Design and Strength Analysis of a Guttering Plough with Two Adjusting Stages

Heng-hui SUN¹, Zheng-yong ZHANG¹,*, Yang LIU¹, Hai-ming XU¹ and En-wei CHEN²

¹Institute of Intelligent Machines, Chinese Academy of Sciences, Hefei, 230031, P.R. China
²School of Mechanical Engineering, Hefei University of Technology, Hefei, 230009, P.R. China

*Corresponding author

Keywords: Guttering plough, Adjust in two stages, ANSYS, The stress and strain distributions.

Abstract. A guttering plough with two adjusting stages was designed in this paper, which can adjust its configure and position in two stages. With these two adjusting movements, the ploughshare of this guttering plough can be put in soil at a deep position, to dig out a deeper channel than normal ones. The boundary conditions including loading and constraint were obtained, when it work normally. Combined with it, and the transformed configure and position in two stages, and the structure and loading characteristics of the guttering plough, a mechanical model was established with finite element analysis method. Then its analysis and solution were carried out by using ANSYS software. Under normal working condition, the stress and strain distributions of each part of this guttering plough were obtained. The calculation results showed that the structure of this guttering plough can meet the requirement of strength, but the positions of the joints were slightly poor, so it should be properly enlarged. Finite element software can be used to analyze the spatial static of this guttering plough, which can be certified as a feasible method for the design and improvement of the plow frame structure.

Introduction

Guttering plough is a kind common agricultural machinery, which is chiefly used in agricultural productions including the construction of canals, wasteland reclamation, afforestation and so on[1], in addition, it also has applications in the mining of forest fire ditch [2], farmland drainage ditch.

With the development of mechanization and scale of agricultural production, it is necessary to combine the theoretical analysis and experimental testing, to design and develop new kind of guttering plough that is multi-function, wider application and higher technology and its subsidiary bodies. This research direction has become the hot point of agricultural machinery researches [1~5].

The finite element method (FEM) is a kind of approximate numerical analysis method to solve complex problems in engineering analysis. According to the mechanical structure and the loading characteristics of guttering plough, a mechanical model was established and simplified with finite element analysis method. Then its analysis and solution are carried out by using ANSYS software, which is an effective method for evaluating the rationality of the structure of the guttering plough. Combining with the experimental test, it also provides a technical basis for the later improvement measures [4, 6 ~ 8].

The Entirety Structure Design of the Guttering Plough

In this paper, one kind of a guttering plough with two adjusting stages that can adjust its configure and position in two stages was designed. With these two adjusting movements, the ploughshare of this guttering plough can be put in soil at a deep position, to dig out a deeper channel than normal ones. To this guttering plough, its structure is compact, its manipulation is simple, and it can effectively realize guttering deeply. The main structure is shown in Figure 1~ 4.
The technical scheme of the guttering plough with two adjusting stages can be described as: the ploughshare is installed on the bottom of the beam through the "U" type rack connector; suspension frame is box shaped and welded by five square steel; first hydraulic position adjusting mechanism is composed of two master hydraulic cylinders and two slave hydraulic cylinders, and is mounted on the upper part of suspension frame; second hydraulic position adjustment mechanism is composed of a master-slave hydraulic cylinder, which is installed at the lower part of suspension frame.

There are two supporting base welded on one flank of plough beam. Up supporting base that is welded on the upper part of one flank of plough beam is connected with the supporting base that is welded on one position of the suspension frame by a support axis, which form a rotating pair, down supporting base that is welded on the lower part of one flank of plough beam is connected with the another supporting base that is welded on another position of the suspension frame by a support axis too, which form another rotating pair.

First hydraulic positioning mechanism is composed of two master-slave hydraulic cylinder, each of two master hydraulic cylinders is connected with the supporting base that is welded on third positions of suspension frame by a support axis to form a rotating pair, and each of two slave hydraulic cylinders is connected with the supporting base that is welded on fourth positions of chassis frame by a support axis to form a rotating pair.

Second hydraulic positioning mechanism is composed of one master-slave hydraulic cylinder, the master hydraulic cylinders is connected with the supporting base that is welded on fifth position of suspension frame by a support axis to form a rotating pair, and the slave hydraulic cylinder is connected with the supporting base that is welded on sixth position of chassis frame by a support axis to form a rotating pair. All hydraulic cylinders are driven by hydraulic oil.

**Calculating the Working Resistance on the Guttering Plough**

When the guttering plough is in the working state, there are two mainly force loading on the guttering plough and its frame [9-10]. One is the tractive force produced by a tractor, which is passed through the chassis frame from tractor to the guttering plough; the other is the resisting forces of soil acting on the share break point, and passing along the structure of the guttering plough [9].

Set \( R_h \), \( R_l \), \( R_z \) as the horizontal resistance, lateral resistance and vertical resistance of soil acting on the share break point of the guttering plough along the forward direction, \( T \) means the tractive force produced by a tractor, \( T = 13720 \text{N} \) [9], then the traditional mode of working resistance can be calculated using the following equation:
For the lateral resistance $R_y$, it can be balanced or partial balanced by the counterforce reacting to furrow that work on landside of the guttering plough. So it has little impact on the guttering plough, and can be ignored in the stress calculating process on the guttering plough with the finite element analysis method. Therefore, under the traditional working conditions:

$$
R_x = \frac{T}{N}
$$

$$
R_y = \frac{1}{3}R_x
$$

$$
R_z = \frac{1}{5}R_x
$$

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$$
R_x = \frac{T}{N} = 4573.33N
$$

$$
R_z = 914.67N
$$

The Simplifying of the Mechanical Model

Generally, the frame structure of the guttering plough is statically indeterminate structure, and the stress distributions of each component acted by the spatial force system are complicated. The strength of the plough can be calculated by the computer with the finite element method on the basis of the data of the external loading on the plough. The finite element method provides the basis for the design and improvement of the frame structure of the guttering plough, it also shorten the design cycle of plough.

The chassis frame of the guttering plough is constructed by square steels, of which the cross section is 80mm×80mm×8mm. The suspension frame is constructed by square steels, of which the cross section is 60mm×60mm×6mm. The plough beam is constructed by square steels, of which the cross section is 100mm×100mm×8mm. All the supporting bears are welded on these three frames.

The frames of the guttering plough are a welded plane steel frame with a symmetry plane. Under the premise of ensuring the structure and strength of the mechanical model is basically consistent to the original structure and strength of the guttering plough, the mechanical model is simplified as following: the first one is to ignore the transition fillet and end chamfering; the second one is to ignore the internal stress in square steels generated during welding; the third one is to ignore the offset of the symmetry center line as square steels related to each other; the fourth one is to ignore the gravity of the guttering plough; the fifth one is to ignore the effects of the pin holes and the screw holes on the stiffness and strength of the guttering plough.

FEA Model Establishment and Mesh Generation

In this paper, the finite element analysis model of the guttering plough is established, and the strength of the guttering plough is analyzed. Among them, the plough beam and the suspension frame are the main supporting body and loading transferring structure, and the stress and strain should be analyzed emphatically. Therefore, in ANSYS, using solid element to build the frame models of the guttering plough, select the tetrahedron unit to finely divide it, and select the hexahedron unit to divide other secondary division, in order to save computing resources.

In addition, the dimensional system of all input data needs to be unified before the model is established. Material properties are homogeneous and isotropic. The constraint is that chassis frame is fixed, $U_1=U_2=U_3=0$, $UR_1=UR_2=UR_3=0$. The resistance along the forward direction and the resistance in the transverse direction are applied on the share break point, and passing along the structure of the guttering plough.
The mesh dividing is generated by 8 node linear entity hybrid element (C3D8H) method, and the mesh seed density is 0.05m. The size of the model is the same as the size of the solid. The material is the same as the solid material, which is structural steel.

According to this method, 249740 nodes and 145026 units are divided, as shown in Figure 3.

![Figure 3. Sketch of nodes and units of the guttering plough.](image)

The material definition is defined by the material parameter order. The elastic modulus of the material is 210 and the Poisson's ratio is 0.3. The supporting bases are defined by the rotating pair module.

### Analysis Results

![Figure 4. The equivalent stress distribution diagram of the guttering plough.](image)

Through the static load calculation of the ANSYS program, the equivalent stress distribution diagram of the guttering plough is obtained, as shown in figure 4. The maximum stress on the chassis frame, suspension frame and supporting bases is shown to be 190MPa. Because the \( \sigma_{\text{max}} = 190 \text{MPa} < [\sigma] \) [10], so the maximum stress of the guttering plough is less than the allowable stress of structural steel, meet the strength requirements.

![Figure 5. The deformation distribution diagram of the guttering plough.](image)
Under normal working conditions, the maximum of the deformation displacement of the guttering plough along the forward direction (X direction) is 21.655mm, as shown in Figure 5, and the tillage quality will not be affected. In the lateral direction (Y direction), the maximum of deformation displacement is 17.213mm. In order to prevent the deformation of the guttering plough, it is suggested that the joint parts that connected the chassis frame with the supporting bases welded on each frames should be properly enlarged.

Conclusion

1) The stiffness of the guttering plough in the lateral direction is poor, especially the deflection of the end of the plough beam is larger, which reaches 17.213mm in the normal working condition. In order to prevent the deformation of the plough frame, it is suggested that the connecting part of the plough beam and the supporting bases welded on suspension frame should be properly enlarged.

2) On normal operating conditions, the stress of each part of the guttering plough is generally below 163MPa. The stress concentration appeared on the connecting part between each frames and supporting based, the highest reached the maximum value of 244MPa, but still less than the allowable stress of structural steel, meet the strength requirements.

3) ANSYS finite element software is used to analyze the static loading problems of the guttering plough. The analysis results can reflect the stress and the deformation condition of the guttering plough well, and can be used as a feasible method for the design and improvement of this and other guttering plough structure.

Acknowledgement

This research was financially supported by the Science and Technology Extension Project of agricultural comprehensive development in Ningxia, “The design and development of precise operating machine for the green production of Chinese wolfberry”, during 2015~2017. We also acknowledge for the support of the National Natural Science Foundation of China (no. 51305426).

Reference


