Project 2: Brake Design Optimization

Design Variables:

- Inner Diameter of the Disc
- Outer Diameter of the Disc
- Rotor Thickness

Design Constraints:

- Volume of the optimized disk should be less than the initial volume
- Disc can't fail due to exceeding material yield strength
- Disc can't fail due to heating passed the melting point
- Surface must support the brake pads

Design Objectives:

- Reduce the volume of the disc as much as possible without compromising safety
- Minimize maximum stress on the disc
- Maximize the first natural frequency of the disc
- Minimize the max temperature in the disc

Potential tradeoffs between objectives:

- By reducing the volume of the disc:
    - The stresses distributed throughout the structure in addition to the max stress increase
    - The natural frequency of the component will also decrease
    - The temperature that the component will reach will increase

Are the variables continuous or discrete/integer:

- Although in the design of experiments our testing points were fixed integers, realistically these values are continuous and are infinitely adjustable

Are there any analytical objective/constraint functions? Are they differentiable?

- The volume can be analytically calculated by reducing the object into smaller calculatable cylinders which can then be further differentiated

Based on the above answers what optimization method should you use?

- For the optimization algorithm, multiobjective generic algorithm (MOGA) was used as there were multiple objectives that needed optimizing

Using sensitivity analysis, comment on the importance of the variables, do you observe monotonicity?

- Using the local sensitivities chart we can interpret the norm of the partial derivatives to see what variables have the largest affect on each objective. The thickness plays the largest role across the board only having an inverse effect on max temperature. The other two variables have a minimal effect comparatively.

Lower and Upper Bounds of Dimensions

Table of Schematic F4: Optimization

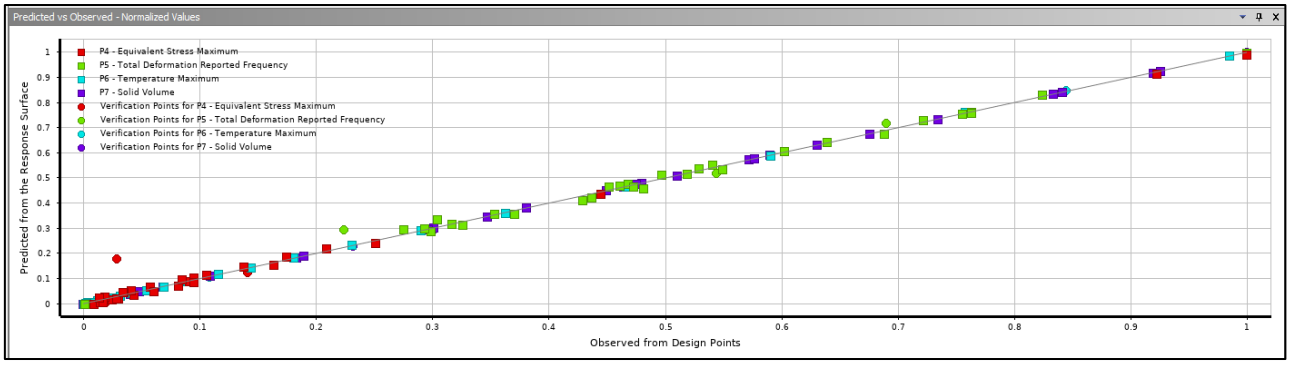
	A	B	C
1	Input Parameters		
2	Name	Lower Bound	Upper Bound
3	P1 - rotor_thickness (mm)	6.35	38.1
4	P2 - rotor_OD (mm)	126	140
5	P3 - rotor_ID (mm)	60	90

Design of Experiments Data

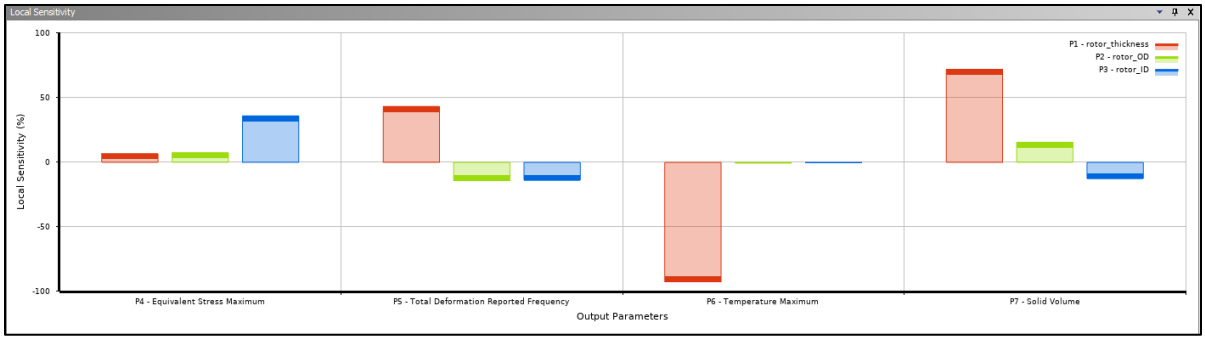
Table of Outline A8: Design Points of Design of Experiments

	A	B	C	D	E	F	G	H
1	Name	P1 - rotor_thickness (mm)	P2 - rotor_OD (mm)	P3 - rotor_ID (mm)	P4 - Equivalent Stress Maximum (Pa)	P5 - Total Deformation Reported Frequency (Hz)	P6 - Temperature Maximum (C)	P7 - Solid Volume (m^3)
2	1	22.225	131.88	61.8	1.0995E+07	1335.4	341.81	0.0011161
3	2	27.305	135.8	79.8	1.2685E+07	1362.9	328.09	0.0012639
4	3	6.985	133	84.6	1.0739E+07	1073.5	696.01	0.00047701
5	4	24.765	139.16	76.2	1.2947E+07	1306.8	333.43	0.0012704
6	5	9.525	128.52	67.8	1.1664E+07	1057.3	542.87	0.00054391
7	6	36.195	134.68	66.6	1.1602E+07	1730.1	322.4	0.0017415
8	7	23.495	136.36	81	1.3052E+07	1269.8	336.9	0.0011208
9	8	34.925	129.64	77.4	1.2033E+07	1650.8	322.7	0.0014064
10	9	15.875	136.92	69	1.089E+07	1143.4	389.32	0.00088863
11	10	13.335	129.08	89.4	2.2498E+07	1120.6	430.28	0.00062748
12	11	18.415	127.4	60.6	1.1151E+07	1247.6	365.05	0.0008913
13	12	12.065	138.6	73.8	1.0984E+07	1020.2	457.42	0.00072883
14	13	20.955	138.04	70.2	1.1308E+07	1275.5	347.38	0.0011251
15	14	28.575	131.32	85.8	1.5213E+07	1347.8	326.59	0.0011377
16	15	17.145	139.72	65.4	1.1414E+07	1085	375.55	0.0010007
17	16	32.385	130.76	82.2	1.2774E+07	1490.1	323.57	0.0012891
18	17	31.115	130.2	72.6	1.2122E+07	1640.5	324.31	0.0013449
19	18	26.035	133.56	87	1.7279E+07	1260.1	330.84	0.0010949
20	19	10.795	126.84	71.4	1.1422E+07	1228.6	496.46	0.00057176
21	20	8.255	135.24	88.2	1.3347E+07	1050	605.52	0.00053221
22	21	19.685	134.12	78.6	1.1254E+07	1286.3	354.97	0.00095429
23	22	33.655	137.48	63	1.3063E+07	1597.5	322.96	0.0017508
24	23	37.465	132.44	83.4	1.4911E+07	1553.8	321.82	0.0014872
25	24	14.605	127.96	64.2	1.0945E+07	1219.1	408.15	0.00073795
26	25	29.845	126.28	75	1.1416E+07	1651.5	326.17	0.001179

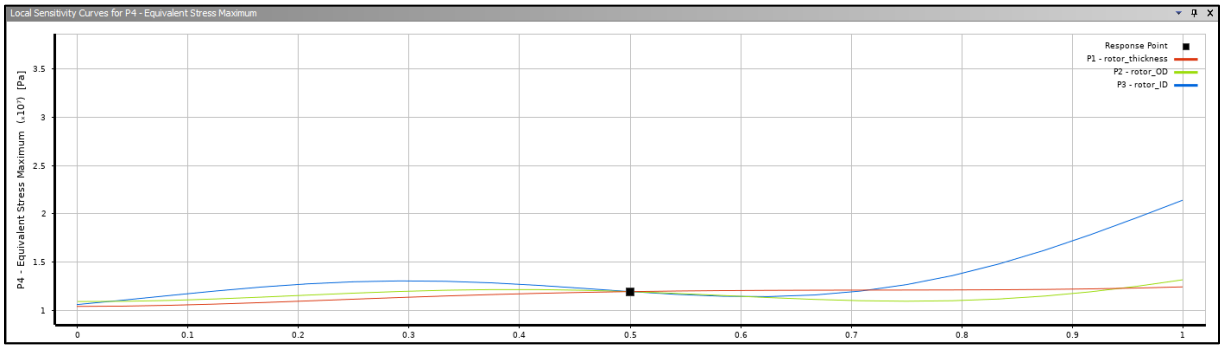
Goodness of Fit



Local Sensitivities



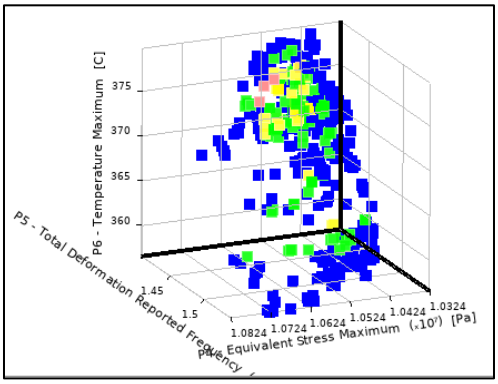
Local Sensitivity Curve



Candidate Points

Candidate Points			
	Candidate Point 1	Candidate Point 2	Candidate Point 3
P1 - rotor_thickness (mm)	17.252	17.097	17.244
P2 - rotor_OD (mm)	126.29	126.71	126.9
P3 - rotor_ID (mm)	69.393	69.419	69.941
P4 - Equivalent Stress Maximum (Pa)	1.0549E+07	1.0498E+07	1.0497E+07
P5 - Total Deformation Reported Frequency (Hz)	1459.9	1445.7	1451.3
P6 - Temperature Maximum (C)	375.97	377.52	375.99
P7 - Solid Volume (m^3)	0.00079519	0.00079541	0.00080107

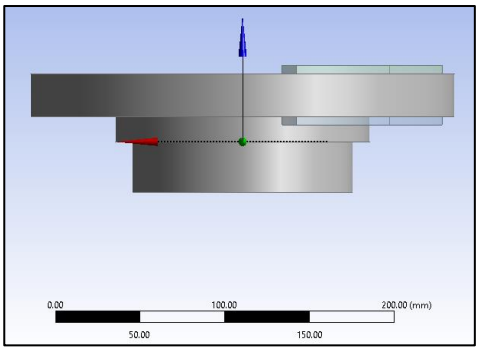
Trade Offs

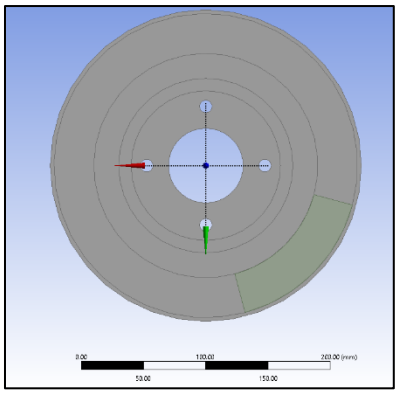


Initial Geometry

Dimensions

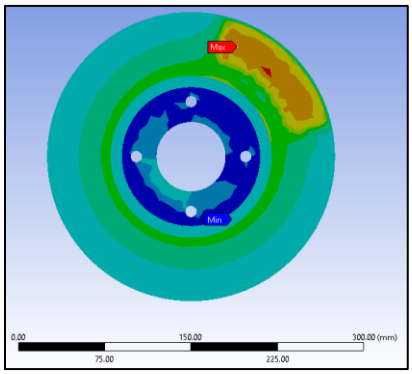
Dimensions: 11	
H18	5 mm
H20	30 mm
H21	35 mm
H27	5 mm
P H28	25 mm
V13	5 mm
V26	30 mm
P V29	125 mm
P V30	75 mm
V31	30 mm
V9	5 mm





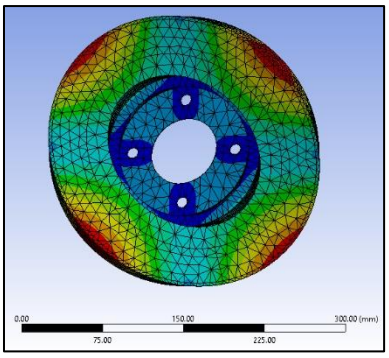
Static Structure Analysis

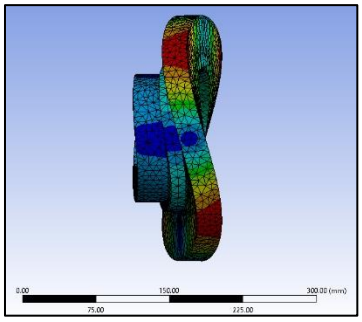
Results	
Minimum	8.5731e-002 MPa
P Maximum	13.09 MPa
Average	3.776 MPa
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Minimum Value Over Time	
Minimum	2.9601e-003 MPa
Maximum	8.5731e-002 MPa
Maximum Value Over Time	
Minimum	2.2925 MPa
Maximum	13.09 MPa



Modal Analysis

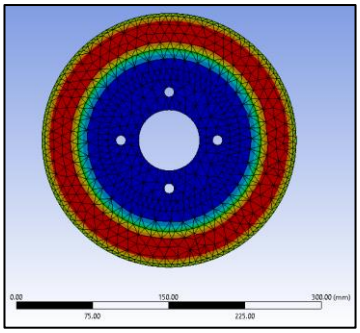
Results	
Minimum	8.1635e-002 mm
Maximum	25.603 mm
Average	9.329 mm
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Information	
P Frequency	1590.4 Hz





Transient Thermal Analysis

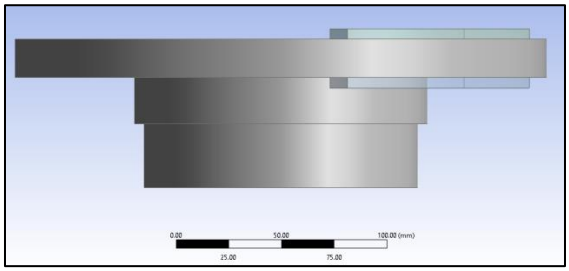
Results	
Minimum	35. °C
P Maximum	335.38 °C
Average	121.83 °C
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Minimum Value Over Time	
Minimum	12.974 °C
Maximum	35. °C
Maximum Value Over Time	
Minimum	49.178 °C
Maximum	335.38 °C

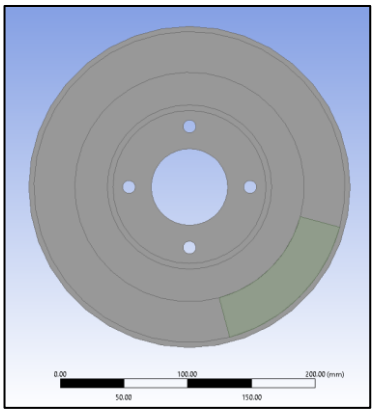


Final Geometry (Volume Reduction 22.49%)

Dimensions

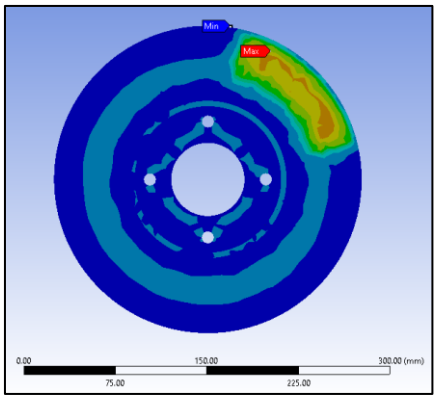
Dimensions: 11	
H18	5 mm
H20	30 mm
H21	35 mm
H27	5 mm
P H28	17.981 mm
V13	5 mm
V26	30 mm
P V29	126 mm
P V30	69.458 mm
V31	30 mm
V9	5 mm





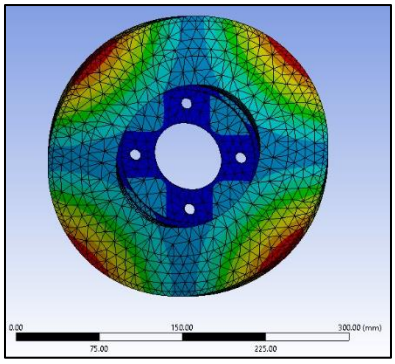
Static Structure Analysis

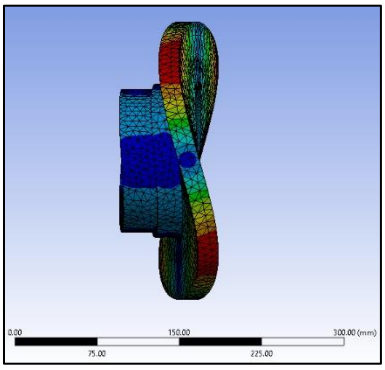
Results	
Minimum	2.972e-002 MPa
P Maximum	11.279 MPa
Average	1.497 MPa
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Minimum Value Over Time	
Minimum	1.9052e-004 MPa
Maximum	2.972e-002 MPa
Maximum Value Over Time	
Minimum	2.2086 MPa
Maximum	11.279 MPa



Modal Analysis

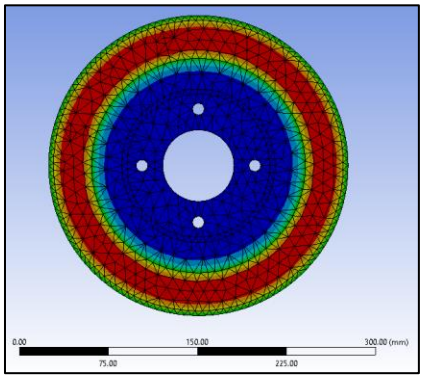
Results	
Minimum	5.2794e-002 mm
Maximum	31.23 mm
Average	9.4759 mm
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Information	
P Frequency	1472.5 Hz



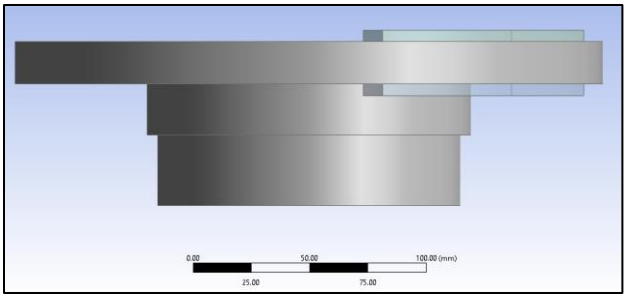


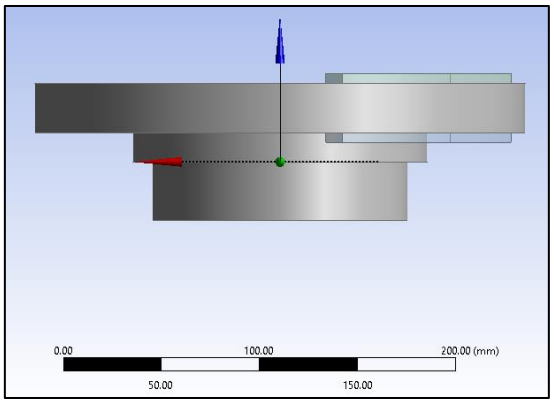
Transient Thermal Analysis

Results	
Minimum	35. °C
P Maximum	369.82 °C
Average	129.29 °C
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Minimum Value Over Time	
Minimum	14.304 °C
Maximum	35. °C
Maximum Value Over Time	
Minimum	53.649 °C
Maximum	369.82 °C



Compare the optimal design to the original design, is it reasonable?





	Initial	Optimized	% Diff
Rotor Thickness (mm)	25	17.981	-32.661
Rotor ID (mm)	75	69.458	-7.673
Rotor OD (mm)	125	126	.797
Volume (m^3)	.00099667	.00079519	-22.488
Max Force (MPa)	13.09	11.279	-14.863
Natural Frequency (Hz)	1590.4	1472.5	-7.699
Max Temperature (C)	335.38	369.82	9.767

The optimized results produced similar values to the values calculated through the analysis modules and can be considered to be a reasonable solution. Although the natural frequency declined and the temp increased, these changes are relatively small compared to the decrease in max forces and the main goal of reducing the overall volume.