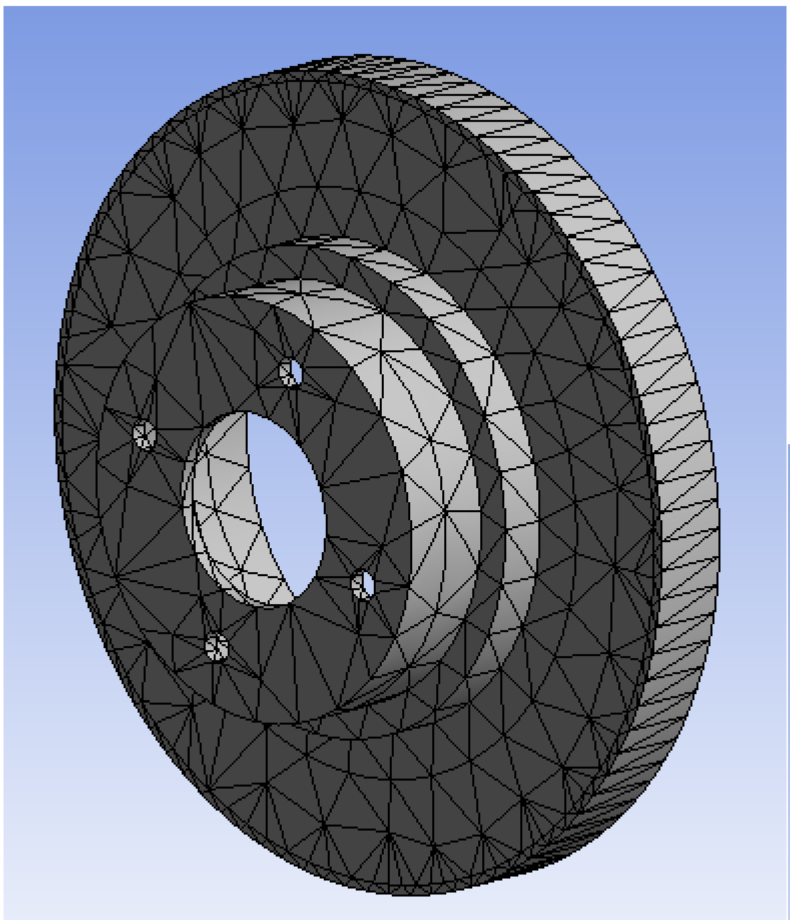
Mesh:

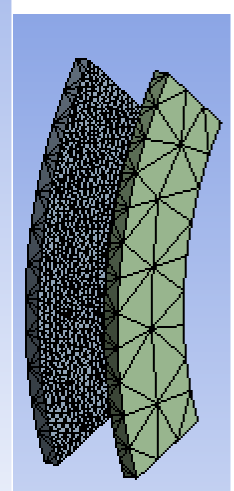
Details of "Patch Conforming Method" - Method

Scope	
Scoping Method	Geometry Selection
Geometry	3 Bodies
Definition	
Suppressed	No
Method	Tetrahedrons
Algorithm	Patch Conforming
Element Order	Use Global Setting

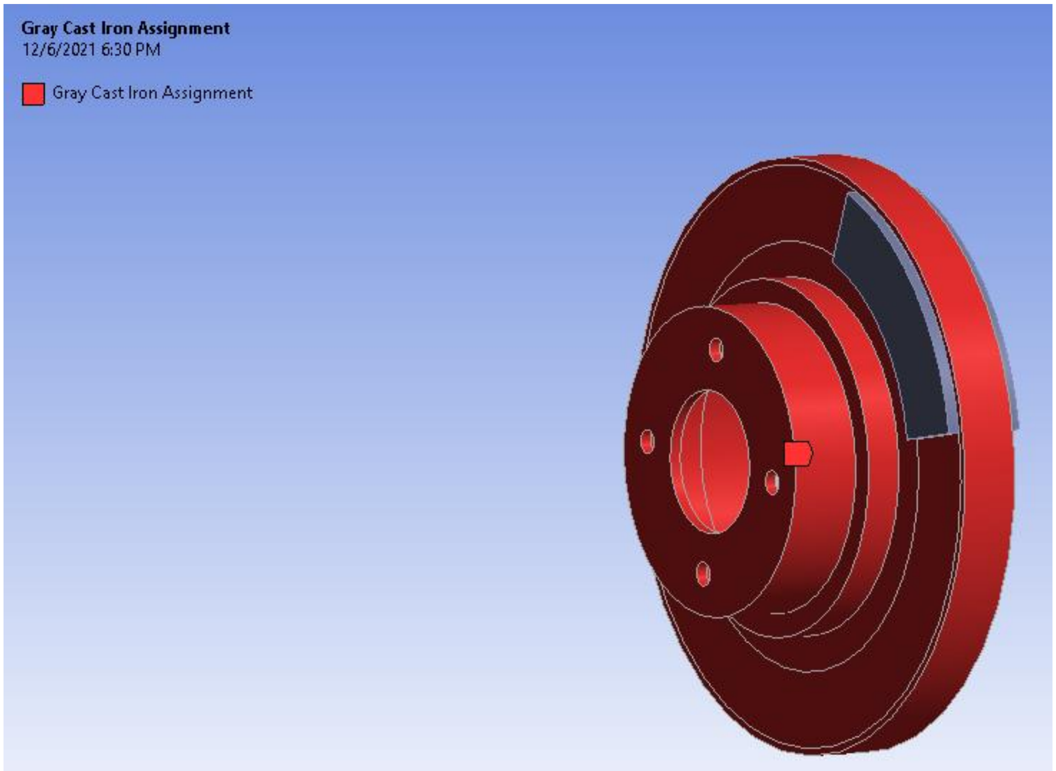
Details of "Face Sizing" - Sizing

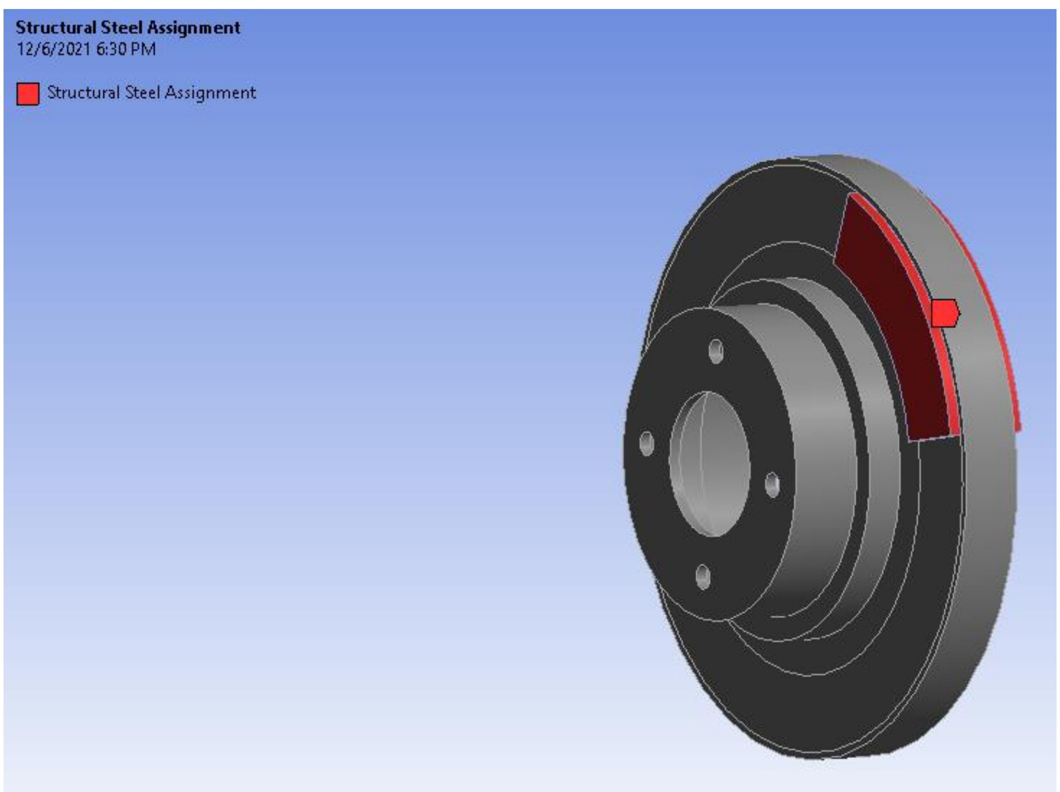
Scope	
Scoping Method	Geometry Selection
Geometry	2 Faces
Definition	
Suppressed	No
Type	Element Size
Element Size	3.e-003 m
Advanced	
Defeature Size	Default
Influence Volume	No
Behavior	Soft



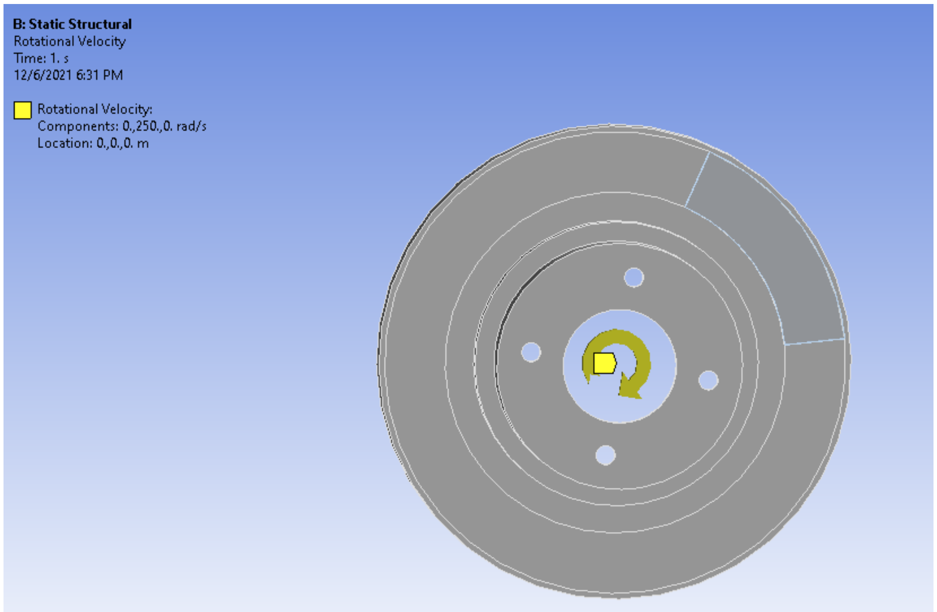


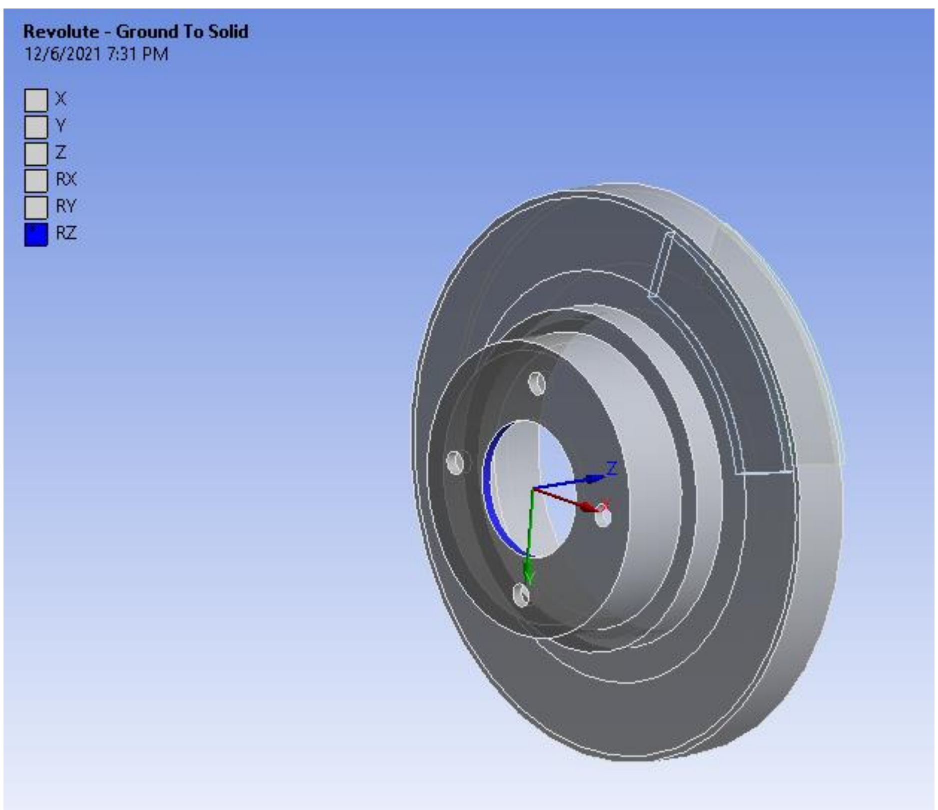
Material Assignment:

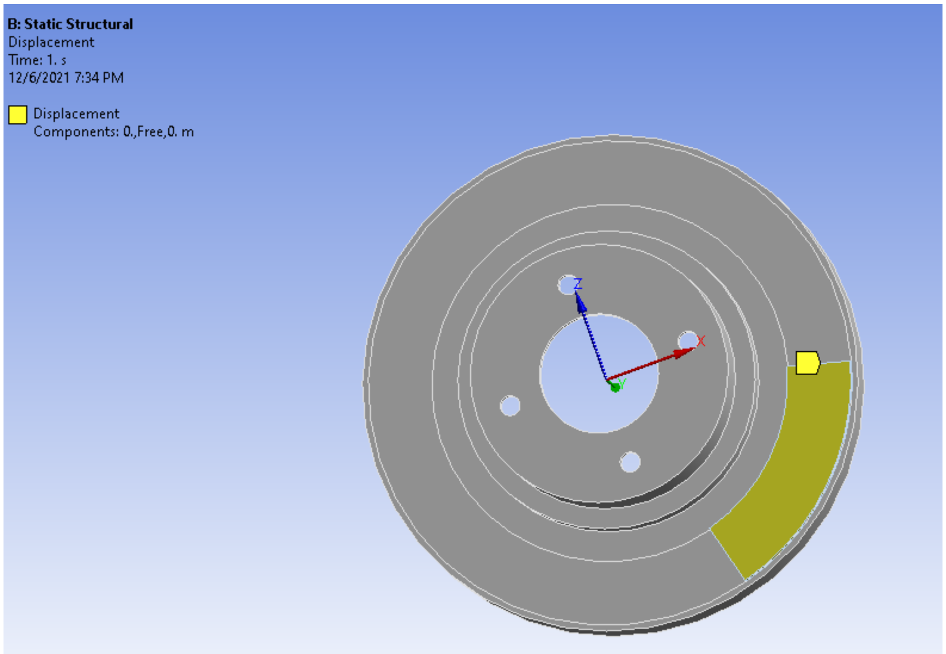




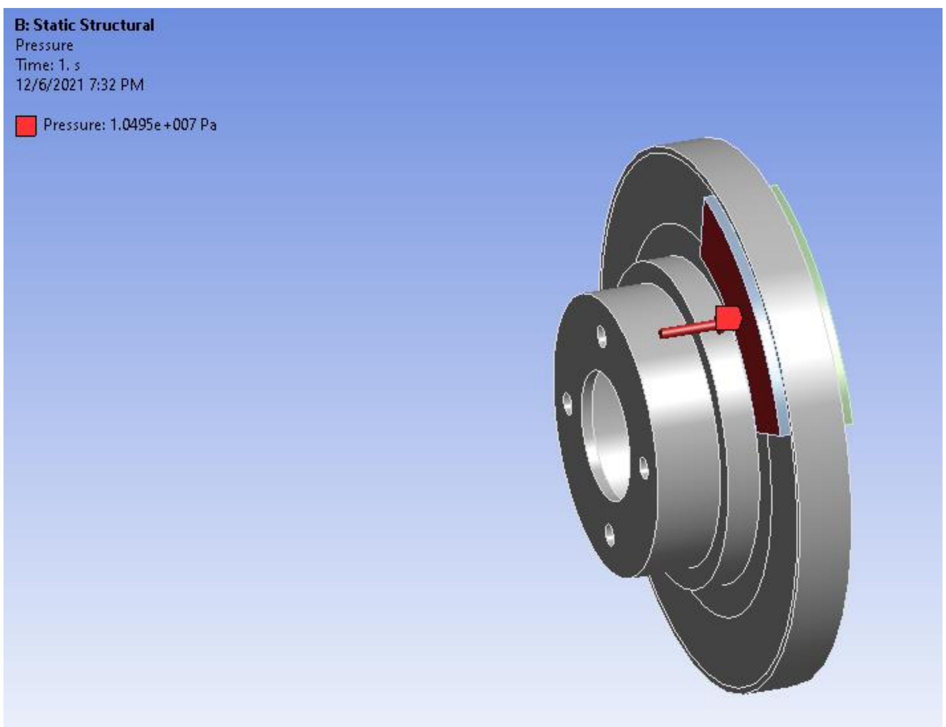
Boundary Conditions:

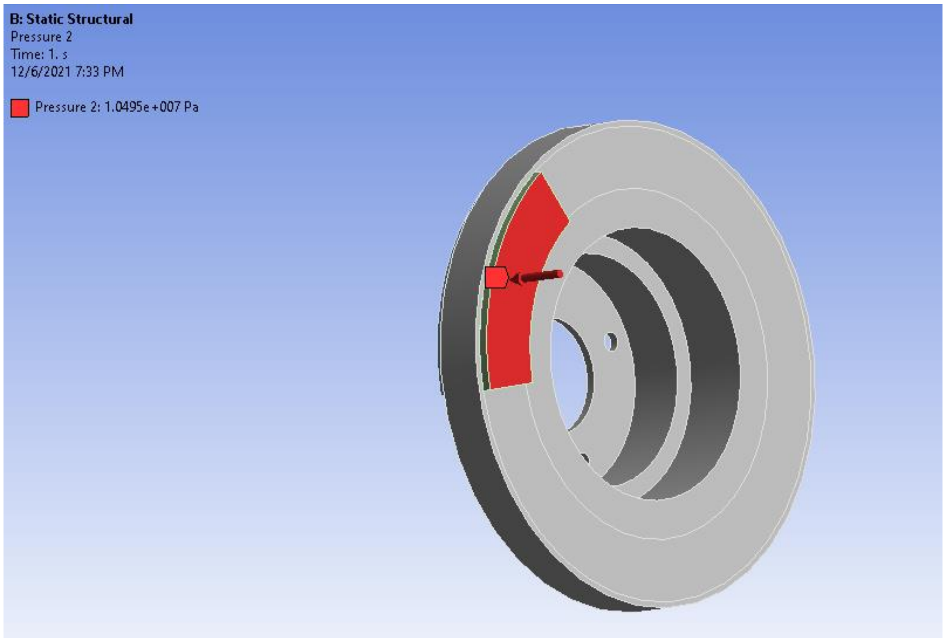


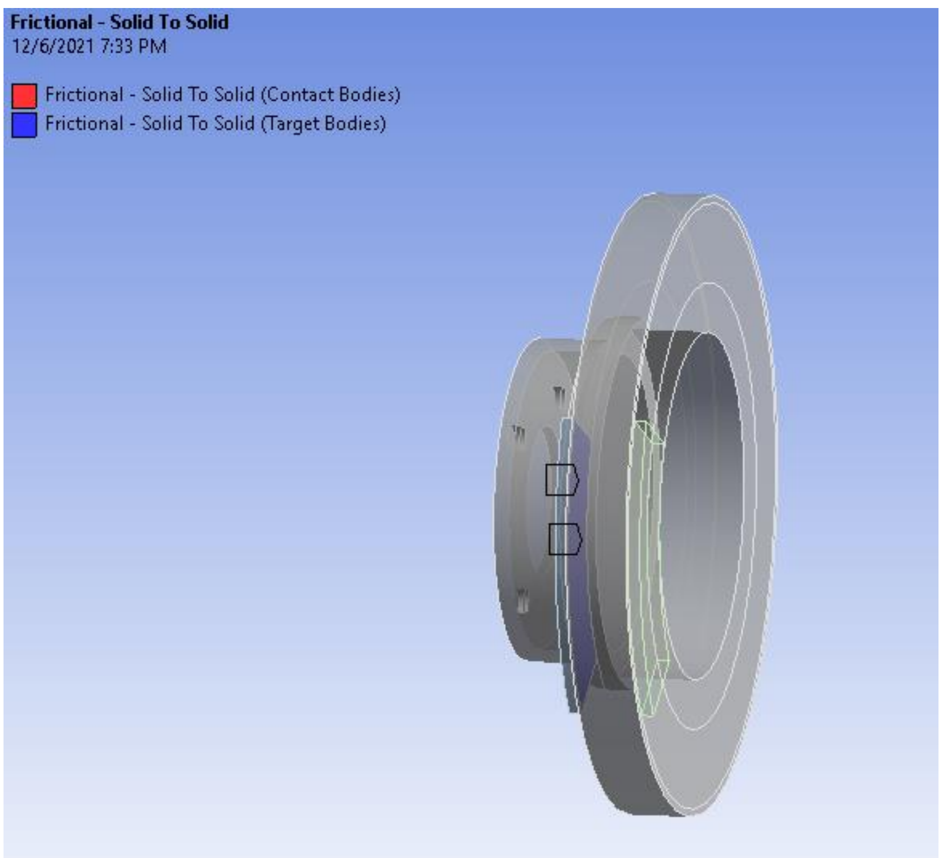


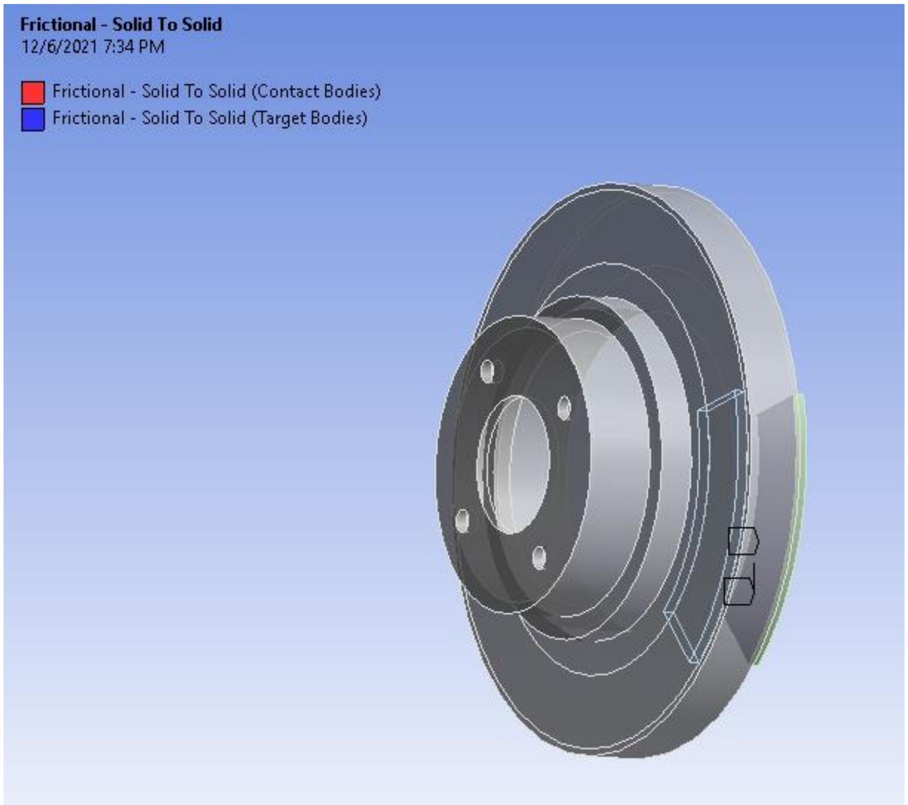


Loads and Contacts




B: Static Structural
Pressure 2
Time: 1. s
12/6/2021 7:33 PM
Pressure 2: 1.0495e+007 Pa


Frictional - Solid To Solid
12/6/2021 7:33 PM
Frictional - Solid To Solid (Contact Bodies)
Frictional - Solid To Solid (Target Bodies)



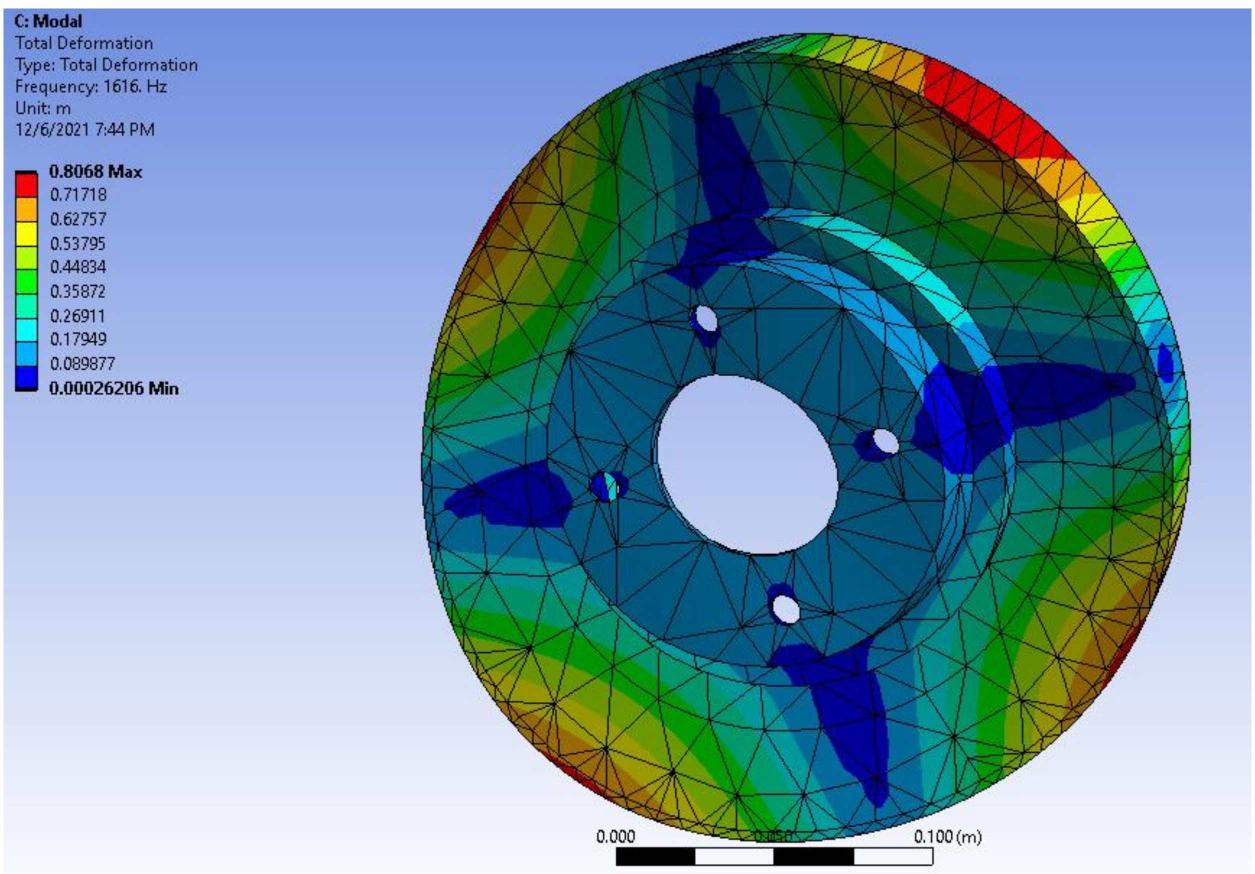
Details of "Equivalent Stress"

Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	1.9084e+005 Pa
P Maximum	1.3503e+007 Pa
Average	5.1069e+006 Pa
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Minimum Value Over Time	
Minimum	10879 Pa
Maximum	1.9084e+005 Pa
Maximum Value Over Time	
Minimum	2.3995e+006 Pa
Maximum	1.3503e+007 Pa
Information	

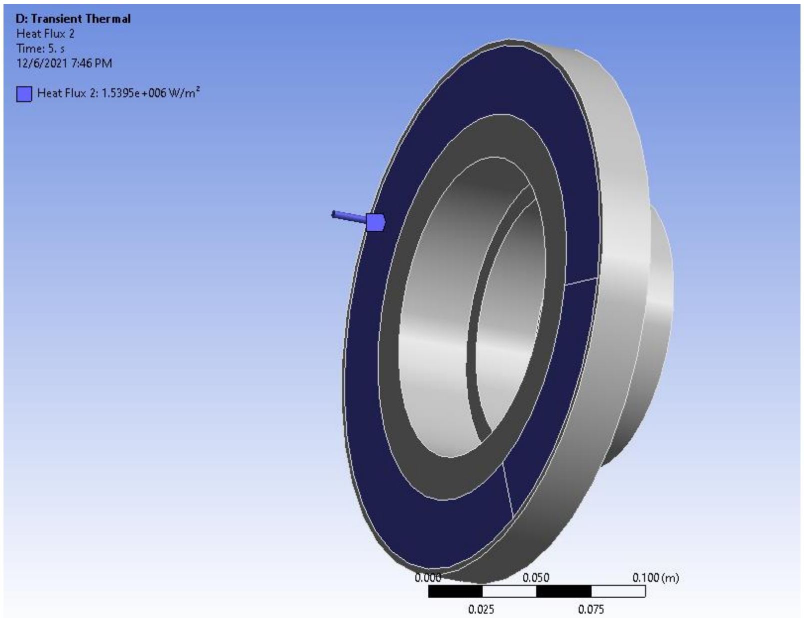
Modal setup:

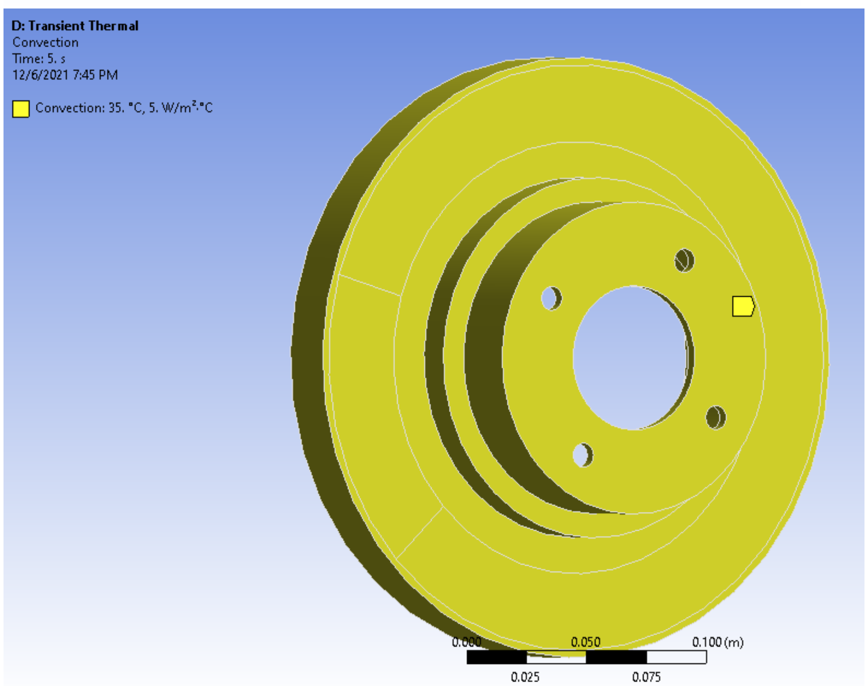
Details of "Total Deformation"

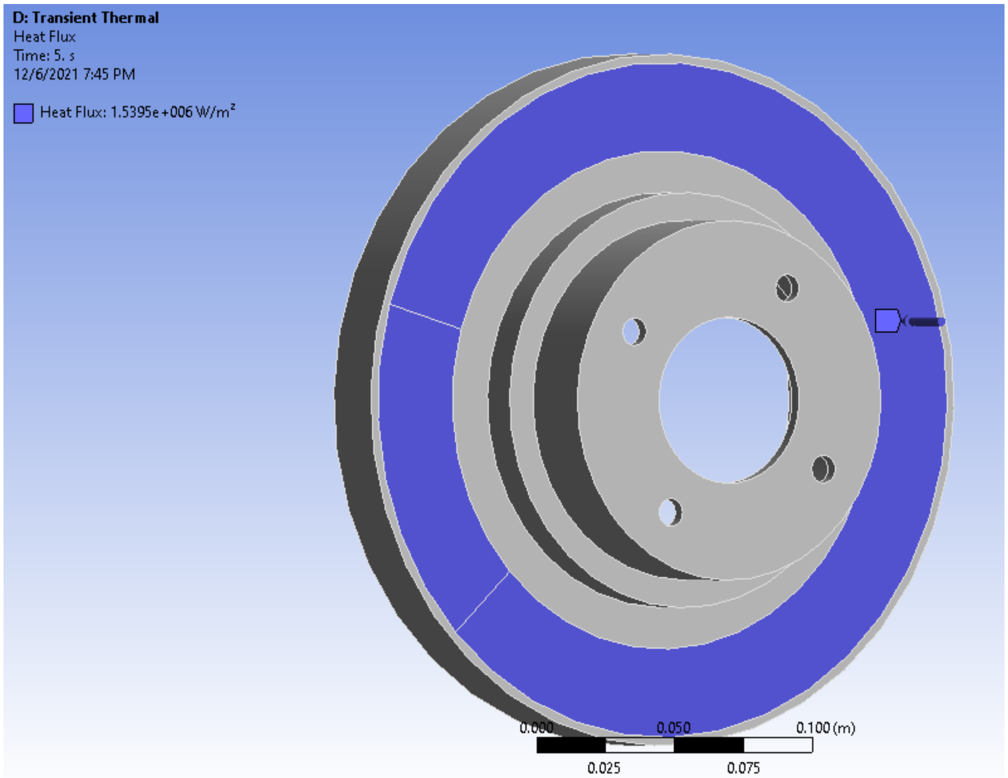
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
Mode	7.
Identifier	
Suppressed	No
Results	
Minimum	2.6206e-004 m
Maximum	0.8068 m
Average	0.34276 m
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Information	
P Frequency	1616. Hz

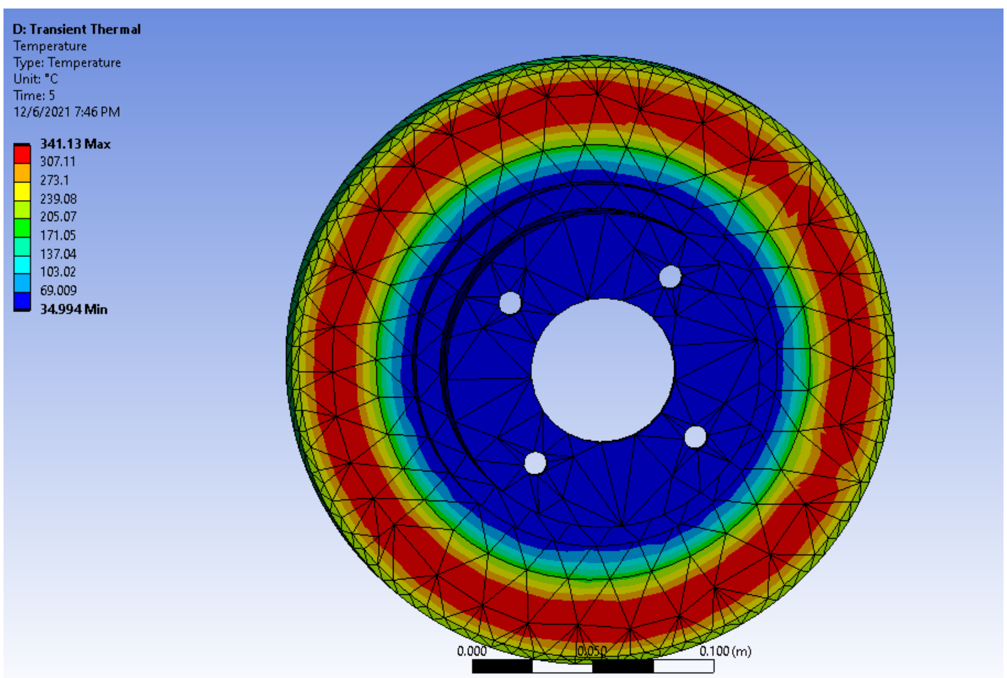


Transient Thermal:






D: Transient Thermal
Heat Flux
Time: 5. s
12/6/2021 7:45 PM
Heat Flux: 1.5395e+006 W/m²
0.000
0.050
0.100 (m)
0.025
0.075


D: Transient Thermal
Temperature
Type: Temperature
Unit: °C
Time: 5
12/6/2021 7:46 PM
341.13 Max
307.11
273.1
239.08
205.07
171.05
137.04
103.02
69.009
34.994 Min
0.000
0.050
0.100 (m)
0.025
0.075

Details of "Temperature"	
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Temperature
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Results	
Minimum	34.994 °C
P Maximum	341.13 °C
Average	145.71 °C
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Minimum Value Over Time	
Minimum	10.476 °C
Maximum	34.995 °C
Maximum Value Over Time	
Minimum	60.307 °C

Input Parameters:

Details View	
Show Constraints?	No
Dimensions: 11	
H18	5 mm
H20	30 mm
H21	35 mm
H27	5 mm
P H28	25 mm
V13	5 mm
V26	30 mm
P V29	125 mm
P V30	75 mm
V31	30 mm
V9	5 mm
Edges: 13	
Line	Ln8
Line	Ln9

Design of Experiments:

The design of experiments method used is optimal space filling with user defined samples as was recommended in the tutorial and ran 50 samples to ensure a decent sample size was reached.

	A	B
1		Enabled
2	Design of Experiments	
3	Input Parameters	
4	Geometry (A1)	
5	P1 - rotor_thickness	☑
6	P2 - rotor_OD	☑
7	P3 - rotor_ID	☑
8	Output Parameters	
9	Static Structural (B1)	
10	P4 - Equivalent Stress Maximum	
11	Modal (C1)	
12	P5 - Total Deformation Reported Frequency	
13	Transient Thermal (D1)	
14	P6 - Temperature Maximum	
15	Charts	
16	Parameters Parallel	
17	Design Points vs Parameter	

Properties of Outline A2: Design of Experiments

	A	B
1	Property	Value
2	Design Points	
3	Preserve Design Points After DX Run	☐
4	Failed Design Points Management	
5	Number of Retries	0
6	Design of Experiments	
7	Design of Experiments Type	Optimal Space-Filling Design
8	Design Type	Max-Min Distance
9	Maximum Number Of Cycles	10
10	Samples Type	User-Defined Samples
11	Random Generator Seed	0
12	Number of Samples	50
13	Design Point Report	
14	Report Image	None

Properties of Outline A5: P10 - rotor_thickness

	A	B
1	Property	Value
2	General	
3	Units	mm
4	Type	Design Variable
5	Classification	Continuous
6	Values	
7	Lower Bound	20
8	Upper Bound	30
9	Allowed Values	Any

Properties of Outline A6: P11 - rotor_OD

	A	B
1	Property	Value
2	General	
3	Units	mm
4	Type	Design Variable
5	Classification	Continuous
6	Values	
7	Lower Bound	122
8	Upper Bound	150
9	Allowed Values	Any

Properties of Outline A7: P12 - rotor_ID

	A	B
1	Property	Value
2	General	
3	Units	mm
4	Type	Design Variable
5	Classification	Continuous
6	Values	
7	Lower Bound	61
8	Upper Bound	88
9	Allowed Values	Any

Table of Outline A2: Design Points of Design of Experiments

	A	B	C	D	E	F	G
1	Name	P10 - rotor_thickness (mm)	P11 - rotor_OD (mm)	P12 - rotor_ID (mm)	P4 - Equivalent Stress Maximum (Pa)	P5 - Total Deformation Reported Frequency (Hz)	P6 - Temperature Maximum (C)
2	1	24.1	124.52	83.95	1.416E+07	1412.5	341.36
3	2	22.9	140.2	78.55	1.1502E+07	1301.2	348.21
4	3	20.5	139.64	66.67	1.093E+07	1242.3	359.22
5	4	26.7	142.44	87.73	1.2207E+07	1206.3	341.06
6	5	20.9	130.12	65.05	1.1183E+07	1427.6	357.44
7	6	29.1	128.44	73.15	1.1854E+07	1663.1	333.97
8	7	23.7	143	86.65	1.1748E+07	1175.1	346.94
9	8	24.9	143.56	62.35	1.1607E+07	1232.3	340.91
10	9	23.5	131.8	76.93	1.1186E+07	1454.5	347.34
11	10	22.3	136.84	61.81	1.1145E+07	1280.4	349.8
12	11	23.1	126.2	63.97	1.1147E+07	1572.6	344.9
13	12	21.1	134.04	72.61	1.1106E+07	1423.9	355.75
14	13	29.9	135.16	78.01	1.24E+07	1495.8	336.72
15	14	26.1	129.56	72.07	1.1829E+07	1596.3	339.79
16	15	22.1	135.72	85.57	1.1459E+07	1252.6	351.44
17	16	25.3	148.04	82.33	1.1978E+07	1186	340.06
18	17	29.7	144.68	71.53	1.2839E+07	1374.8	331.87
19	18	28.7	146.36	81.79	1.29E+07	1262.2	333.75
20	19	20.3	129	79.09	1.1333E+07	1436.7	360.44
21	20	20.7	144.12	73.69	1.1393E+07	1219	360
22	21	20.1	137.4	80.17	1.1097E+07	1295.9	363.23
23	22	22.7	123.4	77.47	1.3737E+07	1555.4	349.34
24	23	28.1	141.88	62.89	1.2509E+07	1362.8	335.76
25	24	21.3	125.64	70.99	1.1443E+07	1597.1	349.78
26	25	24.5	148.6	67.75	1.1406E+07	1188.8	343.22
27	26	24.7	132.92	86.11	1.2143E+07	1305.1	345.3
28	27	26.5	131.24	79.63	1.1625E+07	1465.4	340.15
29	28	25.9	126.76	64.51	1.1324E+07	1645	337.45
30	29	25.5	134.6	61.27	1.1325E+07	1419.1	338.56
31	30	22.5	149.16	76.39	1.1435E+07	1160.4	350.32
32	31	21.5	145.8	83.41	1.1354E+07	1159.2	357
33	32	28.3	132.36	63.43	1.1892E+07	1574	335.16
34	33	23.9	133.48	68.29	1.1172E+07	1477.5	345.54
35	34	29.5	136.28	68.83	1.219E+07	1549.7	338.23
36	35	23.3	141.32	69.91	1.1382E+07	1321.4	346.9
37	36	28.5	125.08	66.13	1.3862E+07	1771.3	334.73
38	37	28.9	138.52	84.49	1.2403E+07	1327.6	335.61
39	38	29.3	127.32	81.25	1.2494E+07	1521.7	334.28
40	39	24.3	122.84	70.45	1.4286E+07	1719.6	343.7
41	40	27.1	122.28	74.23	1.2748E+07	1725	344.42
42	41	25.1	145.24	74.77	1.1509E+07	1276.5	340.18
43	42	27.5	147.48	67.21	1.2635E+07	1278	335.06
44	43	26.9	123.96	82.87	1.2595E+07	1479.1	339.31
45	44	21.7	127.88	85.03	1.1357E+07	1334.5	354.49
46	45	27.7	130.68	87.19	1.2322E+07	1348	338.82
47	46	26.3	137.96	69.37	1.1432E+07	1445.7	336.87
48	47	27.3	149.72	75.31	1.2222E+07	1235.4	335.16
49	48	27.9	140.76	75.85	1.2083E+07	1393.2	334.37
50	49	21.9	146.92	65.59	1.1289E+07	1125	352.37
51	50	25.7	139.08	80.71	1.1653E+07	1334.8	339.77

Response Surface:

For the response surface algorithm I chose kriging because I was not worried about the computation times as my sample size is not particularly large and I wanted my model to fit right through my data points because I trusted I followed the tutorial and got the simulation results I needed

Properties of Outline A2: Response Surface

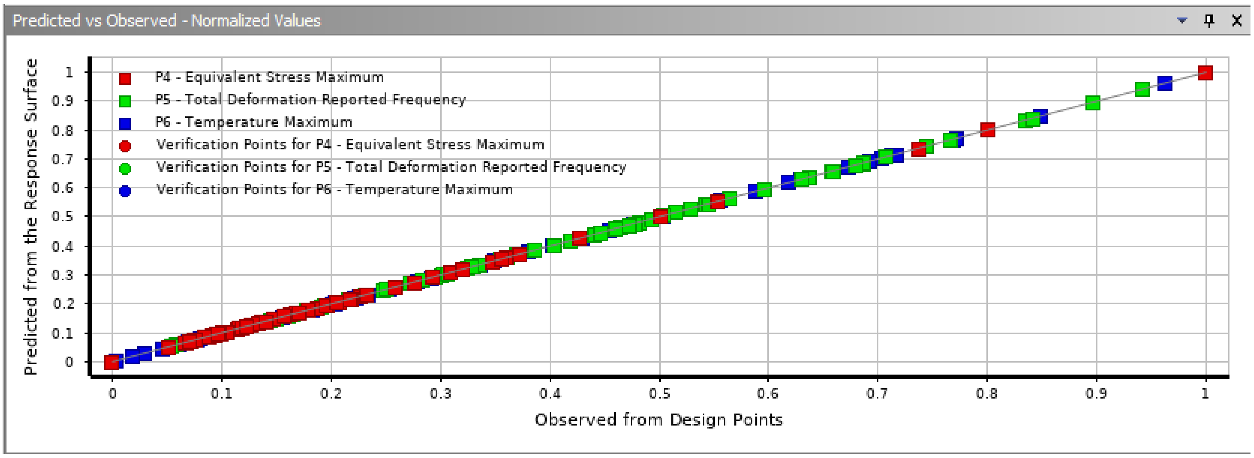
	A	B
1	Property	Value
2	Design Points	
3	Preserve Design Points After DX Run	☐
4	Failed Design Points Management	
5	Number of Retries	0
6	Meta Model	
7	Response Surface Type	Kriging
8	Kernel Variation Type	Variable
9	Refinement	
10	Refinement Type	Manual
11	Verification Points	
12	Generate Verification Points	☑
13	Number of Verification Points	17
14	Design Point Report	
15	Report Image	None

Table of Outline A20: Verification Points

	A	B	C	D	E	F	G
1	Name	P10 - rotor_thickness (mm)	P11 - rotor_OD (mm)	P12 - rotor_ID (mm)	P4 - Equivalent Stress Maximum (Pa)	P5 - Total Deformation Reported Frequency (Hz)	P6 - Temperature Maximum (C)
2	1	29.925	149.85	87.874	1.8404E+07	1164.4	335.46
3	2	20.316	149.54	61.307	1.0358E+07	1026.8	351.24
4	3	20.936	122.03	62.297	1.1697E+07	1590.7	366.35
5	4	29.978	149.53	62.143	1.3563E+07	1272.9	332.05
6	5	29.86	122.13	62.047	1.3372E+07	1856	340.96
7	6	29.706	123.18	71.086	1.2739E+07	1808.3	333.08
8	7	20.054	147.81	87.319	2.126E+07	1075.8	363.08
9	8	20.238	122.05	75.329	1.1426E+07	1613.6	370.97
10	9	26.193	122.02	86.344	1.4418E+07	1397.3	346.08
11	10	29.939	149.8	75.744	1.3185E+07	1281.3	332.67
12	11	29.024	122.2	87.649	1.5824E+07	1409.4	342.14
13	12	20.027	122.27	86.828	1.4248E+07	1299.7	372.45
14	13	20.266	140.32	87.81	1.9092E+07	1152.2	360.83
15	14	20.09	149.19	78.61	1.12E+07	1112.5	363.23
16	15	22.87	149.57	87.767	1.6393E+07	1072.1	349.32
17	16	27.42	149.16	87.538	1.5018E+07	1146.8	337.34
18	17	20.204	149.57	69.85	1.1134E+07	1110	360.99
*	New Verification Point						

Table of Schematic E3: Response Surface

	A	B	C	D
1		P4 - Equivalent Stress Maximum	P5 - Total Deformation Reported Frequency	P6 - Temperature Maximum
2	Coefficient of Determination (Best Value = 1)			
3	Learning Points	1	1	1
4	Root Mean Square Error (Best Value = 0)			
5	Learning Points	0.19662	2.148E-05	3.1029E-07
6	Verification Points	0.158	1.7628E-05	3.8641E-07
7	Relative Maximum Absolute Error (Best Value = 0%)			
8	Learning Points	0	0	0
9	Verification Points	0	0	0
10	Relative Average Absolute Error (Best Value = 0%)			
11	Learning Points	0	0	0
12	Verification Points	0	0	0



Optimization:

For my optimization algorithm I did a combination of SQP and MOGA across multiple runs to find the optimum result. I used MOGA for the run where I was running all three output parameters as optimization objectives and then SQP for when I was running one objective and multiple constraints.

1.Run for all 3 output parameters

Table of Schematic F4: Optimization

	A	B	C	D
1	⊟ Optimization Study			
2	Minimize P4	Goal, Minimize P4 (Default importance)		
3	Maximize P5	Goal, Maximize P5 (Default importance)		
4	Minimize P6	Goal, Minimize P6 (Default importance)		
5	⊟ Optimization Method			
6	MOGA	The MOGA method (Multi-Objective Genetic Algorithm) is a variant of the popular NSGA-II (Non-dominated Sorted Genetic Algorithm-II) based on controlled elitism concepts. It supports multiple objectives and constraints and aims at finding the global optimum.		
7	Configuration	Generate 3000 samples initially, 600 samples per iteration and find 3 candidates in a maximum of 20 iterations.		
8	Status	Converged after 6609 evaluations.		
9	⊟ Candidate Points			
10		Candidate Point 1	Candidate Point 2	Candidate Point 3
11	P10 - rotor_thickness (mm)	24.448	24.436	24.424
12	P11 - rotor_OD (mm)	135.26	135.09	135.57
13	P12 - rotor_ID (mm)	65.402	65.464	65.537
14	P4 - Equivalent Stress Maximum (Pa)	1.0217E+07	1.0216E+07	1.0214E+07
15	P5 - Total Deformation Reported Frequency (Hz)	1410.2	1414.6	1404.9
16	P6 - Temperature Maximum (C)	342.39	342.46	342.5

Design Changes:

Rotor Thickness: 25 mm → 24.448 mm

Outer Diameter: 125 mm → 135.26 mm

Inner Diameter: 75 mm → 65.402 mm

Objective Improvements:

Maximum Von-Mises stress: 1.3503e+007 Pa →1.0217e+007

Percent improvement: 24.33%

Total Deformation Reported Frequency: 1616 Hz → 1396.7 Hz

Percent Improvement: -13.5%

Temperature Maximum: 341.13 C ➔ 342.39 C

Percent Improvement: -0.37%

Percent Improvement overall: 10.46%

2.Run to minimize stress with Freq > 1200 Hz and Temp < 350 C

Table of Schematic F4: Optimization

	A	B	C	D	E
1	⊟ Optimization Study				
2	Minimize P4	Goal, Minimize P4 (Default importance)			
3	P5 >= 1200 Hz	Strict Constraint, P5 values greater than or equals to 1200 Hz (Default importance)			
4	P6 <= 350 C	Strict Constraint, P6 values less than or equals to 350 C (Default importance)			
5	⊟ Optimization Method				
6	MISQP	The MISQP method (Mixed-Integer Sequential Quadratic Programming) solves mixed-integer nonlinear programming problems by a modified sequential quadratic programming (SQP) method . Under the assumption that integer variables have a smooth influence on the model functions, i .e., that function values do not change drastically when in- or decrementing an integer variable, successive quadratic approximations are applied. It supports a single objective and multiple constraints. The starting point must be specified to determine the region of the design space to explore.			
7	Configuration	Approximate derivatives by Central difference and find 3 candidates in a maximum of 20 iterations.			
8	Status	Converged after 69 evaluations.			
9	⊟ Candidate Points				
10		Starting Point	Candidate Point 1	Candidate Point 2	Candidate Point 3
11	P10 - rotor_thickness (mm)	25	24.062	24.018	23.906
12	P11 - rotor_OD (mm)	136	136.44	136.7	137.14
13	P12 - rotor_ID (mm)	74.5	75.752	75.67	75.911
14	P4 - Equivalent Stress Maximum (Pa)	1.0773E+07	1.0377E+07	1.0379E+07	1.039E+07
15	P5 - Total Deformation Reported Frequency (Hz)	1433.2	1400.5	1396.3	1385.5
16	P6 - Temperature Maximum (C)	341	344.39	344.4	344.73

Design Changes:

Rotor Thickness: 25 mm ➔ 24.062 mm

Outer Diameter: 125 mm ➔ 136.44 mm

Inner Diameter: 75 mm ➔ 75.752 mm

Objective Improvements:

Maximum Von-Mises stress: 1.3503e+007 Pa ➔1.0773e+007

Percent improvement: 20.21%

Total Deformation Reported Frequency: 1616 Hz ➔ 1433.2 Hz

Percent Improvement: -11.3%

Temperature Maximum: 341.13 C ➔ 341 C

Percent Improvement: 0.00%

Percent Improvement Total: 8.91%

3.Run to maximize Frequency with Stress < 1.5e+7 Pa and Temp < 350 C

Table of Schematic F4: Optimization

	A	B	C	D	E
1	Optimization Study				
2	Maximize P5	Goal, Maximize P5 (Default importance)			
3	P4 <= 1.5E+07 Pa	Strict Constraint, P4 values less than or equals to 1.5E+07 Pa (Default importance)			
4	P6 <= 370 C	Strict Constraint, P6 values less than or equals to 370 C (Default importance)			
5	Optimization Method				
6	MISQP	The MISQP method (Mixed-Integer Sequential Quadratic Programming) solves mixed-integer nonlinear programming problems by a modified sequential quadratic programming (SQP) method. Under the assumption that integer variables have a smooth influence on the model functions, i.e., that function values do not change drastically when in- or decrementing an integer variable, successive quadratic approximations are applied. It supports a single objective and multiple constraints. The starting point must be specified to determine the region of the design space to explore.			
7	Configuration	Approximate derivatives by Central difference and find 3 candidates in a maximum of 20 iterations.			
8	Status	Converged after 39 evaluations.			
9	Candidate Points				
10		Starting Point	Candidate Point 1	Candidate Point 2	Candidate Point 3
11	P10 - rotor_thickness (mm)	25	30	30	28.14
12	P11 - rotor_OD (mm)	136	122	122	122
13	P12 - rotor_ID (mm)	74.5	65.972	63.76	62.282
14	P4 - Equivalent Stress Maximum (Pa)	1.0773E+07	1.4576E+07	1.3774E+07	1.298E+07
15	P5 - Total Deformation Reported Frequency (Hz)	1433.2	1880.7	1873.3	1804.7
16	P6 - Temperature Maximum (C)	341	336.74	339.31	342.72

Design Changes:

Rotor Thickness: 25 mm → 30 mm

Outer Diameter: 125 mm → 122 mm

Inner Diameter: 75 mm → 65.972 mm

Objective Improvements:

Maximum Von-Mises stress: 1.3503e+007 Pa →1.4576e+007

Percent improvement: -7.94%

Total Deformation Reported Frequency: 1616 Hz → 1876.2 Hz

Percent Improvement: 16.44%

Temperature Maximum: 341.13 C → 338.28 C

Percent Improvement: 1.29%

Percent Improvement Total: 9.79%

4.Run to Minimize Temp with Stress < 1.4e+7 Pa and Freq >1200 Hz

Table of Schematic F4: Optimization

	A	B	C	D	E
1	Optimization Study				
2	Minimize P6; P6 <= 370 C	Goal, Minimize P6 (Default importance); Strict Constraint, P6 values less than or equals to 370 C (Default importance)			
3	P5 >= 1200 Hz	Strict Constraint, P5 values greater than or equals to 1200 Hz (Default importance)			
4	P4 <= 1.4E+07 Pa	Strict Constraint, P4 values less than or equals to 1.4E+07 Pa (Default importance)			
5	Optimization Method				
6	MISQP	The MISQP method (Mixed-Integer Sequential Quadratic Programming) solves mixed-integer nonlinear programming problems by a modified sequential quadratic programming (SQP) method. Under the assumption that integer variables have a smooth influence on the model functions, i.e., that function values do not change drastically when in- or decrementing an integer variable, successive quadratic approximations are applied. It supports a single objective and multiple constraints. The starting point must be specified to determine the region of the design space to explore.			
7	Configuration	Approximate derivatives by Central difference and find 3 candidates in a maximum of 20 iterations.			
8	Status	Converged after 63 evaluations.			
9	Candidate Points				
10		Starting Point	Candidate Point 1	Candidate Point 2	Candidate Point 3
11	P10 - rotor_thickness (mm)	25	29.928	30	30
12	P11 - rotor_OD (mm)	136	138.74	138.51	138.19
13	P12 - rotor_ID (mm)	74.5	69.867	71.383	72.619
14	P4 - Equivalent Stress Maximum (Pa)	1.0773E+07	1.2225E+07	1.2214E+07	1.22E+07
15	P5 - Total Deformation Reported Frequency (Hz)	1433.2	1503.8	1498.2	1495.3
16	P6 - Temperature Maximum (C)	341	332.2	332.9	333.45

Design Changes:

Rotor Thickness: 25 mm → 29.928 mm

Outer Diameter: 125 mm → 138.74 mm

Inner Diameter: 75 mm → 69.867 mm

Objective Improvements:

Maximum Von-Mises stress: 1.3503e+007 Pa →1.2225e+007

Percent improvement: 9.46%

Total Deformation Reported Frequency: 1616 Hz → 1503.8 Hz

Percent Improvement: -6.94%

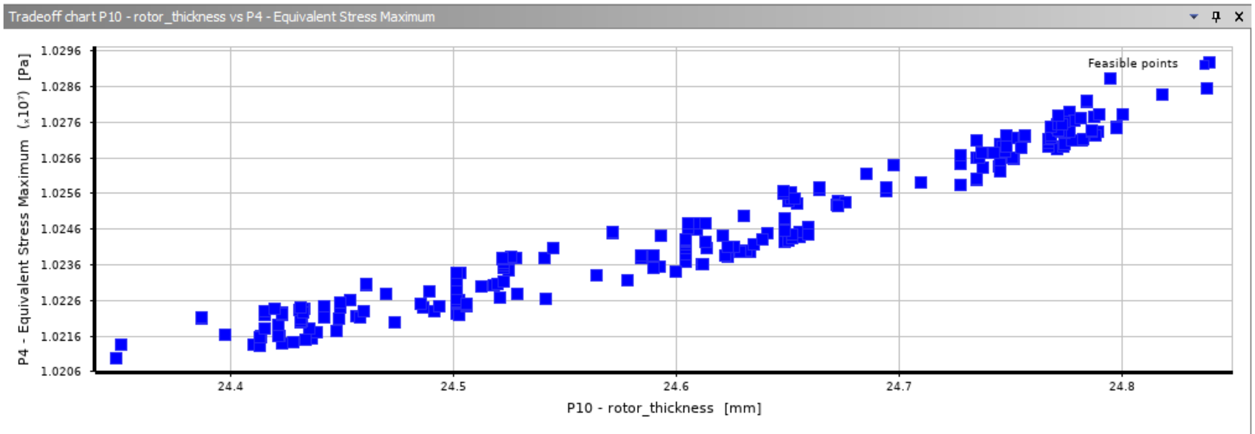
Temperature Maximum: 341.13 C → 332.2 C

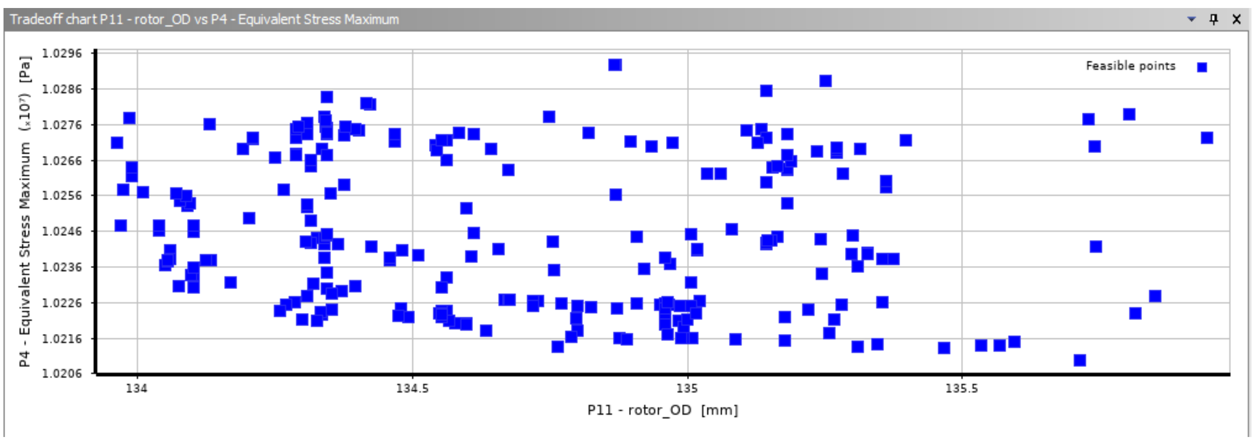
Percent Improvement: 2.69%

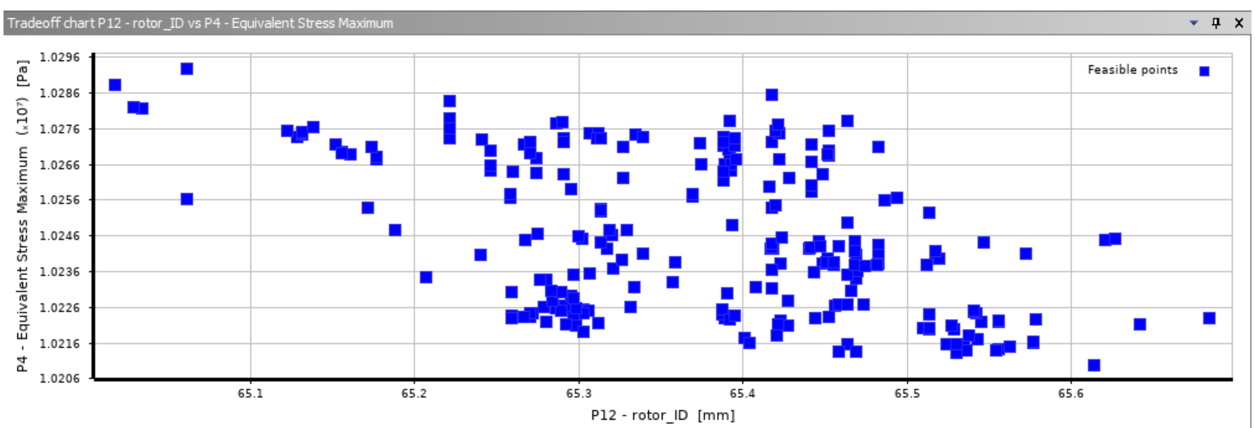
Percent Improvement Total: 5.21%

Trade Offs:

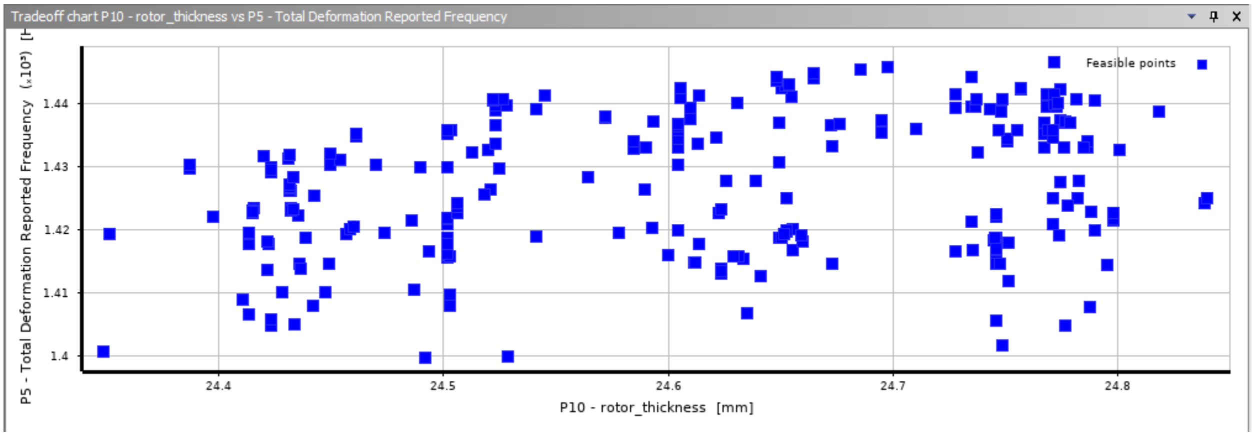
Equivalent stress Maximum:

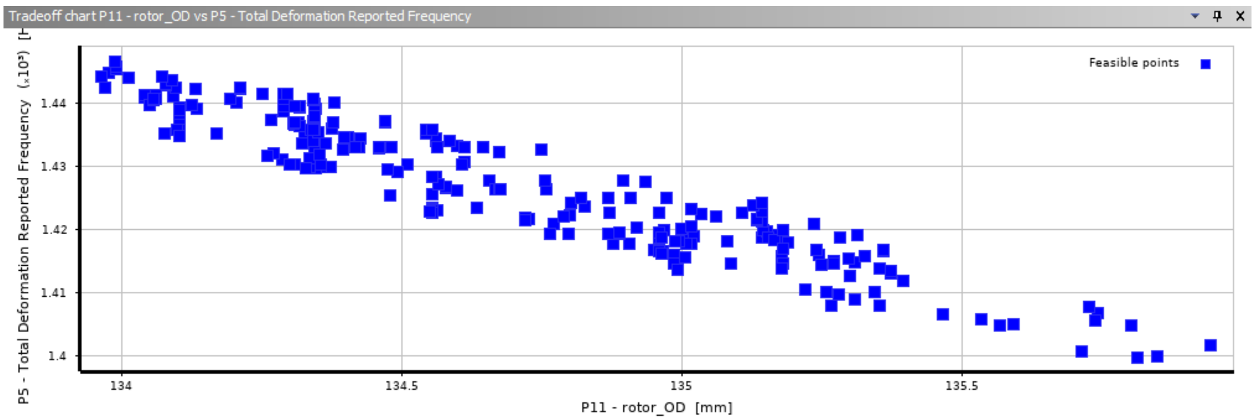


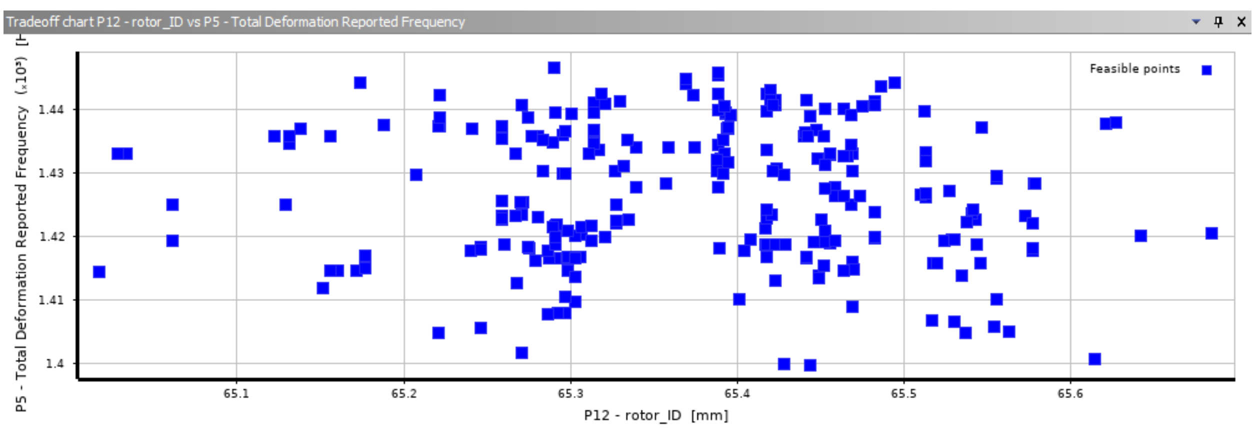




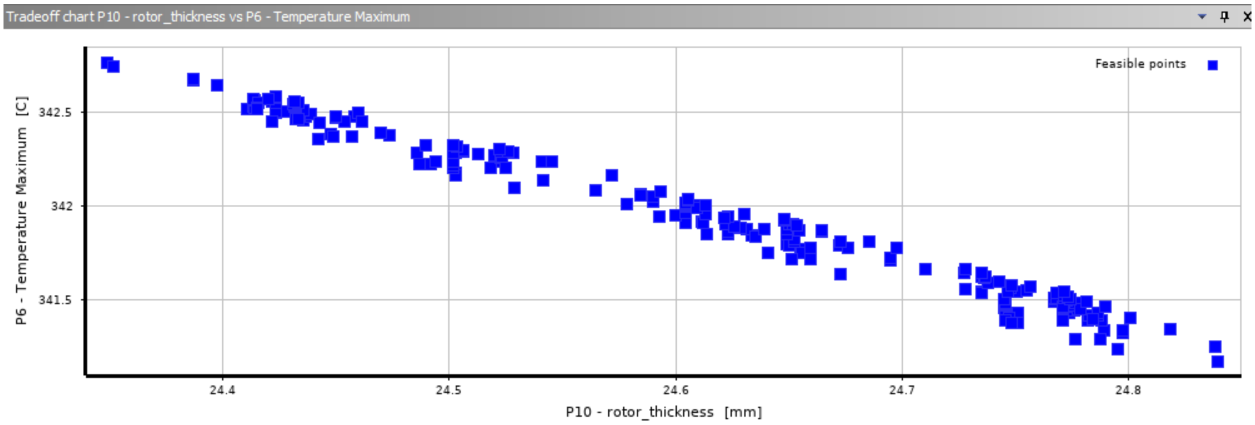
Total Deformation Reported Frequency:

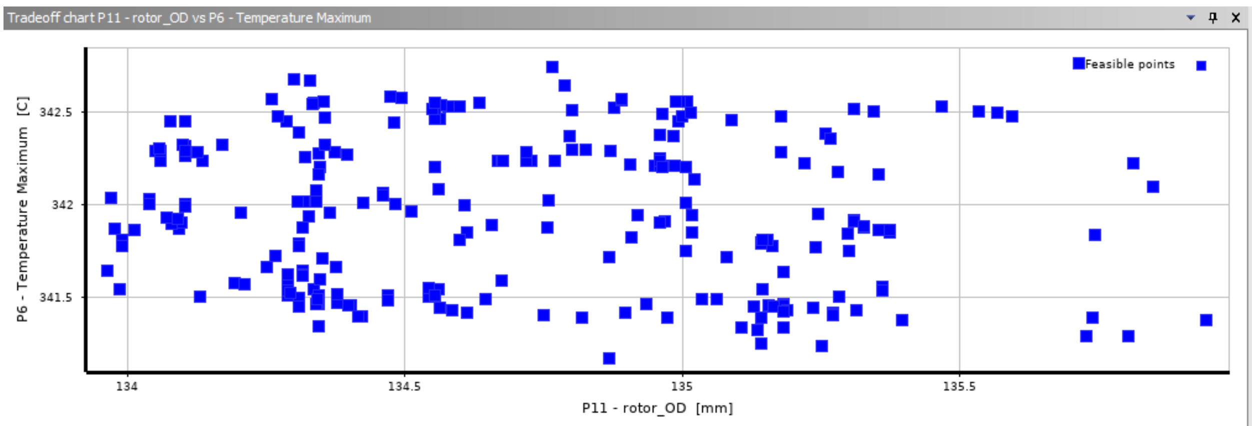


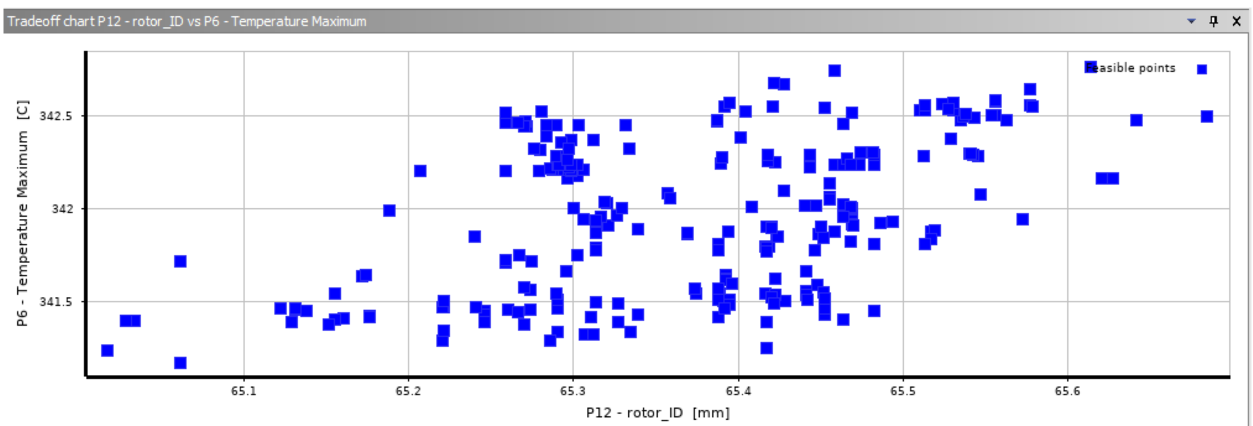




Temperature Maximum:







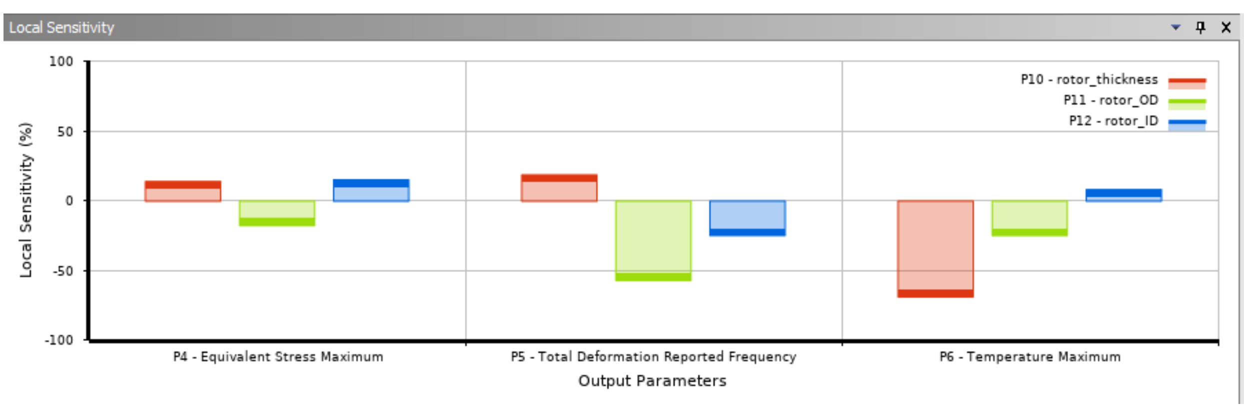
Analysis

Pareto Curve/ Trade-offs:

When optimizing for multiple objectives there will more than likely be trade-offs associated with the design. The trade-offs for these objectives are outlined in the above pareto curves. Here we can see that as we increase the rotor thickness the maximum temperature reached by the rotor decreases however the maximum Von-Mises stress experienced increases, furthermore the first modal frequency seems to have little to no correlation when it come to the thickness of the brake disc. On the subject of rotor outer diameter, it seems that the first modal frequency has a very strong correlation, as the outer diameter increases the first frequency decreases, and the other objectives remain unaffected. Lastly for the rotor inner diameter there seems to be a very slight increase in the maximum temperature and a very slight decrease in the maximum von mises stress.

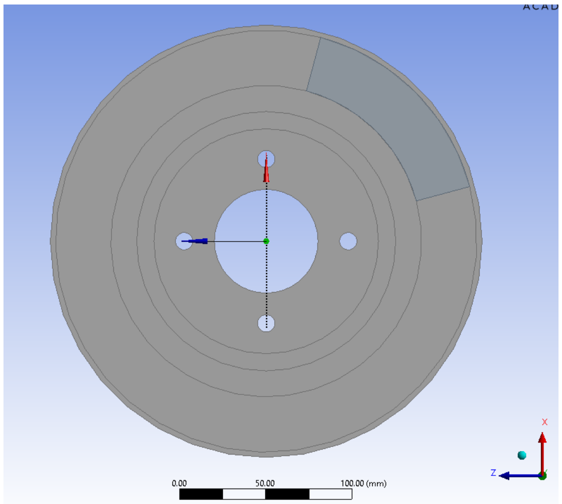
Sensitivity:

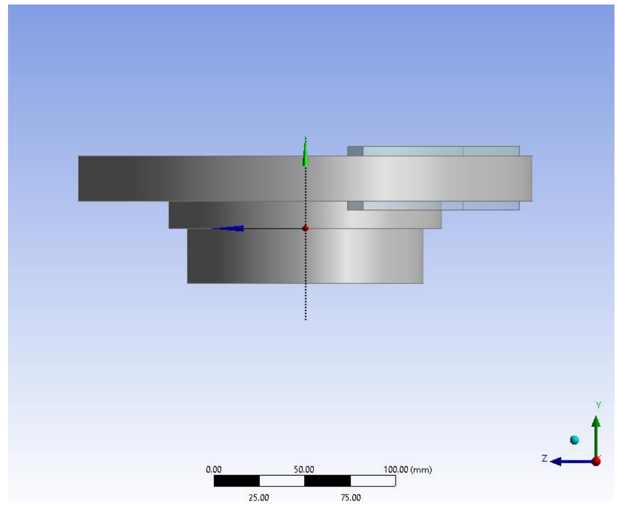
The below graph shows the sensitivity or how much a change in the input parameter effects the output parameter we can see that equivalent stress is not particularly sensitive to any one input parameter however the first modal frequency has a high sensitivity to the rotor outer diameter meaning small changes in the outer diameter can affect the output of the first modal frequency significantly this correlation was also outlined in the pareto curves discussed above. Another section of this graph that stands out is the maximum temperature where a change in the thickness has the most effect by far on the rotor temperature and this was also outlined in the above pareto curves. The variables with the most impact in order are rotor thickness, outer diameter then inner diameter.



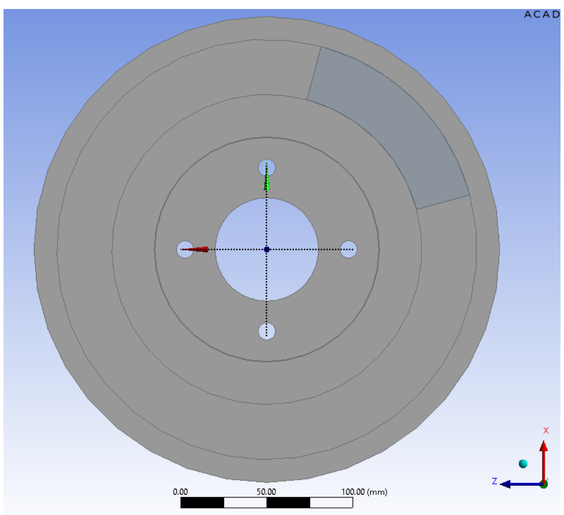
Optimal Design:

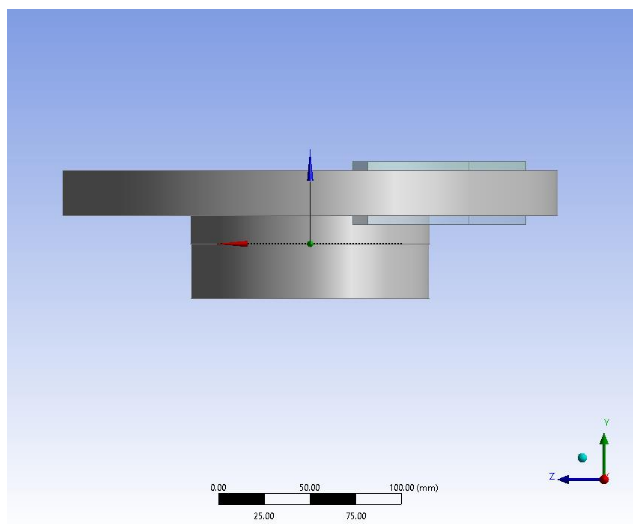
Initial Geometry





Final Geometry





Design Changes:

Rotor Thickness: 25 mm → 24.448 mm

Outer Diameter: 125 mm → 135.26 mm

Inner Diameter: 75 mm → 65.402 mm

Objective Improvements:

Maximum Von-Mises stress: 1.3503e+007 Pa ➔1.0217e+007

Percent improvement: 24.33%

Total Deformation Reported Frequency: 1616 Hz ➔ 1396.7 Hz

Percent Improvement: -13.5%

Temperature Maximum: 341.13 C ➔ 342.39 C

Percent Improvement: -0.37%

Percent Improvement overall: 10.46%

Verification:

Predicted ➔ Actual

Maximum Von-Mises stress: 1.0217e+007 Pa ➔1.128e+007 Pa

Percent error: 9.4%

Total Deformation Reported Frequency: 1396.7 Hz ➔ 1414.2 Hz

Percent error: 1.3%

Temperature Maximum: 341.13 C ➔ 342.39 C

Percent error: 0.22%

Overall, this design seems feasible the only issue that might arise is that during manufacturing the small lip that exists between the main barrel where the rotor is mounted, and the inner diameter may be more expensive than it is worth to produce or potentially the rotor may be too large to fit inside of the wheel of the car. The error on the Von-Mises stress is relatively high, this could be due to a multitude of reasons such as not constraining the model properly.