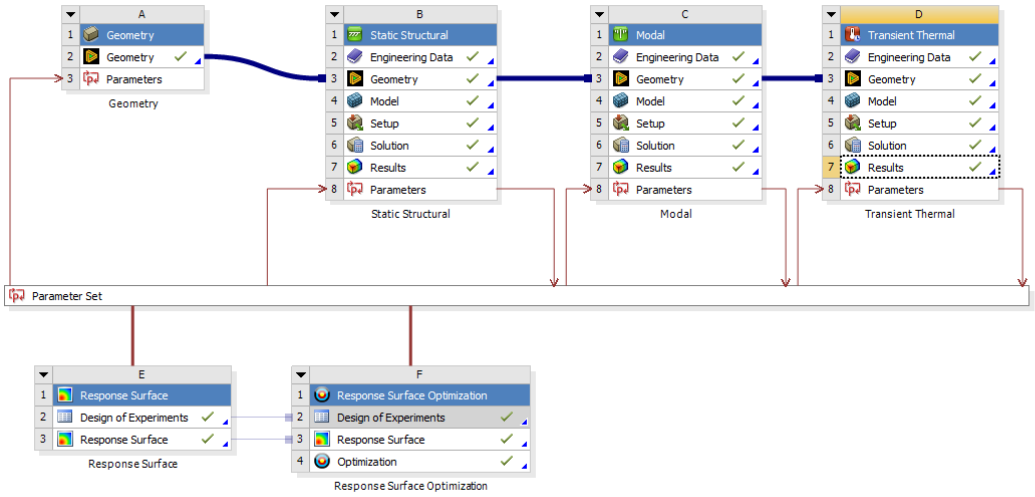
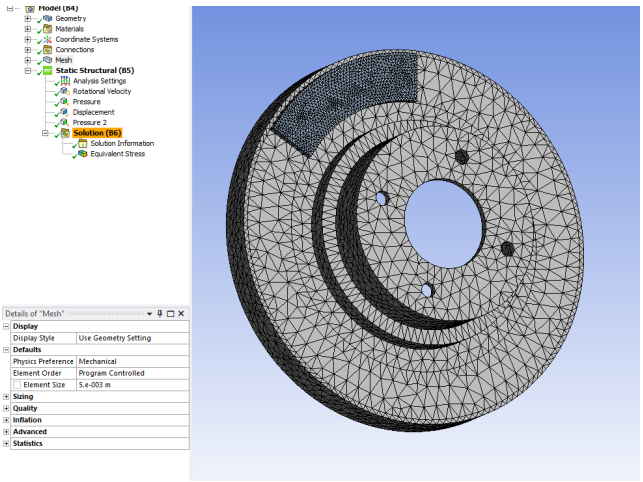
Problem Statement: The objective of the project is to analyse the Brake Disc Geometry and optimize the design using the Optimization Techniques in Ansys. The parameters that need to be optimized are the Maximum stresses that are observed during the braking and also the temperatures. Using the parameters like the radii and thickness of the geometry, we can change the derivables.

The simulations that are done using Ansys are

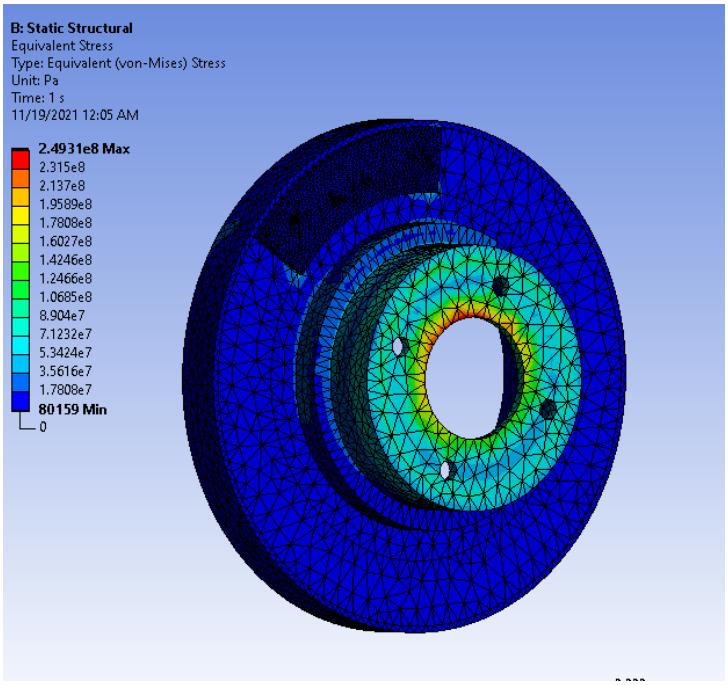
1. Static Structural
2. Modal Analysis
3. Transient Thermal
4. Response Surface and Optimization



The geometry of the Brake Disc is constant throughout the simulation. The mesh used is 5mm Quad throughout the rotor and a refinement of 2mm for the brake pads and is given below:



Static Structural: In Static Structural, the rotor center is fixed and the pressure on brake pads along with a Rotational Velocity is given to the geometry. The figures below are the results of Equivalent Stresses observed.

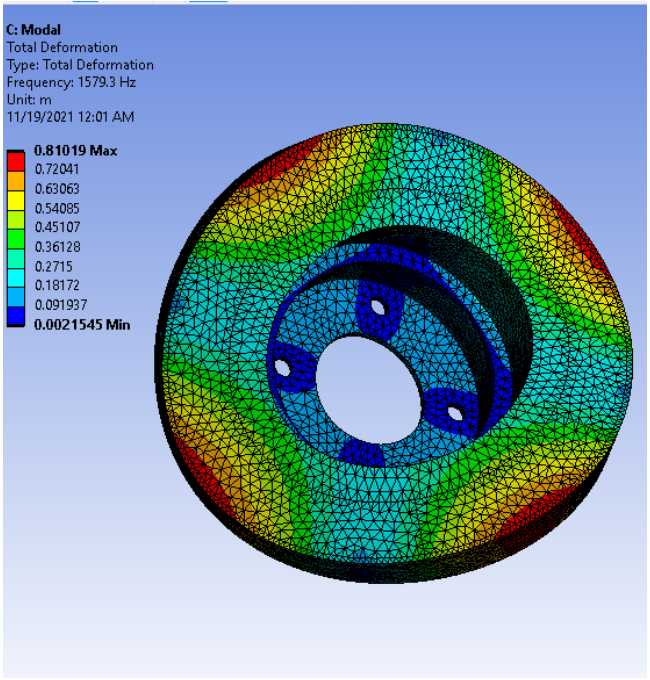


Tabular Data

	Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1	0.2	10735	4.9553e+007	2.8169e+006
2	0.4	26303	9.926e+007	5.6572e+006
3	0.7	33365	1.7411e+008	1.0025e+007
4	1.	80159	2.4931e+008	1.4598e+007

Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Equivalent (von-Mises) ...
By	Time
Display Time	Last
Calculate Time History	Yes
Identifier	
Suppressed	No
Integration Point Results	
Display Option	Averaged
Average Across Bodies	No
Results	
Minimum	80159 Pa
Maximum	2.4931e+008 Pa
Average	1.4598e+007 Pa
Minimum Occurs On	Solid

Modal Analysis: In Modal Analysis, the pads are supressed and the a setting of 7 mode is applied throughout the disc. Then the corresponding frequency is observed.

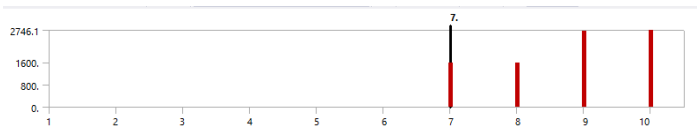


Details of "Total Deformation"

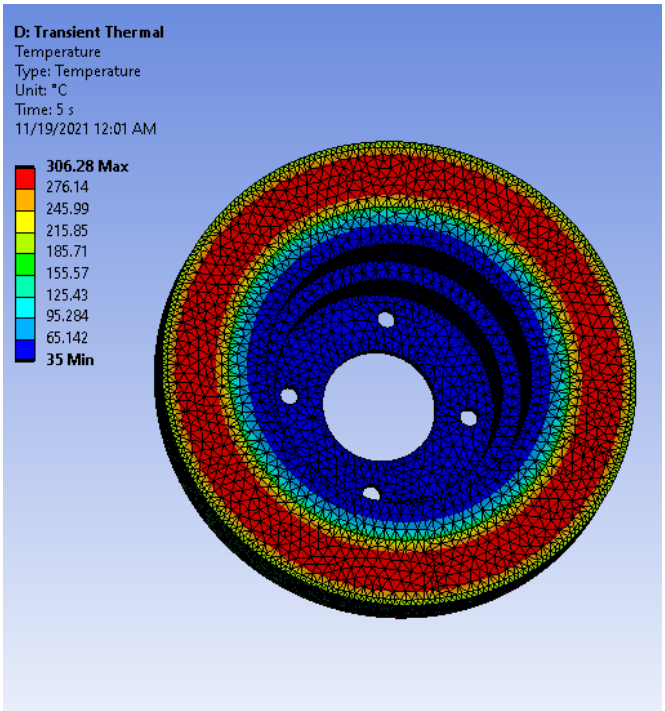
Scope	
Scoping Method	Geometry Selection
Geometry	All Bodies
Definition	
Type	Total Deformation
Mode	7.
Identifier	
Suppressed	No
Results	
Minimum	2.1545e-003 m
Maximum	0.81019 m
Average	0.27287 m
Minimum Occurs On	Solid
Maximum Occurs On	Solid
Information	

Tabular Data

	Mode	Frequency [Hz]
1	1.	0.
2	2.	0.
3	3.	0.
4	4.	0.
5	5.	2.2899e-003
6	6.	3.0306e-003
7	7.	1579.3
8	8.	1584.6
9	9.	2728.7
10	10.	2746.1



Transient Thermal: In Transient Thermal Analysis, the Convection and Heat Flux are applied on the brake disc and the temperature is observed.



Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	1.e-002	25.84	47.46	35.819
2	1.8548e-002	23.547	52.536	36.154
3	2.7096e-002	22.988	56.404	36.454
4	5.2739e-002	22.683	64.319	37.192
5	0.12474	26.413	78.373	38.821
6	0.22474	31.635	92.536	40.753
7	0.32474	33.502	104.11	42.516
8	0.42474	33.898	113.82	44.172
9	0.52474	34.376	122.42	45.754
10	0.62474	34.718	130.26	47.28

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	35. °C
Maximum	306.28 °C
Average	103.25 °C
Minimum Occurs On	Solid
Maximum Occurs On	Solid

These are the results of the simulations that are done on the brake disc and brake pad geometry.

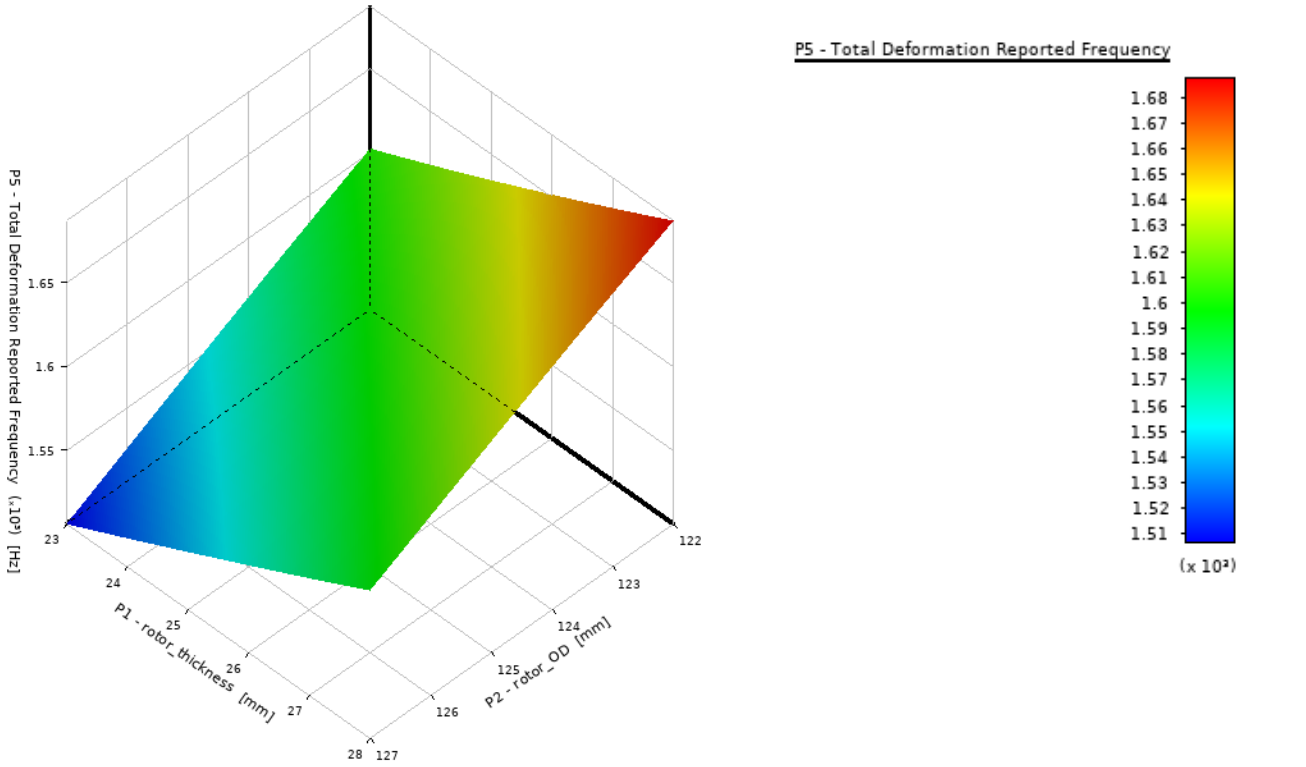
Now, these results are optimized using the Design Optimization Techniques from Ansys software. The Design Points that were considered for this experiment are given in the figure below:

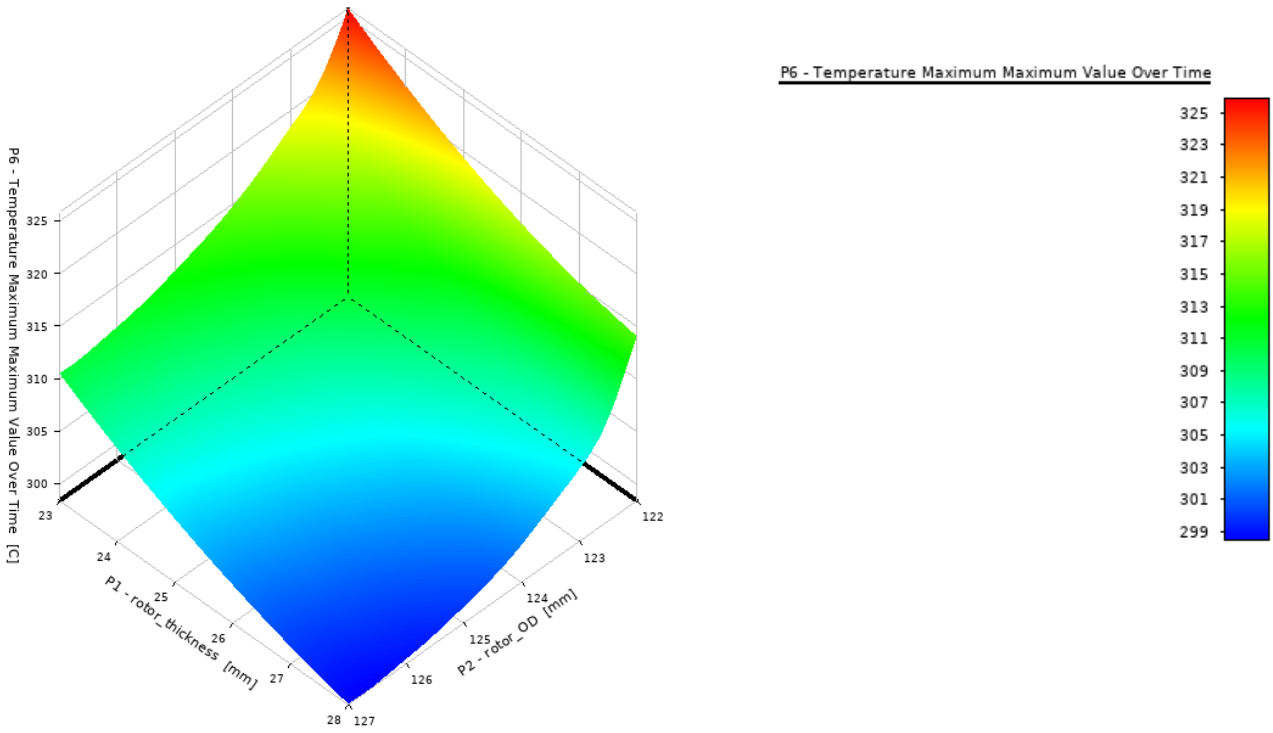
Table of Outline A4: Design Points of Design of Experiments

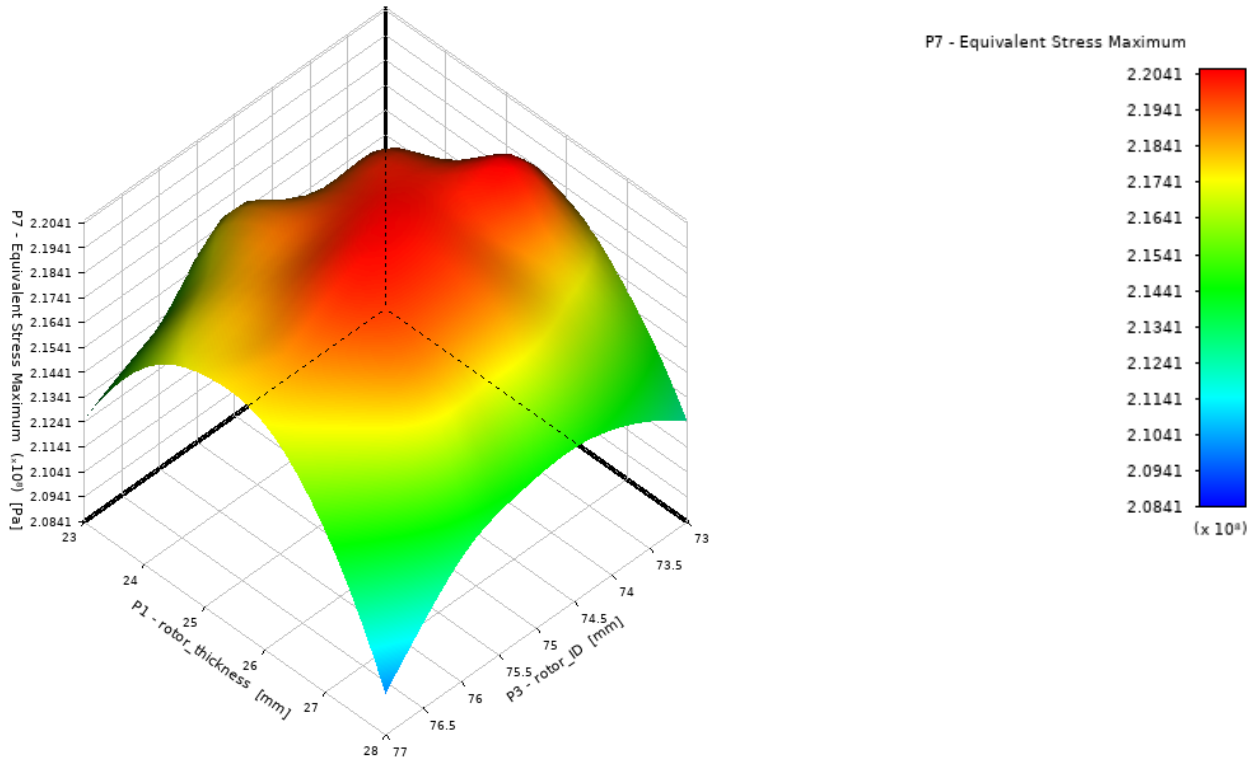
	A	B	C	D	E	F	G
1	Name	P1 - rotor_thickness (mm)	P2 - rotor_OD (mm)	P3 - rotor_ID (mm)	P5 - Total Deformation Reported Frequency (Hz)	P6 - Temperature Maximum Maximum Value Over Time (C)	P7 - Equivalent Stress Maximum (Pa)
2	1	25.25	125.25	73.067	1614.1	305.23	2.1912E+08
3	2	26.083	125.58	74.933	1588.2	302.84	2.1863E+08
4	3	23.083	123.92	75.2	1563.9	314.76	2.197E+08
5	4	25.583	126.25	76.267	1541.7	303.4	2.1868E+08
6	5	23.417	123.25	74	1605.8	315.75	2.1298E+08
7	6	27.583	122.08	76.933	1632.3	314.13	2.1615E+08
8	7	25.417	126.58	74.533	1564.3	303.5	2.197E+08
9	8	27.417	126.42	76.533	1565.1	299.47	2.1857E+08
10	9	24.25	124.42	74.133	1594.1	309.5	2.1948E+08
11	10	23.917	126.92	76	1506.3	307.52	2.1948E+08
12	11	24.583	124.25	75.6	1574.1	308.87	2.1902E+08
13	12	23.75	123.58	73.6	1612.3	313.34	2.1941E+08
14	13	25.083	124.58	76.4	1560.1	306.76	2.1837E+08
15	14	26.417	122.25	74.267	1670.8	312.85	2.2839E+08
16	15	24.417	126.08	75.067	1547.2	306.61	2.1937E+08
17	16	27.083	124.08	74.8	1637	303.21	2.1852E+08
18	17	26.917	125.92	73.733	1619.3	300.81	2.1883E+08
19	18	25.917	123.75	73.467	1650	306.59	2.2047E+08
20	19	23.583	123.08	74.667	1598.7	315.9	2.1386E+08
21	20	23.25	122.92	76.133	1565.7	317.96	2.1321E+08
22	21	24.917	122.42	76.8	1585.3	315.33	2.3306E+08
23	22	27.25	124.92	75.867	1602.7	301.32	2.1831E+08
24	23	27.75	125.75	74.4	1625.3	299.44	2.1891E+08
25	24	24.083	125.08	75.467	1553.2	308.83	2.1937E+08
26	25	26.583	122.58	76.667	1613	309.82	2.1228E+08
27	26	25.75	123.42	73.2	1658.9	308.01	2.1317E+08
28	27	26.75	125.42	75.333	1595.2	301.62	2.1898E+08
29	28	26.25	124.75	73.867	1628	303.63	2.1884E+08
30	29	27.917	122.75	73.333	1708.8	306.2	2.1251E+08
31	30	24.75	126.75	75.733	1528.5	305.12	2.1917E+08

Response Surfaces:

The Response Surfaces/ Charts that are obtained from plotting the Deformation due to frequency, temperature and the Equivalent Stresses along with the parameters are given below:





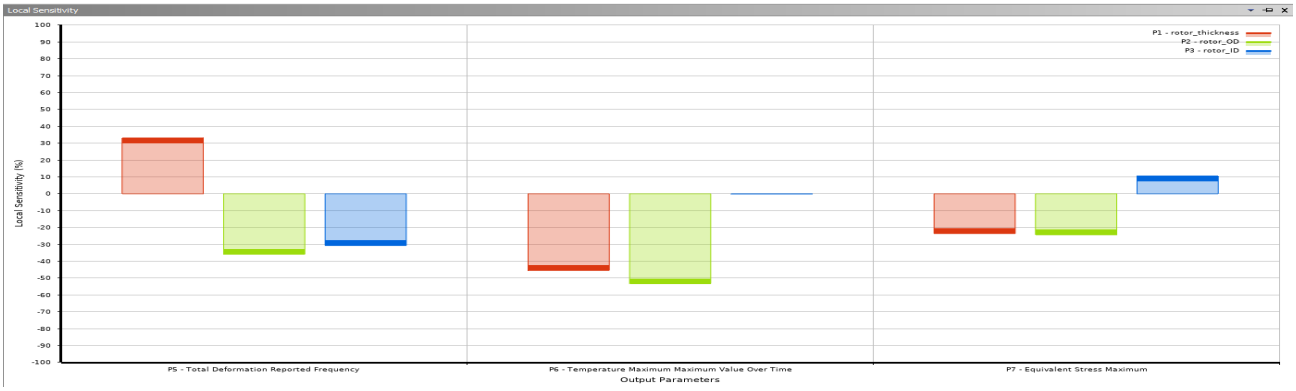


Response Surface Schematic:

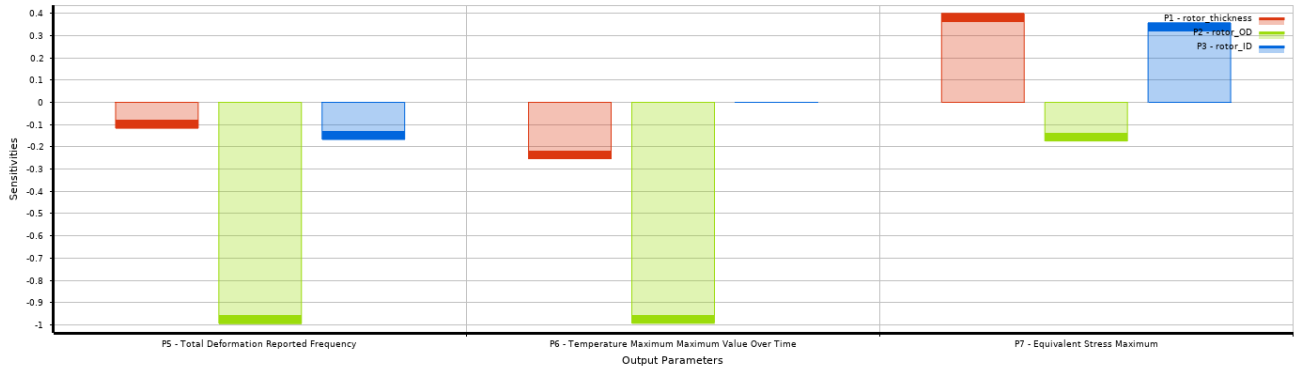
Table of Schematic E3: Response Surface

	A	B	C	D
1		P5 - Total Deformation Reported Frequency	P6 - Temperature Maximum Maximum Value Over Time	P7 - Equivalent Stress Maximum
2	Coefficient of Determination (Best Value = 1)			
3	Learning Points	0.99999	1	1
4	Cross-Validation on Learning Points	0.99997	0.99055	0
5	Root Mean Square Error (Best Value = 0)			
6	Learning Points	0.11995	4.8643E-07	0.23949
7	Verification Points	0.70833	0.77012	6.1235E+06
8	Cross-Validation on Learning Points	0.23695	0.51153	6.3503E+06
9	Relative Maximum Absolute Error (Best Value = 0%)			
10	Learning Points	0.57298	0	0
11	Verification Points	2.4355	25.085	204.64
12	Cross-Validation on Learning Points	0.97942	49.822	451.57
13	Relative Average Absolute Error (Best Value = 0%)			
14	Learning Points	0.22255	0	0
15	Verification Points	1.1451	9.7463	128.01
16	Cross-Validation on Learning Points	0.42568	3.3905	107.97

Local Sensitivity:



Optimized Sensitivity:



Final Optimized Results:

The results that fit the most efficient design are obtained using the Latin Hypercube Sampling Method and Multi-Objective Generic Algorithm and the values are given below:

Table of Schematic F4: Optimization

	A	B	C	D
1	Optimization Study			
2	Minimize P7	Goal, Minimize P7 (Default importance)		
3	P6 <= 317.96 C	Strict Constraint, P6 values less than or equals to 317.96 C (Default importance)		
4	P5 >= 1506.3 Hz	Strict Constraint, P5 values greater than or equals to 1506.3 Hz (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 7619 evaluations.		
9	Candidate Points			
10		Candidate Point 1	Candidate Point 2	Candidate Point 3
11	P1 - rotor_thickness (mm)	23.007	23.004	23.006
12	P2 - rotor_OD (mm)	125.21	125.13	125.06
13	P3 - rotor_ID (mm)	73.002	73.007	73.005
14	P5 - Total Deformation Reported Frequency (Hz)	1576.2	1577.8	1579.4
15	P6 - Temperature Maximum Maximum Value Over Time (C)	312.02	312.18	312.3
16	P7 - Equivalent Stress Maximum (Pa)	2.0808E+08	2.0808E+08	2.0809E+08