MAE 494 Project 2

Ansys DOE and Design Optimization

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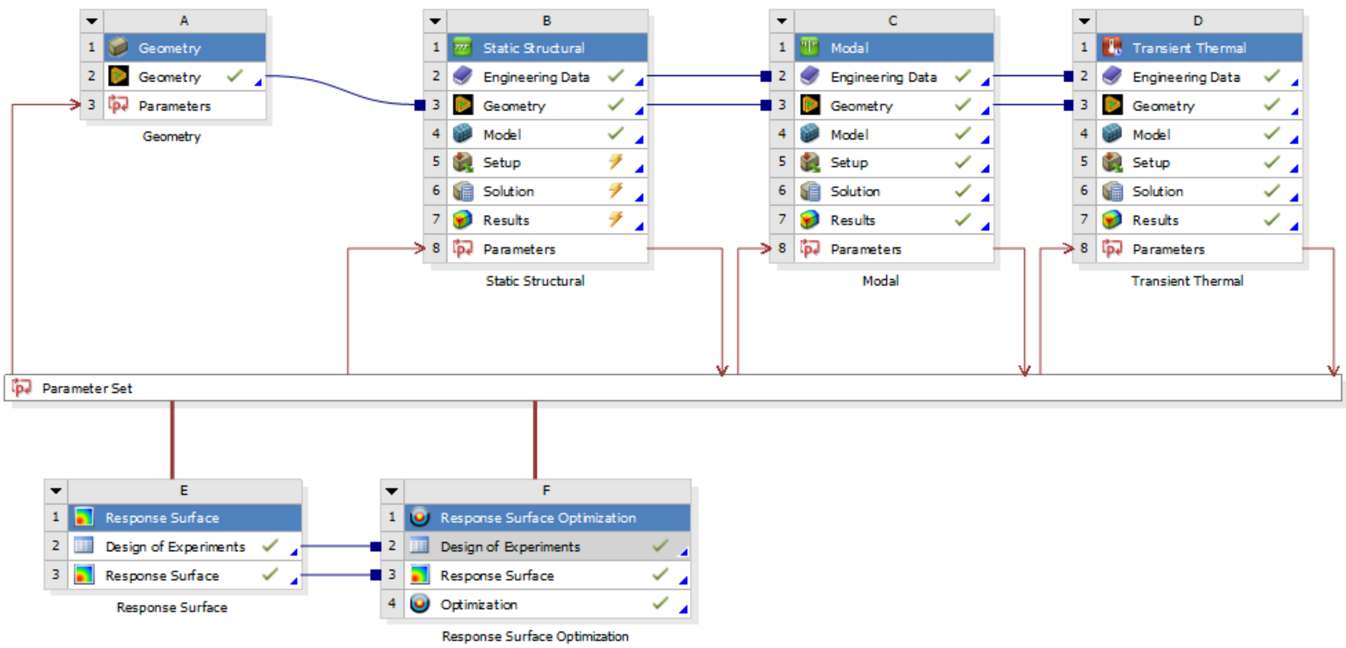
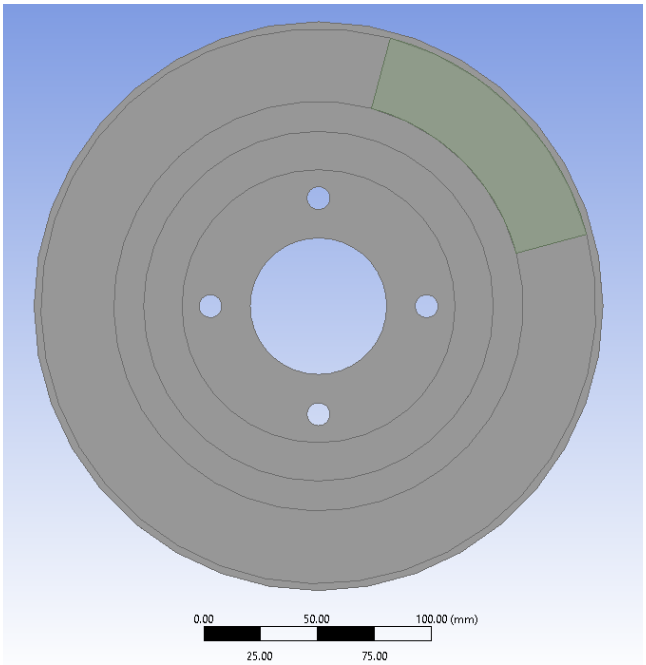
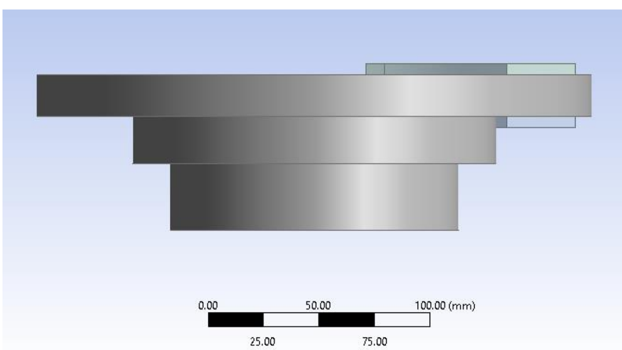
09 December 2022

Project Schematic

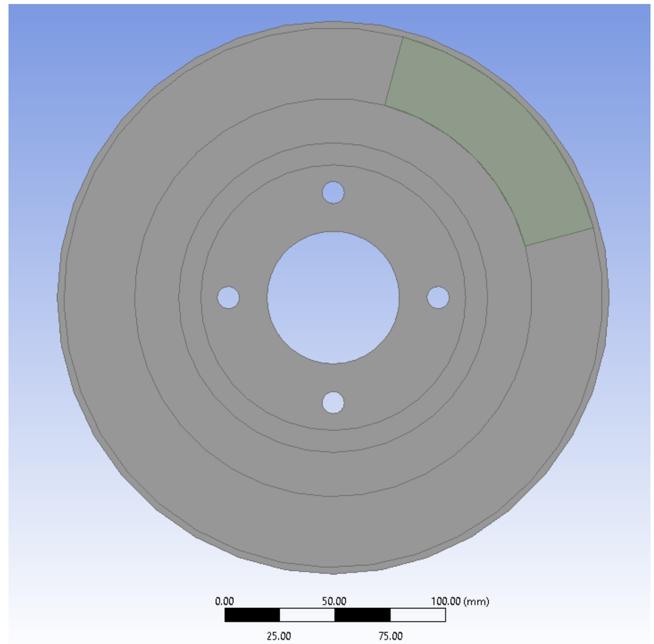


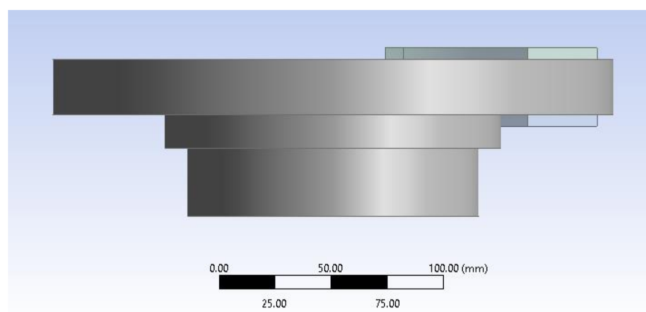
Original Geometry



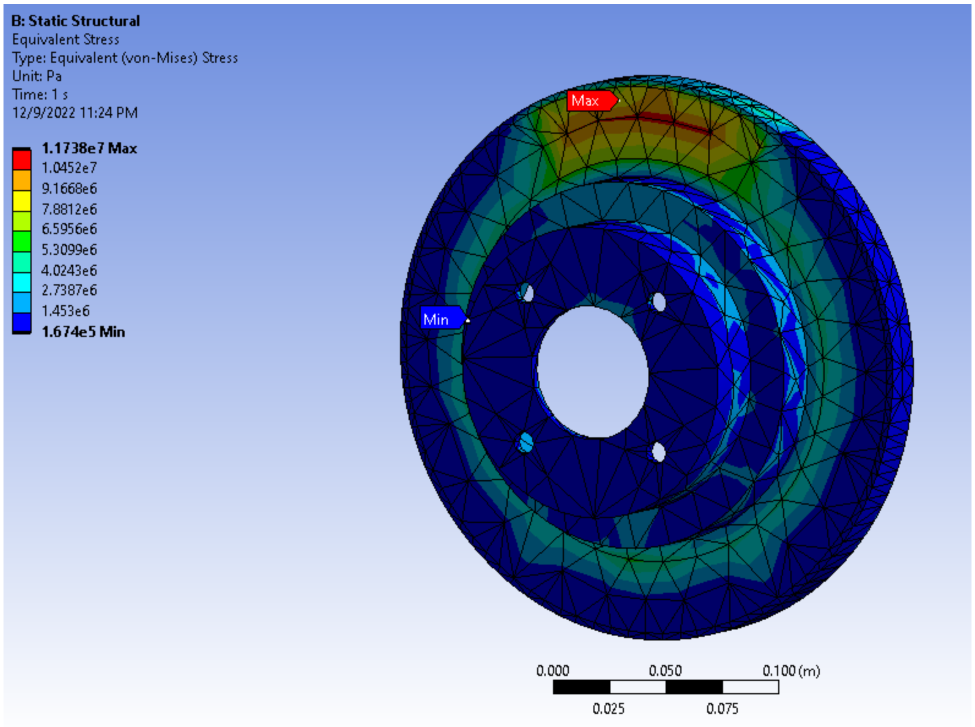


Optimized Geometry

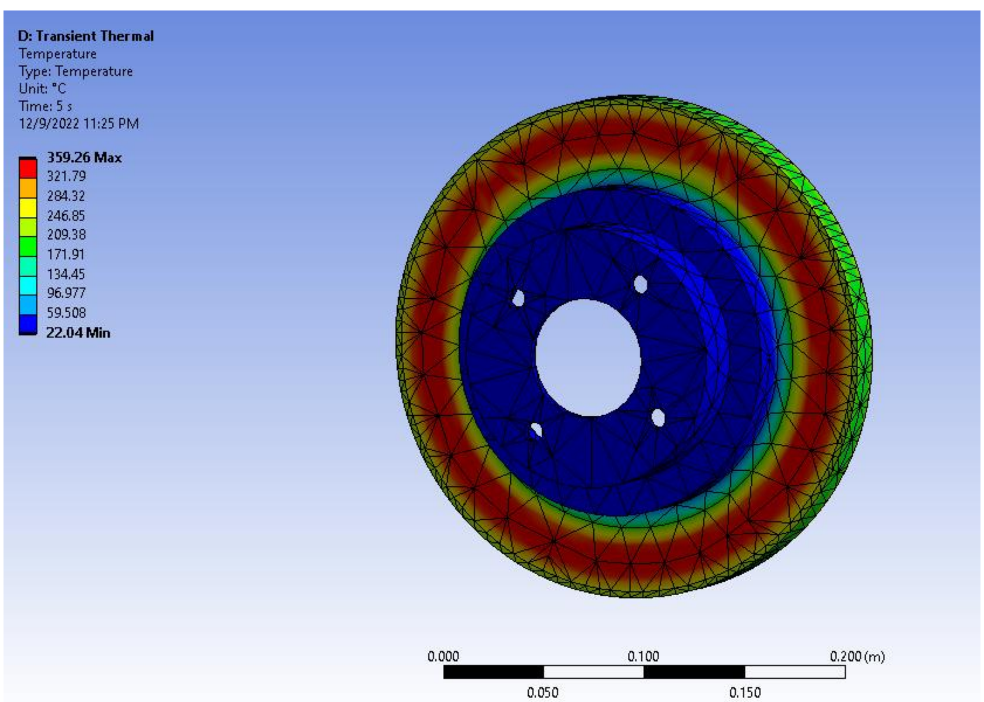




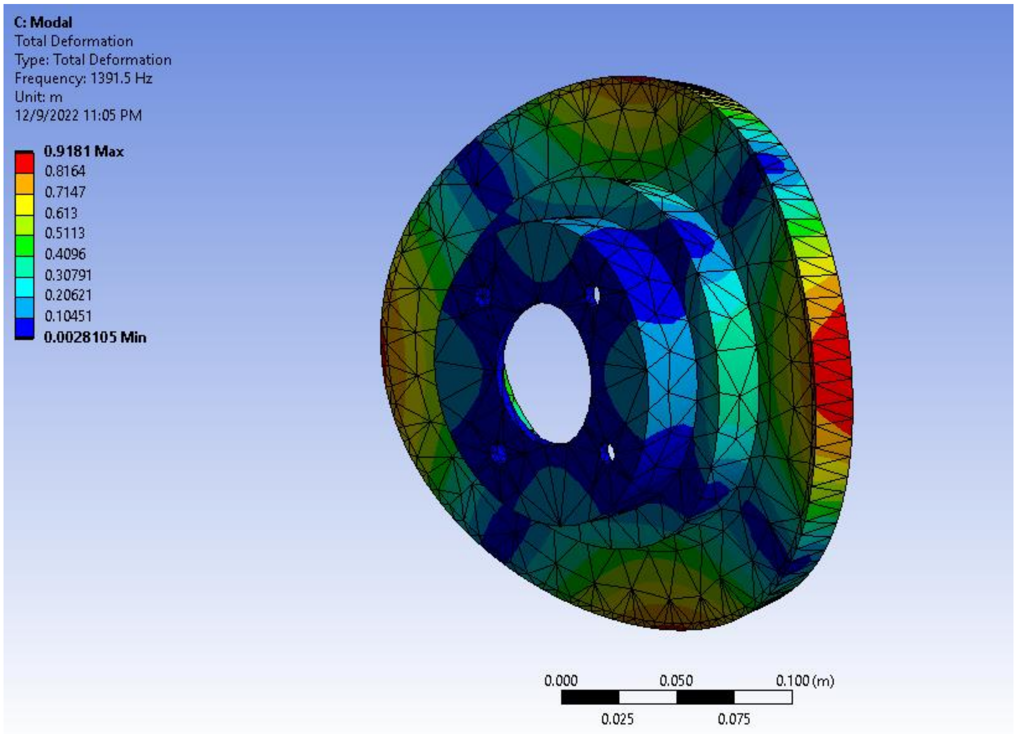
Static Structural Block – Stress Analysis



Transient Thermal Block – Temperature Analysis



Modal Block – Vibration Analysis



DOE Points

Table of Outline A7: Design Points of Design of Experiments

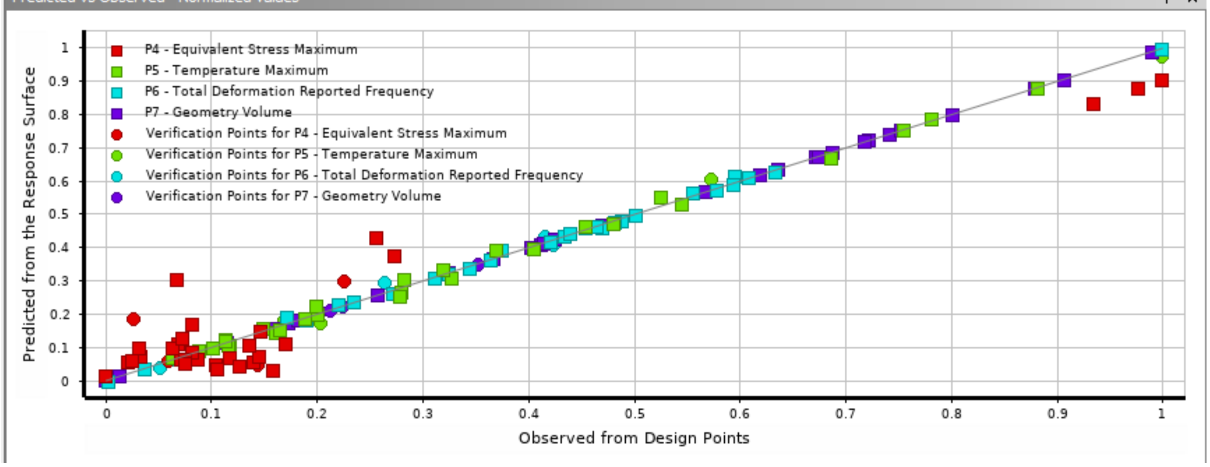
	A	B	C	D	E	F	G	H
1	Name	P12 - rotor_OD (mm)	P14 - rotor_th... (mm)	P15 - rotor_ID (mm)	P4 - Equivalent Stress Maximum (Pa)	P5 - Tempe... Maximum (C)	P6 - Total Deformation Reported Frequency (Hz)	P7 - Geometry Volume (m^3)
2	1	131.75	24.75	70.333	1.1726E+07	329.88	1540	0.001196
3	2	134.25	25.75	79.667	1.2314E+07	330.25	1420	0.0012078
4	3	125.25	20.75	81	1.1167E+07	343.82	1431.9	0.00086304
5	4	132.75	27.75	86.333	1.3406E+07	326.18	1347.1	0.0011745
6	5	126.25	18.75	75	1.1445E+07	356.77	1507	0.00085434
7	7	132.25	28.75	77.667	1.2026E+07	324.83	1516.9	0.001291
8	8	138.25	28.25	87.667	1.9145E+07	323.3	1274.4	0.0013073
9	9	128.75	22.25	75.667	1.1753E+07	339.89	1516.2	0.0010076
10	10	127.75	29.75	85	1.2365E+07	321.64	1452.7	0.001133
11	11	129.75	21.75	83	1.236E+07	340.07	1366.9	0.00095506
12	12	127.25	19.75	73	1.1427E+07	350.41	1525	0.00091399
13	13	131.25	22.75	87	1.3265E+07	339.76	1279.7	0.00098076
14	14	135.25	15.75	76.333	1.1347E+07	390.45	1301.2	0.00086824
15	15	129.25	27.25	80.333	1.247E+07	325.93	1493.5	0.0011433
16	16	137.25	21.25	79	1.2128E+07	343.21	1323.3	0.0011018
17	17	136.75	26.75	73.667	1.1881E+07	326.06	1461	0.0013577
18	18	133.75	20.25	72.333	1.1842E+07	347.45	1412.4	0.0010429
19	19	126.75	18.25	78.333	1.2029E+07	362.21	1441.6	0.00082778
20	20	125.75	17.75	85.667	1.1839E+07	360.49	1292.2	0.000758
21	21	130.75	16.25	89	1.8806E+07	382.02	1181.9	0.00076662
22	22	137.75	23.75	84.333	1.1723E+07	333.2	1263.2	0.0011655
23	23	139.25	26.25	77	1.1371E+07	325.88	1378.8	0.0013639
24	24	128.25	24.25	82.333	1.221E+07	332.17	1423.9	0.0010096
25	25	135.75	16.75	88.333	1.9335E+07	379.87	1161.5	0.00085478
26	26	133.25	19.25	71	1.1689E+07	354.53	1384.9	0.0010021
27	27	136.25	25.25	81.667	1.2556E+07	328.92	1354.8	0.0012141
28	28	134.75	23.25	74.333	1.1787E+07	333.07	1438.7	0.0011672

Response Surface – Goodness of Fit

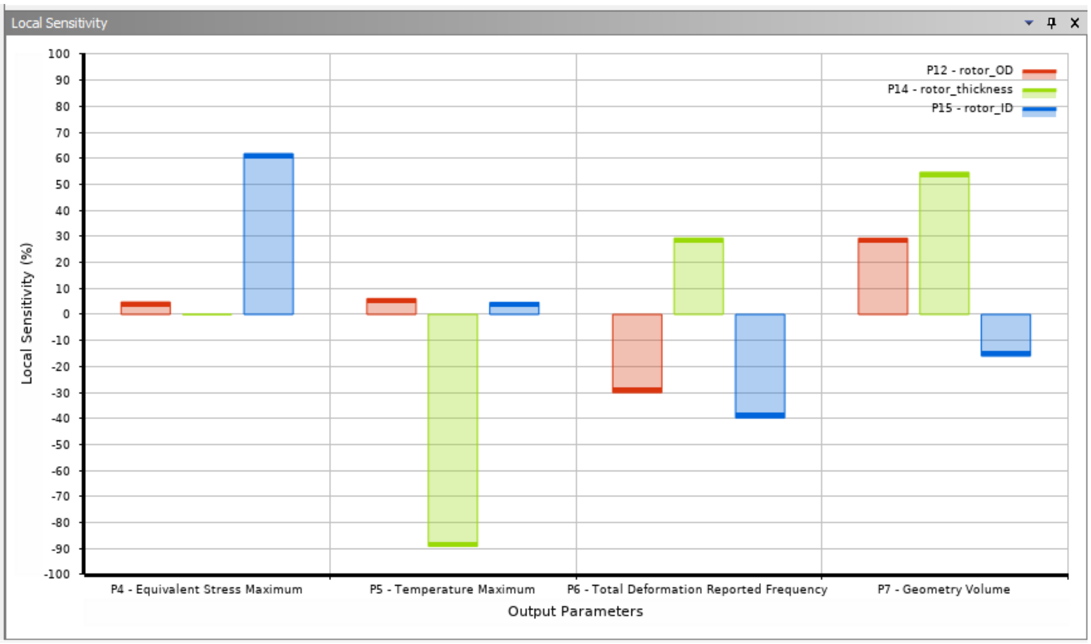
Table of Schematic E3: Response Surface

	A	B	C	D	E
1		P4 - Equivalent Stress Maximum	P5 - Temperature Maximum	P6 - Total Deformation Reported Frequency	P7 - Geometry Volume
2	Coefficient of Determination (Best Value = 1)				
3	Learning Points	0.90733	0.99671	0.99856	1
4	Root Mean Square Error (Best Value = 0)				
5	Learning Points	6.656E+05	1.1204	4.6532	3.2973E-07
6	Verification Points	8.2496E+05	2.1502	12.447	1.0467E-06
7	Relative Maximum Absolute Error (Best Value = 0%)				
8	Learning Points	87.251	11.062	10.342	0.36642
9	Verification Points	62.686	12.547	15.885	1.1793
10	Relative Average Absolute Error (Best Value = 0%)				
11	Learning Points	23.464	4.6767	2.8211	0.14839
12	Verification Points	32.22	9.6035	9.3086	0.39856

Predicted vs Observed - Normalized Values



Sensitivity Analysis



Optimization Results

Table of Schematic F4: Optimization

	A	B	C	D
1	Optimization Study			
2	Minimize P4	Goal, Minimize P4 (Default importance)		
3	Minimize P5	Goal, Minimize P5 (Default importance)		
4	Maximize P6	Goal, Maximize P6 (Default importance)		
5	Minimize P7	Goal, Minimize P7 (Default importance)		
6	Optimization Method			
7	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.		
8	Configuration	Generate 3000 samples initially, 600 samples per iteration and find 3 candidates in a maximum of 20 iterations.		
9	Status	Converged after 6111 evaluations.		
10	Candidate Points			
11		Candidate Point 1	Candidate Point 2	Candidate Point 3
12	P12 - rotor_OD (mm)	125.02	125.01	125.02
13	P14 - rotor_thickness (mm)	18.609	18.726	18.878
14	P15 - rotor_ID (mm)	81.866	81.469	81.06
15	P4 - Equivalent Stress Maximum (Pa)	1.1312E+07	1.1293E+07	1.1285E+07
16	P5 - Temperature Maximum (C)	354.95	354.15	353.13
17	P6 - Total Deformation Reported Frequency (Hz)	1390.8	1400.5	1410.8
18	P7 - Geometry Volume (m^3)	0.00079363	0.00079921	0.00080595

Conclusion: The final version of the brake disk, selected as Candidate Point 1, is geometrically feasible (no conflicts/invalid geometry, and brake pads do not hang over the rim), and the calculated maximum stress is within the ultimate tensile limit of Gray Cast Iron (2.4×10^8 Pa).

On the response surface: Although the response surface was a very good fit with coefficients of determination very close to one, there was no significant difference in the RMS errors between the verification points and the learning points, so there was not excessive overfitting. The increase in RMS error between learning and verification was a factor of roughly 1-3; however, the sizes of these errors were a couple of orders of magnitude smaller than the overall objective values, so the error increase was not a great concern.