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Response Surface Optimization Design of Bookcase Shelf Based on ANSYS Workbench

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ABSTRACT

The Finite Element Analysis（FEA） and response surface optimization is of great significance in furniture design optimization can not only save costs, but also to protect the environment. In our study we are going to use FEA and response surface optimization in order to optimize Total Deformation Maximum and Solid Mass of bookcase shelf in ANSYS Workbench collaborative software. The results showed that: The Total Deformation Maximum mainly due to the positive impact of length, followed by the negative impact of depth, almost without wide impact, The length increases, the Total Deformation Maximum synchronous increase; with decreasing depth, the Total Deformation Maximum increases Solid Mass that is affecting the three parameters, namely the degree of influence length, depth, width. When the length of 773 mm, width of 253.73 mm, depth of 15.157 mm, the Total Deformation Maximum of bookcase shelf is 4.681mm, the Solid Mass of 2.2275 kg, which is attained optimal goal. At the same time, the use of FEA and response surface optimization provides a scientific basis for the bookcase design and a new perspective for the structure optimization of panel furniture.

Key Words: Finite Element Analysis（FEA）, Response Surface Optimization, Panel Furniture, Furniture Design, Design Optimization, Shelf Deformation

1.Introduction

Panel furniture have become mainstream products on the market.Rise of panel furniture, the furniture industry has brought a great change , changing the furniture manufacturing design and production patterns radically. For furniture designers ,it provides a broader creative space ; For furniture industry ,it promotes the standardization and meets the needs about modern , diversified and personalized of furniture [1-2] . Nowadays, furniture design method has been relied on

analogy and experience but lack of in-depth analysis and accurate calculation .The results of one hand the security furniture design ,the strength and stiffness of furniture products can not meet the design requirements , leading to deformation, even damage less than the product life cycle. The other hand, the safety factor is too large , there is no maximum savings of raw materials , resulting in a waste of resources , the design of bulky products , which in turn reduces the artistic charm.

Bookcase is wide used furniture. During the product development process of a bookcase it is necessary specific design criteria to be fulfilled [3].One of the design problem is deformation for the shelf. most manufacturers use multi-block short board design approach, meaning that the use of a small area of segmentation to reduce the large span bearer. Although this method can solve the shelf deformation but increasing the relative surface area of the wood-based panel and costs as well as the release of formaldehyde in the home space. HE-Fengmei have optimized the position connector and connector length of bookcase shelf by ANSYS, though reduced shelf deformation, but optimization methods they use can not see the effect of design variables on the objective function directly[4].The popular response surface optimization, which can describe the relationship between the output parameters and the input parameters, displaying in graphical form. Wu Min, who optimized hook using the local sensitivity diagrams and response surface plo. Therefore, this study uses FEA and response surface optimization to optimize the size of bookcase shelf in ANSYS Workben collaborative software[5].

Design Objective

It is well known bookcase shelf bear static load under applying condition. In our study the only material is particleboard,the density is $\rho = 0.75$ g/cm^3.The load case is the 16 dimensions books((184 mm*260 mm) and the weight of the shelf .For the books,the density is $\rho = 0.75$ g/cm^3, total solid mass of about 350 N,which means that applied external load is 0.001 N/mm^2. Try to determine the length, width and depth of the shelf,when range of shelf length of L is less than 1000 mm, not less than 600 mm; the width of B is less than 320 mm, not less than 250 mm; the depth of H is less than 22 mm, not less than 15 mm.our study requires that shelf for deflection is less than 5 mm (shelf deflection /the length $\leq$0.5%) and the minimum solid mass.

2.Materials and Methods

2..1 Finite Element Analysis and Response Surface Optimization

FEA is a universal numerical analysis method to solve complicate problem like tress - strain and thermal distribution. US company Ansys Workbench is a new product developed for solving practical problems , not only has the basic functions of general finite element analysis , but also incorporates powerful geometric modeling and optimization design features , is a CAD / CAE collaborative environment [6]. In this study, experimental process including static analysis (Creating 3D model, Defining materials properties, Defining a case ,meshing , Defining boundary conditions Solving and viewing the results) , the definition of response surface , response surface optimization (Fig.1).

Response surface describes the relationship between the output parameters and the input parameters, and displayed in graphical form . Response surface can not completely run the entire

solution process , you can get an approximation of the output parameters. Once established response surface , the experimenter can create better manage the response point and responses , while ANSYS Workbench powerful post-processing tools designed to search for the point , understand the input parameters affect the output parameters to guide the experimenters have to modify the design to improve performance , optimized design of product structure [7].

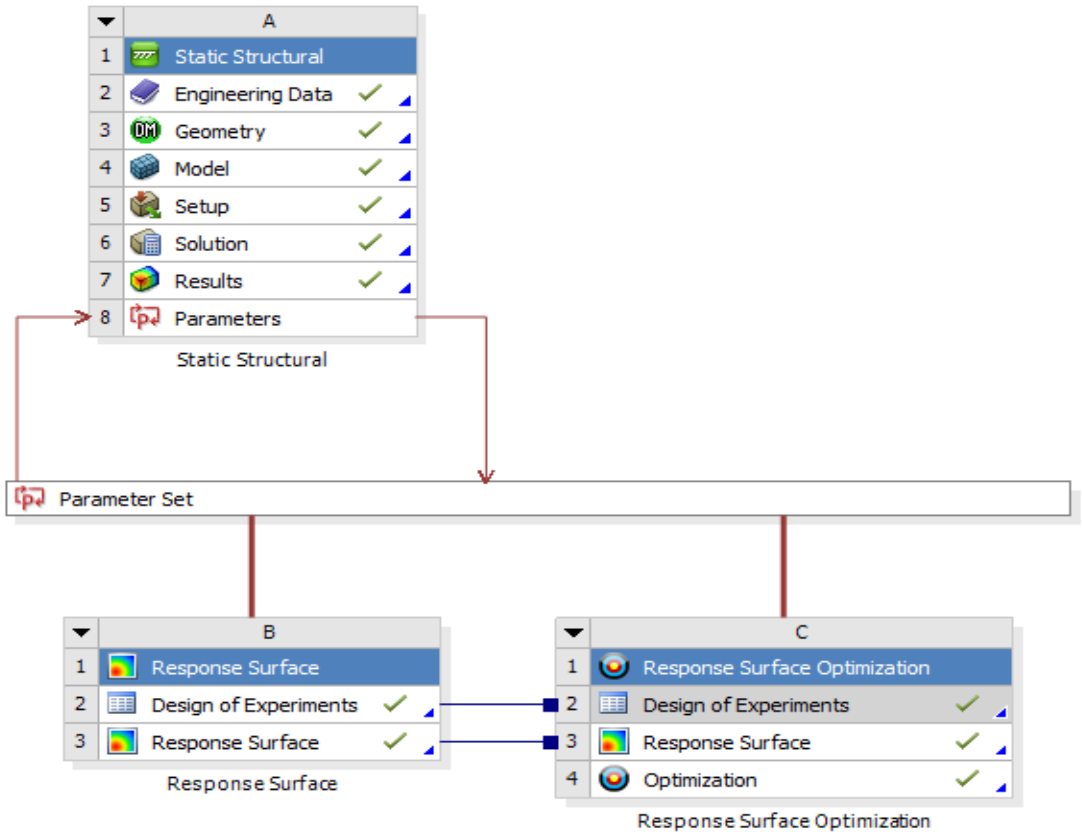


Figure 1 Bookcase Shelf Response Surface Optimization Experimental Process

2.2 The steps of bookcase shelf response surface optimization

2.2.1 Static analysis of shelf bookcase, the following steps:

Fist step: Creat 3D model.The design model dimensins are 900 mm length,280 mm width and 18 mm depth.

Second step:Defining materials properties.In our study the only material is particleboard the Modulus Of Elasticty (MOE) is E=2500 MPa and Poisson's ratio is v=0.2[8].

Third step: Defining a case.The applied external load is 0.001N/mm^2.The load is applied on the upper surface of shelf uniformly (Fig.3).

Fourth step:Meshing.We are going to use an automatic generation method of CAE program and mesh density is 10 mm (Fig. 2).

Fifth step: Defining boundary conditions.In this model the fix DOF's in unique nodes and cannot move in any direction (Fig.3).

Six step: Defining three input variables (length,width,depth).

Seventh step: Solving and viewing the results, including Total Deformation (Fig.4),Equivalent (von-mises) Stress (Fig.5) and Solid Mass.
Eighth step:Defining output parameters(Total Deformation Maxmimum, Solid Mass).

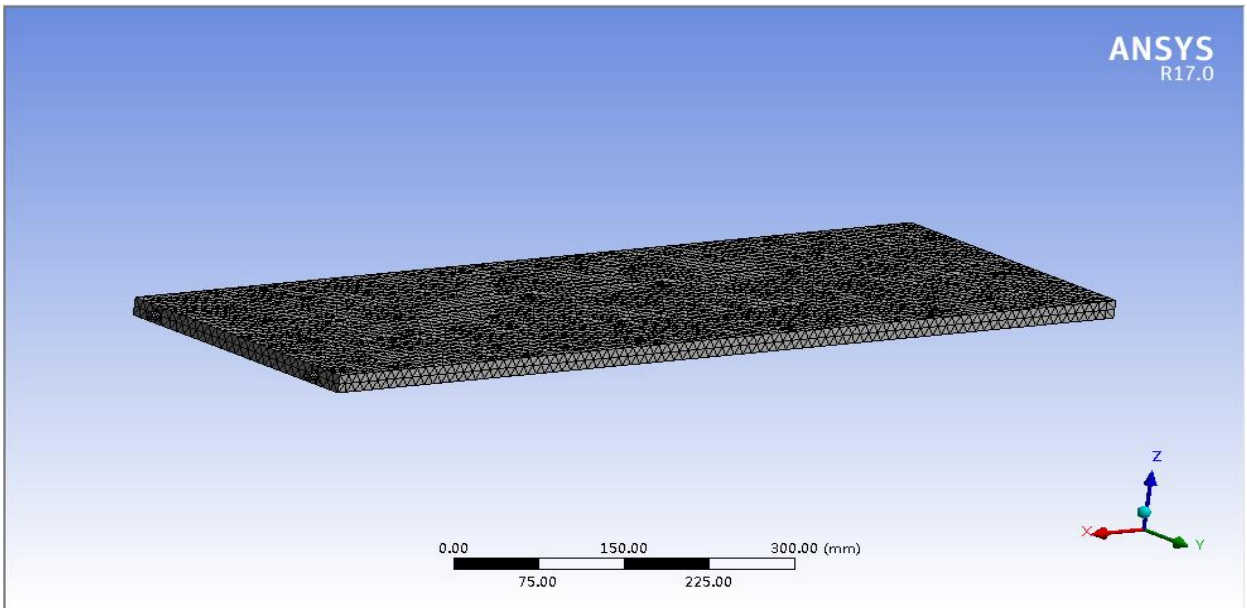


Figure 2 Meshing with Solid Element

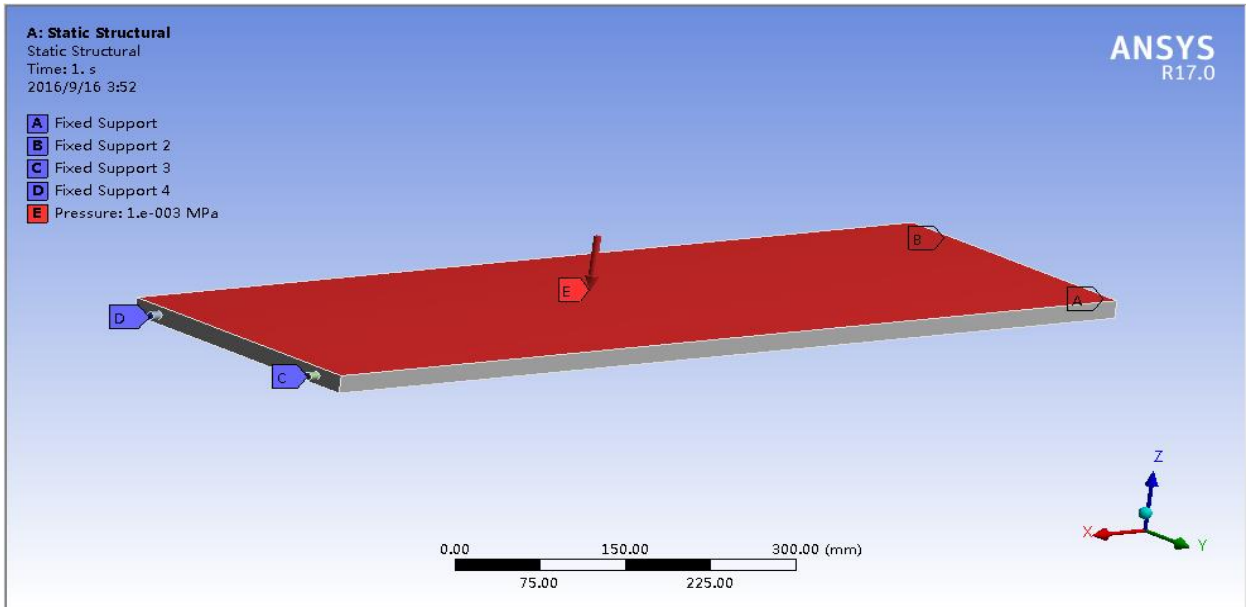


Figure 3 LoadCase and Boundary Conditions Definition

2.2.2 Response surface data update of book case Shelf, the following steps:
Fist step: Adding response surface module.
Second step: Specifying input parameters(The change range of length is 600 mm-1000 mm, width is 250 mm-320 mm, depth is 15 mm-22 mm).
Third step: Updating and viewing Design of Experiment.
Fourth step: Updating and viewing local sensitivity(Fig.6) and response surface(Fig.

7,8,9,10,11,12).

2.2.3 Response surface Optimization of the bookcase shelf, the following steps:

Fist step: Adding response surface Optimization module.

Second step: Response surface optimization (definiting Total Deformation Maximum is less than or equal to 5 mm and the lightest Solid Mass).

Third step: Updating and viewing optimization results (Fig.13).

3.Results and Discussion

The Total Deformation Maximum is 5.5141 mm and is obtained in middle of the bookcase shelf.The Equivalent (von-mises) Stress arise at the joints.The Solid Mass is 3.3928 kg,which does not meet the requirements of the design objectives.It is necessary to carry out structural optimization design.

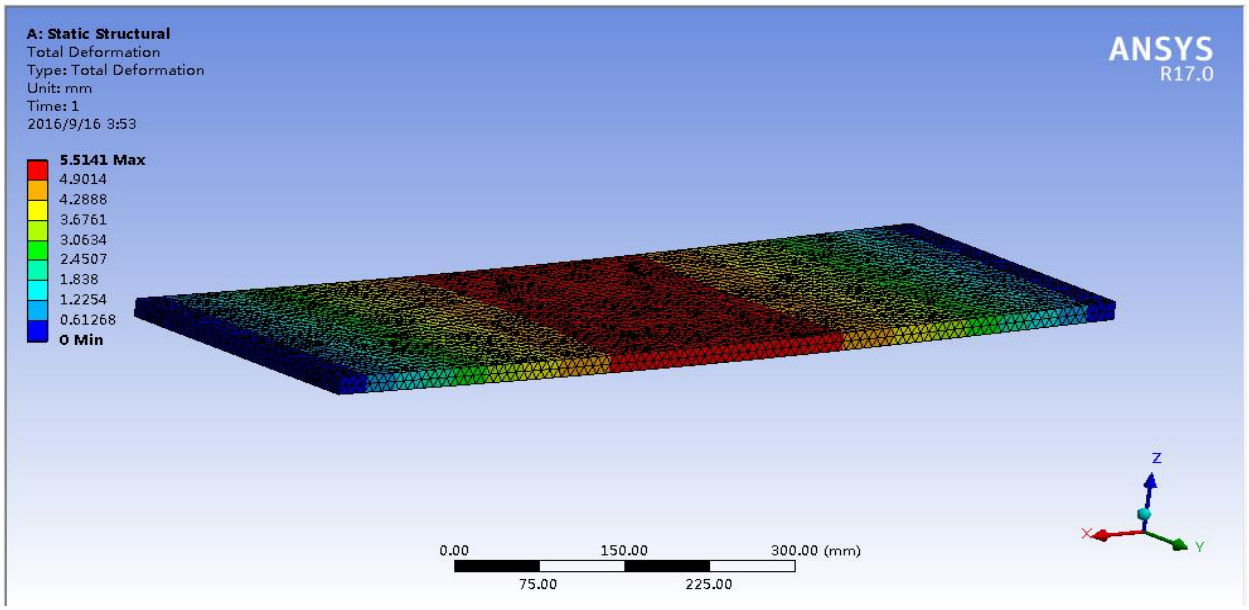


Figure 4 Total Deformation[mm]

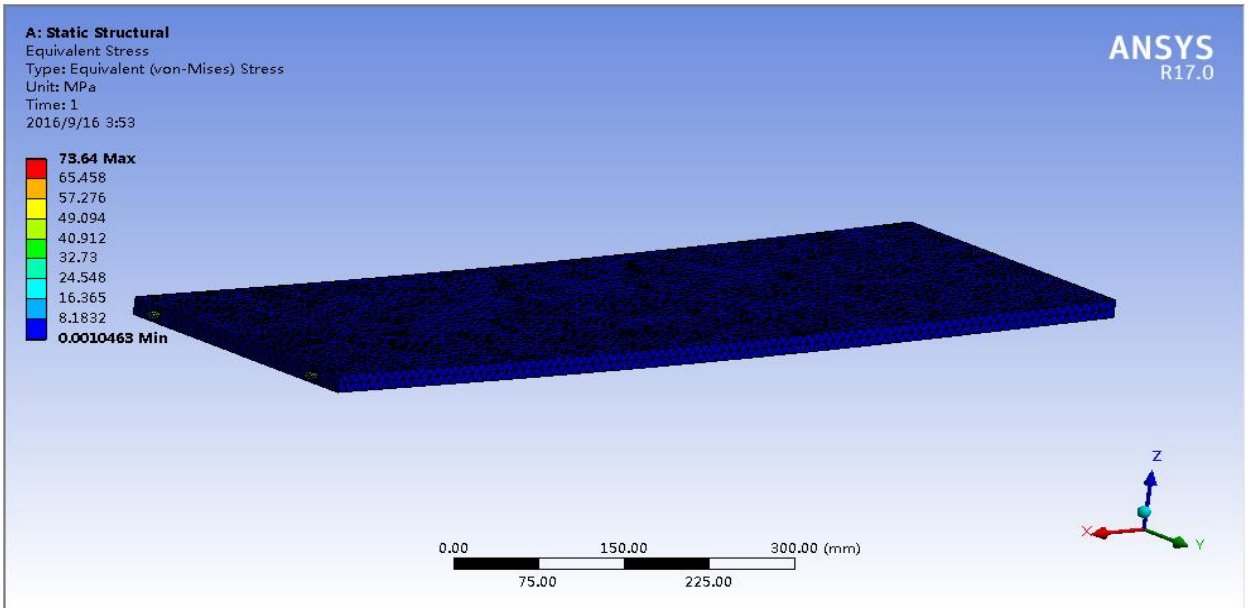


Figure 5 Equivalent (von-mises) Stress[MPa]

As can be seen from the local sensitivity and response surface , the Total Deformation Maximum is mainly affected by the positive impact of length , followed by the negative impact of depth , almost without width impact. As the length increases, the Total Maximum Deformation synchronous increase ; with decreasing depth , the Total Maximum Deformation increases,which is consistent with our design experience and prove that the results have a certain reliability.Solid Mass that is affecting the three parameters , namely the degree of influence length, depth, wide.

Therefore, the following conclusions can be drawn:

1. In order to reduce the Solid Mass ,we need to reduce the width and the width of just little effect on the Total Maximum Deformation.
2. Reduction in length can reduce both the Total Maximum Deformation and the Solid Mass, so the length should be optimized.
3. Depth can increase the Solid Mass and reduce the Total Maximum Deformation, so need to find a compromise point.

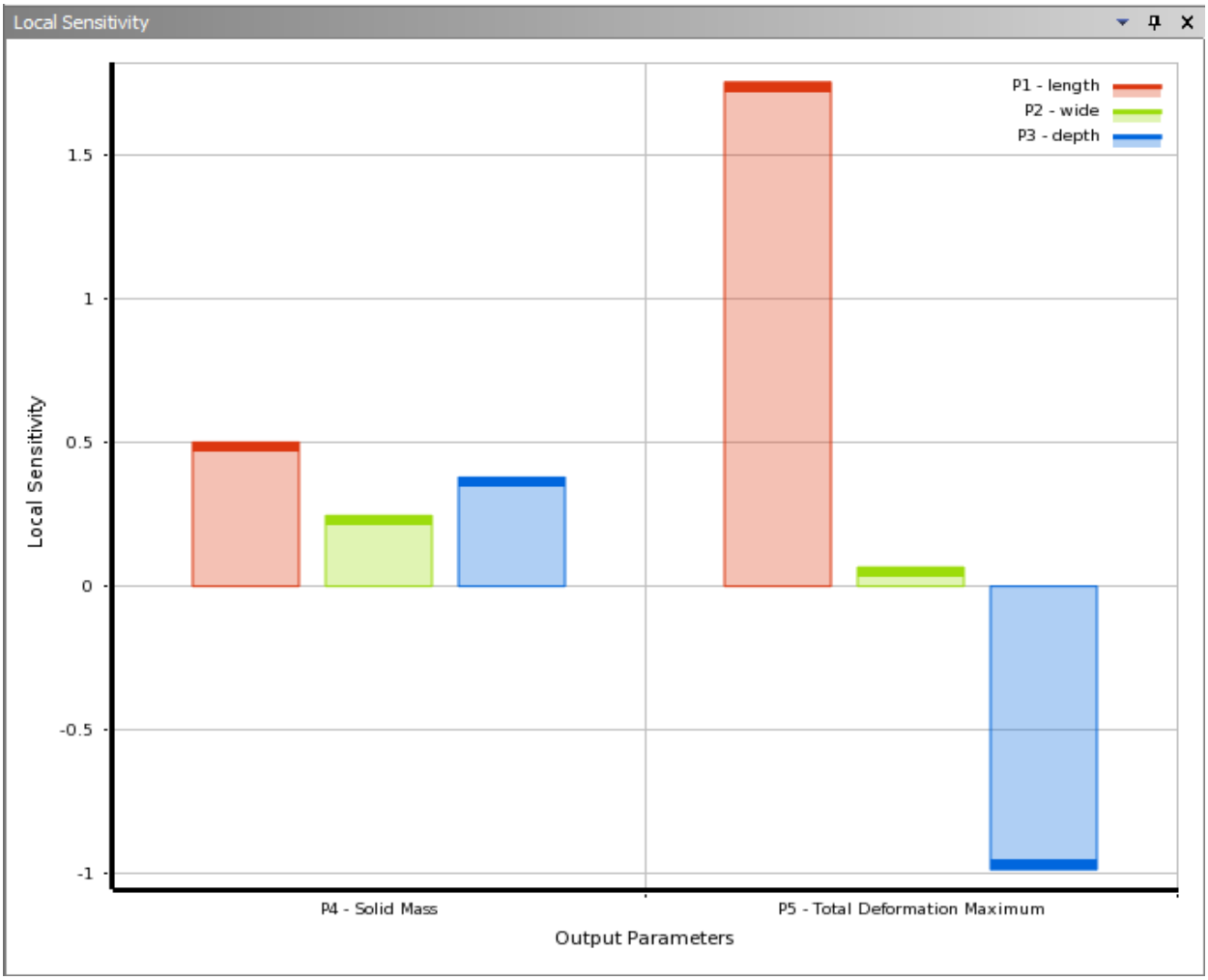
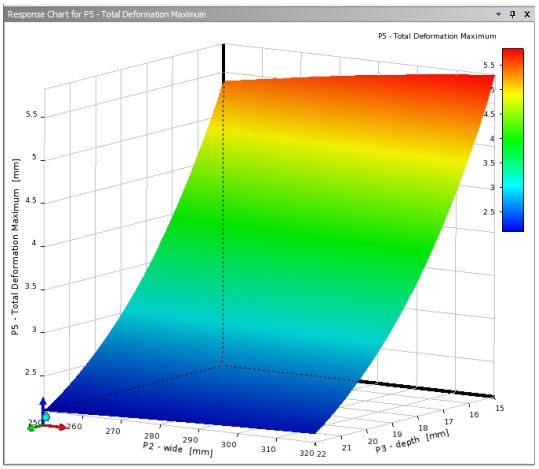


Figure 6 Local Sensitivity



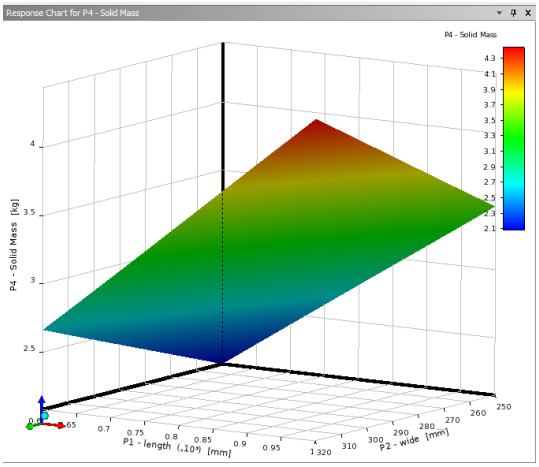
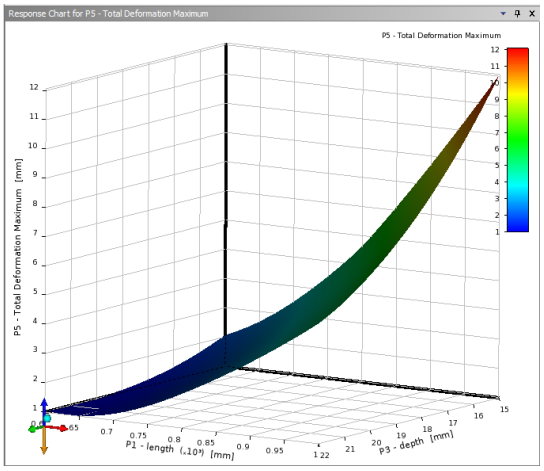


Figure 7 Width –Depth-Total Deformation Maximum Figure 8 Length-Width-Solid Mass



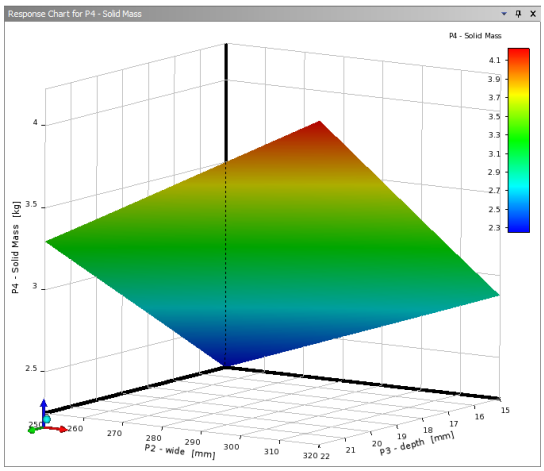
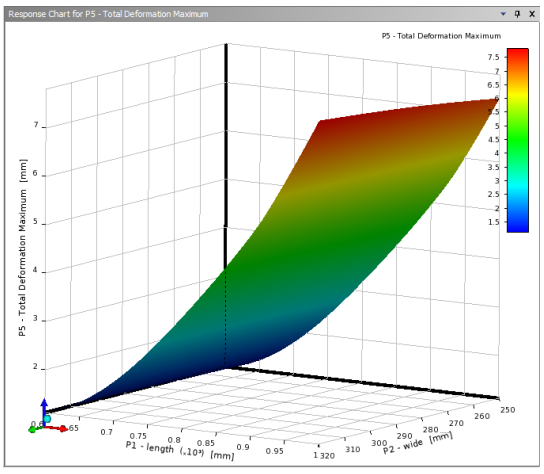


Figure 9 Length-Depth-Total Deformation Maximum Figure 10 Width-Depth-Solid Mass



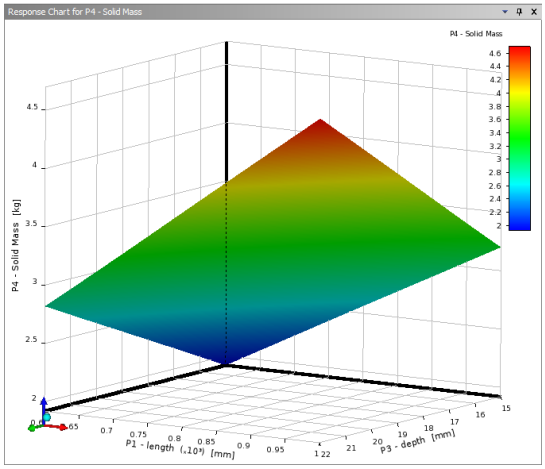


Figure 11 Length-Width-Total Deformation Maximum Figure 12 Length-Depth-Solid Mass

After optimization of response surface, we obtained three points with the optimization goal recommended by the asterisk as the evaluation index, the more stars means more in line with the optimization goal setting. Comparison of three recommendations, 1 point is the best.It shows that

when length is 773 mm, width is 253.73 mm, depth is 15.157 mm, Total Deformation Maximum is less than or equal to 5mm and Solid Mass is light relatively.

From the Table 1, the Total Deformation Maximum is 4.681 mm, compared with that before optimization reduces 15.11% , the Solid Mass of 2.2275 kg, than before optimization reduces 34.45%,which reaching design purposes after response surface optimization .

	Before optimization	After optimization	Optimized rate
Total Deformation Maximum (mm)	5.514	4.681	15.11%
Mass (kg)	3.3982	2.2275	34.45%

Table 1 Comparison of The results Before and After Optimization

	A	B	C	D
1	⊞ Optimization Study			
4	⊟ Optimization Method			
5	Screening	The Screening optimization method uses a simple approach based on sampling and sorting. It supports multiple objectives and constraints as well as all types of input parameters. Usually it is used for preliminary design, which may lead you to apply other methods for more refined optimization results.		
6	Configuration	Generate 1000 samples and find 3 candidates.		
7	Status	Converged after 1000 evaluations.		
8	⊟ Candidate Points			
9		Candidate Point 1	Candidate Point 2	Candidate Point 3
10	P1 - length (mm)	773	729.8	600
11	P2 - wide (mm)	253.73	259.47	250
12	P3 - depth (mm)	15.157	15.042	15
13	P4 - Solid Mass (kg)	★★ 2.2275	★★ 2.1329	★★★ 1.678
14	P5 - Total Deformation Maximum (mm)	★★★ 4.681	★★ 3.8959	★ 1.9622

Figure13 Optimization Results

4.Conclusion

FEA and response surface optimization can effectively optimize the deformation problem of bookcase shelf.it can make the furniture design more scientific and reasonable and will play a role on furniture design at all stages in the future.

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