Structural optimization of thin-walled cantilever beams subjected to uniform loads

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Abstract. The optimal design of the structure can reduce the cost, reduce the energy loss and prolong the service life. In this paper, the thin-walled cantilever beam with rectangular section is studied and analyzed in detail, and the structure is optimized by the response surface method by using Ansys Workbench for simulation and analysis.

Keywords: Thin-walled cantilever beam, Ansys Workbench, Response surface, Structural optimization.

1. Introduction

Response surface optimization is a statistical method of solving multivariate problems by using reasonable experimental design methods, obtaining certain data through experiments, and adopting multiple quadratic regression equations to fit the functional relationship between the factors and the response values, and seeking the optimal process parameters through the analysis of the regression equations. Unlike direct optimization, response surface optimization is based on the generated response surface data. The more accurate the response surface fitting, the more accurate the optimization results.

The following is the specific procedure for optimizing the design of thin-walled cantilever beams subjected to uniform loads using the response surface approach.

2. Description of the problem

The rectangular cross-section thin-walled cantilever beam is analyzed as the object of study, and its structure is schematically shown in Fig. 1, where L is the length of the cantilever beam; the parameters of the corresponding cross-section are shown in Fig. 2.

Figure 1. Schematic structure

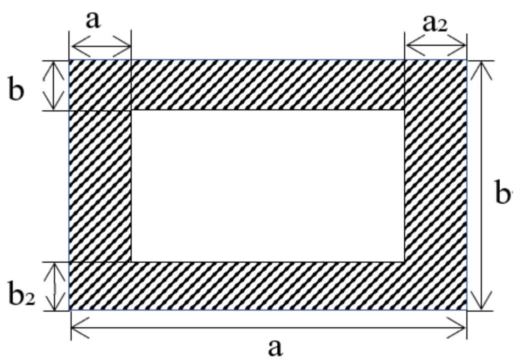

Figure 2. Cross-section parameters

The initial values of thin-walled cantilever beams of rectangular section are taken as shown in Table 1:

Table 1. Initial parameters of thin-walled cantilever beam with rectangular cross-section

starting parameter		a	10mm
L	2000mm	a_2	10mm
a	100mm	b	10mm
b	40mm	b_2	10mm

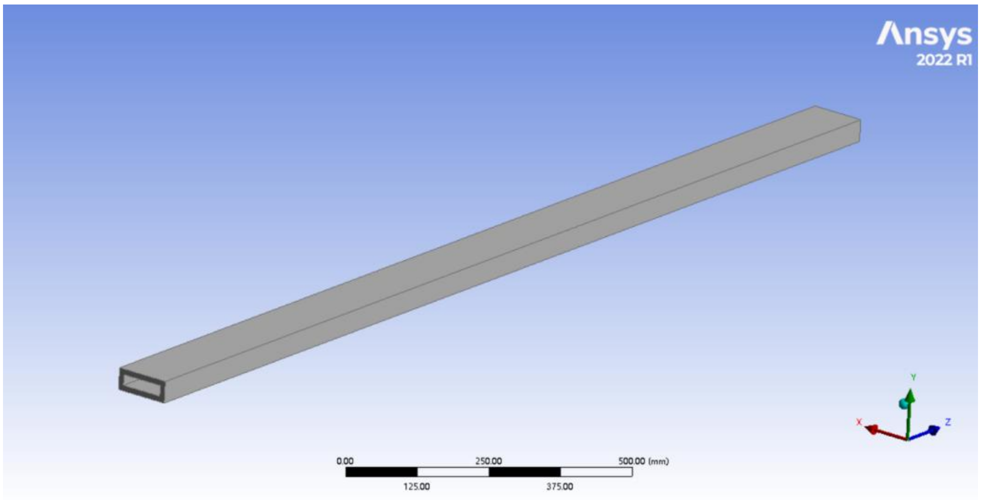

Figure 3. Rectangular thin-walled cantilever beam structure created in Ansys Workbench

A rectangular thin-walled cantilever beam structure is created in Ansys Workbench as shown in Fig. 3, and the design variables L, a, a_1, a_2, b, b_1, and b_2 are defined as the model parameters, which facilitates the quick realization of the model updating in the subsequent designing sessions.

3. Grid division

Then a reasonable mesh division is carried out, and the divided mesh is shown in Fig. 4.

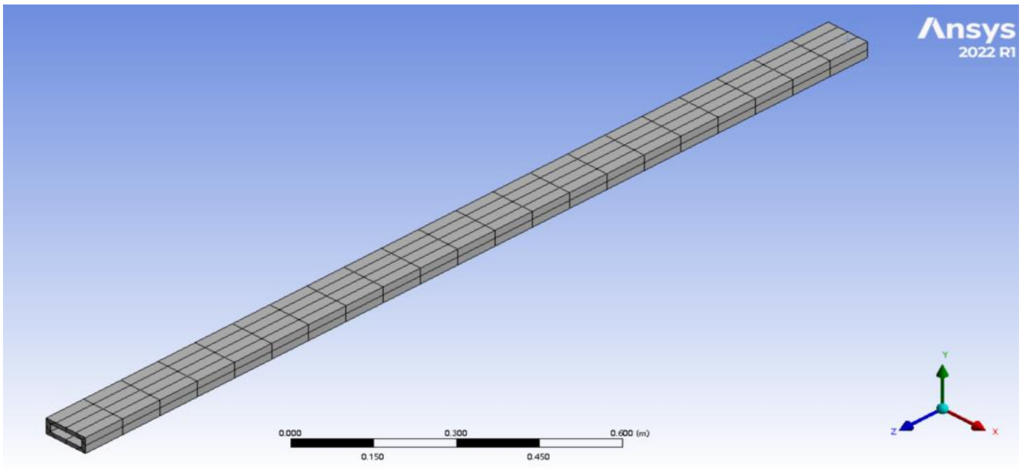

Figure 4. Grid division

4. Imposing constraints

Set the boundary conditions as follows, with the left end as the fixed end and a uniform load of 1000N/m² applied to the upper surface, and parameterize the applied load as shown in Figure 3.1. The minimum safety factor and mass are then parameterized.

5. Preliminary Solution

The results obtained from the solution are shown in Fig. 5, Fig. 6 and Fig. 7.

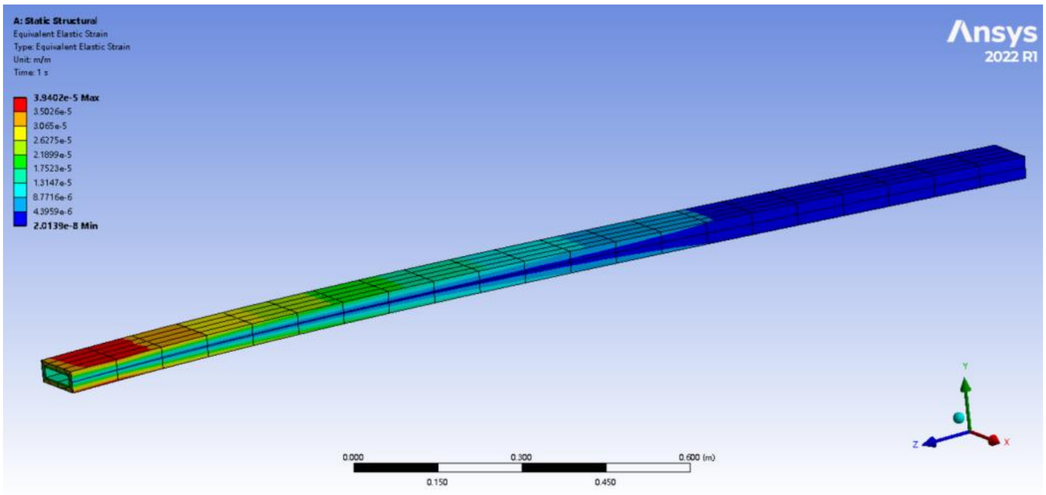

Figure 5. Setting Boundary Conditions

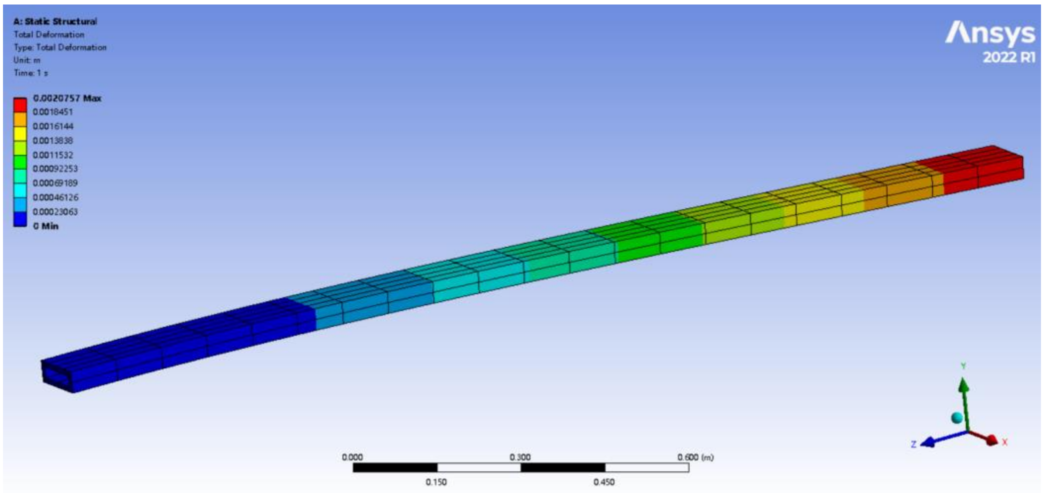

Figure 6. Stress cloud diagram

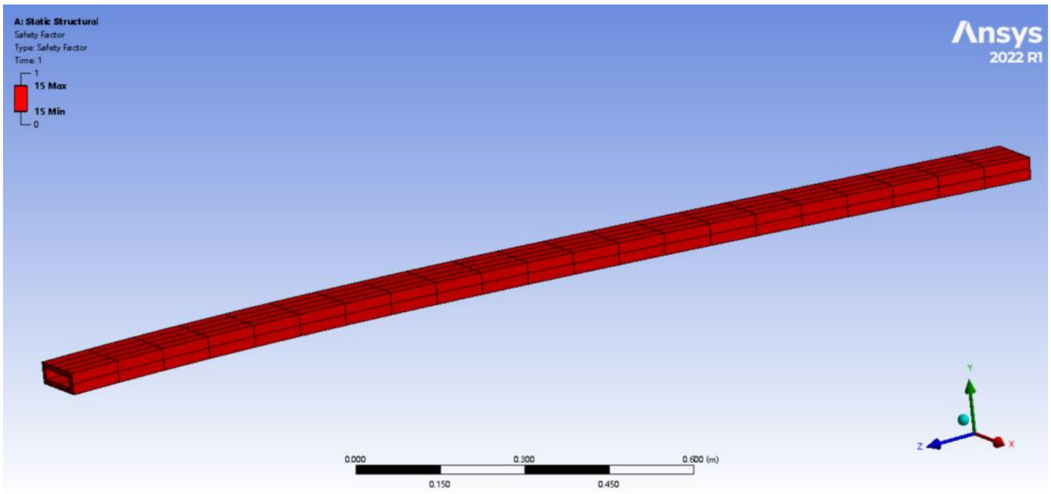

Figure 7. Deformation cloud map

6. Experimental design

Determine the input and output parameters and set the upper and lower bounds for the input parameters. Set L, a, b, and the applied load as input parameters, and set the maximum equivalent force, maximum total deformation, mass, and minimum factor of safety as output parameters. The upper and lower bounds for the input parameters are shown in Table 2. Calculations are performed for the current experimental design point.

Table 2. Upper and lower bounds for input parameters

input parameter	upper bound	(of Gods) descend to the world of mortals
L	2200mm	1800mm
a	110mm	90mm
b	45mm	35mm
applied uniform load	1100N/m²	900N/m²

Then do the experimental design as shown in Table 3 and update the experimental design points to calculate the data (Figure 8).

Table of Outline A2: Design Points of Design of Experiments

	A	B	C	D	E	F	G	H	I
1	Name	P1 - XYPlane .L1 (mm)	P2 - XYPlane .L2 (mm)	P9 - Extrude1 .FD1 (mm)	P10 - Pressure Magnitude (Pa)	P11 - Equivalent Elastic Strain Maximum (m m^-1)	P12 - Total Deformation Maximum (m)	P13 - Safety Factor Minimum	P14 - Solid Mass (kg)
2	1 DP 0	100	40	2000	1000	3.9402E-05	0.0020757	15	37.68
3	2	90	40	2000	1000	3.9396E-05	0.0020694	15	34.54
4	3	95	40	2000	1000	3.9486E-05	0.0020729	15	36.11
5	4	110	40	2000	1000	3.9697E-05	0.0020818	15	40.82
6	5	105	40	2000	1000	3.9454E-05	0.0020781	15	39.25
7	6	100	35	2000	1000	4.9517E-05	0.0029734	15	36.11
8	7	100	37.5	2000	1000	4.3968E-05	0.0024681	15	36.895
9	8	100	45	2000	1000	3.2335E-05	0.0015219	15	39.25
10	9	100	42.5	2000	1000	3.572E-05	0.0017711	15	38.465
11	10	100	40	1800	1000	3.1817E-05	0.001364	15	33.912
12	11	100	40	1900	1000	3.5564E-05	0.0016909	15	35.796
13	12	100	40	2200	1000	5.2558E-05	0.0030418	15	41.448
14	13	100	40	2100	1000	4.8419E-05	0.0025262	15	39.564
15	14	100	40	2000	900	3.5462E-05	0.0018681	15	37.68
16	15	100	40	2000	950	3.7432E-05	0.0019719	15	37.68
17	16	100	40	2000	1100	4.3342E-05	0.0022833	15	37.68
18	17	100	40	2000	1050	4.1372E-05	0.0021795	15	37.68
19	18	90	35	1800	900	3.6053E-05	0.0017541	15	29.673
20	19	95	37.5	1900	950	3.7716E-05	0.001907	15	33.559
21	20	110	35	1800	900	3.6147E-05	0.0017607	15	35.325
22	21	105	37.5	1900	950	3.7752E-05	0.0019113	15	36.542

Figure 8. Selected calculated data results

Table 3. Experimental design

Experiment type design	Intermediate Composite Design
Design Type	focussed
Template Type	reinforce

7. Response surface optimization

The response surface is updated and a series of results are obtained, as shown in Figure 9 and Figure 10.

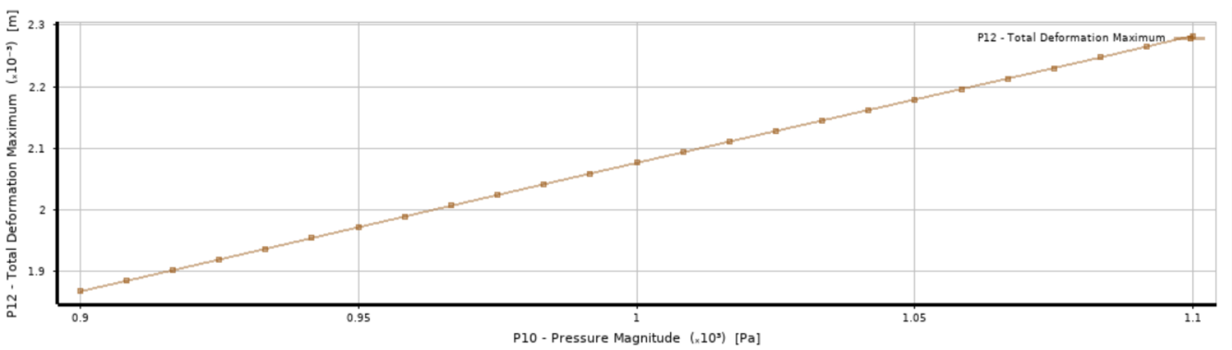

Figure 9. Load and deflection relationship curve

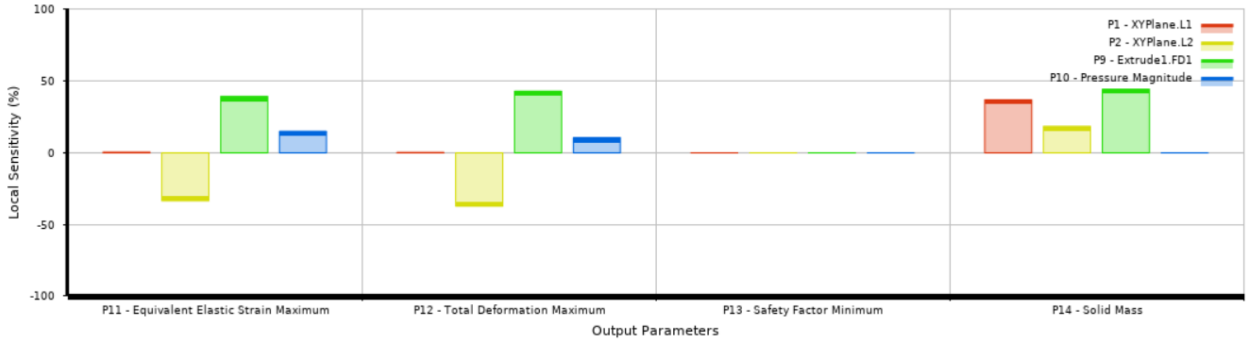

Figure 10. Localized sensitivity

From the load and deformation relationship curve, the maximum deformation and the size of the load is proportional to the size of the load, the greater the applied load, the greater the maximum deformation.

A sample size of 1000 is selected for optimization and the optimization objective is to obtain minimum values for both mass and maximum deformation. After processing the results, three candidate solutions based on the objective optimization were obtained as shown in Fig. 11. The dot plot of mass versus stress is shown in Figure 12. The mass versus stress curve is shown in Fig. 13.

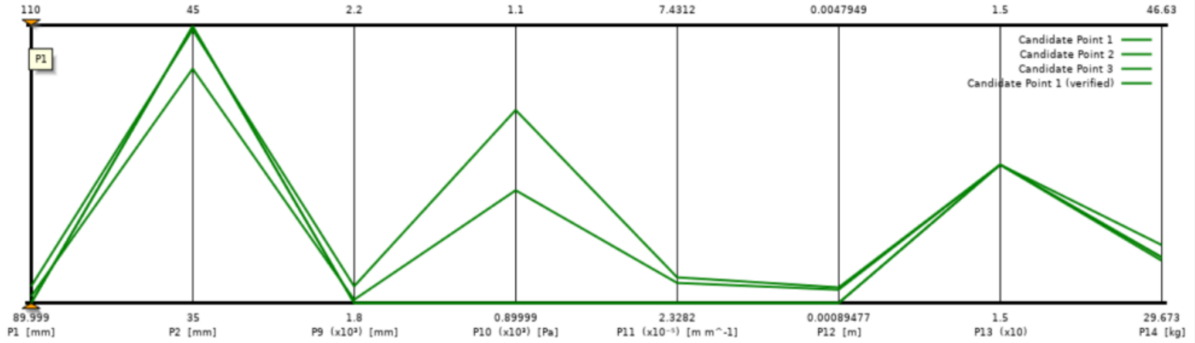

Figure 11. Three candidate solutions for objective-based optimization

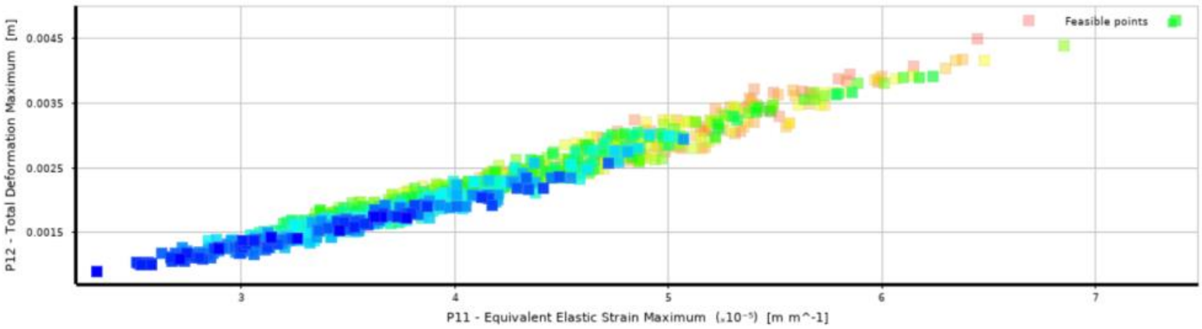

Figure 12. Dot Plot of Mass vs. Stress

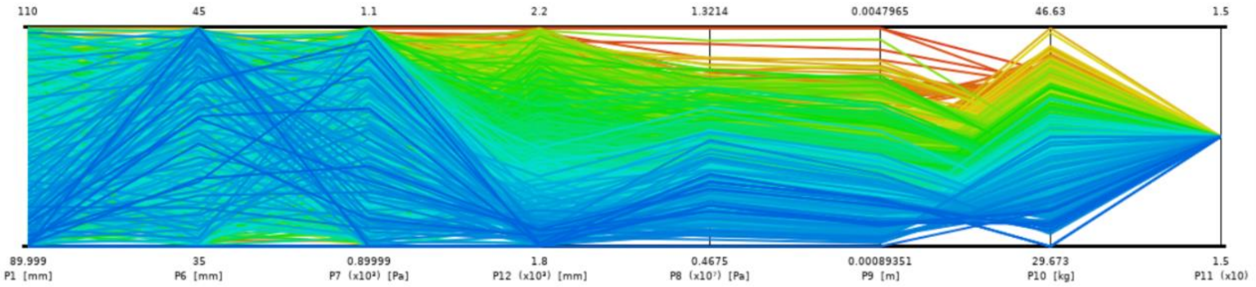

Figure 13. Mass versus Stress Curve

From the mass-stress relationship curve, it can be seen that increasing the mass, the stress distribution will decrease accordingly.

Insert candidate point 1 as a design point. Update the calculation and the results obtained are shown in Figure 14, Figure 15 and Figure 16.

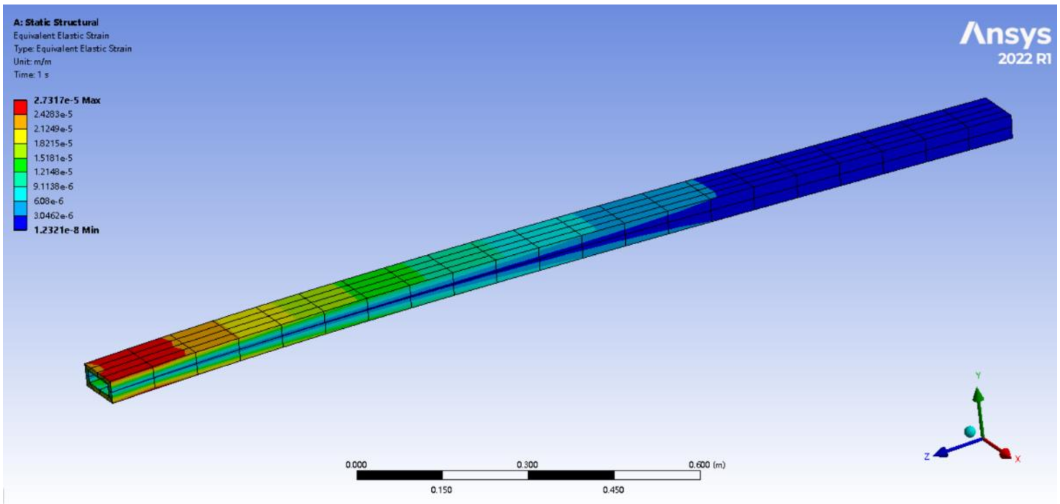

Figure 14. Stress cloud diagram

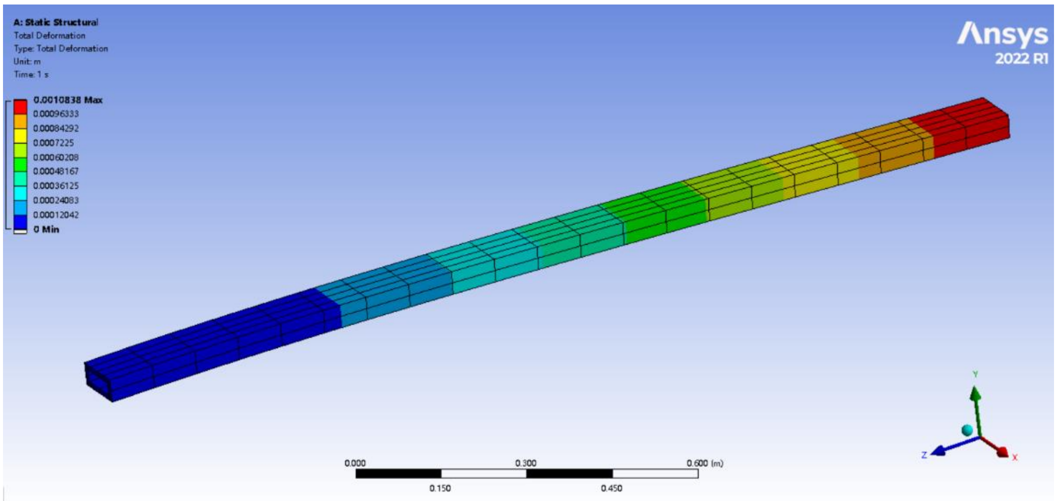

Figure 15. Deformation cloud map

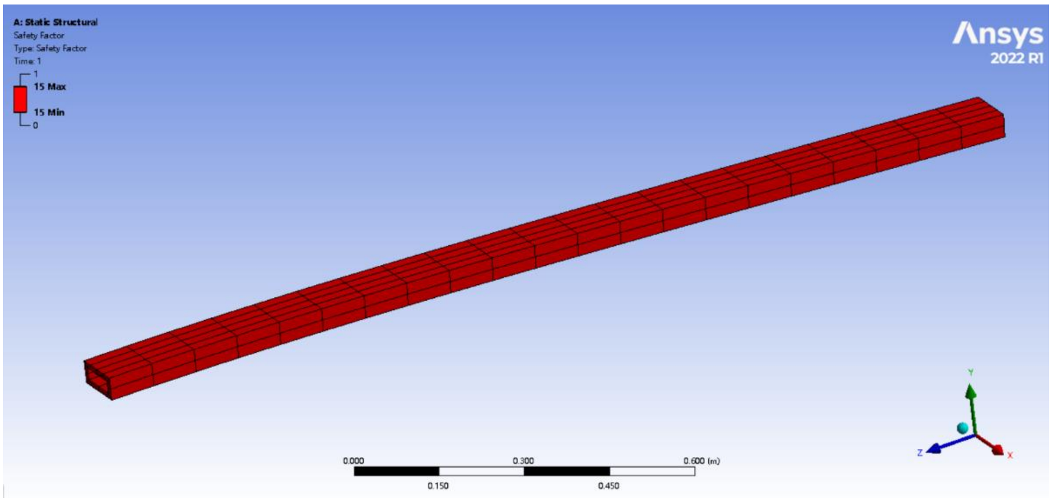

Figure 16. Cloud diagram of safety factors

8. Optimization results

Viewing the results gives the optimized data as shown in Table 4.

Table 4. Optimization results

Optimization parameters	Optimized values
L	1800mm
a	90mm
b	45mm
applied uniform load	900N/m²

9. Conclusion

The above structural optimization of thin-walled cantilever beams of rectangular cross-section shows that the mass as well as the maximum deformation of the structure is smaller when L is smaller, a is smaller, b is larger, and the applied homogeneous load is smaller within the range of variation of the parameters specified in this paper.

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