Development of 1SG-230 Type Intelligent Rear-Mounted Subsoiling and Rotary Tillage Combined Machine for Sugarcane Field

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Keywords: Rear-mounted, rotary tillage, Subsoiling, Combined machine, Intelligent deep pine detection system.

Abstract: In view of the fact that in the sugarcane planting area in southern China, the plow foundation is mainly plowed and the hard plow bottom is formed, and in recent years, there are some problems such as the soil adhesion of soil components, crop stalks and other jamming tools and the high energy consumption of the machine tools in the implementation of conservation tillage techniques. Based on the above problems, we designed the 1SG-230-type rear-mounted subsoiling and rotary tillage combined machine. In this paper, we design and analyze the key components such as the overall mechanism of machine tools, rotary tillage and deep pine, etc., and evaluate the performance of the machine in field experiments with the intelligent subsoiling system.

1 INTRODUCTION

Tillage land operations in sugarcane fields usually use tillage, raking and compaction tillage processes (Qin-Fenglan, 2014; Luo-Quan, 2015). However, long-term mechanical tillage makes the soil form a hard plow bottom, the soil water storage capacity drops, the root of the sugarcane can 't be dug deep and is prone to lodging . Therefore, it is imperative to carry out deep loose soil preparation technology in sugarcane fields. Although the technology of deep loose land preparation machine developed in the north of China is relatively mature, it can 't be used directly in the south because of the large soil viscosity, the abundance of weeds and crop straw, the more stones and so on. According to the conditions of cultivated land and the agronomic requirements of tropical crops in hot areas of China, the compound deep loosening land preparation machinery suitable for agricultural production in hot areas should be designed (Xu-Shucai, 2007).

Therefore, the project team in this paper developed 1SG series deep loosening rotary tillage combined machine for the cultivated land conditions in tropical areas of southern China (Wei-Lijiao, 2013), which initially overcome the problems of soil specific resistance and sticky in the southern hot area. However, the research group in the promotion of the use of equipment found that: tropical crops such as straw, weeds and more serious winding plugging equipment. In order to solve this problem, based on the original model, this paper designed a rear-mounted subsoiling and rotary tillage combined machine. First, the machine smashes the topsoil with a rotary cutter, and then uses the subsoil plough to work on the soil layer after the rotary plowing. In this way, the power consumption and clogging of the implement are greatly reduced. Combined with the national subsoiler job subsidy needs, the developed equipment has installed the intelligent deep loosening detection system, which greatly improves the efficiency of the operation subsidy.

2 MACHINE STRUCTURE AND WORKING THEORY

1SG-230 type rear-mounted subsoiling and rotary tillage combined machine for sugarcane，it is mainly composed of three-point suspension racks, racks, gearboxes, deep loose parts, rotary cutter shaft, movable pallet, cover. The machine is shown in Figure 1and the main technical parameters are shown in Table 1.

Wei, L., Li, M., Dong, X., Huang, W., Li, B. and Yan, X.
Development of 1SG-230 Type Intelligent Rear-Mounted Subsoiling and Rotary Tillage Combined Machine for Sugarcane Field.
In *3rd International Conference on Electromechanical Control Technology and Transportation (ICECTT 2018)*, pages 632-636
ISBN: 978-989-758-312-4

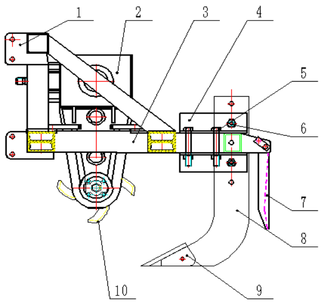


Figure 1: Overall design diagram.

Table 1: Main parameters of machine.

Name	Parameters
Dimensions（Length Width Height, mm）	2500×1350×1250
Supporting Power（kw）	88.3~102.9
Machine Working Width（cm）	230
Subsoil plough Number	4
Number of Blades	Around each 24
Rotary Depth	20cm
Subsoiling Depth	≥35cm

3 DESIGN OF KEY PARTS OF THE MACHINE

3.1 Design of the rotary tillage components

3.1.1 Design of rotary cutter shaft

In the process of machine design, there are some main factors of the design of the rotary cutter shaft which clogging by sugar cane leaves, weeds and other residua. The first factor is the small outer diameter of the rotary tillage shaft will easily entangled sugarcane leaves, weeds and so on. The second factor is the rotational speed of the rotary tiller shaft will not have enough power to cut off the straw. At the same time, the centrifugal force produced is not enough to remove the stubble of the soil. The third factor is weeds are easily entangled when the knife seat is too dense.

3.1.2 The selection and installation of rotary tiller .

According to the characteristics of sugarcane field, the type of the rotary cutter is used for the type of machete. The machete consists of a tangent part and a side part. When the machine works, the left and right machetes are used in combination, and the skid cutting performance is good. When the machine is working, the blade of the machete is cut into the soil by the distance from the center of the blade to the center of the blade so as to cut off the weeds and cut off along the cutting edge. This kind of machete is suitable for use in tropical weeds. The rotary tiller is uniformly arranged in a double helix along the axis of the two parts of the cutter shaft. The cutter seat is opposite in the direction of the left and right half axes, as shown in Figure 2, and the position is symmetrical to ensure the balance of the whole force of the cutter shaft. In order to make the angle of the cutter seat should not be too small, the spacing of the cutter seat should be larger.The number of the design of the machine rotary blade is up to 48 (general rotary tiller is up to 62).

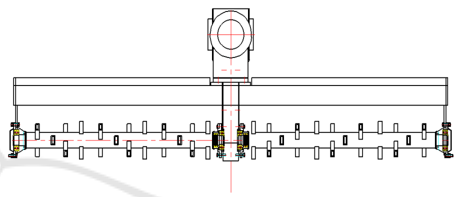


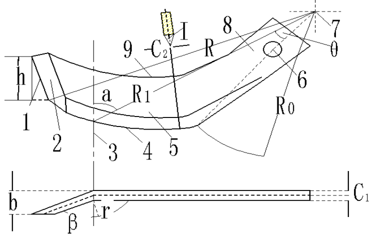
Figure 2: Arrangement of the rotary blade holder.

3.1.3 Determination of the parameters of a machete rotary tiller

According to GB / T 5669, the shank of a machete has two kinds of wide (T) and narrow (S), of which a wide type has a bolt hole and a narrow type has two. According to usage, there are three types of machete, I, II and III. Among them, No. 2 scimitar is mainly used in fields with green manure and more straw. The gyration radius is 195mm, 210mm, 225mm, 245mm and 260mm. The structure of the machete is shown in Figure 2, the work location is tangent and side cut, and one side edge of the arc by Archimedes spiral design (Tang-Jintao, 2014), its function is cutting straw and soil. The function of the side cutting edge is to cut the straw and the soil.The blade body and the tangent part of the scimitar has certain angle, and its function is to throw the soil (Zhu-Liuxian, 2012; Zhang-Lang, 2015).

3.1.4 The main parameters of IIT245 type blade .

The machete knife roller slewing radius R=245mm, the side edge of the initial radius of R0=143, the side edge of end point radius R1=228mm, the cutting edge of the blade wrap angle θ=27° ,the working width b =40mm, the height of the face of the tangent h=45mm, the radius of the tangent section r=30mm, the angle between the end radius and the bending line of the side sectiont a=48° , the tangent bending angle β=120° , the width of the top surface of the side cutC_l=4mm, the Cutting edge thickness C_2=2mm, the edge width I=12mm.



1.Tangent blade;2.Tangent;3.bend fold line;4.side edge line; 5.lateral incisor; 6. Install holes ;7. tool roller center; 8. Knife handle; 9. Back margin

Figure 3: Structure of rotary blade.

3.2 Design of deep loose components

The loosening process of subsoiling plough in soil can be seen as a simple wedge model put forward by Mackis (He-Jin, 2005). The geometric model as shown in Figure 4. The area size of deep loose plough is positively correlated with depth S, plough width K and wedge inclination μ. However, the soil disturbance range does not increase obviously when the depth of deep loosening S exceeds the critical value. It is necessary to avoid excessive traction resistance while ensuring the range of soil disturbance, so the value of relevant parameters should be reasonable (Wu-Haitao, 2013).

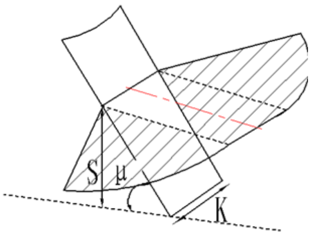


Figure 4: Model of scarifying soil by wedge.

In order to better select the shape of subsoil plough and analyze the influence of plough shape on subsoiling performance more intuitively. Based on the Solidworks software, the circular, obliqueness and no dip deep loosening plough models are established, and three sets of simulation tests of A, B and C are established by using the dynamic analysis program. Simulation of the movement of three kinds of subsoil ploughs in the soil when the speed of advance is 0.7m/s. Among them, the soil model of the deep was 50 cm, the length was 70 cm and the width was 15 cm. The size of the three ploughs is the same. The height was 70cm, the thickness was 3cm, the length of plough was 3cm, and the width of plough body was 11cm.The model was imported into ANSYS, and the rough grid was selected. The time of setting the problem was 1S. After completing the operation steps of LS-DYAN solver, it was saved as K file. The average time spent in the three sets of simulation experiments was 1143 seconds, and the simulation results were checked in LS-PrePost4.0 program.

Because the soil attribute is defined by ordinary plastic model, it can not fully reflect the characteristics of latosol. But in the process of simulation, the deformation of three kinds of wedges with different shapes can be studied when they cross the same plastic object at the same velocity. In 0.75S, the C model in the plastic body in the maximum displacement of YZ plane, followed by the B model, the A model of the minimum displacement ， they are shown in figure 5 to 7, so the soil disturbance ability are no inclination, obliqueness, arc type deep loose plough. Accordingly, plow stress increases. In order to ensure a certain amount of soil disturbance and avoid large traction resistance, the type of plow body is chosen to be obliqueness.

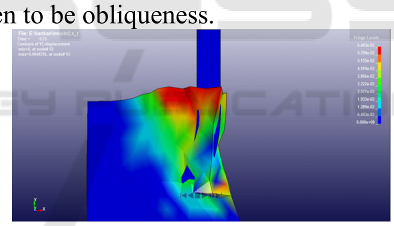


Figure 5: A model YZ surface displacement.

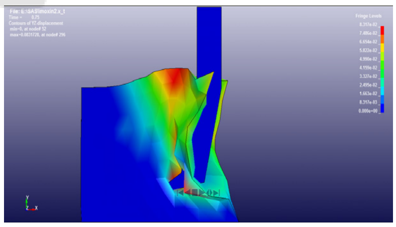


Figure 6: B model YZ surface displacement.

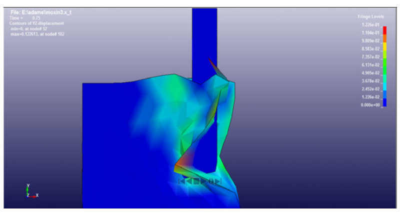


Figure 7: C model YZ surface displacement.

3.3 Connection design of subsoil plough body

The subsoil plough body is connected to the rotary tillage part by the connecting frame. The connection frame is welded on the rotary tillage frame. Subsoil connection frame long 85CM.The distance between the connecting frame beam and the rotary tillage frame is 5cm, so that there is enough distance between the subsoil plough and the axis of the rotary tiller. In this way, it can prevent the movement of interference and blocking the occurrence of the problem. The connection frame is shown in Figure 8.In order to facilitate the adjustment of the plow spacing and the depth of the deep loosening, the deep loose plow body is clamped on the connecting frame through four 80 * 80 angle steel with a length of 20cm, and fixed with a bolt. In the disassembly of subsoiling plough, the machines can also support small tractors used alone as a rotary tiller.

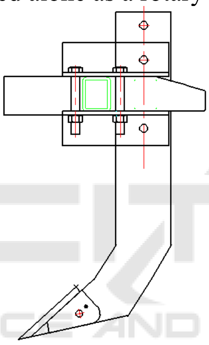


Figure 8: Subsoil plough connection frame.

4 DESIGN OF KEY PARTS OF THE MACHINE APPLICATION OF INTELLIGENT SUBSOILER TESTING SYSTEM AND FIELD EXPERIMENT OF THE MACHINE

4.1 Application of Intelligent Deep Pine Testing System

In order to carry out the supervision and inspection of the deep pine operation more scientifically and rationally, the intelligent control terminal is installed on the machine. The terminal is mainly composed of the depth sensor, machine tool recognition sensor, camera, GPS antenna, display screen, main engine, GPRS antenna and so on. The main engine and display screen are installed in the tractor driver's cab, and the tractor hand can get the depth of depth in real time through the display screen. The host computer mainly converts the information collected by each sensor into a digital signal and uploads it to the data management server through the GPRS antenna. The supervisory staff can log in to the supervisory service system interface through the mobile phone or the computer and watch the real-time operation scene of the equipment online. This can be very convenient statistics and query the comprehensive information about the operation of the machine. The comprehensive information includes depth of subsoiling, work area, compliance and so on, which greatly saves the management of economic costs.

Figure 9: Intelligent subsoil system interface.

4.2 Field test analysis

The machine was tested in the fields of red clay soil, 28.1% moisture content of soil and about kg/m^2 of sugarcane leaf and weeds. After tested, 1SG-230 type rear-mounted subsoiling and rotary tillage combined machine test performance indicators measured results, as shown in Table 2. The experiments show that: the performance of the machine have reached the sugarcane field operations requirements, knife shaft or stalk weeds less, and the intelligent subsoiling detection terminal can accurately measure the depth of subsoiling operation.

Table 2: Summary of test items.

Pilot projects	Unit	Quality Index	Results
The averagesubsoiler depth	cm	35～45	38
Subsoil depth stability coefficient	%	≥80	90.6
Depth detection deviation of intelligent terminal	%	——	2.1
The depth of rotary tillage	cm	12	20
Stability coefficient of rotary tillage	%	≥85	91
Soil crushing rate	%	≥60	80.2
Work productivity	hm^2/h	≥0.2	0.82
Fuel consumption	kg/hm^2	≤40	27.9

5 CONCLUSION

1SG-230 type rear-mounted subsoiling and rotary tillage combined machine is based on the pre-design 1SG series deep loosening rotary tillage combined machine for the study，and it was mainly designed to the sugarcane leaf in the hot area which covers more weeds and other vegetation. The machine implements the effect of multi - use and saving the time of agricultural production. The test was tested to meet the requirements of the sugarcane field. After the successful development of the machine, combining with the application of intelligent subsoiling detection system, the remote and precise supervision of subsoiling quality is realized, which greatly promoted the smooth development of the subsoiling operation subsidy for agricultural machinery.

ACKNOWLEDGEMENTS

This work was financially supported by the Hainan Natural Science Foundation Project (317203).The basic service charge of the Central Public Welfare Research Institute (1630132017001);2016 Guangdong Provincial Department of Agriculture Foreign Cooperation Project"China - Cambodia Sugarcane Management Mechanization Demonstration Base Construction"(Yue Nongji [2016] No.28);Zhanjiang financial fund science and technology special competitive distribution project (2016A03020) and Collaborative innovation and platform environment construction special of Guangdong Province (2017A040406003).

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