Design Of Small High-Gap Tractor Gearbox

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Abstract

Wheat intercropping corn and peanuts is an important high-yield cultivation technique. Although the number of small four-wheel tractors is huge in rural areas, it is suitable for the current level of rural productivity and production scale. However, due to its small track and adjustable ground clearance, it cannot be the wheat field, corn and other inter-row seedlings in the wheat field have seriously restricted the promotion of wheat corn seeding technology. Therefore, the research and development of a new type of tractor with small height and adjustable track spacing is of great significance for the adaptation of corn and peanuts in different areas to wheat field nesting operations, mechanized fertilization, and medicine. This paper designs a small high-gap tractor gearbox separately. The transmission scheme, the overall structure of the transmission box and the chain transmission were designed respectively, and the chain drive shaft was calculated to adapt to different planting specifications. The small high-gap tractor not only satisfies the tractor corn and peanuts in the wheat field, but also realizes the wheat field. The mechanization of management operations such as cultivating, weeding, fertilizing, and fighting drugs has improved the utilization rate of tractors and reduced production costs.

Keywords

Small tractor; high ground clearance; Transmission case; design.

1. Introduction

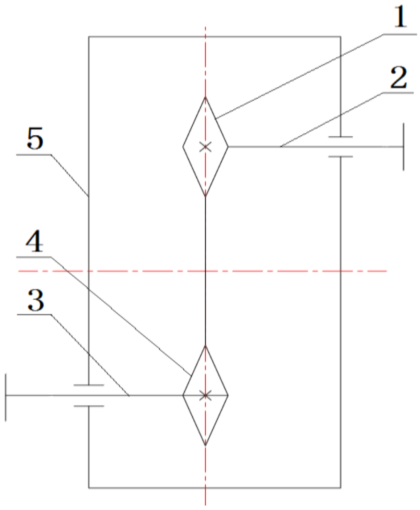
With the rapid development of China's high-gap tractor market, especially in the 12th Five-Year Plan period, the key to transforming the economic growth mode, the related core production technology application and research and development will become the focus of the industry. The merits of technical processes directly determine the market competitiveness of enterprises. Understanding the research and development trends, process equipment and technical applications of the core technology of high-gap tractors at home and abroad is crucial for enterprises to improve product specifications and improve market competitiveness.

2. Transmission Scheme Design

When designing the transmission scheme, the transmission box should meet the characteristics of high ground clearance, and the working state of the transmission box directly affects the driving performance of the tractor.

The main advantage of the chain drive is that there is no slip: in the same working environment, the drive size of the chain drive is relatively compact; the tension does not have to be too large, so the load acting on the sprocket shaft is small; the efficiency is high, $\eta \approx 98\%$ can be achieved; Work in harsh environments such as high temperatures and high humidity [1].

Therefore, the transmission scheme of the chain drive is selected to realize the driving of the tractor, and the wheeled transmission box is installed at the rear wheel to improve the ground clearance of the tractor and smoothly complete the task of field nesting operation.

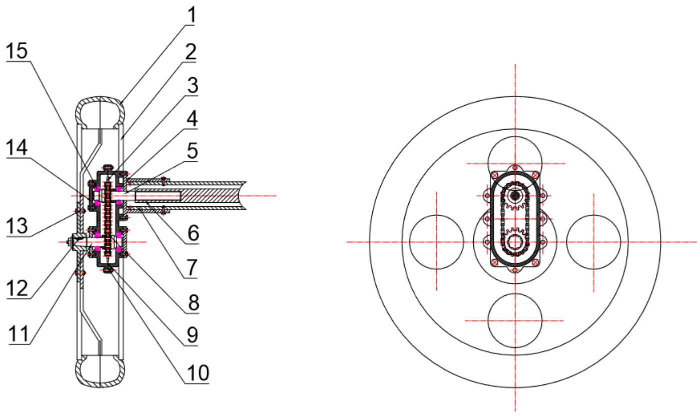


1-acting sprocket; 2-actuator shaft; 3-driven shaft; 4-driven sprocket; 5--transmission housing

Fig 1. Schematic diagram of the transmission box design structure

3. The Overall Structure of the Gearbox

The design of the gearbox must meet the design requirements and meet the working conditions.



1-tire; 2-rim; 3-sprocket; 4-flange tube; 5-input shaft; 6-semi-axle; 7-semi-axle shell; 8-chain; 9-stop ring; 10-shield; 11-output shaft; 12-key; 13-wheel hub; 14-end cap; 15-bearing

Fig 2. Overall structure of the gearbox

When the transmission box is designed, in order to meet the process requirements of manufacturing, installation and maintenance of the transmission case, the two parts of the housing are arranged in the left and right direction. The overall structure of the transmission box is divided into three parts: the main shaft combination, the driven shaft combination and the housing [2].

The main shaft part is mainly composed of input shaft, drive sprocket, deep groove ball bearing, bearing washer, etc. The driven shaft part is mainly composed of output shaft, driven sprocket, deep groove ball bearing, bearing washer, etc. It consists of left and right shells, flange tubes, bearing end caps, shaft end retaining rings, etc.

When arranging the gearbox position, the tractor should be placed in a vertical position due to its compact structure and space saving [3].

4. Chain Drive Design

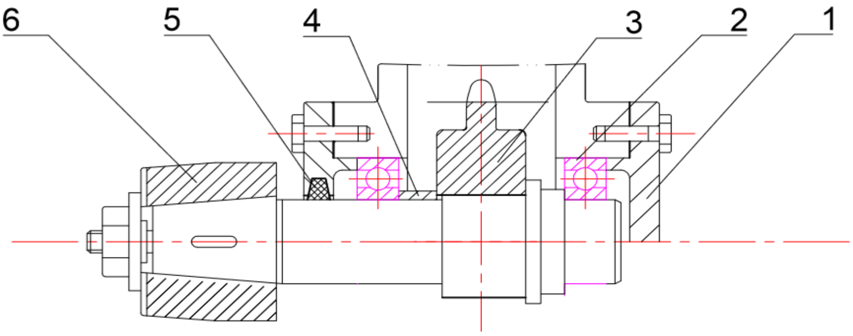
When designing the transmission scheme, if the transmission of the chain transmission is adopted inside the transmission case, the structure is greatly simplified. And the chain drive works stably and reliably, and it still works better when it is affected by clods, mud and transient overload. In this design scheme, in order to meet the design requirements of the high ground clearance, the transmission case has a large manufacturing volume, and the center distance of the sprocket is large, and the design of the chain transmission can better reflect the advantage of the transmission distance of the chain transmission. Compared with the gear transmission, the chain drive has lower installation accuracy requirements, lower cost and high applicability [4].

5. Chain Drive Shaft Design Calculation

The design of the shaft is similar to the design of other parts, and the sub-structure design and work capacity calculation are two parts.

5.1 Output Shaft Structure Scheme

The axial positioning parts designed on the output shaft are: shoulders, sleeves, etc., to prevent relative movement of the sprocket along the axial or circumferential direction. The position between the shafts is used in the case where the axial force is large. In order to facilitate the disassembly and assembly of the sprocket, the bearing, etc., the wear of the mating surface is reduced, and the diameter of the front section of the shaft is taken to be small.



1-bearing end cap; 2-rolling bearing; 3-driven sprocket; 4-sleeve; 5--felt ring; 6-rim

Fig 3. Schematic diagram of the assembly of the parts on the shaft and the shaft

Through the above discussion, the assembly scheme of the on-axis parts plays a decisive role in the structural form of the shaft, as shown in Fig.3

5.2 Calculation of the Axis

The calculation of the axis is performed after the structural design is completed, and the calculation criteria must meet the strength requirements of the shaft. The output shaft is subjected to both bending moment and torque, so it is calculated according to the bending and twisting synthesis conditions[5].

(1) Calculation diagram of the axis

Before the calculation sketch of the axis, first calculate the load of the force-bearing part on the shaft.

$$T = \frac{F_t D}{2} \tag{1}$$

Where: D—the diameter of the driven sprocket, 100mm;

Ft—the lateral force received on the sprocket, 1.01×104N;

T—the torque reaceived by the shaft, N·m.

Put the number into the formula 1

$$T = \frac{1.01\times10^4\times0.1}{2}\,\mathrm{N\cdot m{=}505N\cdot m} \tag{2}$$

Calculate the load that is decomposed into the horizontal and vertical directions

$$F_{NH} = \frac{F_t}{2} \tag{3}$$

$$F_{NV} = \frac{F_P}{2} \tag{4}$$

Where: FNH- the load in the horizontal direction, N;

FNV- the load in the vertical direction, N;

Ft- the lateral force received on the sprocket, 1.01×104N;

FP- the axial force exerted on the sprocket, 1.06×104N.

Put the number of generations into the horizontal surface of the load FNH1, FNH2 is

$$F_{NH1} = F_{NH2} = \frac{1.01\times10^4}{2}\text{N} = 5.05\times10^3\text{N} \tag{5}$$

Put the number into the vertical surface 3 to get the load FNH1, and FNH2 is

$$F_{NV1} = F_{NV2} = \frac{1.06\times10^4}{2}\text{N} = 5.3\times10^3\text{N} \tag{6}$$

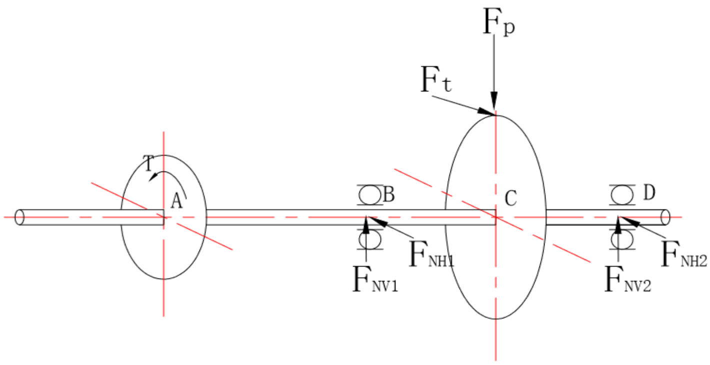


Fig 4. Mechanical model of the shaft

(2) Bending moment diagram

According to the calculation sketch of Fig. 4, the bending moments on the horizontal plane and the vertical plane are respectively calculated, and the bending moment MH diagram on the horizontal plane and the bending moment MV diagram on the vertical plane are made as required, as shown in Fig. 5, Fig. 6; and the total bending moment is calculated according to the formula 9.

Bending moments in horizontal and vertical planes

$$M_H = F_{NH} \cdot a \tag{7}$$

$$M_V = F_{NV} \cdot a \tag{8}$$

Where: FNH- the load in the horizontal direction, 5.05×103N.

FNV- the load in the vertical direction, 5.3×103N;

a- the distance from the force to the center, 36mm.

MH- bending moments on the horizontal plane, N·M;

MV- the bending moment on the vertical plane, N·M.

The horizontal bending moment of the number of substitutions (7) is

$$M_H = 5.05\times10^3\times3.6\times10^{-2}\,\text{N}\cdot\text{m} = 181.8\text{N}\cdot\text{m} \tag{9}$$

The vertical bending moment of the number of substitutions (8) is

$$M_V = 5.3\times10^3\times3.6\times10^{-2}\,\text{N}\cdot\text{m} = 190.8\text{N}\cdot\text{m} \tag{10}$$

Total bending moment of the shaft

$$M_Z = \sqrt{{M_H}^2 + {M_V}^2} \tag{11}$$

Where: MZ- the total bending moment of the shaft, N·m;

MH- bending moments on the horizontal plane, 181.8N·m;

MV- the bending moment on the vertical plane, 190.8N·m.

The total bending moment MZ of the number of substitutions 9 is

$$M_Z = \sqrt{181.8^2 + 190.8^2}\,\mathrm{N \cdot m} = 263.545\mathrm{N \cdot m} \tag{12}$$

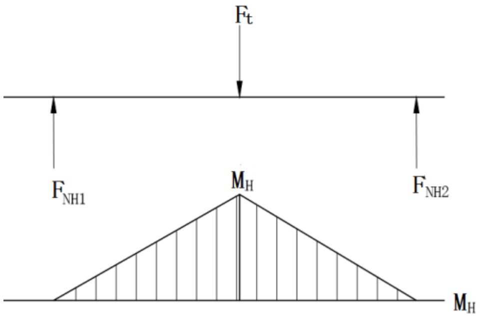


Fig 5. Bending moment diagram on the horizontal plane

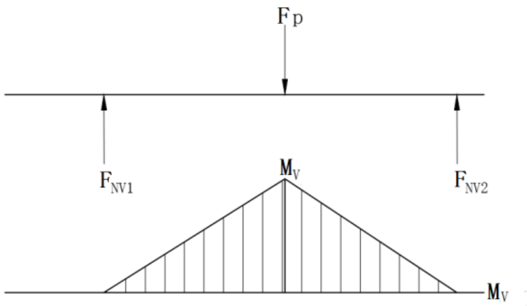


Fig 6. Moment diagram on the vertical plane

(3) Torque map

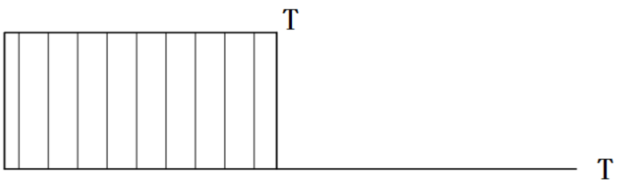


Fig 7. Torque diagram of the force

(4) Check the strength of the shaft

After the bending moment and torque of the shaft are obtained, it can be seen that the output is dangerous section at the position of the sprocket, and the bending and torsion combined strength check is calculated.

The bending section coefficient W of the shaft is

$$W = \frac{\pi d^3}{32} \tag{13}$$

Where: d- the diameter of the shaft, 30mm;

W-the bending section coefficient of the shaft, mm3

Put the number into the formula 11

$$W = \frac{\pi \times 30^3}{32}\mathrm{mm}^3 = 2.65 \times 10^3 \mathrm{mm}^3 \tag{14}$$

According to the third strength theory, the bending and torsion strength condition of the shaft is,

$$\sigma_{ca}=\sqrt{\left(\frac{M_Z}{W}\right)^2+4\left(\frac{\alpha T}{2W}\right)^2}=\frac{\sqrt{{M_Z}^2+(\alpha T)^2}}{W}\leq\left[\sigma_{-1}\right] \quad (15)$$

Where: σca- the calculated stress of the shaft, MPa;

MZ- the total bending moment of the shaft, 2.64×105N·mm;

T- the torque to which the shaft is subjected,5.05×105N·mm;

W-the bending section coefficient of the shaft, 2.65×105mm3.

$\left[\sigma_{-1}\right]$-Allowable bending stress of the axis when the symmetric cyclically deforms stress, Check the table to get $\left[\sigma_{-1}\right]=60\text{MPa}$.

Put the number into the formula 13,

$$\sigma_{ca}=\frac{\sqrt{(2.64\times10^5)^2+(1\times5.05\times10^5)^2}}{2.65\times10^3}\text{MPa}=21.5\text{MPa} \quad (16)$$

The material of the selected shaft is 45 steel, and the quenching and tempering treatment is safe because $\sigma_{ca}<\left[\sigma_{-1}\right]$.

6. Conclusion

The rear drive axle transmission box adopts a chain transmission design, and the ground clearance is adjusted by changing the center distance of the sprocket. The test results show that the small high ground gap not only satisfies the agronomic requirements of tractor corn and peanuts for wheat field intercropping, but also It can realize the management mechanization of cultivating, weeding, fertilizing and fighting drugs in wheat fields, improving the utilization rate of tractors and reducing production costs.

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