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Design and experiment of test-bed for rectangular bale knotter

Zhang Ji, Geng Hao, Geng Aijun, Li Ruxin*
College of Mechanical and Electronic Engineering, Shandong Agricultural University, Tai'an, (CHINA)
Email: rxli@sdau.edu.cn

ABSTRACT

Knotter is the key part of the rectangular baler. Most of knotters used in domestic are imported from abroad and the main types are D type knotter, C type knotter and C-D type knotter. It's difficult to research the knotting process in the normal working state for the quick knotting action and the complicated mechanism. Therefore, it is of great significance to establish a test-bed which has features such as slow knotting-speed action and wide universality for researching the knotting process. This article mainly introduced the general structure design of the test-bed, the bales length adjustment and manual design of the knotter, the experiment of D type knotter, C type knotter and C-D type knotter manually or in normal operation. The experiment was made using the test-bed, the results showed the locking rate was 99.6%, which showed that the overall design project was feasible and laid foundation for further knotter research.

KEYWORDS

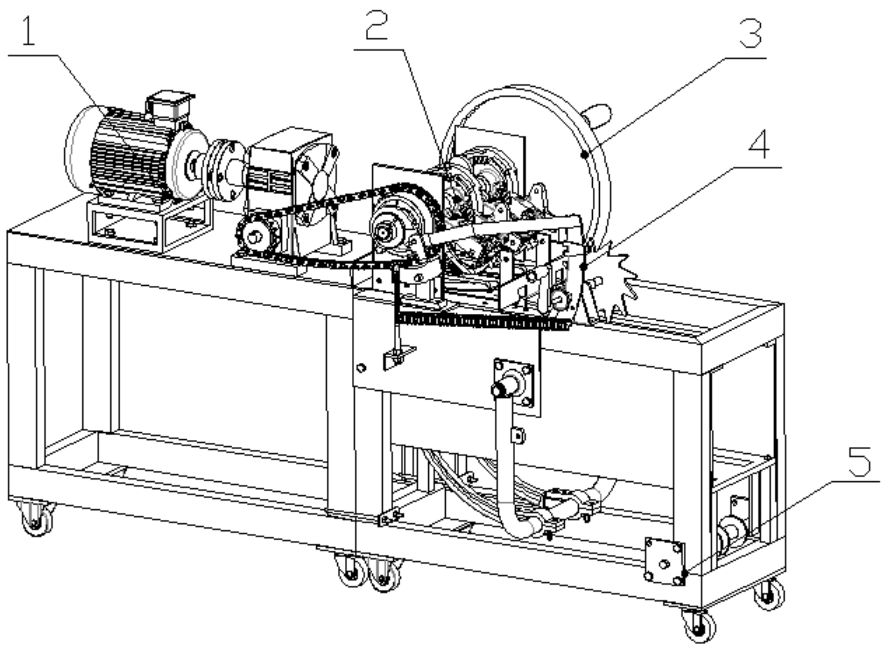
Test-bed; Knotter; Manual design; Test experiment.

INTRODUCTION

The crop straw yield in most of the developing countries in Asia and Oceania is very large. The majority of straw are burned on spot which results in serious environment pollution and biomass resources waste with the limitation of straw collection device[1-2]. China was one of the world's most straw production countries. The major grain-producing regions are mainly distributed in small-scale areas along the middle and lower reaches of the Yangtze and in Huang-Huai Plain, where the rain water is abundant resulting straw go moldy and rotten and resources waste. It is necessary to develop knotter that is suitable for local needs. The foreign bales are mainly round bale and rectangular baler. The rectangular baler has advantages of high production efficiency, high bale density as well as convenient transportation and storage[1-2]. Knotter is in the key position of the rectangular baler which is called the core of the baler[3-4]. The working quality of the rectangular baler is in direct relation to the job performance of the baler[5-7]. At present, C type, D type and C-D type knotter has been developed maturely abroad and been widely used in rectangular baler, however, it’s inconvenient to operate and maintain for the complicated mechanism[8-14]. The economical and practical knotter is urgently needed to realize localization of the knotter and speeding up the mechanization of husbandry. In order to provide convenient conditions for existing knotter research, as well as to lay the foundation for research and design of the new knotter, a test-bed which has features such as slow knotting-speed action and wide universality for three kinds kontter and realizing delivering rope, clipping rope, impacting snap and cutting rope operated at an appropriate time sequence.

EXPERIMENTAL

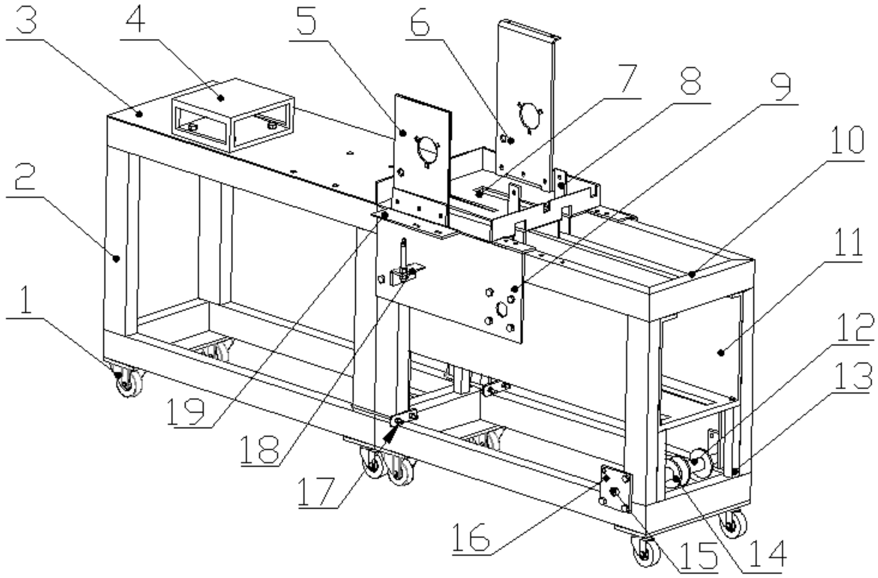
The overall design project of the knotter test-bed



1.drivetrain 2.knotter 3. flywheel 4. assistant devices 4.chassis
Figure 1: The overall design project of the knotter test-bed

The test-bed chassis consisted of the frame, caster, motor installing frame, bale box, knotter mounting plate and assistant device, installing and positioning fastener. The chassis consisted of chassis 1 and chassisc 2, which are aluminum and installed together by triangle fasteners, bolt and nut with directional wheels and universal wheels attached to its bottom to move freely. The drivetrain mounting plate was installed on the upper part of the chassis 1, in order to fix motor installing frame, motor and reducer. Pushing rope plate mounting desktop, knotter frame fixation and knotter mounting plate were installed on the chassisc 2 in order to fix the kontter.

The installation experiment of three kinds knotter was achieved through adjusting bolt and nut to move the fixed position of strip hole on the knotter frame fixation. The bale box was installed inside the chassisc 2, which was fixed by the bale box top pillar at the bottom of the box. The delivering rope device consisted of rope installational axial, rope installational axial positioning plates, rope roller, rope chuck and guide ring for string on the U type frame which mainly supplied rope during the working. U type frame installing and positioning plate was mainly used to position and fix the U type frame. The left mounting plate, chassisc 2 and spring pull rod were used to install the grass length adjustment device. The chassisc 1 and chassisc 2 could both move apart freely and locked together by the U type fastener.

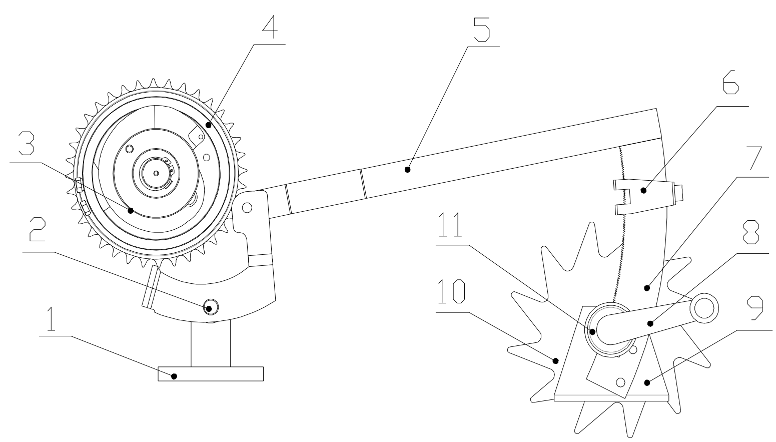


1. caster 2. chassis 3. drivetrain mounting plate 4. motor installing frame 5. knotter left mounting plate 6. knotter right mounting plate 7. pushing rope plate mounting desktop 8. knotter frame fixation 9. U type frame installing and positioning plate 10. chassis2 11.bale box 12. rope roller 13. bale box top pillar 14. rope chuck 15.rope installational axial 16. rope installational axial positioning plates 17. U type fastener 18. spring pull rod 19.left support plate

Figure 2 : The frame of the knotter

The knotter assistant devices

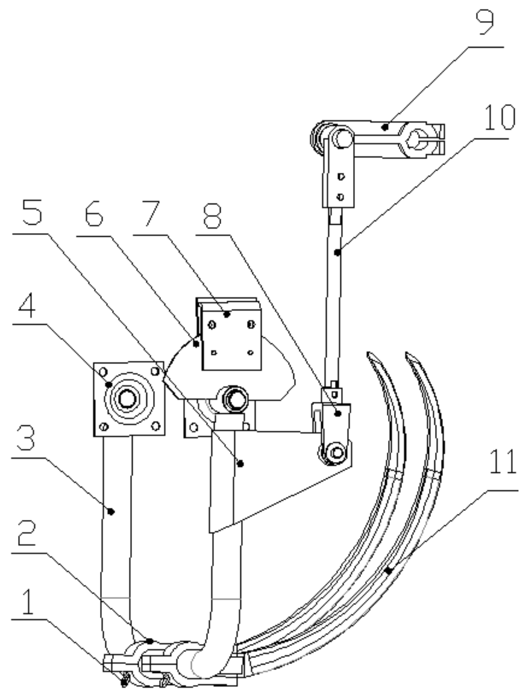
The knotter assistant devices consisted of the grass length adjustment device, delivering rope mechanism, rope transporting device in order to finish assisting knotting action.



1.cam baffle installing frame 2. cam baffle 3. clutch 4. spindle sprocket 5. bending connector 6. locking block 7. incomplete intraoral curved board 8. measuring axle manual crank 9. measuring wheel axle mounting base 10. measuring wheel 11. measuring wheel axle gear

Figure 3 : The grass length adjustment device

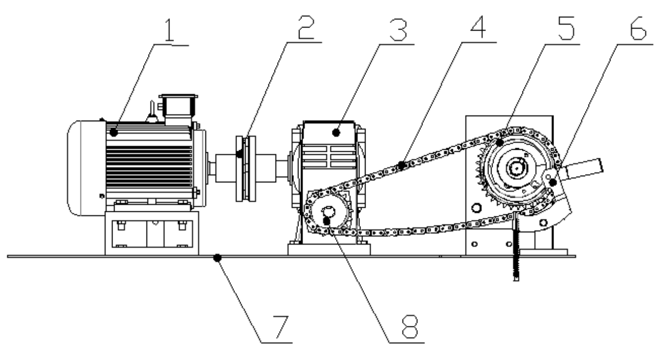
Figure 3 shows the grass length adjustment device. The grass moved forward in the box, turning the measuring wheel which was inserted into grass to drive the measuring wheel axle and measuring wheel axle gear. When the measuring wheel axle gear turned, the incomplete intraoral curved board moved upwards because the gear on the inside meshed the measuring wheel. When the measuring wheel axle gear was stuck into the slot of the incomplete intraoral curved board, the bending connector and the cam baffle rotated around an the cam baffle axle, closing the clutch, the sprocket and the knotter spindle rotating simultaneously to do the knotting action. When the action was done, the grass length adjustment device was returned by the return spring.



1.guide ring for string 2. knotting needle fixed base 3. U type frame 4. U type frame fixed panel 5. triangle plate 6. fan-shaped stopping slice 7. stopping slice splint 8. connector fork 9. delivering rope mechanism driven crank 10. connecting rod 11. knotting needle

Figure 4 :The delivering rope mechanism

The drivetrain



1. motor 2. coupling 3. reducer 4. chain 5. knotter spindle sprocket 6. cam baffle 7. drivetrain mounting plate 8. driving sprocket

Figure 5 : The drivetrain

The drivetrain power was supplied mainly by motor, the output speed was controlled by the admin console. The motor was connected with the coupling which was attached to the reducer. The reducer transmitted the power which the motor developed to the knotter spindle sprocket by the chain which was driven by the driving sprocket.

The selection and design of the important part

The selection of the motor

The speed of the knotter was 90r/min in normal operation. The motor rated speed was set as 144r/min to ensure spindle speed reached the rated speed. The spindle horsepower was 1.89 kw by calculating. 3kw motor and 0.1:1 accelerator was chosen according to the application conditions. Through the control of the admin console, the spindle speed could reach any speed within 90 r/min. the locking rate and the power consumption was calculated under different rotating speed.

The manual design of the device

Figure 6 : Manual crank of the knotting spindle

During the manual experiment, a detachable knotting spindle manual crank was installed on the delivering rope mechanism driven crank. The knotting spindle could rotate by shaking the crank, so the action of the whole knotter and the assistant devices could be researched under a low speed, which laid the foundation for research of new knotter.

The measuring axle manual crank was fixed on the ratchet axle as shown in Figure 3. The adjustment function of grass length could be achieved by taking off the manual crank during the experiment with grass. The simulation of the grass motion in the box could be achieved by shaking the manual crank during the experiment using grass without grass. When the measuring wheel axle gear turned, the measuring axle geared mesh the measuring wheel axle which moved the incomplete intraoral curved board, controlling the closing of the clutch through the bending connector and the cam baffle to make knotter spindle rotate with the spindle sprocket.

The design of the flywheel

The flywheel was added to make knotter axis rotation more steadier for the force the spindle withstands differently during knotting.

The belt pulley made of gray iron was used as the flywheel. According to known the gray iron density ρ =7.2 g/cm³ ,the outer circle radius of the belt pulley R=0.5 m, the inner circle radius r=0.46 m, spindle speed n=90r/min=1.5r/s, The outer circular moment of inertia, thin plate moment of inertia, belt pulley moment of inertia

The power was analyzed to estimate the selection of motor. The power is 1.4kw by the calculation, which was consistent with spindle power.

It was calculated following the corresponding equations:

Outer circular moment of inertia: $J_R = m_R r^2$

Thin plate moment of inertia: $J_r = \frac{1}{2} m_r r^2$

Belt pulley moment of inertia: $J_0 = J_R + J_r$

Angular velocity: $\omega = 2\pi \mathrm{n}$

Normal acceleration: $\alpha = \omega^2 \cdot \mathrm{r}$

Torque: $T = J_0 \cdot \alpha$

Power: $\mathrm{P} = \mathrm{T} \cdot \omega$

Where, r is the inner circle radius, R is the outer circle radius of the belt pulley, n is spindle speed, the gray iron density ρ is known,

The trial production and performance test of the knotting test-bed

Figure 7 : Picture of the knotter test-bed

By drawing three-dimensional model of the test-bed, the simulation of the test-bed was done to perfect the device. 1000 repeated experiment was made manually or in normal operation, the knotting rate was 99.4% and 99.6% respectively, the locking rate was 99.6%. The results of research of decomposition and experiment of the relationship among devices, knotting rate, the rope tension and the power showed that the knotter had reliable work and performance, the test-bed was capable of doing experiment and research about knotter.

CONCLUSIONS

(1) The design of the the knotting test-bed was improved from taking out the knotter of by adding manual device and slowing the knotting action.
The test-bed was applicable to the experiment of D type knotter, C type knotter and C-D type knotter, not only could be used as do research of the knotting action and the analyses of forces acting on the rope, but provided theoretical references of doing indigenous research, verify its capability and improve the interchangeability of each parts.

(2) According to national standards of reliability assessment methods for single knotter of rectangular balers, experiments were carried out and the results showed that rate of knotting and locking reached 99% and 100% respectively. The results showed that the knotter design was feasible and laid the foundation for further optimizing structure, working parameters and evaluation.

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