

Finite Element Analysis and Structure Design of Sub-soiling Shovel

Long Gao^{1,a}, Shanshan Li^{1,b}, Jiangtao Liu^{1,c}, Degang Kong^{1,d}, Jinggang Yi^{1,e}

Mechanical and Electrical Engineering College Agricultural University of HebeiBaoding 071001,
Hebei Province, China

^agaolong@2017@126.com, ^blishanshan2013@126.com, ^cliujiangtao2003@126.com, ^dkongdegang2013@126.com, ^eyijinggang2000@126.com

Keyword: sub-soiling shovel, structural analysis, optimal design

Abstract. The 3D parameterized model of sub-soiling shovel was created using Creo Parametric 2.0 in accordance with material object. According to structures, materials, loads and stress situation of sub-soiling shovel, the static analysis and modal analysis of the model are carried out by using ANSYS Workbench14.0. Then some modifications of sub-soiling shovel configuration were made depending on design requirements and analysis results. After the analysis, the results show that the improved sub-soiling shovel could provides better working performance with less resistance and obtain the expected effect. At the same time, it also provides the basis for further study of sub-soiling shovel.

1. Introduction

With accelerating urbanization and growing population of china, much more is required of the grain production. A great deal of domestic and overseas studies indicated that deep Loosing can improve soil structure and fertility as well as soil properties .it also can increase the soil's water absorption and improve soil workability under conservation tillage, which can improve crop yield and achieve the purpose of protection of agricultural ecological environment. Therefore, in recent years, subsoiling technology has become essential mechanization technology to raise food production [1-3].

Sub-soiling shovel is a key part of subsoiling technology. sub-soiling shovel cut soil to achieve the purpose of increasing production, thereby its structure directly affects the operating performance of equipment. According to the soil condition in the area of Hebei, we select the 3s-2.6 type of sub-soiling shovel produced by Yucheng Yili Machinery Co Ltd for deep loosening test. In the test, the soil resistance is too large and the quality of the soil with deep loosening is not good. In order to obtain the optimum structure parameters sub-soiling shovel, we use Creo Parametric 2.0 to create three-dimensional parameterized model of sub-soiling shovel, and use ANSYS Workbench 14.0 to analyze structural strength, stiffness and modal in this paper. It is desirable to have a reasonably structure parameters[4], reduce working resistance, improve operational performance and ensure the quality of the soil with deep loosening.

2. Model Establishment

3s-2.6 type of subsoiler consists of frame and sub-soiling shovel that is made up of shovel blade and shovel shaft. Shovel shaft is fixed on the frame that not directly involved in Subsoiling. Shovel blade and shovel shaft contact with the soil and contribute to cutting cultivating soil. 3D data model of the subsoiler was created in Creo Parametric 2.0. sub-soiling shovel is one of key components in subsoiler, so the 3D parameterized model of sub-soiling shovel was created using Creo Parametric 2.0 in accordance with the actual size of material object.

For the convenience of the update and analysis, We need to simplify the model and ignore the chamfer, fillet and small hole. The author identify the key dimensions of the sub-soiling shovel by consulting the correlation data, as indicated in Fig.1.

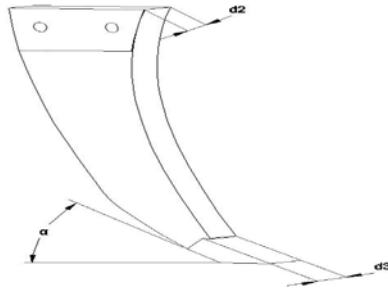


Fig.1 The model sub-soiling shovel

3. Finite Element Analysis

3.1 The Definition of Material Properties

In the application environment of ANSYS Workbench 14.0, we select “Static Structure” module and “Modal” module, and create a relationship between the two module (units: kg, mm, s). The actual material of sub-soiling shovel is Carbon Constructional Quality Steel 65Mn. So we need to set the model material for 65Mn in ANSYS Workbench 14.0 (Figure 2). And then import the model that is created in Creo Parametric 2.0 into ANSYS Workbench 14.0.

Outline of Schematic A2, B2: Engineering Data				
	A	B	C	D
1	Contents of Engineering Data	Source	Description	
2	1			
3	2			
4	3	Structural Steel	Fatigue Data at zero mean stress comes from 1996 ASME BPV Code, Section 8, Div 2, Table 8-110.1	
Properties of Outline Schematic A2				
	A	B	C	D
1	Property	Value	Unit	
2	Density	7.85E-05	kg mm ⁻³	
3	Isotropic Elasticity			
4	Derive from	Young's Modulus and Poisson's Ratio		
5	Young's Modulus	2E+05	MPa	
6	Poisson's Ratio	0.3		
7	Bulk Modulus	1.6667E+11	Pa	
8	Shear Modulus	7.6923E+10	Pa	
9	Tensile Yield Strength	430	MPa	
10	Tensile Ultimate Strength	735	MPa	

Fig.2 The physical parameters of 65Mn

3.2 Mesh Generation

Enter the model module, and divide the mesh of sub-soiling shovel, the form of grid is “Hex Dominant method”. The default value of “Relevance” is 0, which means meshes is sparseness and non-uniformity. Here, we have set the value to 90 and also set “Element Size” to 4.0mm. sub-soiling shovel is divided into 107 512 nodes, 73 049 units. While solving the fine mesh long time, but the results are more accurate.

3.3 The Boundary Conditions and the Load

Judging by the field research, we find the depth of soil loose in Hebei Province is 200 ~ 400mm. The experiment about stress measurement of 3s-2.6 type of subsoiler has conducted in soil bin test bench in No.3 Branch Factory of Agricultural University of Hebei and the test depth is 300mm. In order to obtain accurate data, we use the actual installation location. When Using FEM software ANSYS Workbench 14.0, we use the experimental data to analyze sub-soiling shovel. The author use “Fixed support” method to fix two surface which contact with frame and use the “Frictionless support” method to fix locating hole on the shovel. The load using “Force” method is applied to shovel blade. Force along the X direction is -3100N, and along the Y direction is -1600N, as is shown in Fig 3 .

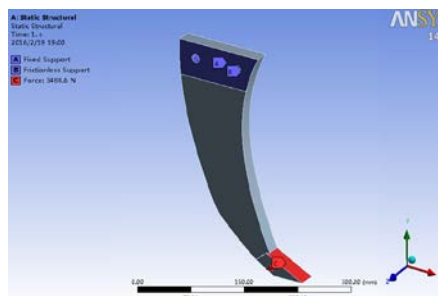


Fig.3 Boundary constraint of sub-soiling shovel

3.4 Analysis of Stiffness and Intensity

After the setup of material definition, grid division and loading and boundary are complete. We select the “Equivalent Stress”, “Equivalent Elastic Strain”, “Total Deformation” and “Safety Factor” to calculate in the “Solution” module. Next the force conditions of sub-soiling shovel is analyzed by running ANSYS Workbench 14.0. The results are shown in the table 1.

Table 1 Stress analysis results

Parameter	The maximum value	The minimum value
Equivalent stress /M Pa	60.726	0.008775
The equivalent elastic strain	0.000359	6.1182e-8
Deformation /mm	0.224880	0
Safety factor		7.0809

Table 1 shows that safety factor of sub-soiling shovel is 7.0809. The largest equivalent stress and equivalent elastic strain appear at the tip of interface between sub-soiling shovel and frame (equivalent stress as shown in Figure 4). While the maximum deformation occurs in the tip of shovel blade.

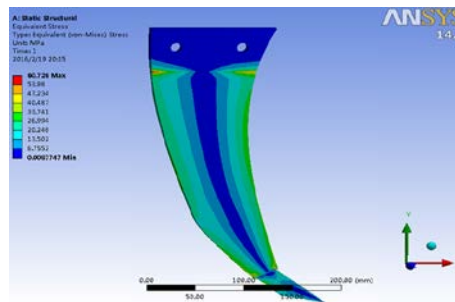


Fig.4 Equivalent stress of sub-soiling shovel

3.5 Modal Analysis

Modal analysis is intended to determine the natural frequency of sub-soiling shovel in fixed constraints. The analysis of model is carried out after the analysis of static. The first order modal deformation mainly swing along the Z-axis direction. The maximum displacement is 47.469mm, which is located at the tip of shovel blade. as shown in Fig 5. From the results of analysis we can also get the Interval of Modal frequencies between 2 and 3 modal is small.

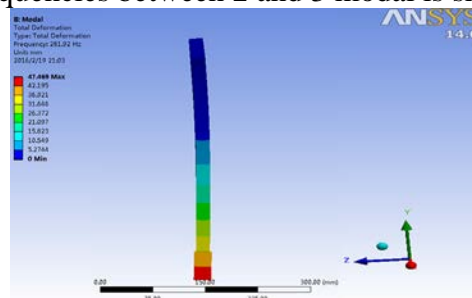


Fig.5 The first mode 1 response graph

When existing frequency of interference which close to 2 order and 3 order frequency, it can produce superposition of ground motion, they are harmful to the sub-soiling shovel.

4 Structure Improvements

By analyzing strength and mode of sub-soiling shovel, it showed that the safety factor of sub-soiling shovel is large enough. So there is no breakage and fracture to happen to sub-soiling shovel. But the safety factor is big, which means the structure and size of shovel body structure is too large. It will increase the resistance that consume more energy of subsoiler, and lead the driving wheel of the tractor to skid. While subsoiling operations, external disturbance can easily cause the shovel body occurred torsion, resulting in the large deformation in shovel blade. Therefore, we need to adjust the parameters of the shovel body. Modify the key dimensions of sub-soiling shovel in Creo Parametric 2.0, and use the ANSYS Workbench 14 .0 to resolve the model. After that we make

comparison between the two models as shown on Table 2. The new modal frequencies are shown in table 4.

Table 2 Comparison for parameters and analysis results between original design and modified

Parameter	Original design	Modified design
Thickness of shovel blade/mm	20	15
Thickness of shovel shaft/mm	25	20
Penetration angle/°	30	25
Equivalent stress/ M Pa	60.726	80.049
Maximum deformation/mm	0.224880	0.2659
Safety factor	7.0809	2.9744

After modification, sub-soiling shovel has a lighter weight, thinner thickness, and a smaller friction area. The penetration angle α of shovel blade change becomes small, so that the work of the resistance is reduced, and it also ensure the ability of penetration of sub-soiling shovel that can achieve the subsoiling requirements. Factor of safety is 2.9744, meeting the requirements of between 2 to 4. The maximum deformation is 0.2659 mm appearing in the tip of shovel blade. The new results that there is a greater gap between the modal frequency of sub-soiling shovel. When getting interference, there will not be the case that produces superposition of ground motion in subsoiler.

5. Summary

In order to reduce subsoiling resistance, reduce the energy consumption of subsoiler, improve working quality, we use Creo Parametric 2.0 to create three-dimensional parameterized model of sub-soiling shovel which is equal proportion of actual size. And then the model is imported into ANSYS Workbench 14.0 for static analysis and modal analysis. According to the analysis results, we change the key parameters of model and re-analyze it. and then comparing with the results and analysis .It is showed that improved sub-soiling shovel is designed to meet the need of expectation, including safety factor, amount of deformation and modal analysis.

References

- [1]. Xin Liu , Xia Lu, Shuai Wang, Analysis on the Current Development in China's Subsoiling Machinery and Proposals for Further Growth. Agricultural Science&Technology and Equipment. (2011)No. 2, p. 130-131.
- [2]. Guang-ming Yang, Yun Zhu, Rui-qin Zhang, et al, Estimation of abrasion limitation and surplus life of DZ(DSZ)-35 plowshare. Hunan Agricultural Machinery vol. 36(2009)No. 5, p. 7-10.
- [3]. Lei Li, Rongying Zhang, Haiyan Chen, et al. The Development of Bionic Subsoilers and Outlooks. Journal of Agricultural Mechanization Research. (2015)no. 2, p. 265-268.
- [4]. Xia Li, Junfeng Fu, Dongxing Zhang, et al. Experiment analysis on traction resistance of vibration subsoiler. Transactions of the Chinese Society of Agricultural Engineering. vol.28(2012)No. 1, p. 32-36.