MAE 598 Design Optimization Project 2

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This project is to find the optimum solutions through industrial software by using existing brake disc model. The content of the project is separated into three parts: model analysis, model optimization and conclusion.

1 Model Analysis

The flowchart for brake disc model optimization is shown in figure 1, which includes static structural, modal and transient thermal. The brake disc geometry is prepared in ANSYS as shown in figure 2. The design variable of brake disc optimization is rotor thickness (P1), rotor inner outer radius (P2) and rotor inner radius (P3). The initial value of these variable are set as 25 mm, 125 mm and 75 mm respectively.

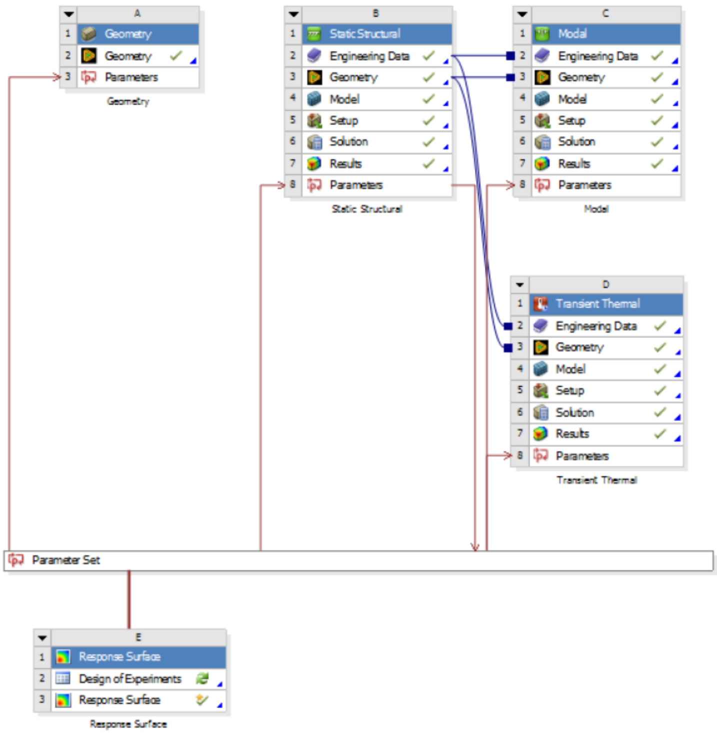


Figure 1: ANSYS optimization flowchart

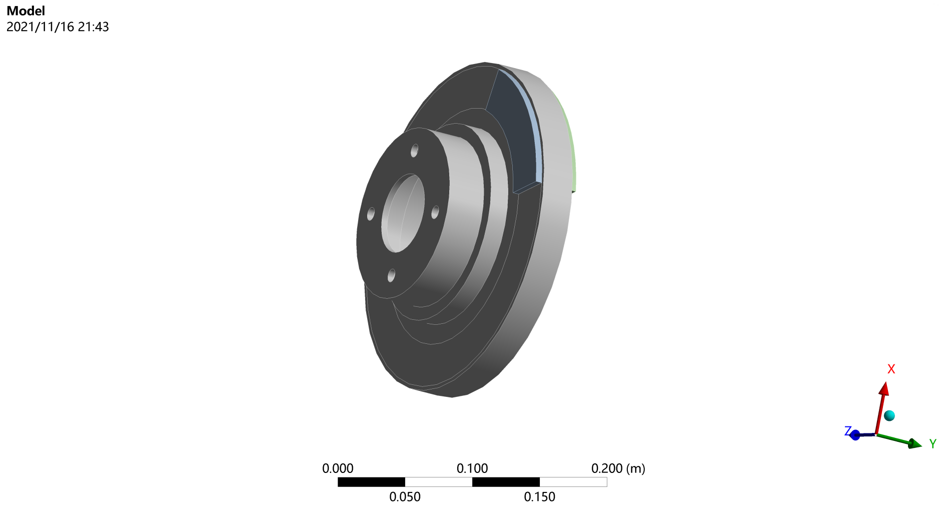


Figure 2: Disk brake CAD model

1.1 Structural Analysis

Static structural analysis is implemented after loading the constraint and pressure for the brake disc, which is shown as follow. Figure 3 shows the analysis result.

- Revolted joint is applied to the inner diameter of disc, which is in contact with the shaft.
- Rotational velocity is set as 250 rad/s in the Y axis for the disc.
- Brake pads are constrained on the X and Z axis.
- Frictional contact is set between the brake caliper pads and disc.
- 10.495 MPa pressure is applied on the brake pads face.

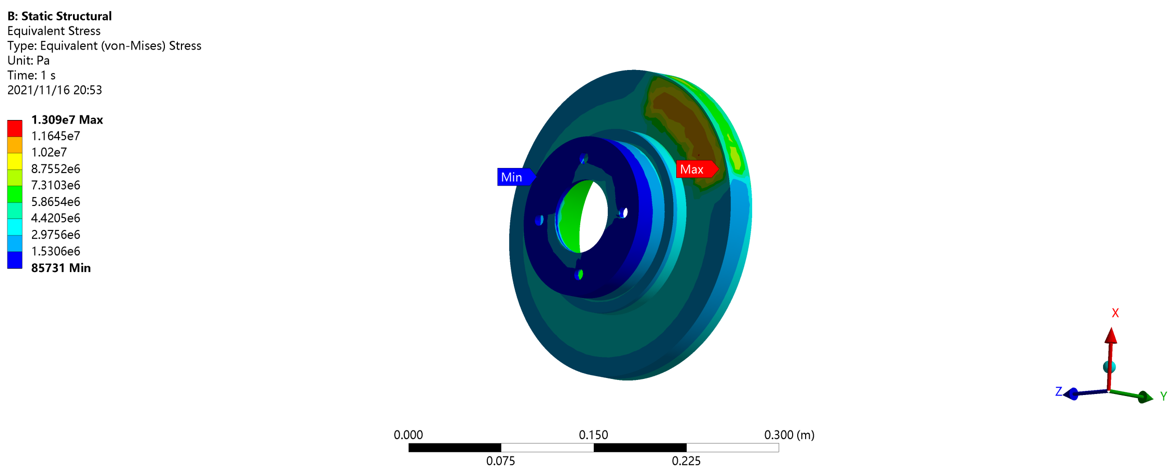


Figure 3: Static structural analysis for initial condition

1.2 Modal Analysis

Modal analysis is implemented to determine the disc nature frequency after having the total deformation. Figure 4 shows the analysis result.

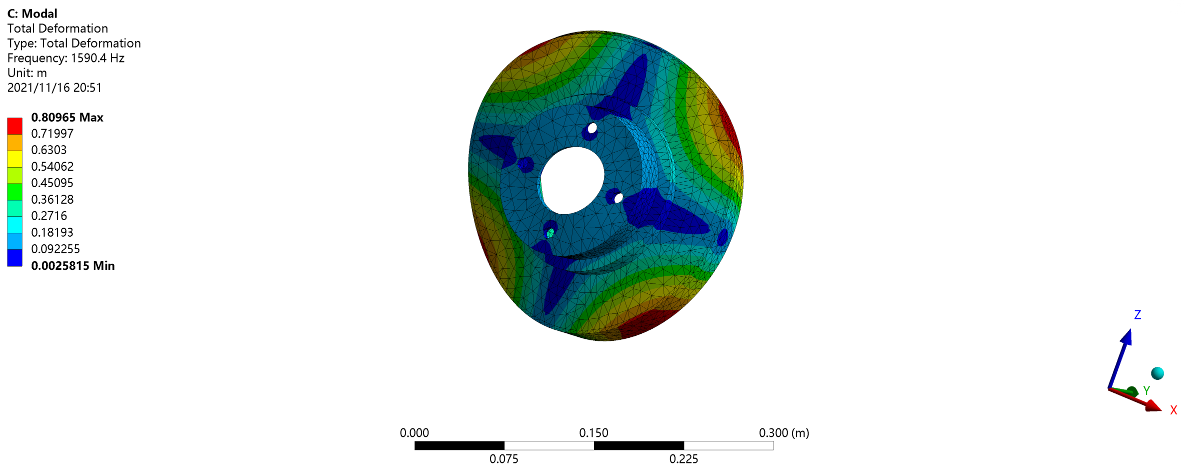


Figure 4: Modal analysis for initial condition

1.3 Thermal Analysis

Thermal analysis is implemented to observe the maximum temperature rise after the braking operation. Figure 5 shows the analysis result. The maximum temperature is 335.38 °C

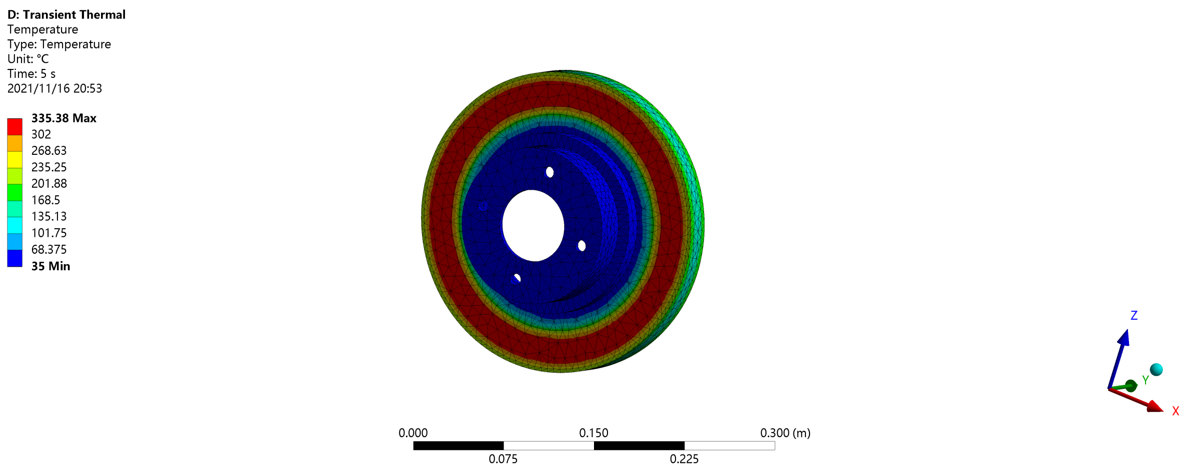


Figure 5: Thermal analysis for initial condition

2 Model Optimization

After we have the initial analysis for the structural, modal and thermal, the relationship between the design variables (P1, P2, P3) and output response is known. All of the design variables are continuous. In this section, we will implement DOE and ANSYS build-in optimized method to find the optimum solutions when the objective function is the stress and volume of the brake disc.

2.1 Design of Experiment

We use Latin Hypercube Sampling (LHS) to sample the data from the given data space and then create the output response. After the design of experiments process, we obtain various combinations of design variables and the corresponding output response. 14 total DOE points are generated in figure 6.

Table of Outline A2: Design Points of Design of Experiments

	A	B	C	D	E	F
1	Name	P1 - rotor_thickness (mm)	P2 - rotor_OD (mm)	P3 - rotor_ID (mm)	P4 - Equivalent Stress Maximum (Pa)	P7 - Solid Volume (m^3)
2	1	21.65	135.33	78.5	1.1684E+07	0.0010501
3	2	24.35	130	79.5	1.1722E+07	0.0010365
4	3	14.45	131.33	72.5	1.1185E+07	0.00074713
5	5	15.35	123.33	73.5	1.1942E+07	0.00067914
6	6	27.05	122	71.5	1.2386E+07	0.0010298
7	7	22.55	138	82.5	1.3108E+07	0.001105
8	8	26.15	134	81.5	1.2997E+07	0.0011639
9	9	18.05	124.67	77.5	1.1575E+07	0.00076073
10	10	17.15	132.67	84.5	1.2508E+07	0.0008091
11	11	19.85	127.33	75.5	1.1652E+07	0.00086863
12	12	16.25	136.67	74.5	1.1221E+07	0.00087972
13	13	20.75	128.67	76.5	1.1957E+07	0.00091419
14	14	25.25	139.33	70.5	1.1776E+07	0.0013418
15	15	18.95	126	80.5	1.162E+07	0.00079011

Figure 6: LHS DOE points

2.2 Response Surface

After DOE, a response surface is generated for all the design variables and the corresponding output response through neural network, which the number of cell is 3. Also, we set up 3 verification points. The goodness of fit plot for the structural analysis is shown below.

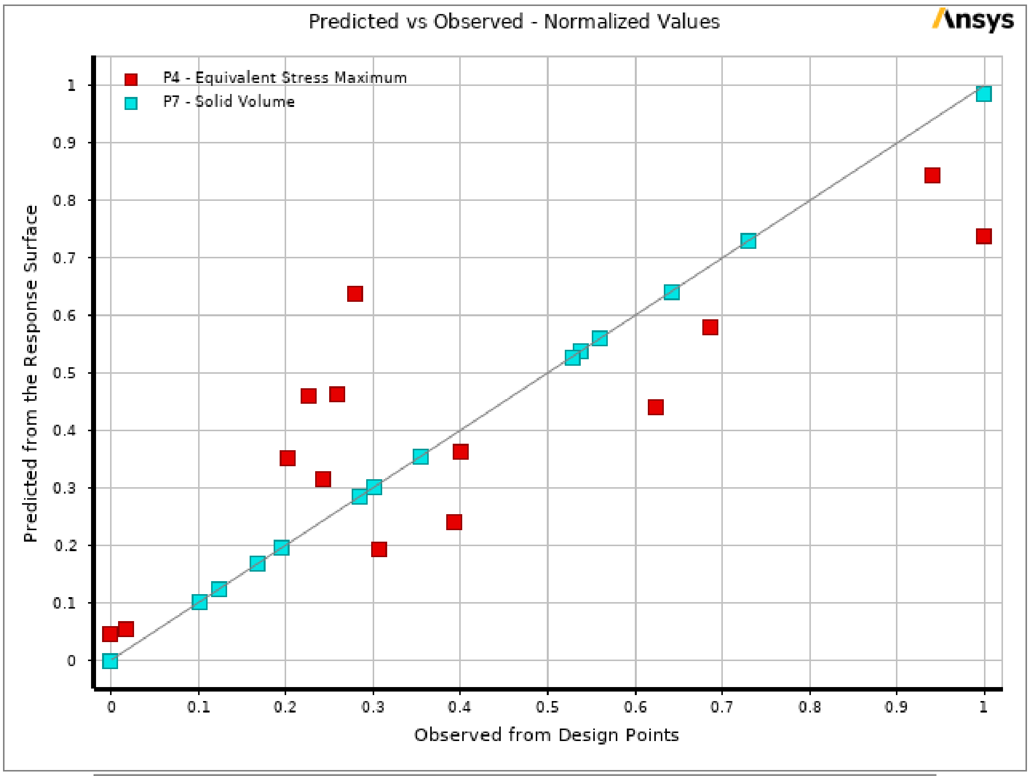


Table of Schematic E3: Response Surface

	A	B	C
1		P4 - Equivalent Stress Maximum	P7 - Solid Volume
2	Coefficient of Determination (Best Value...		
3	Learning Points	0.66138	0.99988
4	Root Mean Square Error (Best Value =...		
5	Learning Points	3.316E+05	1.9994E-06
6	Relative Maximum Absolute Error (Best Value = ...		
7	Learning Points	116.87	3.9985
8	Relative Average Absolute Error (Best Value =...		
9	Learning Points	47.672	0.29772

Figure 7: Goodness of fit plot for structural analysis

Besides, we also show the sensitivity analysis as below. We can find the optimum solutions through ANSYS build-in optimization method after loading the pressure and constraint for the brake disc.

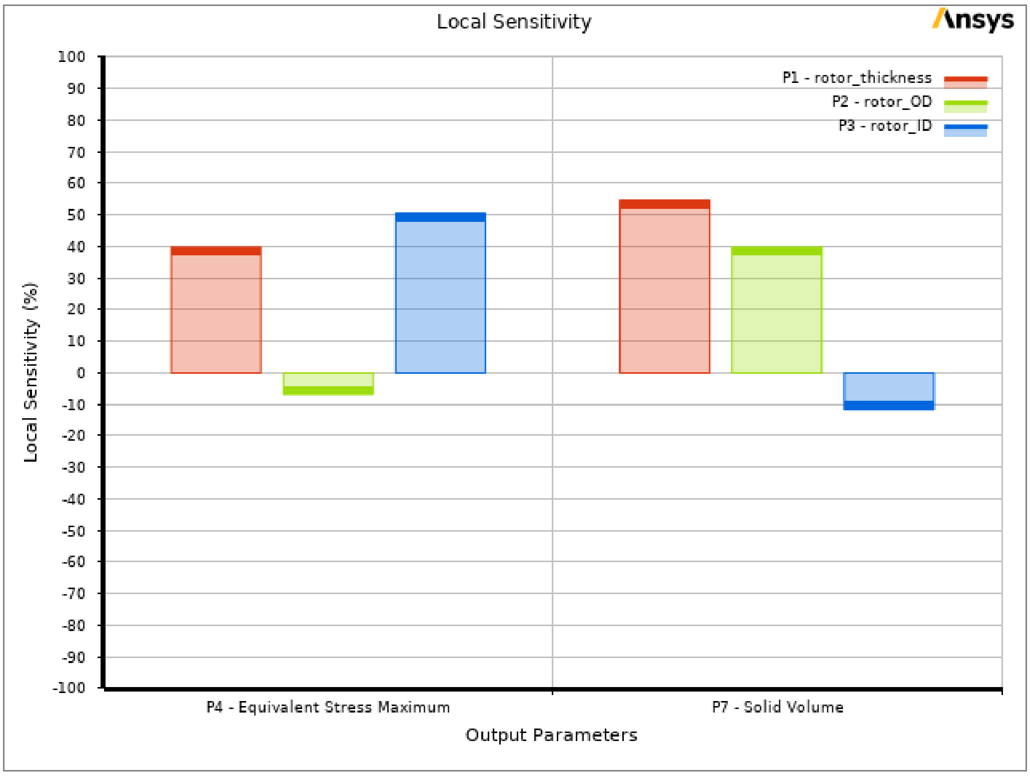


Figure 8: Local sensitivity analysis

Figure 9 shows the response curve of stress (y-axis) with respect to the design variables (P1, P2, P3).

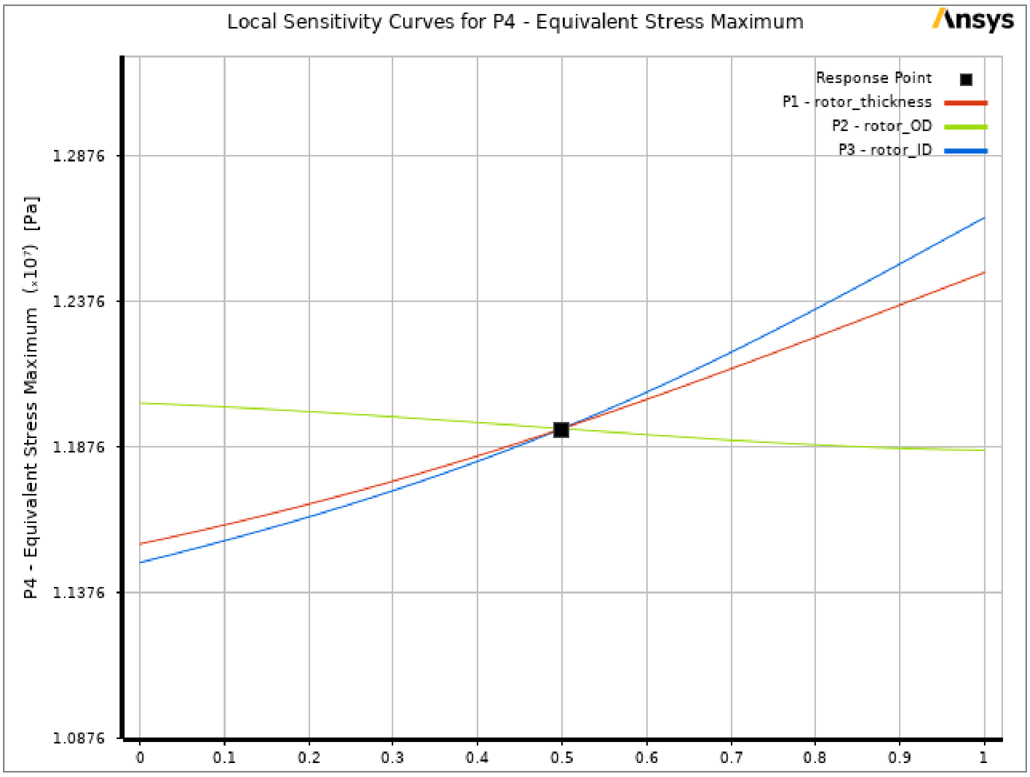


Figure 9: Stress sensitivity analysis

Figure 10 shows the response curve of volume (y-axis) with respect to the design variables (P1, P2, P3).

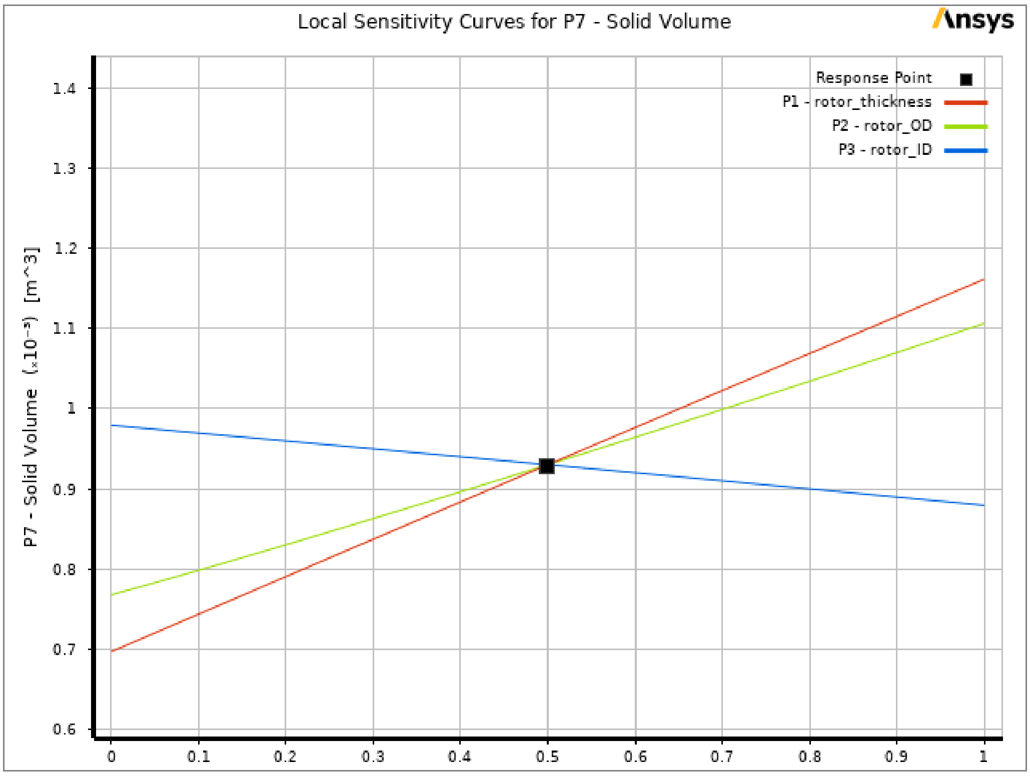
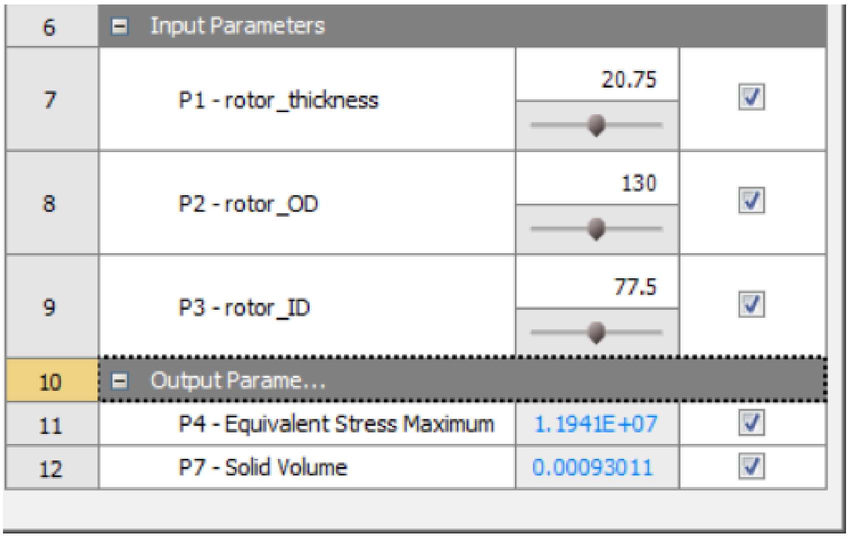


Figure 10: Volume sensitivity analysis

Figure 11 shows the optimum solutions through ANSYS build-in optimization method.



6	Input Parameters		
7	P1 - rotor_thickness	20.75	☑
8	P2 - rotor_OD	130	☑
9	P3 - rotor_ID	77.5	☑
10	Output Parame...		
11	P4 - Equivalent Stress Maximum	1.1941E+07	☑
12	P7 - Solid Volume	0.00093011	☑

Figure 11: Optimum solutions

3 Conclusion

This project firstly completes three analysis for the brake disc including structural, modal and thermal and then implements DOE with neural network to obtain optimum solutions for the objective function, which is the stress and volume of the brake disc. Through the analysis, we can find that the volume of the brake disc is reduced from 0.00099667 m^3 to 0.00093011 m^3 after loading the pressure and constraint, which volume reeducation is 6.68 %.