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Kinematic Simulation of Vibrating Disc No-till Seeder Based on Creo Software

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Abstract. In order to solve the problems of wheat no-till seeders in annual double cropping area of North China Plain such as large amount of straw-covering, stubble-bulky, residue-blocking, and bad passing capacity and planting quality, the new vibrating disc no-till seeder was designed. This paper analyzed the structure and elaborated the working principle. Creo software was used to establish three-dimensional motion simulation model, and add the constraints of seeder's parts to realize the movement of seeder and its anti-blocking device. The change of displacement, velocity and acceleration of vibrating disc was obtained by simulation. The result showed that there was no collision between components of the seeder, and the main circular motion occurred in y direction, which was beneficial to cut the straw. The study provides theoretical basis for the trajectory optimization and dynamics simulation analysis of vibrating disc no-till seeder in the future.

Keywords: vibrating disc no-till seeder, eccentric wheel, kinematics simulation, Creo software

1 Introduction

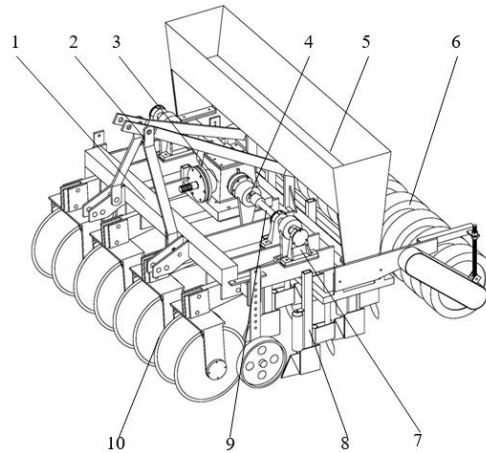
Conservation tillage that includes no tillage or reduced tillage and covered straw, is an advanced tillage technology, which can reduce soil and water erosion, and improve soil fertility and drought resistance ability [1-2]. In two crops one year of North China Plain, the main problem of conservation tillage includes that openers is apt to block and planter has bad passing ability and sowing quality during no-till planting, especially in the field with maize straw covering, the blockage problem is worse due to large amount of straw, stocky stubble and small-spacing wheat[3-4]. Hence, the key factor of designing wheat no-till planter is to solve the blockage of openers. At present, there are two main kinds of anti-blocking device for no-till planters: active and passive anti-blocking device. Passive anti-blocking device has weak anti-blocking ability, hence it is only suitable for field with small amount of straw, such as elastic claw anti-blocking device for no-till planter designed by Zhao Wuyun[5], reduced-tillage and covering planter developed by Liu Yinghui[6]; active anti-blocking device is suitable for field with large amount of straw, such as powered hammering blade no-till wheat seeder developed by He Jin[7], strip chopping anti-blocking no-till planter developed by Zhang Jinguo[8], active anti-blocking device has the disadvantage of higher rotary speed, strong vibration and noise, and bad safety.

At present, strip chopping anti-blocking no-till planter is common in the one year two crops areas of North China. For the planter, the straw in front of openers could be chopped by the anti-blocking device and mixed with soil; however, the planter has the advantages of large power consumption, low efficiency and heavy damage of soil structure. Moreover, straw and mulch threw by the rotary blade is apt to fall onto the seedbed, and blocks the openers [9-10].

To solve above problems, a kind of vibrating disc no-till seeder was designed. To discuss the motion regulation, the kinematics simulation analysis of anti-blocking disc, eccentric wheel and vibrating frame was conducted in this paper. The variation trend of response curve was analyzed to obtain visual effects. The study would provide reference for the improvement of planter performance.

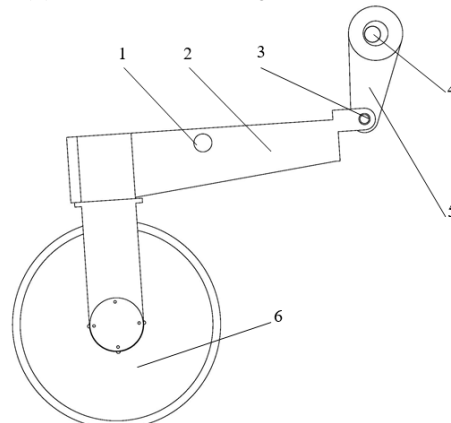
2 Structure and Working Principle of Vibrating Disc No-till Seeder

Vibrating disc no-till seeder was made up of vibrating disc anti-blocking device, frame, gear box, coupler, opener, soil packer, seed and fertilizer box and three point linkage, etc. and the key component of the seeder was vibrating disc anti-blocking device. The device was made up of crank axis, connecting rod in eccentric motion, bearing, working frame, pin roll and two discs, and the disc was installed directly in front of the openers, therefore a vibrating disc anti-blocking device serviced for two openers. Structure of vibrating disc no-till seeder was shown in Fig. 1.



1. frame 2. three point linkage 3. gear box 4. coupler 5. seed and fertilizer box 6. soil packer
7. bearing 8. opener 9. crank axis 10. vibrating disc anti-blocking device

(a) Structure of vibrating disc no-till seeder



1. pin roll 2. working frame 3. pin roll 4. crank axis
5. connecting rod in eccentric motion 6. disc

(b) Structure of vibrating disc anti-blocking device

Fig. 1. Structure of vibrating disc no-till seeder

When seeding, gear box was powered by tractor through cardan, the rotate speed was slow down by the gear box and transmitted to crank, and the crank rotated with a constant speed. Disc was driven to move up and down by crank-link mechanism and the straw and stubble was cut due to the movement of disc. The main function of the disc was to cut off the straw and stubble, loose soil and provide favorable condition for opener. Additional Information Required from Authors

3 Kinematic Simulation and Results

3D model of vibrating disc no-till seeder was established by Creo Parametric, and kinematically simulated in the Mechanism module. The simulation could detect the interferences between components, simulate the motion of key components, and obtain the trajectory, position, velocity and acceleration. The process of kinematic simulation was shown in Fig. 2.

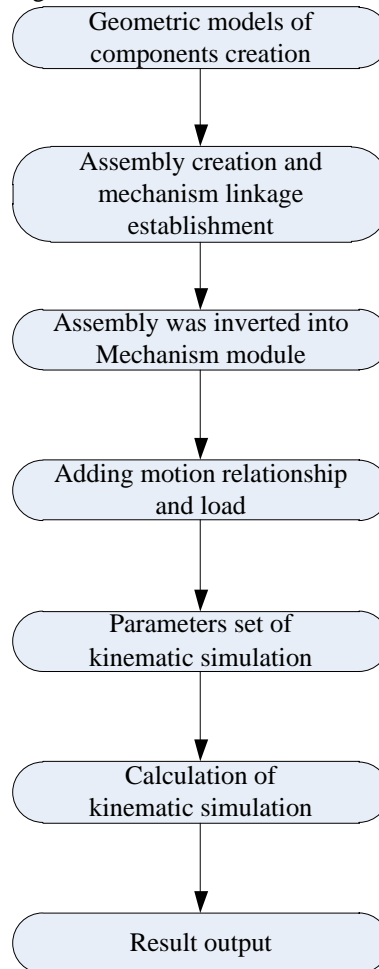


Fig. 2. Process of kinematic simulation in Creo Parametric

3.1 Geometric Modelling

According to the actual dimension of vibrating disc no-till seeder, the three-dimensional solid modeling drawing of components was created on the 1:1 scale, and assembly was established according to the mechanism linkage (Fig. 3).

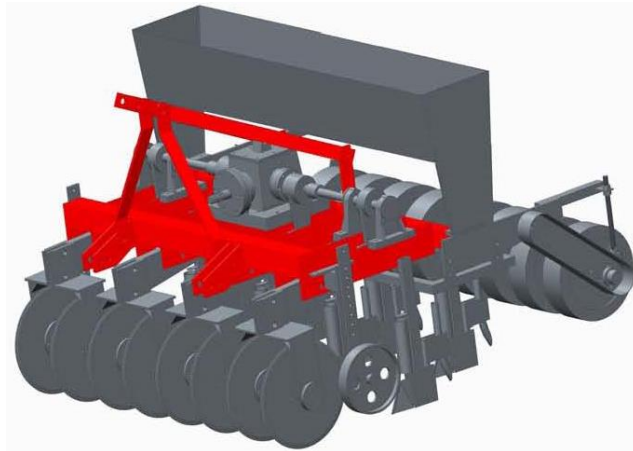


Fig. 3. Three-dimensional solid modeling drawing of the vibrating disc no-till seeder

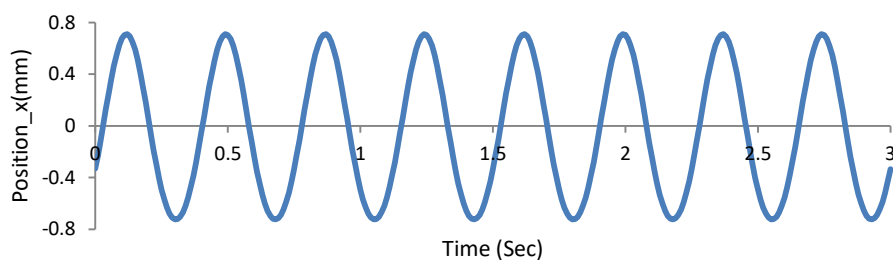
3.2 Kinematic Modelling

Three-dimensional solid modeling drawing of the vibrating disc no-till seeder was inverted into Mechanism module of Creo Parametric. The kinematic simulation included the steps as following: (1) Click the button “CONNECTIONS”, and set the motion relationship between output shaft of gear box and crank axis, crank axis and connecting rod, connecting rod and working frame, working frame and discs respectively; (2) Click the button “GEAR”, and set the meshing relationship between input shaft and output shaft of gear box. The tooth number in different gear was the same to simplify the motion structure. (3) Click the button “MOTOR”, select input shaft of gear box as the motion axis, and set the motor rotate velocity. (4) Click the button “MECHANISM ANALYSIS”. In the analysis, select “KINEMATICS”, set running time and click the “RUN” button, then the kinematic process would be observed. To analyze the kinematic parameters, the run result was saved. (5) Click the “REPLAY” button, select “GLOBAL COLLISION DETECTION”, “BELL ALARM AND STOP WHEN COLLISION”, and click “OK”. If there is collision, the structure is amended according to the reminder until the collision removed. (6) On the basis of the kinematic simulation without collision, click “MEASUREMENT”, select a point on the disc to measure the position, velocity and acceleration and output the result.

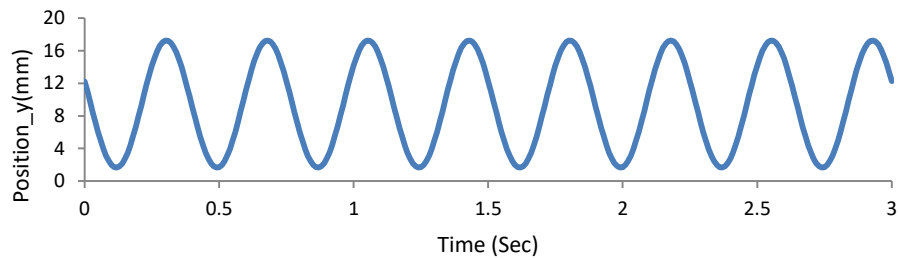
3.3 Result Analysis

1. In the process of collision detection, no bell alarm and stop occurred, which meant there was no collision between components of the seeder. In other words, the structure was rational.

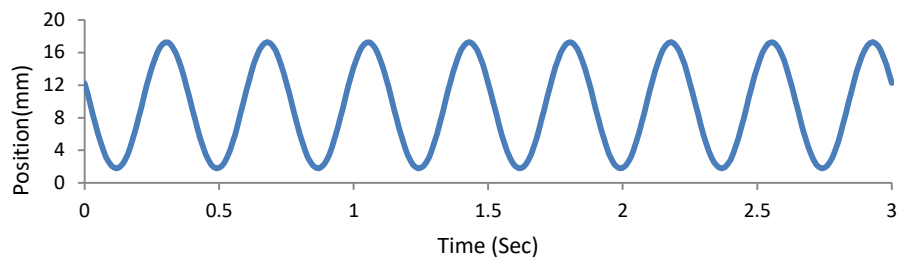
2. Set the motor rotate velocity 320 r/min, the endpoint of the disc was measured and the characteristic curve of velocity-time, velocity x direction-time, velocity y direction-time, acceleration-time, acceleration x direction-time and acceleration y direction-time in 3s were obtained (Fig. 4-Fig. 6).



(a) Characteristic curves of position in x direction and time



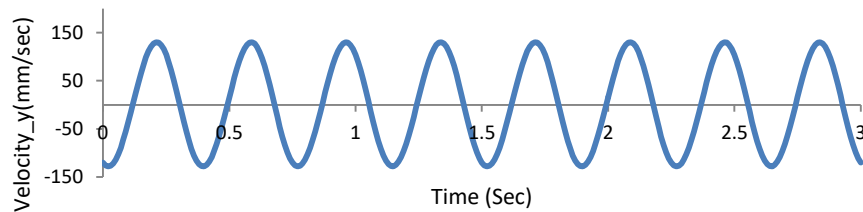
(b) Characteristic curves of position in y direction and time



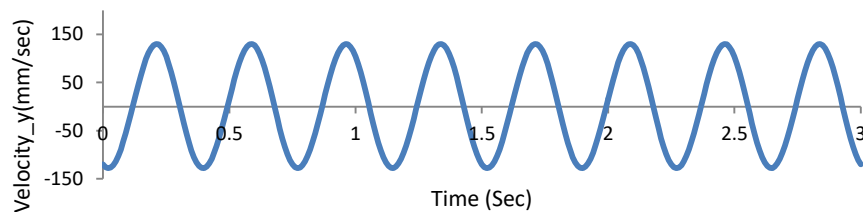
(c) Characteristic curves of position and time

Fig. 4. Characteristic curves of position and time for endpoint of disc

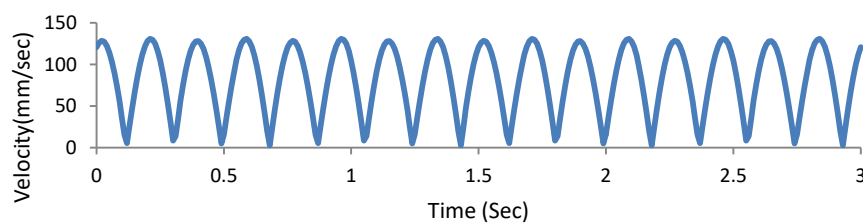
The position curve (Fig. 4c), position in x direction (Fig. 4a) and y direction (Fig. 4b) curve by time all assumed a sine distribution, the cycle was 0.375s (Fig.4). The variation range in x direction was -0.8mm to 0.8mm (Fig. 4a), and it in y direction was 0 to 20mm (Fig. 4b), which meant the main circular motion occurred in y direction. It was beneficial to cut the straw.



(a) Characteristic curves of velocity in x direction and time



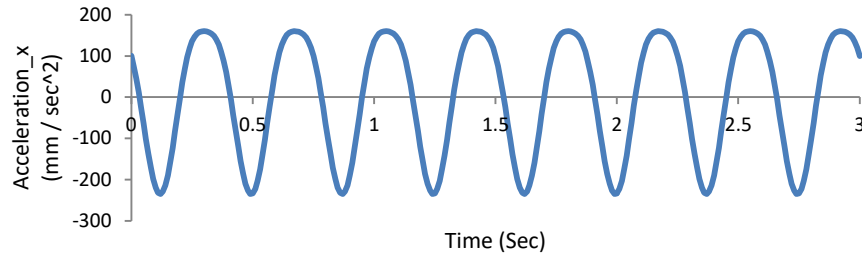
(b) Characteristic curves of velocity in y direction and time



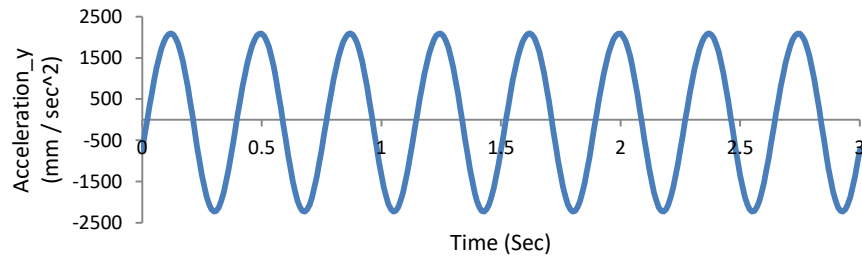
(c) Characteristic curves of velocity and time

Fig. 5. Characteristic curves of velocity and time for endpoint of disc

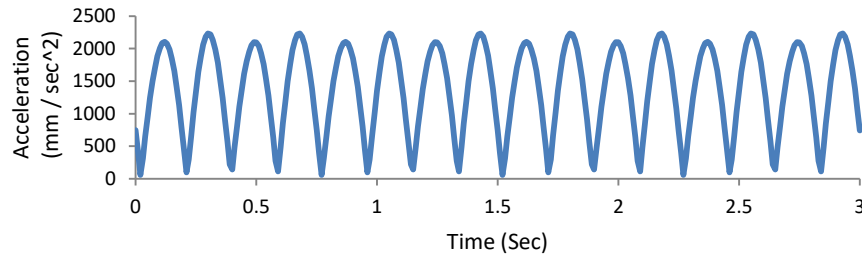
The velocity in x direction (Fig. 5a) and y direction (Fig. 5b) curve by time both assumed a sine distribution, and the cycle was also 0.375s (Fig.5). The variation range in x direction was -12mm/sec to 12mm/sec (Fig. 5a), and it in y direction was -130mm/sec to 130mm/sec (Fig. 5b), which meant the main velocity changes occurred in y direction. The result was the same with position curve variation. The combined velocity (Fig. 5c) curve by time assumed a half-sine distribution, and there were 16 cycles in 3s and the variation range was 3mm/sec to 131 mm/sec.



(a) Characteristic curves of acceleration in x direction and time



(b) Characteristic curves of acceleration in y direction and time



(c) Characteristic curves of acceleration and time

Fig. 6. Characteristic curves of acceleration and time for endpoint of disc

The acceleration in x direction (Fig. 6a) and y direction (Fig. 6b) curve by time also assumed a sine distribution, and the cycle was also 0.375s (Fig.6). The variation range in x direction was -235mm/sec² to 160mm/sec² (Fig. 6a), and it in y direction was -2200mm/sec² to 2100mm/sec² (Fig. 6b). The combined velocity (Fig. 6c) curve by time assumed a half-sine distribution, and there was 16 cycles in 3s and the variation range was 60mm/sec to 2300 mm/sec. The result was the same with velocity curve variation. The theoretical analysis showed that above results were rational. The collision existing in the structure could be detected, and the kinematic parameters and variation trend could be directly obtained through the kinematic simulation by Creo, which could provide theoretical basis for the design of no-till planters.

4 Conclusions

The vibrating disc no-till seeder was designed, and three-dimensional solid modeling drawing was established by Creo Parametric software on the 1:1 scale.

Kinematic simulation of vibrating disc no-till seeder was conducted by the Mechanism module of Creo Parametric. The collision analysis result showed that there was no collision between components of the seeder. In other words, the structure

was rational.

The variation regulation over time of velocity, velocity in x direction, velocity in y direction, acceleration, acceleration in x direction, acceleration in y direction for endpoint of disc was obtained by kinematic simulation. The result showed that the main circular motion occurred in y direction, which was beneficial to cut the straw.

Acknowledgment

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