Optimization design of Subsoiling components

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Abstract. This article is based on the subsoiler as the research object. 3D model is established using large finite element analysis software analyze and optimize the structure afterwards. The structure and thickness of the subsoiler have been optimized and the feature parameters have been changed from different degrees. Ultimately, the maximum stress increases by 12.3% while the maximum stiffness increases by 3.9%. Accordingly, the total mass reduces by 24.05%, in this way, life cycle of the subsoiler is improved and the energy consumption is reduced meanwhile the cost of the deep scarification is also reduced. Designing the deep loosening knife needs some theoretical basis.

1. Introduction

The subsoiler which is the key part of the deep loosening machine is influenced by force of complex and random change in the work. In the process of deep loosening the soil, the soil is cut by the deep loosening knife in order to loose soil. The shear resistance, the friction and the adsorption force of the soil must be overcome in the process of deep loosening shovel through farming. Deep loosening shovel load changes along with the hardness of the soil[1-3]. With the development of finite element technology, the finite element method has been used as an effective method on studying tillage implement. Therefore, when designing the subsoiler requirements of use is that it should be made sure not be affected[4].

Finite element analysis method is used on the research object based on the subsoiler. And the size of the subsoiler is optimized by optimizing objective function of the constraints condition. The test shows that the subsoiler can meet the operating requirements.

2. The establishment of the subsoiler's model

The subsoiler consists of three parts: the shovel hand, the blade and the shovel head. The shovel hand is used to fix the subsoiler on the rack. In order to make sure that the finite element model matches to the actual structure, the subsoiler's actual size should be accorded to the 3D model. In order to avoid influencing the truth of the solution, the chamfers, round corners and small circular holes should be ignored when we are modeling. As are showed in Fig1.

Fig1. The subsoiler's CAD model

3. The establishment of the finite element model

Because of the small subsoiler's model and considering the model precision and computational effciency, the size of 4mm hexahedron mesh units are decided to be taken [1].

HyperMesh is used to establish the hexahedral grid, meanwhile pentahedron grid is allowed in the model. Besides, the material 65Mn is given to be the subsoiler's material properties. The material properties are showed as table1.

Table 1 The characteristics of 65Mn

Material name	Tensile strength	Yield strength	Poisson ratio	Modulus of elasticity	Density
65Mn	1000MPa	800MPa	0.3	2E+05MPa	7.85E-06/mm3

Because of the subsoiler's gravity is so small compare to the working resistance, its own gravity can be ignored.The subsoiler's model whose total number of units is 5136 is established eventually. A total of 4948 grid, including 60 hexahedron grid, 40 pentahedron grid[5]. The finite element model is showed in Fig 2.

Fig 2 .The finite element model of subsoiler

4. The subsoiler's strength analysis before optimization

In the north China plain, the soil moisture is nearly 10% and the loosening depth is 350mm; when the loosening velocity is 3.6 km/h, the average loosening resistance is measured to be 5.9 kN. In the deep loosening process the subsoiler is subjected to sudden changes load, so 2.0 safety factor should be taken. The subsoiler's load should be loaded into the shovel 2200 nodes. The bolts are used to connect the deep knife shovel's handle and the deep tillage machine with each other, so the mounting holes which connect together with the bolt should be fixed. Meanwhile the rotation of the X direction should be kept and the model should be analyzed after load is applied.

The maximum stress which is 225.2Mpa occurs in the front of the shovel hand. the yield strength of 65Mn is 800Mpa. The operating requirements of structural strength can be met and it has a higher safety coefficient.

The maximum displacement occurs on the top of the shovel which conforms to the actual deformation. The maximum displacement is 4.52mm. The larger displacement mainly occurs in the shovel. The part of the shovel handle's displacement is less than 0.5mm. In conclusion, the requirement of the subsoiler's deformation can be met.

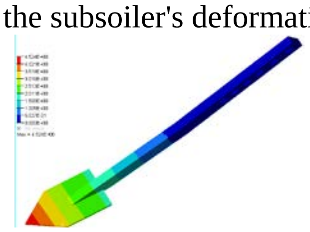

Fig.3 Displacement Cloud

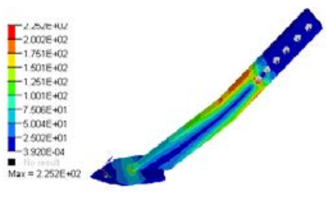

Fig4. Stress Cloud

5. Set the size optimization and parameter

Optimal design variables, objective function and constraint conditions of optimization are included by the size optimization parameter settings.

5.1 Design the optimal variables.

Too many design variables may lead the compute to become complex and the time consumed will be extended so the design variables ought to be selected reasonably. The optimization design variables should be set in the functional modules of size. The subsoiler's thickness is the design variable and at the same time the initial values in the upper and lower limit are set.

5.2 Objective function of the optimization.

The quality response function is definite by response function panel. Its objective function is definite in the objective function module of optimization panel. The objective function is to obtain the minimum value of mass under the defined conditions.

5.3 The objective function.

Not only the material science should be salved maximally but also the strength and stiffness of structure should be satisfied in the process of structure optimization design. Therefore, the design variable values need to be limited by the constraint conditions and finally the requirements of objective function is met. Stress is defined as a constraint function in the function panel which is in the optimization panel. At the same time, we define stress response function as the constraint function, and then the upper limit of the stress in optimization panel is set up as 500Mpa. So the mathematical model of the subsoiler's optimization as follows:

The objective function ： $\min M = \rho g \sum_{i=1}^{n} v_i$ （1）

The constraint of stress： $\sigma_{\max} \leq \sigma_e$ （2）

The constraint of design variable ： $x_i^l \leq x_i \leq x_i^u$ （3）

In the formula, M as the subsoiler's weight; ρ as the density of the subsoiler; n as the unit number; v_i as the unit volume; $\sigma_{\max}$ as the maximum stress value for the node; σ_e as the allowable maximum stress; x_i as the design variables; x_i^l as the lower limit value; x_i^u as the upper limit value.

6. The optimization results

The result is cheated in the post treatment which is conducting in the HyperView by Optistruct analyse solver. It gives us a curve that the quality (objective function) changes in the iterative process. After optimization dimensions, it is shown in the graph 2.

Table 2 The Comparison table before and after the optimization

Optimization variables	initial value	After optimization	change rate
quality	14.00kg	10.64	24.05%
The maximum stress	225.2MPa	253.0MPa	12.3%
maximum displacement	4.52mm	4.70mm	3.9%

Here the graph shows that the subsoiler's total quality was reduced by 24.05% than the original.

7. Verification the results of the optimization

The attributes are given to the model of subsoiler which is designed finally. The constraint conditions and the size of load which is the same as the one that has not been optimized are also exerted to it. The optimized model is analyzed. The results are showed in figure 5 and figure 6.

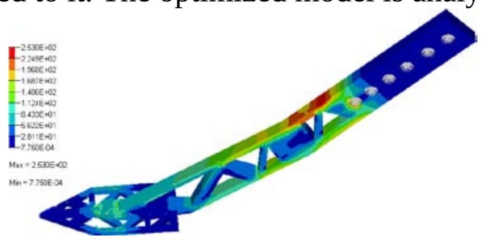

Fig.5 Stress Cloud

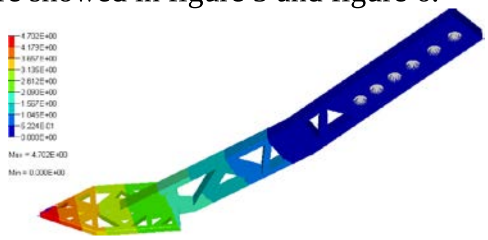

Fig.6 Displacement Cloud

It is known from the fig 5 that the maximum stress of the deep loosening knife occur at the bending position. The value is 253Mpa and the deep loose edge stress distribution is from 20 to 50Mpa. Otherwise, the shovel handle stress is under 20Mpa and the stress which is near to the shovel head bolt hole reaches to 150Mpa. It is known from the fig 6 that the subsoiler's deformation is almost the same as the one which has not been optimized. The maximum vertical displacement is 4.7mm in the position of shovel head and blade.

8. Conclusion

The structure and thickness of deep loosening are optimized while the subsoiler's feature parameters are changed in different degrees. Among them, the maximum stress and maximum strain increased by 12.3% and 3.9% and the scope of the design requirements is not exceeded.

Although the maximum deformation of the subsoiler is increased after it was optimized, the subsoiler's total quality reduced by 24.05% which makes its blade thickness reduced. In this way not only the resistance of the shear in the process of deep loosening is reduced, but also the life cycle of the deep loosening shovel is improved, the energy loss and the cost of the deep plough are reduced. It brings some certain economic benefits to the farmers as well as provides a certain basis theoretical foundation to designer.

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