Key Structure Design and Performance Analysis of Small High Ground Gap Tractor

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Abstract

Taking the small high-gap tractor as the research object, combined with the actual situation, the rear wheel, flange tube and driving rear wheel of the small high-gap tractor were designed, the front axle strength was checked, and the traction performance and minimum turning of the tractor were also checked. The radius and stability were analyzed and the best design was obtained. It provides a basis for the design and improvement of small high-gap tractors in the future.

Keywords

Small high ground clearance tractor; flanged pipe; drive rear wheel; performance analysis.

1. Introduction

The emergence and development of agriculture is roughly no more than 10,000 years.It began to domesticate and breed animals and grow grain around 8000 BC, and humans entered the primitive agricultural stage[1]. In the late Neolithic period, the application of pottery and the invention of bronzes marked the end of the era of obscurity in the history of human culture and the beginning of the barbaric era.

The main working method: slash and burn. A ripper tool appeared. Bronze farming tools appeared during the Shang and Zhou dynasties, but they were not widely used. The main farming tools are still rafts, skeletons, and sarcophagi[2].

General purpose tractors are mainly used for land preparation, sowing, harvesting, transportation and farmland basic construction. They are characterized by wide walking gear, low grounding pressure, low ground clearance, and generally no adjustment of wheel (rail) distance or adjustment range. Large, with good flat passability, traction performance and stability[3].

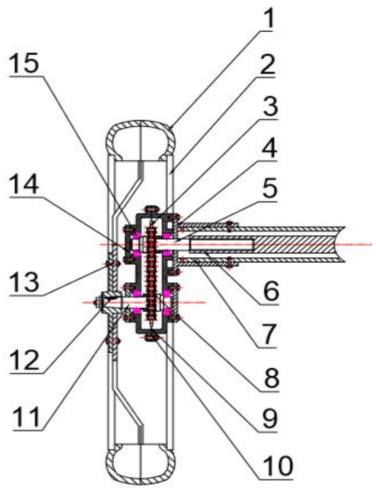
The tractors are mainly used for intercrop management, such as weeding, loose soil, fertilizer application and spraying[4].It is characterized by narrow travelling device, high agronomic ground gap, adjustable wheel distance in a larger range (special cultivator tractor wheel (rail) distance can be fixed), and good inter-row passage, steering control and vision.

All-purpose cultivator tractor has the function of both cultivator tractor and general purpose tractor, the gap of agronomy is 400 ~ 800mm.

The agricultural clearance of the tilled tractor reaches 800 ~ 1000mm.

2. Rear Wheel Assembly Design

In the realization of the requirements of high ground clearance, the rear is mainly to install a wheeled transmission box. The distribution of the rear part of the installation is mainly as follows: the central horizontal axis is installed between the transmission boxes, and the two half shafts are set on the horizontal axis to respectively connect the outputs. The shaft and the output shaft are connected to the rear wheel, and the drive of the transmission box is transmitted to the wheel to realize the driving of the tractor [5]. With the characteristics of high ground clearance, the tractor can perform functions such as weeding and fertilizing during the driving process, which improves the utilization rate of the tractor, reduces the production cost, and enables the operator to complete long-term production operations.



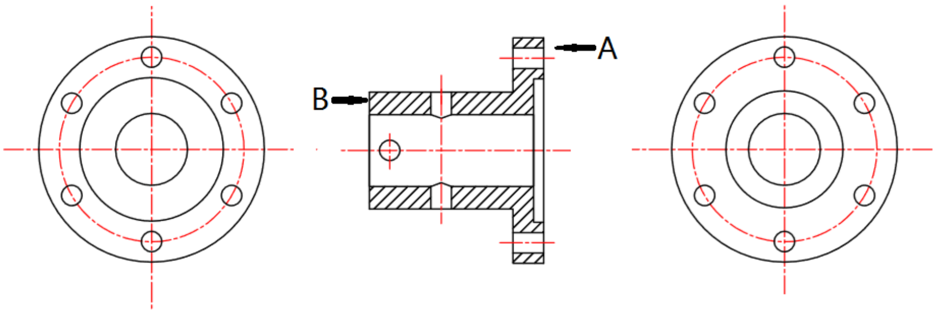
1-tire; 2-rim; 3-sprocket; 4-flange tube; 5-input shaft; 6-semi-axle; 7-semi-axle shell; 8-chain; 9-stop ring;10-shield; 11-output shaft; 12-key; 13-wheel hub; 14-end cap; 15-bearing

Fig.1 Schematic diagram of the overall structure of the rear wheel

3. The Design of the Flange Tube

3.1 Transmission Box Flange Tube Design

The two ends of the transmission box are connected to the half shaft, the input shaft sleeve is placed in the half shaft, and the front end is sleeved on the flanged tube with holes to realize the adjustment of the track distance.



A Direction B direction

Fig.2 Schematic diagram of the transmission box flange tube

The flange tube has six bolt holes for connecting the hub and the other end to the output shaft of the gearbox. The material is HT-200 gray cast iron[6].

In order to meet the requirements of reducing the weight of the whole vehicle and improving the carrying capacity of the tractor, the output shaft is made into a hollow shaft with a hollow ratio of α=0.64.

4. Drive Rear Wheel Design

There are three design schemes for driving the rear wheel. The design scheme is shown in Figure 3-6. The first solution designed the wheels to be strong and sturdy, but the overall size is cumbersome and material waste. The second scheme is designed to have poor wheel strength and stiffness, and is not practical[7]. Therefore, the third option is adopted, and the material selected is Q232 steel plate.

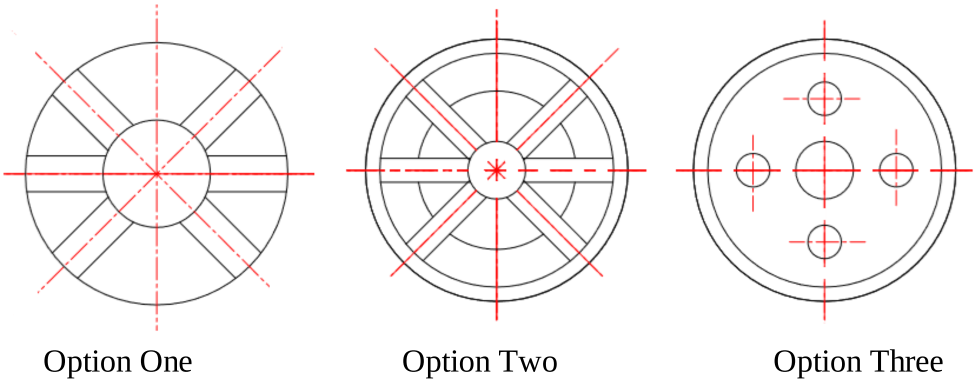


Fig.3 Design of the rear wheel

Determination of rim section width

$$B \geq \frac{Q}{K} \tag{1}$$

Where: Q—the vertical load acting on the wheel, 3500N;

K—rim unit width allowable load, 300N;

B—The width of the rim section, cm.

Put the number into the formula (1)

$$B \geq \frac{3500}{300}\text{cm} = 11.67\text{cm} \tag{2}$$

According to the agricultural technical requirements for wheat sowing, the spacing between the rows and the rows is 20 cm, and the width of the wheel is determined to be B=15 cm.

5. Front Axle Strength Check

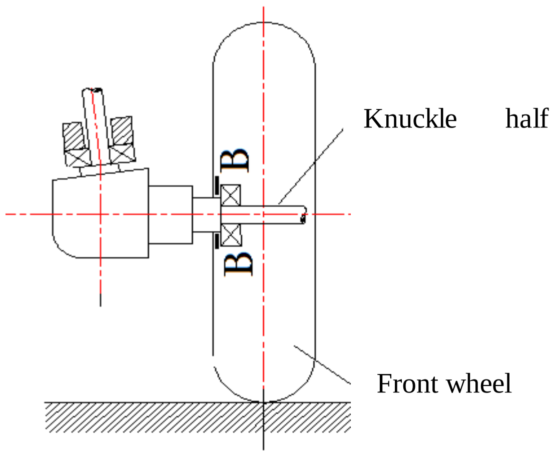


Fig.4 Schematic diagram of the knuckle half shaft structure

When the front axle is working, the B-B section is less affected than the A-A section, but the influence is also considered. The material specification is 40# steel. Strength check is performed on section B-B.

$$\sigma_{\max} = \frac{M_{\max}}{W} \leq [\sigma] \tag{3}$$

$$W = \frac{\pi D^3}{32}(1 - a^4) \tag{4}$$

Where: W——the bending section coefficient on the section, m3;

d——the inner diameter of the front axle, 40mm;

D——the outer diameter of the front axle, 50mm;

a——hollow ratio,a=d/D=0.8.

Put the number into the formula (3), and the formula (4)

$$\sigma=\frac{1200}{\frac{\pi}{32}\times 0.05^3\times\left[1-(\frac{0.04}{0.05})^4\right]}\text{Mpa}=165\text{Mpa}\le[\sigma_W] \tag{5}$$

The material selection is 40# steel, and the allowable stress is $[\sigma_W]=200\sim 220\text{Mpa}$, It can be seen that the conditions of bending are met and there is a large safety reserve.

6. Performance Analysis of High Ground Clearance Tractor

6.1 Tractor Traction Performance

6.1.1 Driving Force of the Tractor

(1) Effective torque Me

$$T=N_{eN}\cdot\lambda_t\cdot\lambda_d\cdot\lambda_v \tag{6}$$

$$M_e=9550\times\frac{T}{n} \tag{7}$$

In the formula: $N_{en}=8000N$,let $\lambda_t=0.85$, $\lambda_d=0.95$, $\lambda_v=0.90$;

n—Calibration speed,2000r/min.

Put the numbers into equations (6) and (7)

$$M_e=\frac{9550\times 8\times 0.85\times 0.95\times 0.9}{2000}\text{N}\cdot\text{m}=30\text{N}\cdot\text{m} \tag{8}$$

Drive torque,

$$M_Q=M_e\cdot\eta_c\cdot i_\Sigma \tag{9}$$

$$i_\Sigma=\frac{n_0}{n_t} \tag{10}$$

Where: take $\eta_c=0.91$

Substituting the above formula:

$$n_t=\frac{1900}{60\times 3.14\times 1.35}\text{r/min=7.5r/min} \tag{11}$$

$$M_Q=\frac{30.6\times 0.91\times 2000}{7.5}\text{N}\cdot\text{m=7426N}\cdot\text{m} \tag{12}$$

6.1.2 Tractor Traction

Driving force determined by engine capacity

$$P_{eN}=\frac{M_Q}{r_q}-f_z\cdot G_\mu \tag{13}$$

Put the number into the formula (13)

$$P_{eN}=\frac{7426}{0.675}-0.1\times 7350\text{N}=10270\text{N} \tag{14}$$

6.2 Minimum Turning Radius of the Tractor

$$R_{\min}=L\cdot\cot\alpha_{\max}+M/2=2620\text{mm} \tag{15}$$

Where: L—wheelbase, mm;

αmax—the maximum steering angle of the inner and outer wheels, usually 45°;

45°—the distance between the left and right steering joint vertical shafts, mm;

6.3 Tractor Stability

6.3.1 Horizontal Stability

(1) Uphill limit tipping angle

$$\alpha_{\lim} = \arctan\frac{a}{h} = 33^{\circ} \tag{16}$$

Where: a—the longitudinal coordinate of the centroid;

h—the height coordinate of the centroid;

$$h = \frac{L}{3} + 225 = 721.7\text{mm} \tag{17}$$

(2) Downhill limit rollover angle

$$\alpha_{\lim} = \arctan\frac{L-a}{h} = 52^{\circ} \tag{18}$$

Where: a—the longitudinal coordinate of the centroid, 467mm;

h—the height coordinate of the centroid;

slip angle,

$$\alpha_{\Phi} = \arctan(\phi\frac{L-a}{L-\phi h}) = 30^{\circ} \tag{19}$$

7. Conclusion

Through the analysis of the rear wheel, flange tube and drive rear wheel of the small high-gap tractor, and the check of the strength of the front axle, the tractor traction performance, the minimum turning radius and the stability analysis, the small high-gap tractor can be maintained. The good passing performance in the field operation satisfies many functions. The design and development of the high-altitude and wide-wheel-variable modified tractor provides a good research and development idea for the development of other modified tractors in the future.

Acknowledgements

The paper is completed from the initial drafting of the draft to the completion of the first draft. The whole process is divided into three stages. The first stage is mainly to collect various information related to agricultural tractors. The second stage begins to study the information found in the research and the current agricultural use. The advantages and disadvantages of the mechanical status quo have been initially understood; the third stage is to use the various knowledge learned, and at the same time consult all kinds of mechanical journals and engineering manuals, and gradually complete the design tasks.

Here, I would like to express my heartfelt thanks to the students who helped me write my thesis and the teachers who gave me patient guidance. In the process, Dandan Zong played a very important role in my guidance. Her eclectic thought gave me endless enlightenment. Overall, this paper has benefited me a lot, which gives me the opportunity to combine the knowledge I have learned during college, improve and enhance my ability to comprehensively apply my knowledge, and also learn about machinery. The design steps and methods have laid a solid foundation for my future work in the machinery-related industry. I believe this is the most valuable experience on my learning path.

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