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Optimization of Steel Storage Rack Pothook Hole Base on ANSYS Workbench

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Abstract: *The pothook hole of the steel storage rack column is used to connect the column and the beam, which is one of the important factors affecting the bearing capacity of the steel storage rack. With common composite lip as steel storage rack section shape, finite element analysis model is established for steel storage rack, based on ANSYS Workbench software for the solution of the stress and deformation features and optimization function of MATLAB, the steel storage rack in the equivalent stress and total deformation of two indexes as the optimization goal, with peg holes the size of the input parameters, strives for the best, obtained the different pothook hole considering the stress and deformation of the superior pass, provide a basis for the design of steel storage rack pothook hole.*

Key words: *steel storage rack ; Pothook hole; Optimization design; ANSYS Workbench*

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I. INTRODUCTION

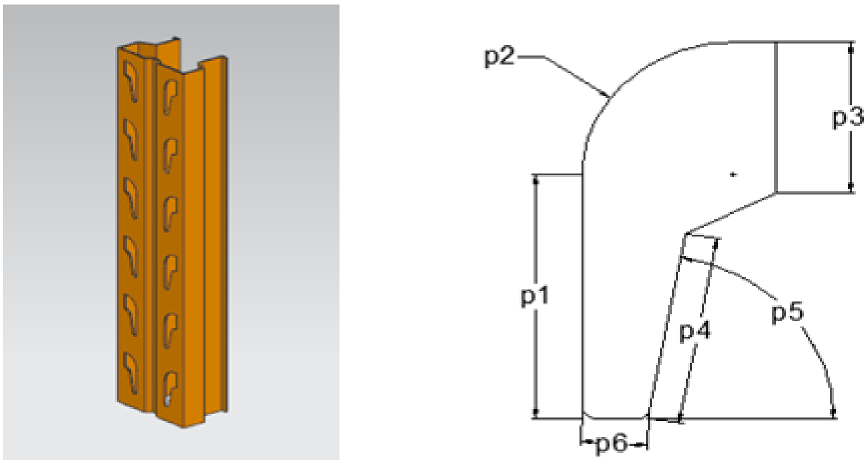
The pothook hole type of the steel storage rack has a great influence on its service performance. The pothook hole on the steel storage rack is used to connect the stand column and beam of the steel storage rack. The hole surface directly bears the vertical load. If the load is larger, the bearing surface under the vertical load will be larger, which is conducive to reducing the stress. But on the other hand, the peg hole assembly made shelves overall increase with the decrease of the overall deformation stiffness, so how to set the pothook hole size to make it suitable for the needs of users is a problem worthy of study. At present, the common types of pothook holes in the market include rectangular round edge holes, gourd holes, butterfly holes, etc. Butterfly hole because of its unique riveting model in the installation of no need to use screws, so that the pothook hole type of steel storage rack installation and disassembly is very convenient. The aim of this paper is to optimize the pothook hole of the steel storage rack.

1. Steel Storage Rack Model

The shape of the steel storage rack column remains constant in the longitudinal direction. A section of steel storage rack is cut off in the longtitudinal direction for simulation analysis, which can simplify the calculation data of simulation analysis without changing the loading state of the steel storage rack. The height of the steel storage rack designed in this paper is 200mm. The 3d model of the steel storage rack was built in the software UGNX, and its section shape adopted the composite lip shape commonly seen in the market with a thickness of 1mm. The shape of butterfly pothook hole is determined by 6 dimensions (p1, p2, p3, p4, p5, p6). Their initial values are shown in table 1. The size of the butterfly hole is renamed with DS_ prefix using the expression command so that these dimensions can be identified when importing ANSYS Workbench for optimization. The three-dimensional model of steel storage rack and the two-dimensional picture of butterfly hole are shown in figure 1.

Table 1. The measure of hole

P1	P2	P3	P4	P5	P6
12.5	7	8	10	80	3



(a)Model of goods steel storage rack (b) Outline of the hole

Figure 1. The model of goods steel storage rack and the outline of the hole

Use the array and mirror feature command to create all butterfly holes so that all butterfly holes are related in size and can be optimized simultaneously. After the 3d model of steel storage rack is established, the shortcut key in the menu bar of UGNX is used to enter ANSYS Workbench for finite element analysis of the model. The 6 dimensions of butterfly hole were added as input parameters for the rack model in the model module.

II. FINITE ELEMENT ANALYSIS

2.1. model material

The material is set as Q235 for the model, whose properties are shown in table 1. Material data are added to the steel storage rack model according to the parameters in table 1.

Table 2. Material attribute of Q235

material	Density/(Kg*m^{-3})	poisson ratio	Elasticity modulus/(Gpa)
Q235	7.85	0.3	210

2.2 mesh generation

Finite element analysis, the grid division have a direct effect on the results of the subsequent analysis, the influence of the number of grid cell affect the speed of analysis and calculation, the type of grid cell affect the accuracy of the analysis and calculation.There are two kinds of mesh partition in ANSYS, free partition and mapping partition, the former is suitable for the model of irregular shape, and the latter is suitable for the model of shape rule.

In this paper, the tetrahedron grid was divided into shelves using the method of mapping and grid division. The grid unit size was set to 2mm, and a total of 90662 nodes were divided into 44356 units as shown in figure 2.

2.2. Analysis types and load constraints

To add constraint and load model, according to the real work environment use Fixed on the bottom of the steel storage rack support constraint, Add z-axis negative force to the round Angle at the bottom of the third pair of butterfly holes. The load size is 100N. Take the maximum value of Total Deform and Equivalent stress as output parameters.

2.4 Sensitivity analysis

The variation range of each size is set to 20%. After solving the problem, the equivalent effect force and the sensitivity of the total deformation of each size of butterfly hole can be obtained as shown in figure 2. The higher the absolute value of the sensitivity, the greater the influence of the size on the output parameters. The positive sensitivity means that the increase of this parameter will cause the increase of output parameters, while the negative sensitivity means the opposite. It can be seen from figure 2 that both p1 and p6 parameters have positive equivalent effect force and sensitivity of total deformation, so their minimum value in the range can make the two output parameters optimal. The sensitivity of p3 and p4 parameters to equivalent stress is zero, and the sensitivity to total deformation is positive. The sensitivity of parameter p5 to total deformation and equivalent stress is zero, so its value does not change at the current optimization stage. The sensitivity of p7 parameter's equivalent effect force is negative and the sensitivity to total deformation is zero. Therefore, the minimum value of the parameter p7 in the range can be taken to optimize the output parameter. The sensitivity of p2 to total deformation is negative, and the sensitivity of equivalent effect force is positive. Therefore, in order to design the steel storage rack that best meets the requirements of steel storage rack operation, additional optimization design of p2 is required.

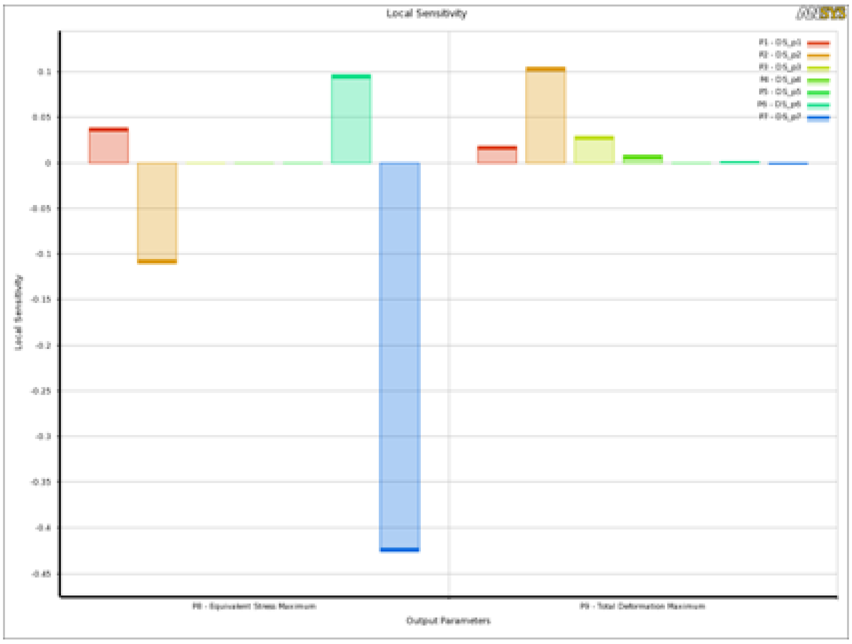


Figure 2. The sensitiveness of the parameters

III. OPTIMIZE THE SIZE OF RACK POTHOOK HOLE WITH MATLAB

3.1 Curve fitting

Through the function of ANSYS Workbench's Response surface, the relationship curves and nodes of the relationship curves between parameter p2 and total deformation and equivalent stress can be obtained, as shown in Fig.3 and Fig.4.

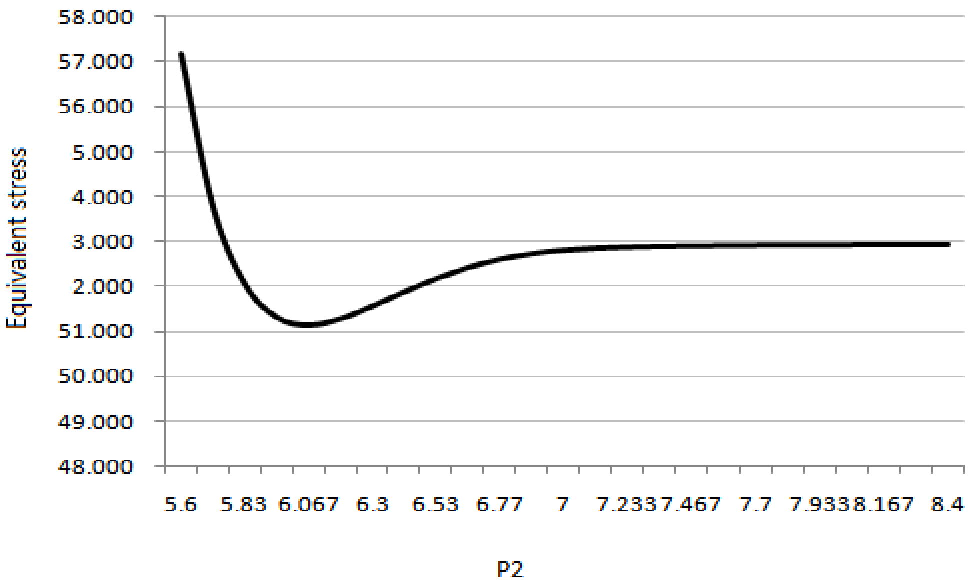


Figure3. the curve about the relationship of p2 and equivalent stress

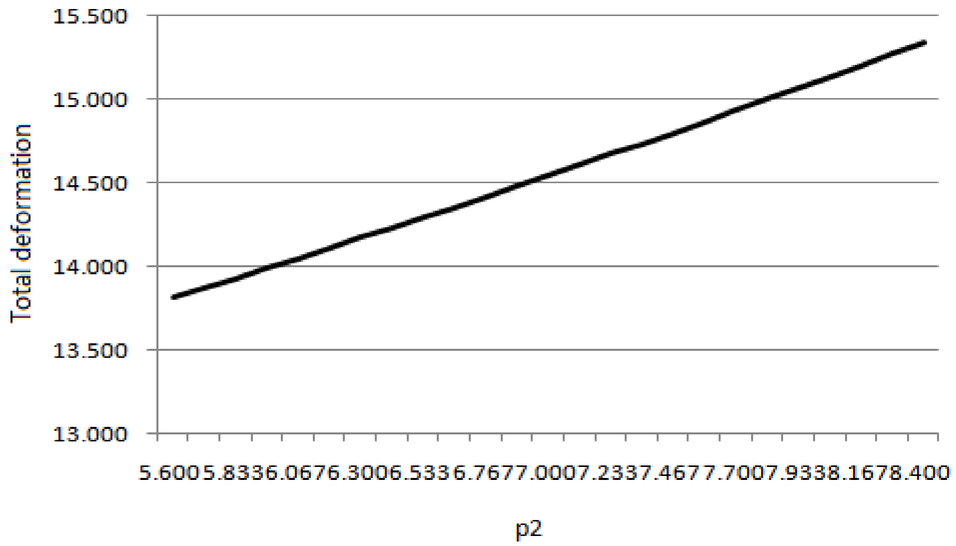


Figure 4. the curve about the relationship of p2 and total deformation

Take the nodes of p2-p8 and p2-p9 curves and import them into MATLAB. MATLAB curve fitting function can be used to quickly find the most consistent curve with the node group. 2 curve nodes of parameter p2 were imported into MATLAB to change the order of the fitting curve. In order to simplify the operation, the function equation with low order is taken as far as possible to ensure the accuracy of fitting. Finally, the equation of p2 to the total deformation was taken as:

0.54424 x2+10.7465

The functional equation of equivalent effect force is:

(-0.326)*x^8+(16.8485)*x^7+(-372.6604)*x^6+(4572.5525)*x^5+(-33611.6883)*x^4+(148002.6378)*x^3+(-361429.9961)*x^2+(377616.8228)*x^1

3.2. Optimal value solution

Due to the total deformation and the equivalent stress of different dimensional cannot directly make a comprehensive optimization, it needs to be based on user demand for products, remove the unit total deformation and the equivalent stress of two parameters, and then weighted optimization. The weight of 1,000/1mm is given to the total deformation and 1/1Mpa is given to the equivalent effect force. The relationship curves of the two parameters were evaluated by deunitization and weighting. The weighted data is applied to the minimization program, which is as follows:

```
x1=L;x2=H;
yx=@(x)( y(x) );
[xn0,fval,exitflag,output]=fminbnd(yx,x1,x2)
```

By solving the program, the optimal value of p2 is 5.7954mm.

IV. VERIFICATION

The equivalent stress obtained for the model under the initial parameter value is 54.591Mpa total deformation 0.01457mm, as shown in Fig.5. The optimal parameter value obtained by MATLAB is applied to the model, and then the equivalent stress and total deformation of the optimized model are solved. After using the same materials, grid division and constraints as the original model, the maximum equivalent stress of the steel storage rack is 39.408Mpa, and the maximum total deformation is 0.013593mm, as shown in figure 6. The two results show that the optimized model reduces the equivalent effect force by 27.8% under load and the total deformation by 6.56%, which is in line with the original optimization target.

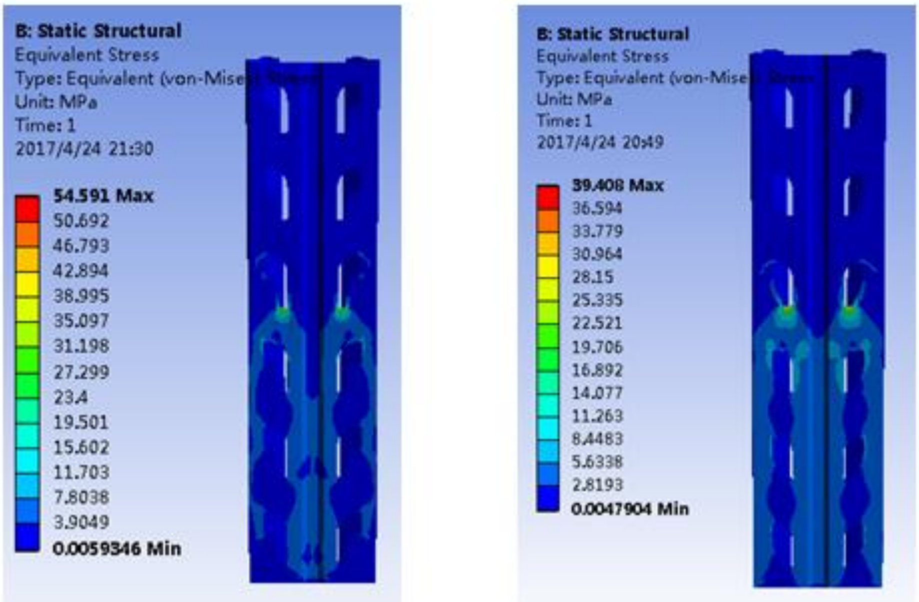


Figure 5. the equivalent stress of the Storage Rack Under the initial parameters (left) and optimized parameters(right)

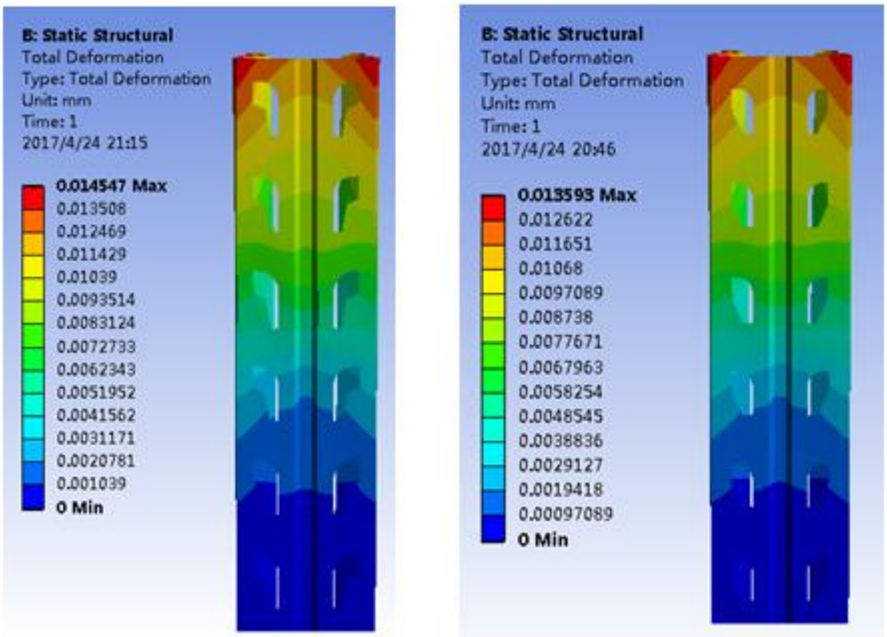


Figure 6. the total deformation of the Storage Rack Under the initial parameters (left) and optimized parameters(right)

V.CONCLUSION

Using ANSYS Workbench, the relationship curves and nodes of each parameter of butterfly hole to the equivalent stress and total deformation of steel storage rack were obtained.Two targets with different units are weighted and then optimized.Through the calculation of MATLAB, high performance butterfly hole steel storage rack was obtained. While leaving out the subsequent optimization steps of ANSYS Workbench, the shelves that meet users' requirements are obtained directly through the setting of weights. This paper provides a scheme to design a steel storage rack with better load bearing capacity.

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