INTERNATIONAL JOURNAL OF MECHANICS
DOI: 10.46300/9104.2023.17.3 Volume 17, 2023

Design and test of a new type of coupling weeder

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Received: May 29, 2022. Revised: January 11, 2023. Accepted: February 17, 2023. Published: March 13, 2023.

Abstract—In order to improve the efficiency of mechanical weeding and reduce the injury rate caused by work. This paper improves the shortage of traditional weeding machinery, and designs a new combined mechanical weeding device by optimizing the internal structure and increasing the operation function. In this device, the structure of the cutter tooth is optimized and the operation function is added. Secondly, the effect of the weeding is further enhanced by increasing the flame nozzle. Finally, the finite element analysis of the blade and the nozzle is carried out by CFD and COMSOL software, and the rationality of the improvement is explained. The field weeding test showed that the average weeding rate of the machine was 86% and the rate of injured seedlings was 3.5% under the conditions of different advancing speed (0.5, 1, 1.5m/s) and the soil depth of the weeding wheel (3, 6, and 9cm). According to the speed and width of the machine, the efficiency of the machine is 0.7~2hm2/h. The collection performance and operation efficiency meet the technical requirements of weeding operation in dry field machinery. Through the comparison test of mechanical weeding, heat weeding and the effect of combined mechanical weeding, the efficiency of combined mechanical weeding in the test area is higher than that of other weeding methods. This study can provide a reference for the effect of weeds treatment on the dry field weeding machine.

Key word—Agricultural machinery; Finite element analysis; Mechanical weeding; Flame equipment; Curved cutter tooth

I. INTRODUCTION

Weed in field is one of the main factors that affect crop growth[1,2].It is reported that the loss of crops caused by weeds is a great loss. The annual crop reduction caused by grass damage is about 15-20%[3]Therefore, effective prevention and control of weeds in rice fields is of great significance for improving crop yields.

Crop weeding is mainly based on chemical weeding, but a large number of high frequency pesticides will cause[4,5], such as weed resistance, soil hardening, environmental pollution and so on.In recent years, with the expansion of crop production, an effective non chemical weeding method is needed to control weed[6,7]in the field.There are some non chemical weeding methods such as mechanical weeding and heat weeding, and mechanical weeding is a kind of weed free method without chemical pollution and good environment. It can also loose the soil in the field, thus increasing the oxygen content of the soil and promoting the growth of the cro [8,9].Hot weeding is a kind of weather free, easy to operate, faster and cheaper[10] than manual weeding.But the technology of weeding in China is low and the weeding way is simple. There are various problems in practice.Therefore, the research of new crop weeding machine is of great significance.

A lot of researches have been done at home and abroad.The hob type weeding rake in the United States has the working parts along with the machine, driving the axis of the knife, cutting the root of the blade on the edge of the cutter, and realizing the purpose of weeding, the efficiency of weeding is high, and the power

consumption is small.The JD886 interrow management weeding machine in the US has adjustable seedling guard plates, which can effectively protect crop[11] during weeding.Germany has developed a machine for removing wheatgrass, which uses grasses and grips to rake the deep surface. The ice grass has been pulled up and plucked to feed pigs or [12].Because of various factors such as planting mode, land condition and economic development, most of the[13-15] of the weeding machinery in foreign countries are tractive, and the working face is very large and the efficiency is high.Its structure and performance are not in line with China's national conditions.Liang Yuan et al. Combined with the key techniques of farming and weeding, and designed an all directional ploughing machine[16] with 59.2 to 88.9kW series of tractors that can be completed in one time, such as deep loosening, side deep fertilization and intelligent measurement, interline and intershoot weeding.The 5ZSC-50 type hand loosen weeding machine developed by Liaoning State Forest Farm administration has solved the problem of large amount of weeding and high cost. [17].The 3ZS-2 type weeding machine, developed by the Scientific Research Institute of agricultural machinery engineering of Heilongjiang Province, is based on the frame of GTX-2/3 type small general-purpose tillage machine, and the field weeding [18] is carried out by the vertical double disc herbicidal components.Zhou Fujun and others developed a cam rocker swaying corn weed removal device to improve herbicidal efficiency, but the labor intensity was [19,20].There are still many problems in the domestic mechanical weeding [21-24], such as high rate of injury, poor quality of weeding and low efficiency of operation.

In order to improve the efficiency of mechanical weeding and the quality of mechanical weeding and reduce the rate of injured seedlings, this paper optimizes the internal structure on the basis of the original weeding machine and combines with the flame system, so as to realize the plant weeding joint operation machinery. After that, the weeds test model is established by Sholdworks and COMSOL software, and the comparison of the experimental data is made. Finally, the results are analyzed and the conclusion is drawn.

1 whole machine structure design

1.1The structure and working principle of the whole machine

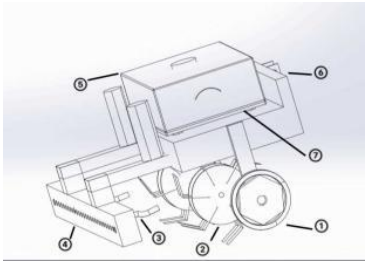
The joint mechanical weeding structure developed in this paper is mainly composed of tractors, adjustable wide adjustable bracket, hydraulic regulating system (including electromagnetic valve, oil tank velocity, hydraulic cylinder), cutter tooth weeding wheel and flame control system.

1) powered by the Oriental red tractor, the power is about 15kw (rated power).2) control by controlling the opening and closing of the solenoid valve to control the expansion of the hydraulic cylinder.3) the whole frame is mainly welded by a long x width x thick 2080mmx1085mmx261mm rectangular plate with a long cross section. It is connected with the rear suspension system of the tractor chassis and is equipped with a spring tightening device.4) the flame system is composed of capacity 200L oil tank, nozzle, control valve and so on. It uses the burner of liquefied petroleum gas to remove the grass and control the intensity of flame through air pressure.

The height of the weeding wheel is adjusted according to the height of seedling growth before the work, so as to prevent the frame from pressing seedlings.The hydraulic lifting system is adjusted to meet the requirements of weeding depth in different fields.When working, the machine implements a certain speed and controls the expansion of the lateral adjustable hydraulic cylinder to control the movement of the inner sliding beam, so as to achieve the left and right wing weeding wheels.The machete gear is rotated with the transmission device. In the process of rotation, the machete is first cut down to the soil to cut the weeds, and the root and soil are turned into shear and tilling to complete the preliminary weeding operation.To start the flame system, the flamethrower swiftly aligns the weeds under the cutting of the knife teeth. By heating the water in the plant tissue to control weeds for two weeding operations, this effect can effectively kill all types of weeds and improve the quality of herbicide and soil organic matter.

1.2 The 3D modeling ofweeding wheel

Solidworks software is used for 3D modeling of weeding machine.First, the various parts of the weeding machine are created, and then the modeling parts are assembled.First create the assembly, insert the components, use the command to define the constraints, and finally complete the 3D modeling of the weeding machine, as shown in Figure 1.



1. Tires 2. Weeding wheel 3. Flame nozzle 4. Flame device 5. Natural gas tank 6. Traction bolt 7. Tank pipe opening

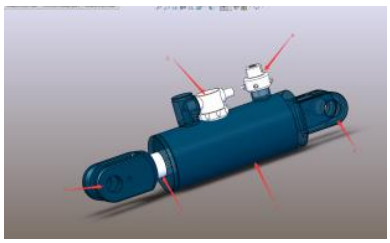
Fig. 1 3D model of weeding machine

II. MATH

2 key components design

2.1 hydraulic control system design

Based on the tractor system, the hydraulic control system of the whole machine is designed, including oil tank, filter, hydraulic cylinder, electromagnetic valve and other components, as shown in Figure 2.



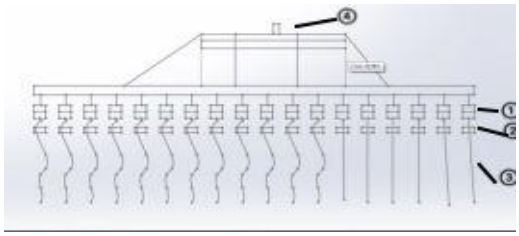
1. Connecting end 2.expansion link 3.ram pot 4.Connecting port 5.filter 6. electromagnetic valve

Fig. 2 hydraulic regulating system

When working, start the tractor, connect the end to connect the cutter head, and control the rear suspension system by manual adjustment control valve, so that the machine is at the right height. By controlling the movement of the piston rod of the hydraulic cylinder, the weeding wheel on the two wing frames can be moved horizontally. When the machine is walking in the field, according to the distribution of weeds, the weeding parts are controlled in real time to avoid the seedlings and control the intensity of the flame.

2.2 wide frame frame design

In order to improve the working efficiency and reduce the number of turning of the ground [25], the whole machine is designed to configure 18 weeding wheels, the distance between the weeding wheels is 0.3m, the length of the frame is 5.5m, and the frame is divided into the middle frame, the left and the right wing, each installation of 6 weeding wheels.hen working with the tractor, the two wings are running on both sides, and the position of the herbicide wheel can be adjusted at any time. The map of the wide frame is shown as shown in Figure3.the rear suspension system of the tractor is about 0.45M from the ground and the overall height of the rack is 0.5m.



1. Weeding wheel trace 2. flame sprinkler marks 3. Weeding trace

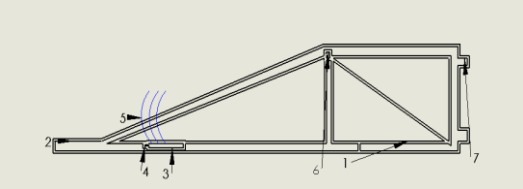
Fig. 3track diagram of weeding wheel

In order to facilitate transportation, a hydraulic cylinder is used to connect the middle frame and the wing frame, and the wing frame is expanded and closed through the extension and contraction of the piston rod of the hydraulic cylinder.To some extent, the working state can balance the torque caused by the resistance of the weeding wheel.

2.3 horizontal adjustment frame design

The combined mechanical weeding machine designed in this study can handle 9 groups of work 1 times per work. In order to prevent the change of the position of the group seedlings, the blade of the herbicide wheel can be prevented. The lateral adjustment device is designed on the two wing frames, and the position of the weeding wheel is adjusted in real time during the work.The adjustment mode is based on each weeding wheel and row spacing, and the square tube is inserted into the supporting beam under the wing frame as sliding beam. The rectangular groove of 180mm is used for the installation and sliding of the herbicide wheel on the wall surface of the lower wing of the wing frame, and the transverse adjustment of the

two ends of the hydraulic cylinder is connected to the supporting beam and the sliding beam respectively, and the telescopic control of the hydraulic cylinder is controlled by the sliding beam. The [26] of the lateral position of the weeding wheel is achieved by sliding, as shown in Figure 4.



1. Transverse sliding beam 2. Supporting beam 3. Transversely regulated hydraulic cylinder 4. Weeding wheel mounting port 5. Oil pipe 6. Hydraulic cylinder base 7. Sleeve

Fig. 4 hydraulic structure

The wing is equipped with 6 weeding wheels, by calculating the M= (p*a (2xC+b) /L) material 36a I-steel and span 4.5m, and the load is safe to use within two 80KN.In order to make the sliding beam slip normally, it is necessary to select a hydraulic cylinder that meets the requirements. This design selects a double acting hydraulic cylinder, whose model is CDT3. According to the actual situation at any time, the manual control of the hydraulic rod is used to adjust the left and right sides.

2.4Design of flame nozzle

The flame and thermal space distribution of different types of nozzle flame herbicides are different. The circular nozzle produces a long and narrow flame, which is suitable for the removal of grass with selective heat sensitive crops.Wide sprinkler generates short and wide flame, which is evenly distributed and suitable for weeding.When working, the sprinkler is usually above the ground and the angle of 10-20cm to the horizontal plane is 22.5-45.0.In the process of weeding, the flame nozzle is at the bottom of the machete gear, and the working temperature can be controlled by changing the pressure and speed to achieve a more comprehensive coverage and faster driving speed.

The flame system is equipped with 18 flame sprinklers, each of which corresponds to a flame sprinkler after each weeding wheel, and a panel behind the sprinkler prevents weeds and Mars from extinguishing the fire.When working, the weeds weeded by the weeding wheel will roll back according to inertia, and the flame system will be directly aimed at the fire, so that the deep damage can be prevented early and prevented from retrogradation.

2.5Design and analysis of flame system

In order to prevent the change of the position of the herbicide wheel in order to prevent the flame injury from the change of the position of the herbicide wheel, it is necessary to adjust the position of the flame tube in real time during the working process.The adjustment mode is based on each weeding wheel and the flame tube, and the square tube is inserted into the supporting beam under the frame of the flame as the sliding beam. The rectangular groove is used for the installation and sliding of the weeding wheel at each interval of 180mm on the wall surface of the lower frame of the frame, and the two ends of the hydraulic cylinder are connected to the supporting beam and the sliding beam respectively, and the other end is connected with the automatic spring.Control the expansion and control of the hydraulic cylinder to control the lateral slip of the sliding beam so as to realize the lateral position adjustment of the flame tube. At work, the flame is ignited by igniting the gas, and the red represents the normal temperature. The test can be carried out normally, as shown in Figure 5.

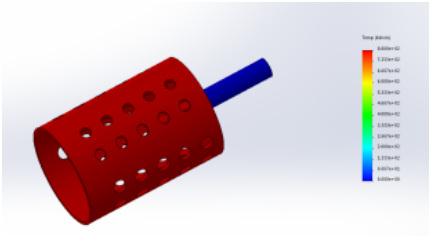
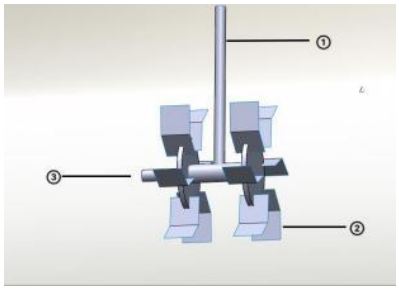


Fig. 5temperature analysis diagram

2.6Design of a herbicide wheel

The weeding unit is the key part of the weeding machine. In order to realize the [27-29] of the small power tractor, the work resistance of the herbicide wheel is small and the soil disturbance is strong.According to the analysis of soil mechanical properties, we can see that the soil has strong shear resistance and can not shear the soil in shorter stroke.Therefore, the design of the dust removal gear is a streamlined cutter tooth. On the basis of making full use of the small cutter tooth resistance and easy to shear the disturbed soil, the action area of

the soil is increased and the soil resistance is reduced and the service life of the cutter tooth is increased.Using a machete steel sheet as a tool tooth material, the tooth edge grinding edge is used to increase the shear capacity and rotate around the axis to increase the effective area of the soil, and the welding is embedded in the wheel plate, as shown in Figure 6.



1.connecting link 2.stermline cutter tooth 3.live shaft

Fig. 6 structural chart of weeding wheel

Finite element analysis of cutter teeth

The weeds growth environment is more complicated by the finite element analysis of the herbicide wheel, and the necessary theoretical model [30,31] is lacking in the finite element analysis. It is difficult to make a comprehensive analysis of weeds, soil and weeding wheels.Therefore, this section indirectly studies the performance of weeding wheel by studying the force and displacement process of weeding wheel and soil.

Mechanical weeding generally destroys the soil in the field, so the analysis object of the herbicide wheel should be the mixture of the cutter tooth and the soil. The mesh wheel grid adopts the Lagrange algorithm, the material is 316L stainless steel body material, the pressure N perpendicular to the slope and the friction force F along the direction of the edge of the blade surface, and the mechanical model of the force analysis, such as As shown in Figure 7:

$$P = \mathrm{pb} = 2\,phtg\theta$$
$$P = 2(N\sin\theta + F\cos\theta)$$
$$F = \mu N$$

In the form: μ-Friction coefficient of soil and cutter teeth; p-Impact force; P-Unit force; b-The width of the plunge in the part；h-The knife teeth plunged into the depth; θ-The blade angle of the cutter tooth;

By formula (1)

$$N = \mathrm{pht}g\theta/(\sin\theta + \mu\cos\theta)$$
$$F = \mu phtg\theta/(\sin\theta + \mu\cos\theta) \quad (1)$$

Mechanical analysis (Fig. 7) shows that pink represents uniform pressure and does not affect the test.

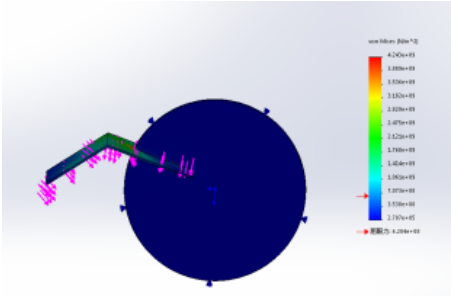


Figure 7 Mechanical analysis diagram

3.Field experiment and result analysis

3.1Test conditions and index setting

The field weed control effect in Taigu experimental field was compared.Herbicidal experiments were conducted with herbicidal rate of Cr (%) and seedling injury rate of Ir (%).among

$$C_r = Z\text{-}S/zx100\% \quad (2)$$
$$I_r = I/M\ x100\% \quad (3)$$

Z is the total number of weeds in the test area, and S is the total number of remaining weeds in the test area after the weeding operation, and the number of I is the number of damaged, uprooted and lodged in the experiment area after the weeding operation, and M is the total number of the total seedlings in the test area.

3.2experimental design

3.2.1Selection method of weeding machine

Three 15kw tractors of the same type were selected to connect ordinary machinery (including common herbicidal knife teeth), thermal herbicidal machinery and combined herbicidal machinery.

3.2.2Herbicidal test method

9 20m long regions were selected as the test area, and each area reserved for 4m long before and after each test area was used as a safety area to ensure that the machine could enter and pass the test area in a stable state. In the test area, 2 two rows of x10m were randomly selected for 3 testing areas, and the weed control rate and seedling rate in the 3 test areas were statistically analyzed.

The full factor test method [32] was used to select the speed of the weeding machine and the soil depth of the weeding wheel [33] as the test factor, and the performance of the weeding machine was tested in the field.0.5m/s, 1m/s and 1.5m/s are selected for the advancing speed. The depth of the weeding wheel is selected 3, 6, and 9cm. The depth of the earth is designed to be 100mm based on the radius [34,35] of the herbicide wheel. When its depth exceeds the radius, the soil will block the rotation of the weeding wheel. Therefore, the maximum soil of the weeding wheel is 90mm, and the cutter tooth can be stabilized in the test. The soil depth of soil minimum test is 30mm.

3.3Results and analysis

3.3.1Analysis of test results

Table 1 Mechanical weeding test

Test number	Speed of advance m/s	Weeding wheel depth cm	Weeding rate %	Seeding injury rate %
Mechanical weeding	0.5	3	81.7	3.5
Mechanical weeding	0.5	6	83.5	3.8
Mechanical weeding	0.5	9	83.0	7.5
Mechanical weeding	1	3	81.6	7.4
Mechanical weeding	1	6	87.2	3.0
Mechanical weeding	1	9	92.0	4.3
Mechanical weeding	1.5	3	79.6	8.7
Mechanical weeding	1.5	6	72.6	7.1
Mechanical weeding	1.5	9	76.8	8.0

According to the results of Table 1, the main factors affecting herbicidal rate are speed of machine and depth of weeding wheel.As machine speed increases, weeding takes the lead and then decreases.As the herbicide wheel is driven by the driven rotation, the speed of the rotating speed is proportional to the speed of the machine. When the speed is slow, the capacity of the soil is weak, the rate of weeding is lower, the speed of the machine is increased, the rate of weeding is rising, and the highest in 1m/s is reached.And too fast will cause the grass wheel to slip, and the insufficient soil will lead to the decrease of weeding rate.With the increase of the soil depth of the weeding wheel, the area of the weeding wheel and the soil increased and the capacity of the weeds increased, so the rate of herbicide continued to rise and reached the highest in 9cm.

The primary and secondary order of the factors affecting the injury rate was the speed of the machine, the depth of the weeding wheel.With the increase of machine speed, the rate of seedling injury continues to rise, because with the increase of the speed of the machine, the weeding wheel is not accurate enough to cause injury.The soil depth of the weeding wheel has a certain influence on the injured seedlings. When the depth of the soil is larger, the probability of the action of the herbicide wheel and the seedling root system increases and the rate of the injured seedling rises.

Table 2 Mechanical weeding test

Test number	Speed of advance m/s	Weeding wheel depth cm	Weeding rate %	Seeding injury rate %
Joint mechanical weeding	0.5	3	93	4.2
Joint mechanical weeding	0.5	6	93.2	5.8
Joint mechanical weeding	0.5	9	94	6.7
Joint mechanical weeding	1	3	92.5	4
Joint mechanical weeding	1	6	96.4	4.2
Joint mechanical weeding	1	9	97.1	5
Joint mechanical weeding	1.5	3	89	8
Joint mechanical weeding	1.5	6	82.6	7.4
Joint mechanical weeding	1.5	9	84.2	7.9

The results of Table 2 analysis show that the flame intensity is constant. When the speed is slow, the time of the action of the flame and the weeds increases, and the destructive power of the weeds is enhanced, so the highest rate of grass is rising in 0.5m/s.The increase of the speed of the machine will result in the short time of flame spraying weeds and the insufficient internal structure and organization, resulting in the decrease of weeding rate.With the advance of machine speed, the rate of seedling injury continued to decline. Due to the increase of machine speed, the contact time between flame sprinklers and rows of seedlings was short. When the speed is slow, the duration of the flame intensity is longer, which increases the probability of seedling root interaction and increases the seedling injury rate.

Table 3 combined mechanical weeding test

Test number	Speed of advance m/s	Weeding wheel depth cm	Weeding rate %	Seeding injury rate %
Fire weeding	0.5	0	92.5	4
Fire weeding	1	0	87	2.5
Fire weeding	1.5	0	86	1.5

According to the results of Table 3, too fast speed will cause slippage of the weeding wheel, insufficient soil and short time of weeds, resulting in a decrease in weeding rate.With the increase of the soil depth of the weeding wheel, the area of the weeding wheel and the soil increased and the capacity of the weeds increased, so the rate of herbicide continued to rise and reached the highest in 9cm.The dust removal rate and seedling rate under different factors were taken into consideration, and two groups of better combinations were obtained according to the technical requirements of the weeding machine quality in the technical specification for the quality evaluation of the weedling machine.The speed of advance is 1m/s, and the depth of weeding wheel is 6cm. At this time, the weeding rate is 96.4% and the seedling rate is 4.2% ; The speed of advance is 0.6m/s, the depth of weeding wheel is 9cm, the herbicidal rate is 97.1% and the injury rate is 5%.

The average weeding rate of the machine is equal to that of the machine with different advance speed and depth of weeding wheel.The average weeding rate of the machine is equal to that of the machine with different advance speed and depth of weeding wheel. At the same time, according to the speed and width of the machine, the efficiency of the machine can be measured to be 0.6~1.8hm2/h, which meets the requirements of the quality and efficiency of mechanical weeding.

V. CONCLUSION

(1) develop a combined mechanical weeding machine, which is powered by tractors.The hydraulic cylinder is used to adjust the wide frame to realize the lateral adjustment of the position of the herbicide wheel. The weeding wheel, the flame jet and the soil and the weeds are used to weed out the weeds ; It needs no power transmission structure, simple structure and easy operation ; Long frame length can reduce frequent turn around and increase efficiency.

(2) this machine has designed a hydraulic driving two wing lateral adjustment mechanism, which has solved the problem of different seedlings in the process of weeding ; Combined with the soil mechanics characteristics and the existing weeding wheel structure, a cuttine knife tooth weeding wheel is designed and analyzed by finite element method.This machine is equipped with flame mechanism, and has high safety when working. The baffle plate can protect and extinguish fire, and can effectively adapt to different environments.

(3) the performance test of the whole machine was carried out respectively. The results of the experiment showed that the rate of weeding was higher than that of other machinery. This study laid a foundation for the design and application of weeds treatment in dryfield weeding machines.

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