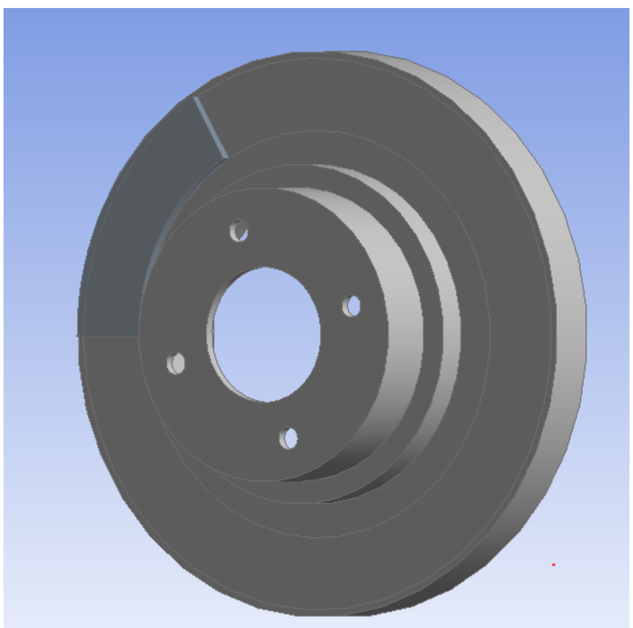
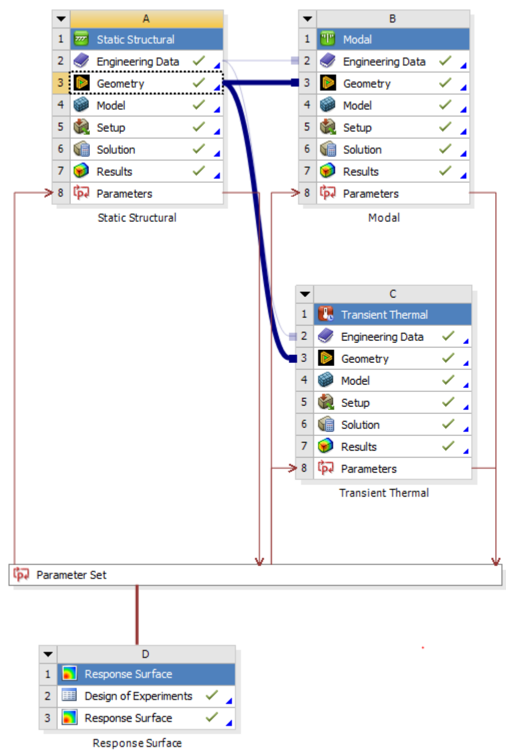
Design of Optimization: Project 2

In this project, we optimize a brake disc structure by using Design of Optimize (DOE) in ANSYS R21 student version. In the following, we will discuss three sections, including simulation analysis model, design of optimization, and optimization result.

1. Simulation Analysis Model

Figures 1a and b show the optimized geometry and the flow chart of the optimization process. The analysis includes static structural, modal and transient thermal. The design variables are brake disc inner diameter (V1), outer diameter (V2), and thickness (V3).





(a) (b)

Figures 1. Geometry and the flow chart of the optimization.

a. Static Structural Analysis

After importing the geometry, we define meshing for the structure and apply the boundary conditions as shown in table 1. The revolute connection and the manual contact regions are set up for the brake disc and bake pad. The equivalent von-Mises stress are chosen as the output parameter.

Rotational Velocity	250 rad/s
Pressure	1.0495×10^{7} Pa
Number of elements	6753
Number of nodes	13404

Table 1: Boundary conditions and meshing elements.

Figure 2 shows the stress distribution in the brake discs. The maximum stress is observed at the contact between the brake disc and brake pad which is predictable, and the maximum value is 13.7 MPa

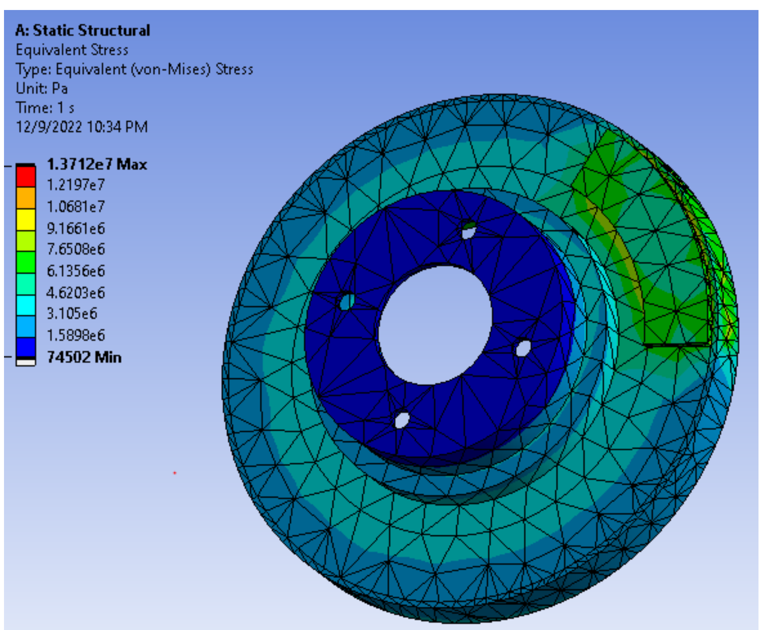


Figure 2. Stress distribution.

b. Modal Analysis

With the same setup for geometry and meshing in static structure analysis, in this section, deformation is chosen as the output parameter. The brake pads are compressed since we want the natural frequency of the brake disc only. Figure 3 shows the deformation of the brake disc with the maximum value of

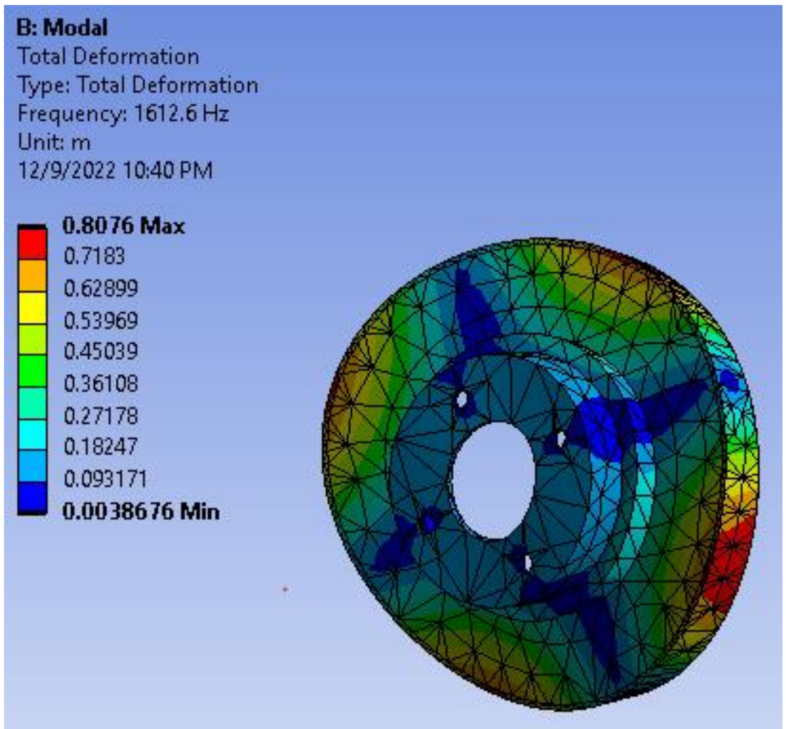


Figure 3. Deformation distribution

c. Thermal Transient Analysis

The setup for geometry and meshing is kept similar to the previous two analyses. The initial temperature is set at 35 °C. The convection heat transfer is applied on all the faces of the brake disc with the film coefficient of 5 W/m^2 °C. The sides of the brake disc are also exposed to a constant heat flux of 1.5395×10^6 W/m^2. Figure 4 shows the temperature distribution within the brake disc.

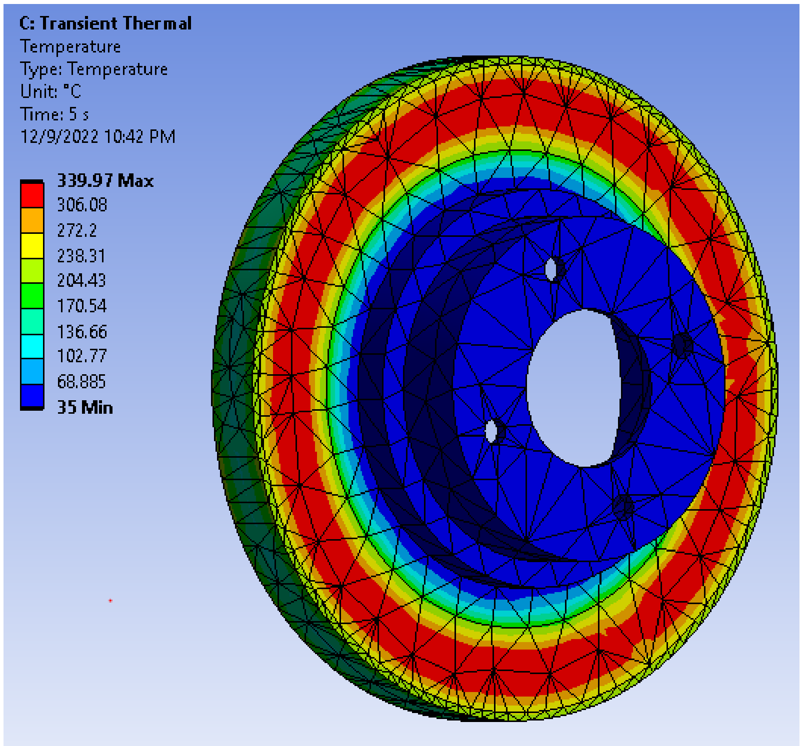


Figure 4. Temperature distribution

2. Optimization

In this part, we optimize the brake disc with three variables V1, V2, and V3 by using design of periment (DOE) in the ANSYS package. The optimized objectives are stress, temperature, volume, and frequency of the brake disc.

a. DOE

Latin Hypercube Sampling (LHS) with user-defined sample points is chosen to collect the design points. The bounds of variables are set in the table 2.

Inner diameter (V1)	70-85
Outer diameter (V2)	122-140
Thickness (V3)	14-30

Table 2: Bound constraint for design variables.

we observed errors for any design points that had an outer diameter of less than 122. Therefore, 122 is set as the lower bound for the outer diameter. A total of 10 design points are generated and shown in Fig 5.

Table of Outline A2: Design Points of Design of Experiments

	A	B	C	D	E	F	G
1	Name	P8 - rotor_OD (mm)	P9 - rotor_ID (mm)	P10 - rotor_thickness (mm)	P4 - Equivalent Stress Maximum (Pa)	P5 - Temperature Maximum (C)	P6 - Total Deformation Reported Frequency (Hz)
2	1	131.9	70.75	14.7	1.0738E+07	417.44	1310.4
3	2	124.7	84.25	17.5	1.1842E+07	378.17	1325.1
4	3	126.5	79.75	27.3	1.2068E+07	336.01	1529.3
5	4	128.3	72.25	20.3	1.1526E+07	361.08	1533.3
6	5	137.3	75.25	25.9	1.1547E+07	338.28	1421.2
7	6	133.7	81.25	21.7	1.1839E+07	354.16	1347
8	7	139.1	82.75	16.1	1.1526E+07	399.67	1208
9	8	130.1	73.75	23.1	1.1962E+07	347.31	1523.2
10	9	135.5	78.25	24.5	1.1722E+07	341.55	1400.3
11	10	122.9	76.75	18.9	1.5671E+07	371.64	1543.7

Fig 5. LHS design points

b. Response Surface

The results from DOE are used for response surface for prediction purposes. In this work, we used a neural network with a number of cells of 3 as the method for the response surface. The response surface allows us to perform sensitivity analysis to figure out the most important variables for the optimization. Figure 6 shows the prediction for design points. Local sensitivity which shows the norm of partial derivatives of the chosen objective and the local sensitivity curve which shows the response curve as described in Figures 7, 8, 9 and 10 respectively.

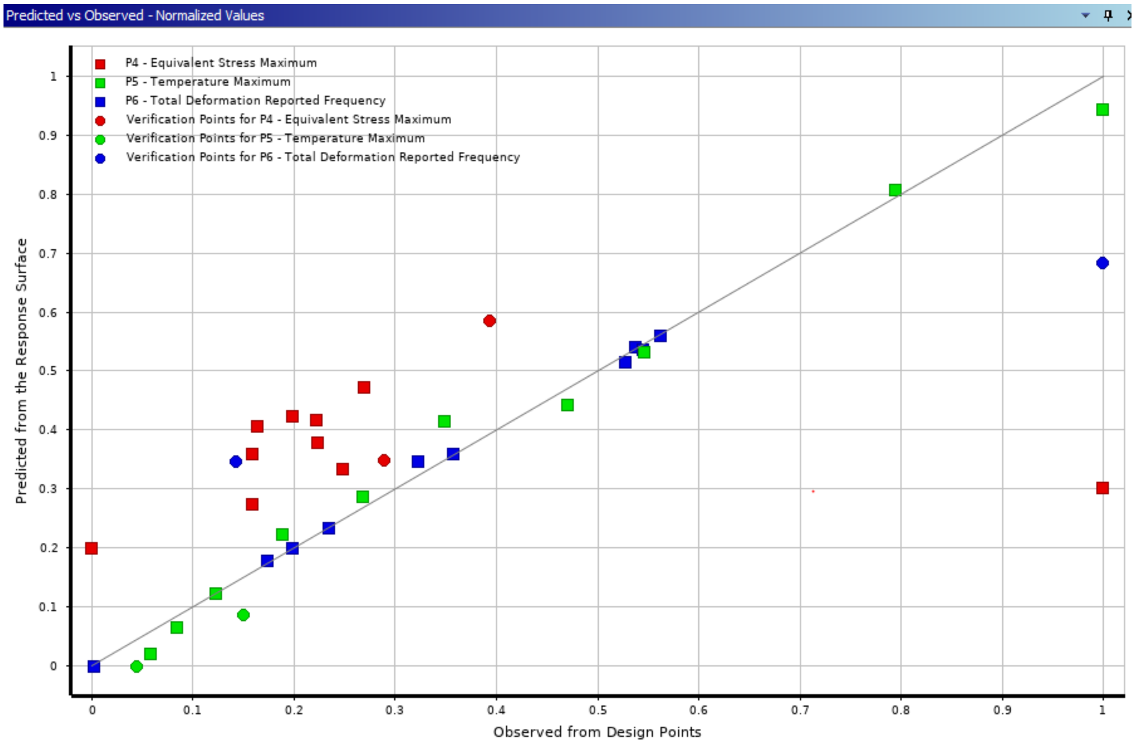


Figure 6. Predictions for design points.

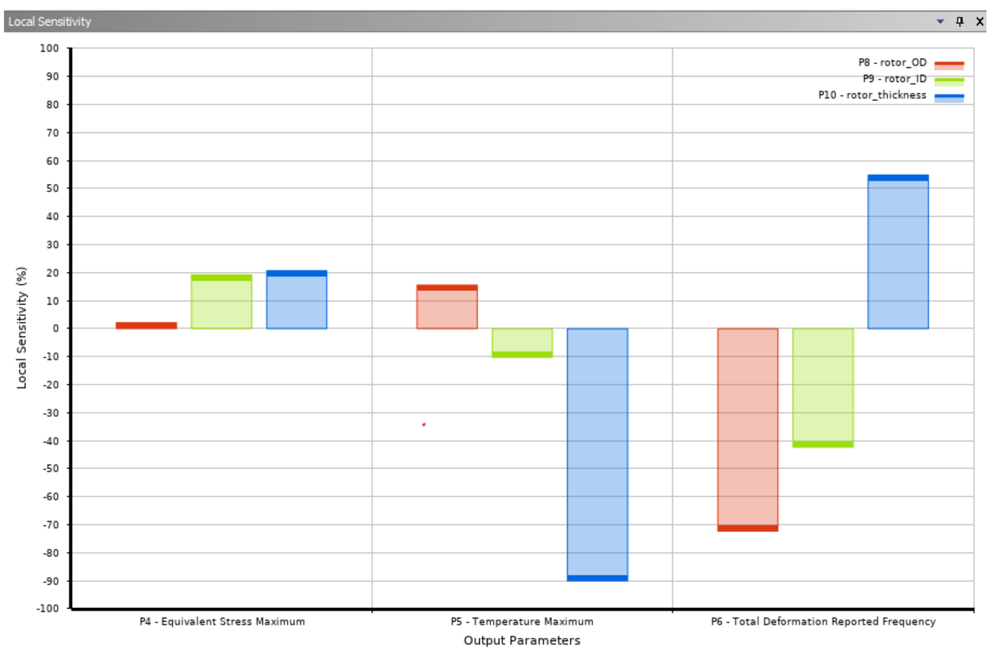


Figure 7. Local Sensitivity.

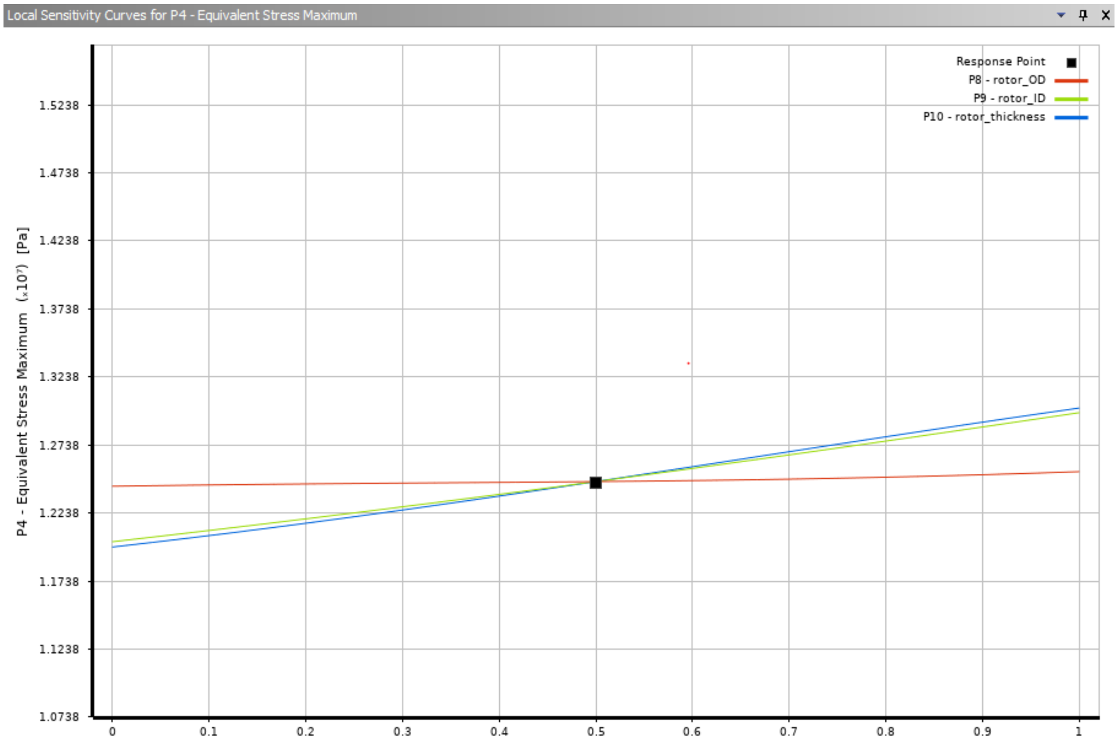


Figure 8. Stress sensitivity curve.

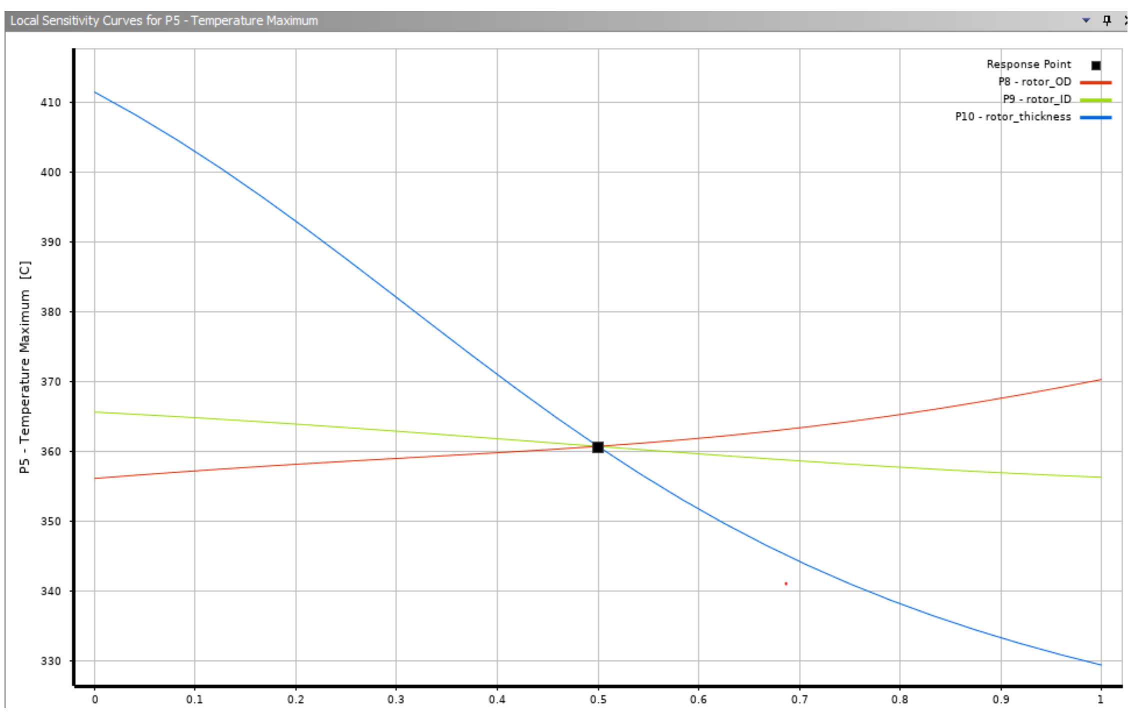


Figure 9. Temperature sensitivity curve.

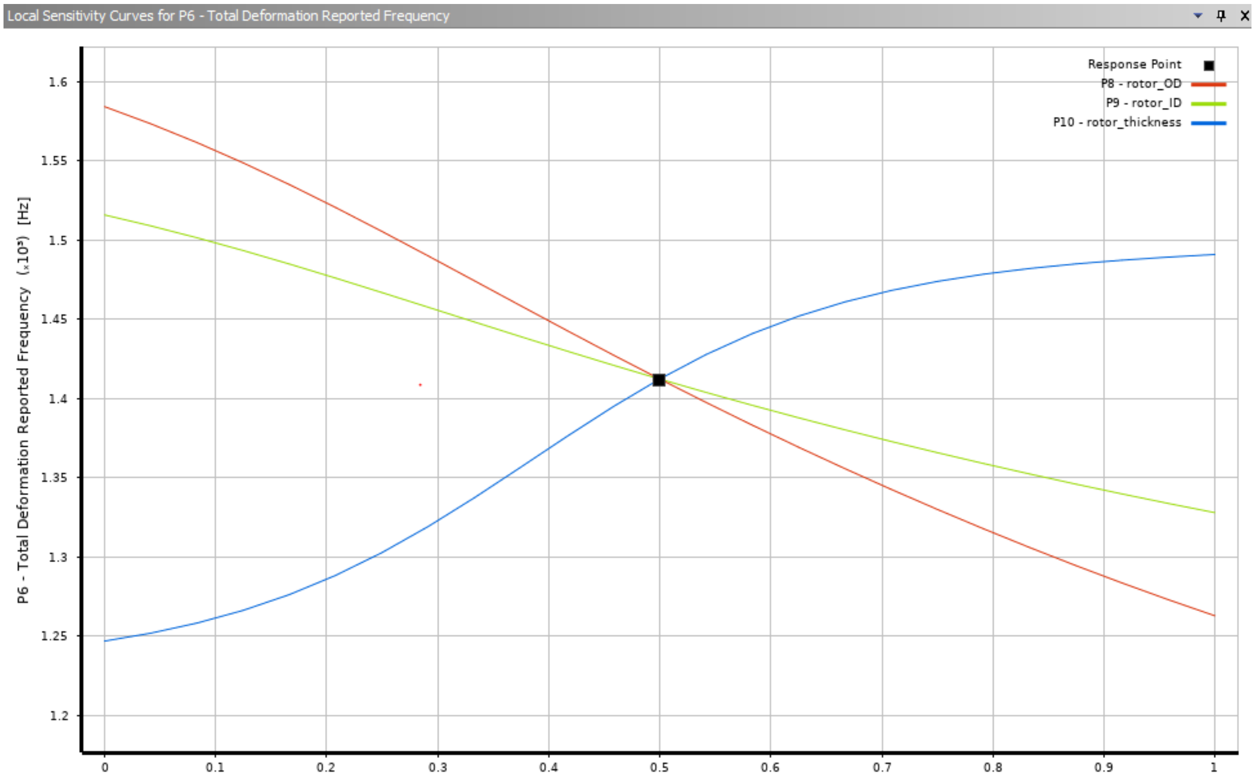


Figure 10. Total deformation sensitivity curve.

3. Optimization Result.

Table 3 compares the optimal design and the initial points. The optimal design reduces the volume, the frequency by around 6% and 12% compared to the original design. However, an increase in maximum temperature of around 20 °C is observed while the maximum stress shows a slight decrease.

Designs	Inner Diameter (mm)	Outer Diameter (mm)	Thickness (mm)	Maximum Stress (MPa)	Maximum Temperature (°C)	Frequency (Hz)	Volume (m^3)
Initial points	75	125	25	13.7	339.7	1612	0.0009967
Optimal points	77.5	131	21	12.5	360.7	1412	0.0009388

Table 3. Comparison between the optimal design point and the initial point.