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Abstract. In this paper the mechanical analysis of the film picking forks roller tooth in field -cleaning machine was done. A finite element analysis model was built and used by the non-linear finite element analysis method. It is obtained from the result of post-processing calculation and analysis that according to the Fourth Strength Theory, the maximum equivalent stress on the pole tooth root under the uniform load. Root strength should be strengthened to ensure the evenly stress overall the pole tooth, because pole tooth root department would be deformed easily. And the largest stress is at the end of pole tooth and decreases gradually from end to root, and deformation is also the same. Based on the analysis of strength and rigidity, the bearing forces and deformation of the film picking forks roller tooth in work were predicted and validated. It was found that the finite element analysis and the result of test were well coincided. The reliable tool was provided for the design of the film picking forks roller tooth by the finite element analysis. The Roller tooth was designed and improved according to the requirement of deformation and operation.

Keywords: Field Cleaning Machine, Film Picking Forks Roller Tooth, Non-linear Finite Element

1 Introduction

The pole tooth ought to have enough strength to provide a safe space because of the big propellers to the pole tooth by soil after it sowing into the layer when the field cleaning machine recycled the remnant film in the coated cultivated land. It needs a long period using the traditional experience design method. In recent years,

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more and more techniques are used in simulating nonlinear reaction of agricultural machine’s working parts under the static load from different directions. However, there is still less study of the deformation of agricultural machine’s working parts under uniform loading of soil pressure [1-6].

There are three processes for picking up film of picking forks roller tooth, including push film, pick film and upward transportation. The stressed deformation of picking forks roller tooth in field cleaning machine in working process is simulated and studied by using finite element method in this paper. Finite element model was established in software ANSYS and the pole tooth’s stress and deformation was got based on nonlinear finite element analysis[7-8]. The structure design was improved after the analysis that the variation was to meet the recovery requirements of remnant film as well. Reliable basis was provided for the design of picking film device in field cleaning machine according to accuracy test of finite element model in different speeds. The innovation of this paper is that, by the finite element analysis working with uniform load instead of the concentrated, the method simulated more accurately the actual force situation of picking forks roller tooth in field cleaning machine in operation.

2 Establishment of Mechanics Model for Picking Forks Roller Tooth

2.1 End Shovel Resistance of Picking Forks Roller Tooth

2.1.1 Cutting Resistance of Blade Positive

The cutting resistance expression[9] of blade positive was got by professor Dechao Zeng of China Agricultural University in soil cut process with ploughshare blade simulated by wire when he was researching curved-surface resistance of the body of bottom plow.

$$P = \frac{q_0}{S}[\frac{S}{2}\tan(\frac{\pi}{4}+\frac{\phi}{2})+\frac{S}{2}\frac{1}{\tan(\frac{\pi}{4}-\frac{\phi}{2})}]^n \quad (1)$$

q_o ——Penetration resistance coefficient;

n ——Regression coefficient;

S ——Shovel blade thickness;

ϕ ——Soil internal friction angle.

Resistance expression for shovel blade inclined an angle γ:

$$\Pr = p\sin\gamma + fp\cos\gamma \tag{2}$$

f ——Friction coefficient between metal edges and soil.

2.1.2 Friction Resistance

It is kind of mixture composed of water film, colloid, pollutants, soil particles in the contact area between metal and soil. It is essentially a relative motion between contact area materials about the relative sliding between metal and soil. Stafford. J.V deems it a linear relationship [10] between friction stress and positive pressure when the sliding speed must.

$$pf = C_p + \tan\phi_a \delta_n \tag{3}$$

C_p ——Sticky gathered force between metal and soil when the sliding speed of them must;

ϕ_a ——Vertical stress on metal surface;

δ_n —— The friction angle of soil and metal.

Friction resistance calculation formula of end shovel of picking forks roller tooth was quoted from the research of Dr. Yusu Yao:

$$pf = 0.8(C_1 + A\ln V_r)[\frac{1}{2}(n_1 + n_2)\ w] + pv\tan\phi a \tag{4}$$

2.2 The Stress of Up Film Device

Stress shown in figure 1 and the test point stress results shown in table 1 were got from testing the field cleaning machine in the field with the instruments as speed device, force measurement device, etc, after reasonable test design [11] .

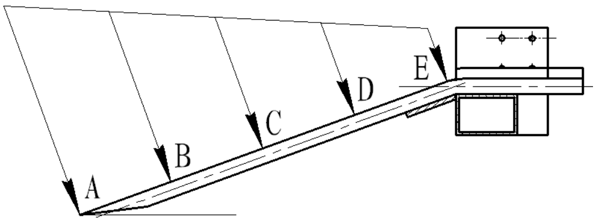

Fig.1 Bearing forces of roller tooth

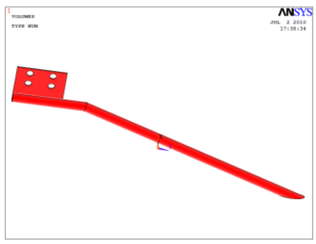

Fig.2 Geometry model of roller tooth

2.3 Force Calculation of Up Film Device

Approximate the whole force on linear interpolation after mastering the point stress through the experiment above.
It is line integrals to point pressure for the whole rods. Set stress equation for A, B two point is $f(x)$, then get stress equation in A, B section for:

$$F = \int f(x)dx \tag{5}$$

Take torque to the supporting point from stress point in A, B section for:

$$\mathrm{M}_{\mathrm{A0}} = M_{B0} \tag{6}$$

So the stress position of concentrated force can be concluded.
The only method can be used is approximate processing in linear interpolation because the approximate treatment can be done only by linear interpolation and it is impossible to analyze the whole stress.

3 Finite Element Analysis of Picking Forks Roller Tooth

3.1 Material and Finite Element Model

Take a single pole tooth of up film fork row of field clearing and ploughing machine for study object in order to reduce the complexity of computation and simplify the simulating process for computer. The connected steel of the pole tooth and the root is Q235, and the yield limit σ_s =235Mpa. Define material performance in software of ANSYS, elastic modulus of the connected steel of pole tooth and root =200GPa, Poisson's ratio μ =0.3, density ρ =7.8×103kg/m3. Effective working length of pole tooth is 750mm, diameter is 20mm, acorns angle is 20°, and the thickness of the connected steel welding with pole tooth is 10mm. Geometric model of the pole tooth is established as is shown in figure 2 by directing the pole tooth for the X axis.

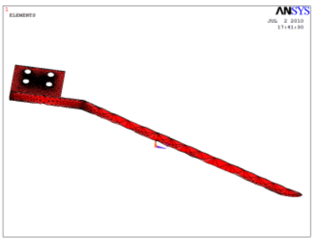

Fig.3 Entitative model after plotting mesh of roller tooth

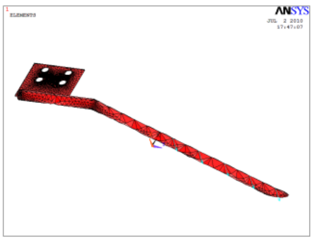

Fig.4 Surface freedom and force on poles of roller tooth

3.2 Network Division and Unit Selection

Create three-dimensional entity model with computer-assisted designing software Pro/E and then import it into ANSYS[12]. Define unit type respectively and divide pole tooth in free grid in grid division. The entity unit number of pole tooth is 11165,and the node number is 19723. Unit division of pole tooth is shown in Fig 3.

3.3 Processing of Constraint and Loading

Constraint processing: Constraint all displacement and rotation for the hole of connecting board and exert boundary conditions to pole tooth due to fixed connection of the fork platoon with frame, and pole tooth with fork platoon. It means that limiting all DOF except effective acorns part of pole tooth.

Loading processing: Work parts of the fork row pole tooth must be acorns and picking the remnant film. Soil mainly forces to the surface of pole tooth. Thrust of soil applied to the pole tooth surface is in uniform load. Corresponding parameter data was measured based on the testing of field cleaning machine in the field. Average stress was got through calculating for measuring point. In Fig 1, A, B, C, D, and E imposed respectively forces as PA=432 N , PB=335 N , PC=254 N , PD=157 N , and PE=87 N . Shown in Fig 4 is the DOF constraint of pole tooth and forces on it.

3.4 Calculation and Analysis

Through the post-processing calculation and analysis, it is possible for reading the original data file in and restoring other data item, and also showing analysis results in many ways through postprocessor. It helps users to check for the influence of the model because of loading on it.

3.4.1 Stress Analysis

Equivalent stress distribution for pole tooth is shown as shown in Fig 5. It is obtained from the result of post-processing calculation and analysis that according to the Fourth Strength Theory, equivalent stress is 6633～6984 kPa in most areas pole tooth, and the maximum equivalent stress on the pole tooth root is 6984 kPa under the uniform load. So pole tooth root department would be deformed easily. Therefore, root strength should be strengthened to ensure the evenly stress overall the pole tooth, and that the static strength safety coefficient can meet the specified design of the field cleaning machine.

3.4.2 Deformation Analysis

The deformation of pole tooth after being loaded is shown in Fig 6. From analysis, the largest stress is at the end of pole tooth and decreases gradually from end to root. Deformation is also the same. The largest deformation in the Y direction is 11.713 mm .

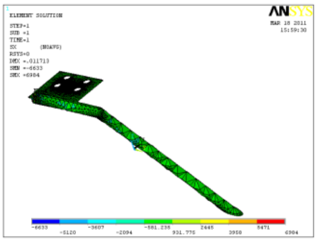

Fig.5 Distribution nephogram of roller tooth bearing force

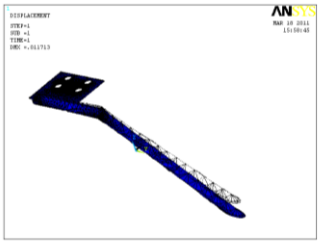

Fig.6 Anamorphic map of roller tooth

4 Designing Improvement for Structure

According to the results of finite element analysis, it would influence the operation quality if deformation of the pole tooth is too big because the ploughing layer of the field cleaning machine is 100～120mm. In order to meet operational requirements, the structures should be improved[13] as increasing the diameter of the pole tooth to 25mm, strengthening the thickness of the connection plate in root to 12mm.

Deal with the improved entity model of picking forks roller tooth improved and establish corresponding finite element model. Exert boundary conditions according to the actual force in working. The force imposed in place of A, B, C, D and E is consistent with Fig 4. Restarted the finite element analysis and got the result that the largest equivalent stress on the root of pole tooth was 220413 Pa and the largest deformation in the Y direction was 1.158 mm. So the deformation of improved pole tooth meets the operational requirements. The distribution of equivalent stress for pole tooth is shown in Fig 7. The deformation of pole tooth by the load effect is shown in figure 8. The deformation of other testing point is shown in table 1.

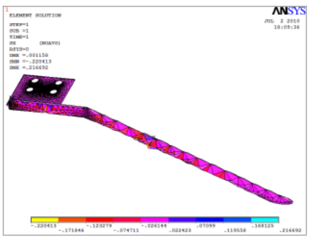

Fig.7 Distribution nephogram of roller tooth bearing force

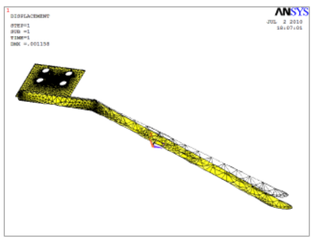

Fig.8 Anamorphic map of roller tooth

5 Experimentally Verification

Conduct field experiment on the structure improved pole tooth with the field cleaning machine shown in figure 9 in plowed cotton land with sand soil whose moisture content is 28.9% in Southern Xinjiang. Connect resistance strain gauge into test to ensure the reliability of the test data and close to actual working condition. Influence on operation of its front-end deformation and torsion deformation is greater according to force analysis of Pole tooth. Point the pole tooth in equal and fix test points as A, B, C, D and E. Patch direction is the horizontal direction corresponding to the X direction of finite element model of pole tooth. The test and analysis results were shown in table 1. Determinate each testing points for five times and calculate average. The stress and deformation results of testing points were shown in Tab 1.

Fig.9 Test in field

Tab.1 Results about bearing forces and deformation of testing points

Items	Testing points				
	A	B	C	D	E
Average stress of each point for five tests $/N$	432	335	254	157	87
Average deformation of each point in test $/mm$	1.135	0.932	0.758	0.539	0.340
Deformation of each point in finite element analysis $/mm$	1.158	0.912	0.745	0.557	0.350
Error of deformation finite element analysis relative to test $/\%$	2.0	2.2	1.7	3.2	2.8

Test out the deformation of picking forks roller tooth in actual working testing in field. It showed that the deformation of pole tooth decreases gradually from ends to root and the largest deformation 1.135 mm occurred at the end.

6 Conclusions

(1) Improved the structure of pole tooth and shorten the design cycle through nonlinear finite element analysis of picking forks roller tooth according to its working requirement.

(2) Compared the deformation in actual working with finite element simulation of the picking forks roller tooth and got the deformation error of each testing point. The largest one is 3.2%, which is less than 5%.

(3) By the nonlinear finite element analysis and actual test of remnant film picking-up of picking forks roller tooth with specific product examples, got the result from the data contrasting between ANSYS simulation and actual testing. The result verified the correctness of the finite element theory analysis and laid the foundation for the next step of structure optimization designing. Its method of analysis has certain practical value for enterprise product development.

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