

# Design study on spoon type precision seeding mechanism of small hilly area special seeder

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**Abstract.** Spoon type precision seeding mechanism is an important part of the small hilly area special seeding machine, and this paper's spoon disk is the first part of the seeding, which directly affects the accuracy of the seeding device for precision seeding. Its shaft member as Spoon type precision seeding mechanism the core component, which greatly affects the seeding efficiency of the spoon disk, this paper carries out the calibration of the shaft parts and the force analysis of the spoon disk for the spoon type precision seeding mechanism.

**Keywords:** Spoon precision seeding mechanism, spoon disk, shaft member calibration, structural design.

## 1. Introduction

China's research on precision seeding technology started late in the 1970s, when it began to develop a variety of traditional mechanical precision seeding machines, and less research on electric-driven seeding equipment. The quality of seeding will directly affect the production cost, yield and profit. Therefore, a precision sowing mechanism was designed, which is of great significance for the development of agricultural economy. Chen Shufa [1] from the School of Mechanical Engineering, Jiangsu Ocean University, etc., for the traditional seeder sowing, due to the chain drive caused by the ground wheel clay, slippery lead to leakage, replanting and other problems, the combination of automatic navigation and precision sowing technology, designed a precision seeder, which can be a one-time completion of rotary tillage, trenching, fertilizer, precision seeding, mulching and suppression of a number of operations. However, the 2QXP-1 air-absorbing precision seed dispenser has a complicated structure and is expensive and not suitable for use in small hilly areas as a specialized seeder.

## 2. Optimization and design of seeding mechanism

Combine the terrain characteristics of hilly areas to determine the design objectives of the seeding machine, such as stability, flexibility and adaptability. Multi-stage variable speed mechanism is adopted to adapt to different terrain conditions; adjustable seeding depth control device is designed to ensure that the seeds can be evenly and accurately buried in the soil, and to ensure that the machine runs smoothly and is energy-saving, as shown in Figure 1 Shown.

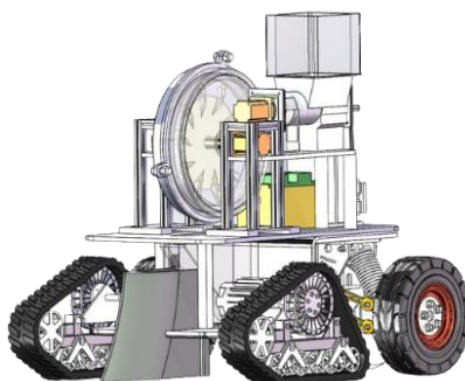


Figure 1. Overall modeling diagram of the equipment

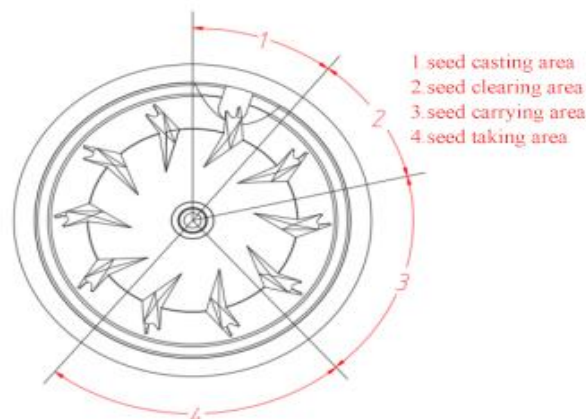
For the spoon type precision seeding mechanism [2], through the installation in the spoon wheel circumference of the seed picking spoon for precision seed picking, the seed will be along the spoon wheel tangential to enter the seed picking spoon type holes, at the same time, the seed picking spoon in the radial direction of the installation has a certain angle of inclination, which can improve the picking spoon pick up the seed capacity and is conducive to the seed by its own gravity automatically clear the seed.



**Figure 2.** Model diagram of spoon precision seeding mechanism

### 3. Design of spoon disk

The working process of the seed spoon type precision hole seeder [3] can be divided into four stages: seed taking, seed carrying, seed clearing and seed casting.

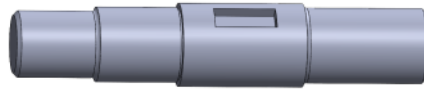


**Figure 3.** Structure of spoon type precision seeding mechanism

The working principle is Shown in Figure 3, when working, the seeds in the seed box through the side cover of a certain height of the seed inlet limited into the spoon type precision hole sowing seed dispenser in the seed filling cavity to form a pile up, the spoon wheel combination following the seed discharge axis counterclockwise rotation, the seeds in the gravity, the interaction force between the seeds and the seeding spoon perturbation of the common effect of quantitative entry into the seed picking spoon type holes; picking up the spoon to continue to rotate, when it reaches a certain height, the picking up the spoon type hole external When the seeding spoon continues to rotate, when it reaches a certain height, the seeds outside the seeding spoon type hole slide down to the seed filling area by their own gravity; when the seeding spoon rotates to the position of the side plate notch, due to the disappearance of the support force of the side plate to which the seeds are subjected, the seeds inside the hole fall from the notch of the seeding spoon and pass through the notch of the side plate, and flow out from the seed guide tube, realizing the process of seed discharging.

## 4. Calculation and analysis of shaft members

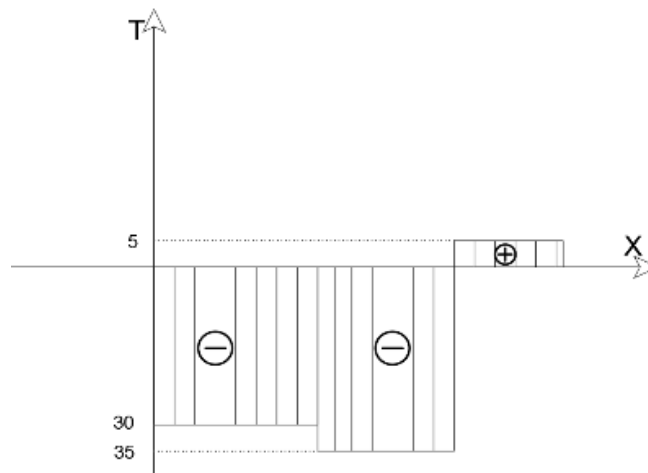
### 4.1. Stresses on shaft members



**Figure 4.** Shaft Parts Diagram

Shaft is one of the main parts of the machine. The main function of the shaft is to support the rotary parts and transfer the motion and power, the modeling diagram of the shaft is as follows Fig. 4 shows.

According to the design requirements of the spoon type precision sowing mechanism, the following shaft parts are designed and analyzed as follows Figure 5 Shown.



**Figure 5.** Torque diagrams for shaft components

### 4.2. Shaft member checking

When calculating the strength check of shafts, the corresponding calculation method should be adopted according to the specific load and stress situation of the shaft, and the permissible stress should be selected appropriately. For only (or mainly) bear the torque of the shaft (drive shaft), should be calculated according to the torsional strength conditions; for only bear the bending moment of the shaft (mandrel), should be calculated according to the bending strength conditions; for both bear the bending moment and bear the torque of the shaft (rotary shaft), should be calculated according to the bending and torsion synthetic strength conditions. When needed, it should also be accurately calibrated according to the fatigue strength conditions. In addition, for shafts with large instantaneous overloads or severe asymmetries in the stress cycle, the static strength should be checked for peak loads to avoid excessive plastic deformation. Calculated for torsional strength conditions.

$$\tau_T = \frac{T}{W_T} \approx \frac{955000 \frac{P}{n}}{0.2d^3} = \frac{4 \times 10^4}{0.2 \times 20^3} \approx 25 \text{ Mpa} \leq [40] \text{ Mpa} \quad (1)$$

$\tau_T$ —torsional shear stress, MPa;

T—Torque on the shaft, N·mm;

$W_T$ —Torsional cross-section coefficient of the shaft,  $\text{mm}^3$ ;

n—Shaft speed, r/min;

P—Power transferred by the shaft, kW;

d—Calculate the diameter of the shaft at the cross section, mm;

$[\tau_T]$ —Permissible torsional shear stress, Mpa.

The diameter of the shaft is obtained from equation (1)

$$d \geq \sqrt[3]{\frac{955000P}{0.2 \times [\tau_T] \times n}} \approx 15.85mm \quad (2)$$

It should be noted that when a keyway is provided in the shaft cross-section, the shaft diameter should be increased to take into account the weakening of the shaft strength by the keyway. For shafts with diameters  $d > 100mm$ , the shaft diameter increases by 3% with one keyway and by 7% with two keyways. For shafts with diameter  $d \leq 100mm$ , the shaft diameter should be increased by 5% to 7% when there is one keyway and 10% to 15% when there are two keyways. Then round the shaft diameter to the standard diameter. It should be noted that the diameters thus obtained can only be used as minimum diameters of the shaft segments that are subjected to torsional moments  $d_{min}$ .

The shaft will produce bending or torsion deformation under load. If the deformation exceeds the permissible limit, it will affect the normal work of the parts on the shaft, or even lose the machine's due performance. For example, the installation of gear shaft, if the bending stiffness (or torsional stiffness) is not enough to lead to deflection (or torsion angle) is too large, will affect the correct meshing of gears, so that the gears along the direction of the width and height of the gear contact is poor, resulting in a serious uneven distribution of load in the tooth surface. Another example is the use of sliding bearing shaft, deflection is too large and lead to journal deflection is too large, will make the journal and sliding bearing edge contact, resulting in uneven wear and excessive heat. Therefore, when designing shafts with stiffness requirements, it is necessary to carry out stiffness checking calculations.

The stiffness checking calculation of the shaft is usually to calculate the deformation of the shaft under load and control it to be no greater than the permissible value.

The torsional deformation of the shaft is expressed in terms of the torsion angle per meter of length  $\varphi$  to indicate. Torsion angle of key shaft section  $\varphi$  [in ( $^\circ$ )/m] is given by:

$$\varphi = 5.73 \times 10^4 \times \frac{T}{GI_p} = 5.73 \times 10^4 \times \frac{4 \times 10^4}{2 \times 10^5 \times \frac{\pi \times 20^4}{32}} = 0.72^\circ \quad (3)$$

T—Torque on the shaft, N.mm;

G—Shear modulus of elasticity of shaft material, Mpa, For materials,  $G = 2 \times 105Mpa$ ;

$I_p$ —Extreme moment of inertia of the axial section,  $mm^4$ , Extreme moment of inertia of the axial section,  $I_p = \frac{\pi d^4}{32}$ ;

Where  $[\varphi]$  is the permissible angle of torsion per meter of shaft length, which is related to the occasion of shaft use. For the general transmission shaft [4], can be taken  $[\varphi]$  is equal to  $0.5 \sim 1(^\circ)/m$ .  $1(^\circ)/m$ ; for the precision drive shaft, it can be taken as  $[\varphi] = 0.25 \sim 0.5(^\circ)/m$ ; for shafts with low accuracy requirements,  $[\varphi]$  may be greater than  $1(^\circ)/m$ .

## 5. Shaft member finite element analysis

### 5.1. Stiffness analysis calculation

As Figure 6 As shown in Fig. 6, the deformation distribution of the shaft member is analyzed by Solid works as shown in Fig. The maximum deformation of the shaft member is distributed at the outermost side of the part, and the deformation gradually decreases inwardly, and the maximum deformation is  $7.22 \times 10^{-3}mm$  to meet the material stiffness requirements.

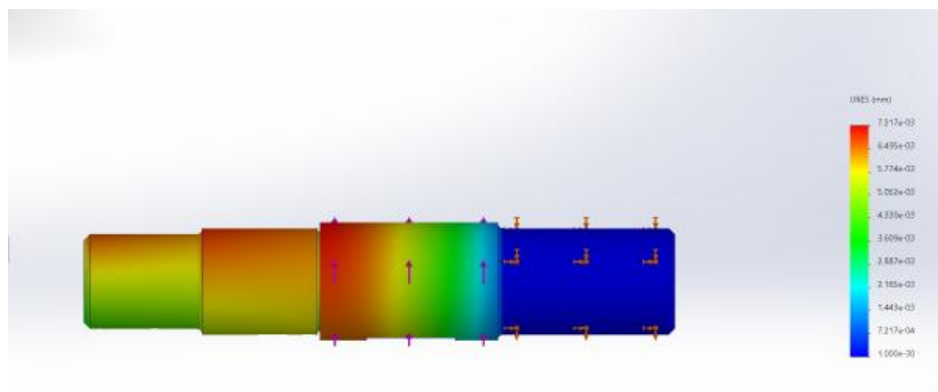


Figure 6. Displacement deformation diagram of the shaft member

## 5.2. Strength analysis calculation

As Fig. 7 Stress diagram of the shaft member The stress distribution of the shaft member analyzed by Solid works is shown in Figure The maximum stress is distributed in the position where the shaft member is coupled with the external force and where the shaft member is connected with the swept disk, and the maximum stress of the shaft member is  $1.752 \times 10^8$ MPa, maximum yield strength  $2.068 \times 10^8$ MPa so it meets the part requirements.

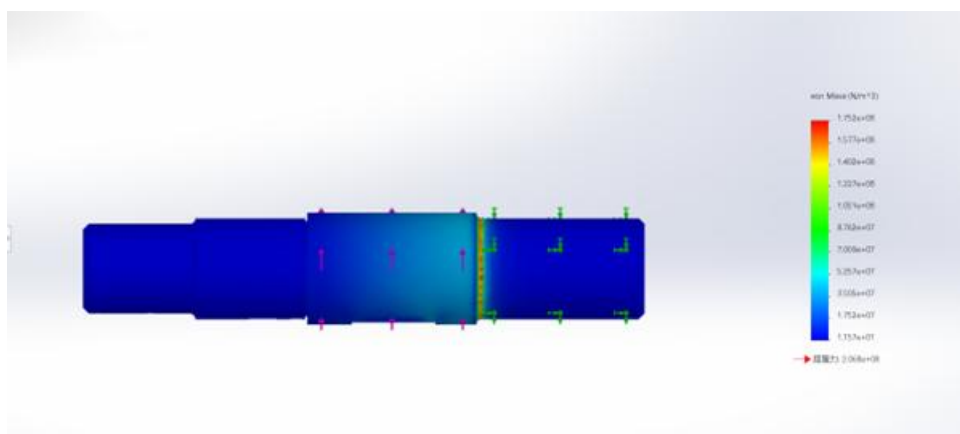


Figure 7. Stress deformation diagram of the shaft member

## 6. Conclusion

After the pre-program design, theoretical calculations and experimental verification by simulation, all the functional performance indexes meet the requirements of agricultural machinery for seeding operations in hilly areas.

In this study, a spoon type precision seeding mechanism for small hilly area special seeder [5] is designed, which is suitable for a variety of crop seeds, such as soybeans, peas, corn, peanuts and so on. The seeding mechanism has the advantages of high seeding efficiency, high working reliability, simple machine structure, low manufacturing cost, easy maintenance, etc. It can meet the requirements of hilly rural areas for vegetable seeds, and has a wide range of application prospects, which is conducive to the promotion of the modernization of agriculture and rural areas.

## References

- [1] CHENShu-Fa, LIU Xing, YU Chao, et al. Structural design and test of precision planter based on Beidou navigation system [J]. Agricultural Mechanization Research, 2022, 44 (11): 90 - 95.
- [2] CHENYe, DONG Xin. Experimental research on hemispherical cavity-shaped air suction precision planter [J]. Journal of Northeast Agricultural University, 2016, 47 (11): 100 - 108.

- [3] ZHANGQingsong, YU Qi, WANG Lei, et al. Design and test of oilseed rape spoon type precision hole seeder [J]. Journal of Agricultural Machinery, 2020, 51 (06): 47 - 54+64.
- [4] ZHANGZunhao, FAN Honggang, MAN Weiwei, et al. Test machine for central drive bearing of aero-engine [J]. Bearing, 2024, (12): 18 - 23.
- [5] LiuHongjun. Research on key technology of seeder suppression device in hilly areas of Northeast China [D]. Northeast Agricultural University, 2019.