Computer assisted intelligent mechanical design applied in alkaline soil based on Fischertechnik and 3D technology

Yuhan Pang [a], ZhiJie Yang [b, *], Zhangjie Li [c], Yanlin Kou [d], Tao Yang [e], Yuxuan Xu [f], Tong Lei [g]

Wuhan University of Technology Wuhan, China

[a] frag05@163.com, [b] yangzhijie@whut.edu.cn, [c] anhmcy@whut.edu.cn, [d] 1725847495@qq.com, [e] 3221449423@qq.com, [f] 1181689983@qq.com, [g] 573481513@qq.com

Abstract. Based on Fischertechnik, this paper proposes and designs an alkaline soil restoration and vegetation planting machine. This device prossess the chemical restoration mode and plant restoration mode, and realizes self-adaptive soil detection and treatment. This paper also proposes an efficient workflow. The four-station conversion module can realize mechanism scheduling and the switch of restore modes, which save space and improve flexibility.

Keywords: Alkaline soil restoration; Fischertechnik; Station conversion module.

1. Introduction

According to the survey, the area of China's alkaline soil has reached 99.14 million hm^2. The alkaline soil is not suitable for the growth of crop.The soil conditions are poor, and loose when dry, and the soil is too cohesive when the humidity is high.There is too much alkaline in the soil, which seriously obstruct the agricultural development. It has become an serious ecological problem which cannot be ignored.

Alkaline soil restoration technology which already existed has relatively long restoration cycle and huge cost.Meanwhile, the restoration technology using plants has the problem of low survival rate, the existing mechanized equipment is difficult to effectively combine a variety of ecological restoration technologies, and the manual efficiency is low in planting and chemical restoration, so it is necessary to design a mechanized device that combines the above ecological restoration technologies. Therefore, this paper proposes and designs a soil remediation and planting machinery for alkaline soil.

Fischertechnik is an ideal teaching tool to display scientific principles and technical processes, but also a learning tool that embodies the world's most advanced educational concepts, providing the best carrier for innovative education and innovative experiments.

2. Construction and Geometrical Dimensions of Specimens

Soil repair and planting machinery in alkaline soil consists of soil breaking module, soil composition testing module, chemical spraying module, sapling transportation module, drilling module, planting module, soil flatting module, soil mixing module, soil gathering module and so on.

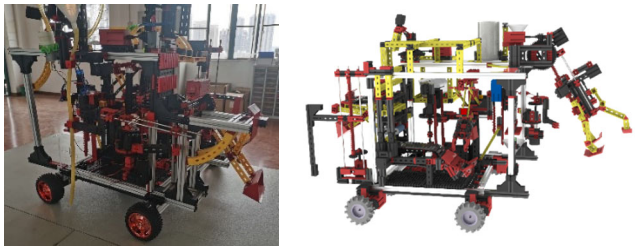


Fig.1 Physical picture and 3D Model picture

The front of the device is the soil composition detection module and the soil breaking module, the four-station conversion module installed on the the middle part, and the rear is the soil gathering module. The drilling module[2],planting module, soil flatting module[3] and soil mixing module are

installed on the four directions of the rotating table. The soil mixing module used for chemical restoration was installed opposite to the soil flatting module, and the drilling module used for plant restoration was installed opposite to the planting module similarly. The four institutions operate in a certain order, which saving space and improving flexibility.

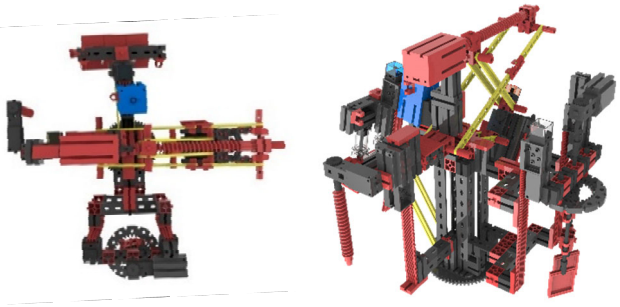


Fig.2 3D module of the conversion module

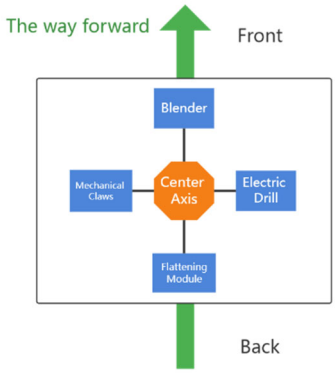


Fig.3 Schematic diagram

The device can select two restoration modes, namely chemical restoration mode and plant restoration mode. The soil detector is inserted into the soil through the screw mechanism to detect the soil composition, and the restoration mode is recommended according to the soil detection results.

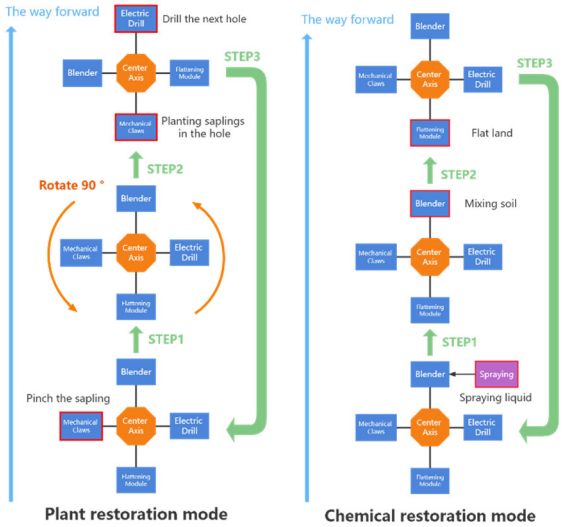


Fig.4 Plant restoration mode and Chemical restoration mode

In chemical restoration mode, the breaking module loosens the soil and the spraying module sprays the chemical. The four-station conversion mechanism rotates to the specified position to realize the mixing of the soil and the flattening of the treated soil to prevent the loss of chemical reagent components and soil erosion caused by the soil being too loose.

In the plant restoration mode, after the soil was loose by the ground-breaking mechanism, the four-station conversion mechanism rotated to the another specified position, the drilling module drilled the

hole, and the sapling transport module worked in cooperation with the mechanical claw[6] to transport the saplings to the tree hole. Finally, the soil gathering module was closed to cover the soil, and the saplings were fixed in the tree hole.

2.1 Detection Module

The device has a gear chain and lead screw mechanism, used for lifting soil composition sensor, soil composition sensor can be inserted into the soil for detection. The soil composition sensor can detect the temperature and humidity of the soil and the content of nitrogen, phosphorus and potassium[4].The data is sent to the computer for display, and the system can analyzes and processes the data to facilitate the user to choose the treatment scheme.

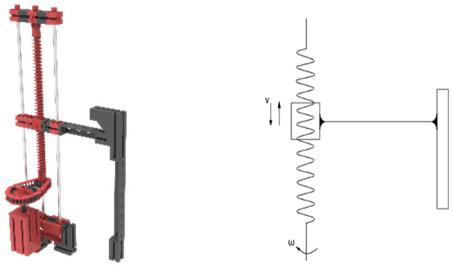


Fig.5 Detection module and schematic diagram of lifting mechanism

2.2 Ground-breaking module

The earth-breaking mechanism adopts crank and connecting rod mechanism. The device is designed with a cam locking mechanism. When the ground-breaking machine is not working, the ground-breaking mechanism is accommodated in the internal space provided by the frame chassis, which will not affect the normal driving of the vehicle.

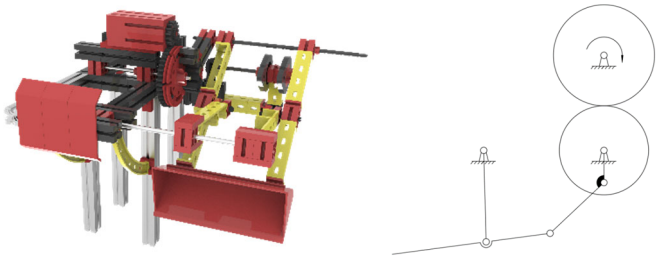


Fig.6 Ground breaking mechanism and the schematic diagram

2.3 Tree Planting moudle

The planting function depends on the cooperation of electric drill, friction wheel, mechanical claw and earth gathering mechanism.

This mechanism uses two motors to realize the main motion rotation and feed motion forward of the electric drill. The rise and fall of the rack and pinion mechanism realized the effect of electric drilling, so as to drill holes suitable for the size and depth of saplings in the land, ready for planting saplings.

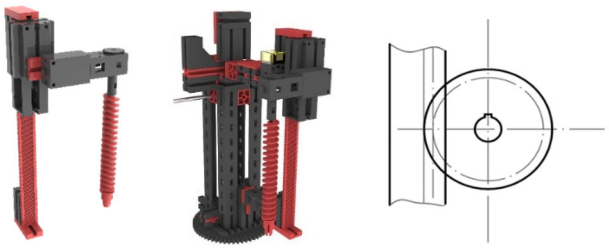


Fig.7 Drilling mechanism and the schematic diagram

The paper idealizes the saplings into stick objects. The saplings above the friction wheel fall into the middle of the friction wheel through the opening. When the friction wheel is stationary, the saplings will not fall. When the motor drives the friction wheel to rotate, the saplings fall into the hollow groove through the friction generated by the rotating motion of the friction wheel for the mechanical claw to grab.

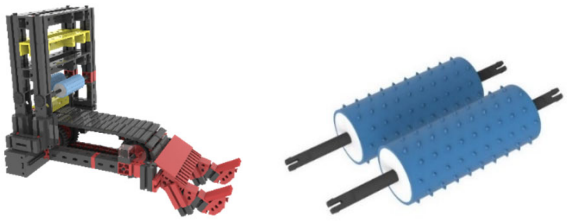


Fig.8 Convey belt mechanism and Friction wheel

Mechanical claw movement enables the transfer of stick saplings from the belt to the drill hole. Motor drive screw rotation, mechanical claw downward rotation of a certain Angle of movement and grab saplings. After clamping, the mechanical claw is lifted by the movement of the screw, while the chassis rotates, the mechanical claw is rotated to the top of the funnel, and the saplings are released, and the saplings fall into the tree planting hole vertically through the funnel.

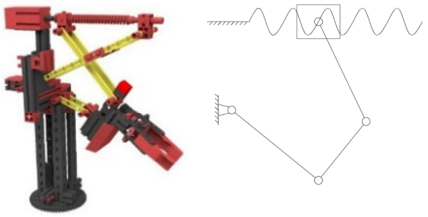


Fig.9 Grab institutions and Azimuth adjusting mechanism

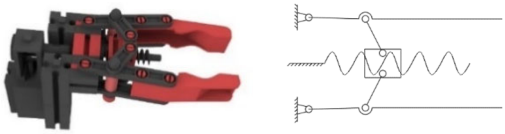


Fig.10 Mechanical paw and the schematic diagram

Soil gathering mechanism is composed of near the soil sheet, screw mechanism, rocker mechanism, three motors respectively drive three screw rotation, so that the connecting rod mechanism movement, and then make the claws in a certain Angle range of rotation. The bottom piece of the soil for tensione movement, the sapling around the soil gathered into the sapling hole. The worm mechanism is used to realize the up-rotation and down-rotation of the earth gathering module, and the screw mechanism is used to realize the rise and fall of the soil gathering mechanism.



Fig.11 Soil gathering mechanism

2.4 Chemical restoration function

The function is completed by spraying device module, stirrer and coordination.

The spraying module uses the crank structure to realize the spinning in and out, to prevent the interference of spraying mechanism and other devices. The spraying mechanism is installed at the end of the crank, the motor drives the turntable to rotate, and the card slot limit is used to realize the spraying nozzle swinging and spraying in circular path, so as to improve the spraying area and effect.

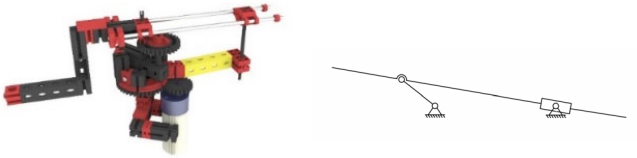


Fig.12 spraying device module and the schematic diagram

The principle of rack-and-pinion lifting and planetary gear rotation is adopted to realize the mixing of soil. Centers round the sun and on either side of the planet wheel and gear ring plane, gear wheel installed on the motor driven by the sun round the sun, installed on the planet gear of the stirring blades in the opposite phase rotation, mix the soil particles and medicament, improve drug penetration and governance effect, at the same time lifting device can use the gear and rack in order to realize the deep mixing effect.

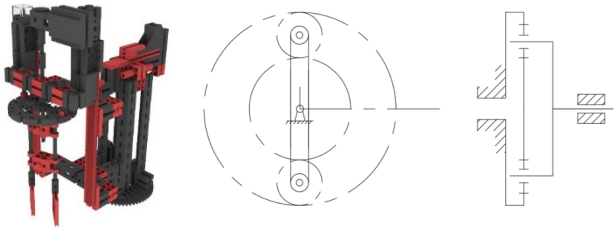


Fig.13 Mixing agencies with planetary gear

After mixing agents and soil particles, the soil flatting module is needed to flatter the soil.The device uses a cylinder to promote thrust, and uses a solenoid valve to realize the on-off of the air pump, so as to realize the push and lift action of the starting device.

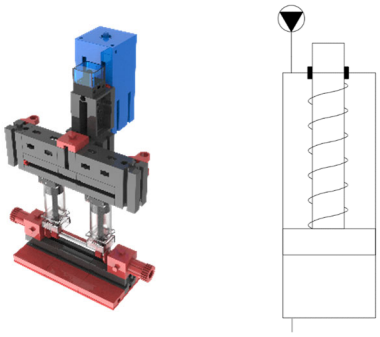


Fig.14 Soil pressure institutions

3. Structural analysis

3.1 Sprinkler module

Define abbreviations and acronyms the first time they are us The sprinkler module is a crank rocker mechanism that realizes the sprinkler mechanism to probe out, which can be obtained from the cosine theorem:

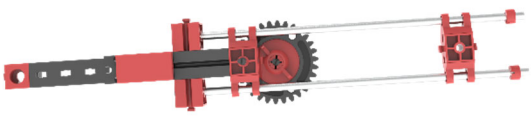


Fig.15 The sprinkler module

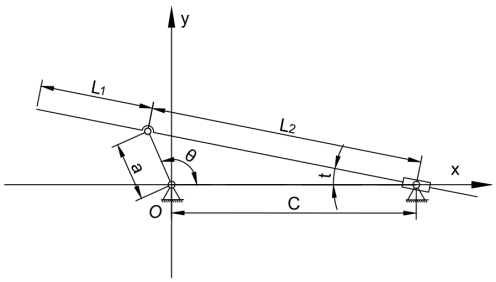


Fig.16 Schematic diagram of mechanism

$$L_2 = \sqrt{a^2 + c^2 - 2accos\theta} \tag{1}$$

According to the sine theorem:

$$\frac{L_2}{sin\theta} = \frac{a}{sint} \tag{2}$$

The motion parameter equation with motor Angle θ as parameter is:

$$\begin{cases} x = acos\theta - L_1 cost \\ y = asin\theta + L_1 sint \end{cases} \tag{3}$$

The motion equation of the nozzle can be obtained by substituting:

$$\begin{cases} x = acos\theta - L_1 \dfrac{2c^2 - 2accos\theta}{2L_2 c} \\ y = asin\theta + L_1 \dfrac{asin\theta}{\sqrt{a^2 + c^2 - 2accos\theta}} \end{cases} \tag{4}$$

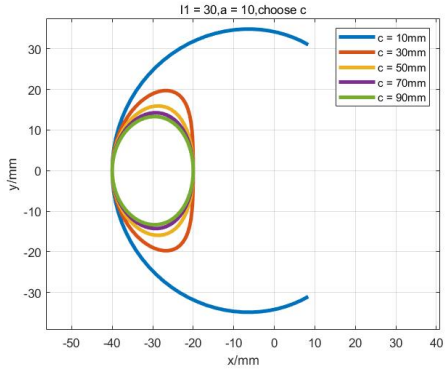


Fig.17 Choose c as variable

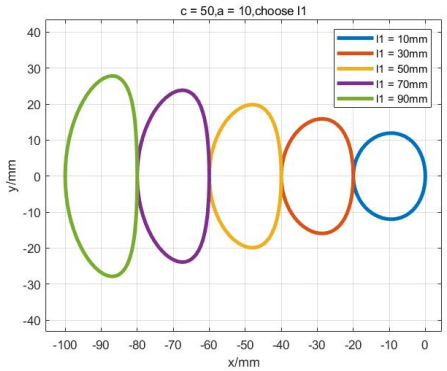


Fig.18 Choose L1 as variable

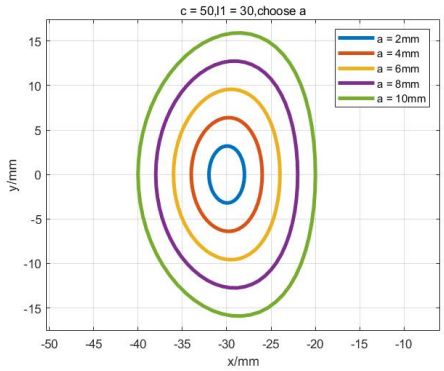


Fig.19 Choose a as variable

It can be found from Fig.17 that when c >30mm, the motion trajectory equation of the mechanism is approximately elliptic, realizing th to analyze e uniform distribution of agents. Therefore, c=50mm was taken L_1 and a. It can be seen from Fig.18 that L_1 determines the spraying distance, and from Fig.19 that a determines the spraying area. c=50mm, L_1= 50mm, and a=8mm were further selected according to the installation position of the mechanical structure.

3.2 Soil Gathering Module

The soil collecting module is a rocker mechanism, which is pushed by a lead screw to complete the soil collecting action. Analyzing the movement of the soil collecting module, a Cartesian coordinate system is established with the O point as the center, which can be obtained by the cosine theorem:

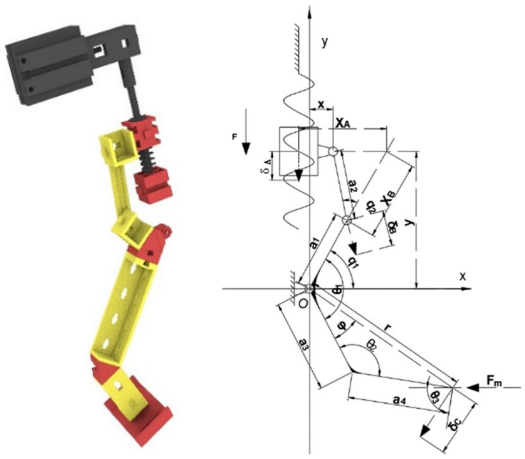


Fig.20 Mechanical claw and schematic diagram of mechanism

$$q_2 = \operatorname{acos}\left(\frac{x^2 + y^2 - a_1^2 - a_2^2}{2a_1a_2}\right) \tag{5}$$

Then calculate the value of q_1:

$$q_1 = \operatorname{atan}\left(\frac{y}{x}\right) - \operatorname{atan}\left(\frac{a_2 sinq_2}{a_1 + a_2 cosq_2}\right) \tag{6}$$

The distance r between the end of the soil and the origin O is:

$$r = \sqrt{a_3^2 + a_4^2 - 2a_3a_4cos\theta_2} \tag{7}$$

By the sine theorem, the rotation angle φ is:

$$\varphi = \operatorname{asin}\left(\frac{a_4 sin\theta_2}{r}\right) \tag{8}$$

The parametric equations at the end of the soil gathering device are obtained as follows:

$$\begin{cases} x = rcos(q_1 - \theta_2 - \varphi) \\ y = rsin(q_1 - \theta_2 - \varphi) \end{cases} \tag{9}$$

The parametric equations at the end of the soil gathering device are obtained as follows:

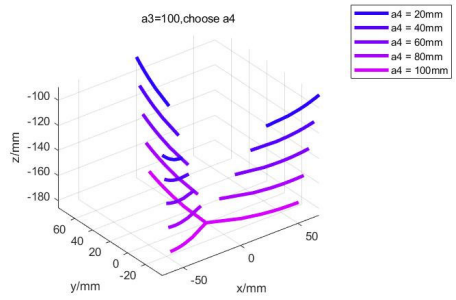


Fig.21 Choose a4 as variable

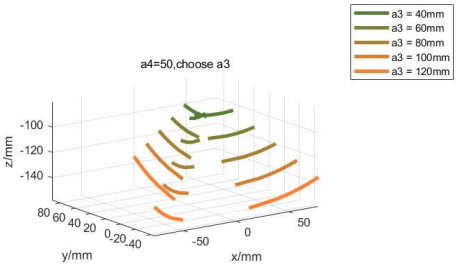


Fig.22 Choose a3 as variable

Analysis of the above figure shows that a_3=100mm, a_4>100mm or a_4=50mm, when a_3<40mm, the soil claws will collide. Therefore, when designing the rod length, a_3 should not be too short, and a_4 should not be too long. The drive module of the soil gathering a_4 mechanism is driven by a screw rod.

According to the screw thrust formula, the linear thrust of the screw rod can be obtained:

$$T = \frac{FI}{2\Pi n} \tag{10}$$

Where T is the motor input torque; F is the output thrust of the screw; I is the screw lead; n is the screw transmission efficiency.

The operation process of the soil gathering mechanism can be regarded as a stable dynamic structure, and it can be simplified to a static equation during instantaneous analysis. As shown in the figure, assuming that the virtual displacement of the slider is δ_A, which is parallel to the rotation axis of the screw, the virtual displacement at the rotating joint is δ_B is located on the same straight line as the connecting rod, and the virtual displacement of the soil gathering part is δ_C, and the direction is perpendicular to r. According to the virtual displacement theorem and D'Alembert's principle, the mechanical equation is established:

$$F\delta_A = F_m\delta_C cos\theta_3 \tag{11}$$

$$\frac{\delta_A}{X_A} = \frac{\delta_B}{X_B} \tag{12}$$

$$\frac{\delta_B}{a_3} = \frac{\delta_C}{a_4} \tag{13}$$

Since the direction of F_m will change during operation, the value range of F_m can be obtained. It can be obtained from the above formula:

$$F_m = F\frac{a_3X_A}{a_4X_B cos\theta_3} \tag{14}$$

From the torque calculation formula, F is 23.864N, then F_m is 11.932N, which is much larger than the force required to move the soil.

4. Conclusion

The device develops two working modes. The choice of different modes makes the device suitable for various states of saline-alkali soil conditions. It not only realizes the combination of chemical

treatment and biological treatment, but also solves the problem of low artificial planting efficiency in vegetation planting.

1) A multi-station conversion mechanism is designed by using the worm mechanism to realize multi-mechanism rotation operation and save space.

2) Use friction wheel to fill saplings in turn, design multi-link mechanical claws to grasp saplings, use planetary gear motion law to design agitator, use lead screw rocker to complete the opening and closing action of soil, and achieve mechanical innovation.

3) The device has developed two working modes, namely chemical restoration and plant restoration. Users can choose restoration routes according to soil conditions, which has good environmental adaptability and opens up application prospects of the device.

Acknowledgments

The 10th National College Student Mechanical Innovation Design Fischertechnik Group Competition Fischertechnik Engineering Technology Innovation Competition (2022).

References

[1] ZHAO Xiufang, XIE Zhiyuan, ZHANG Tao, et al. Environmental sanitation engineering,2017,25(2):94-96. DOI:10.3969/j.issn.1005-8206.2017.02.029.

[2] Li Shiwei. Agricultural Machinery Science and Technology Promotion,2003(4):35. (in Chinese)

[3] Yin Jinsong, NI Wenbin. Jiangsu agricultural sciences,2018,46(18):208-212. (in Chinese) DOI:10.15889/j.issn.1002-1302.2018.18.053.

[4] Sun Yuechun, WANG Kun. Spectroscopy and spectral analysis,2007,27(10):2017-2021. (in Chinese) DOI:10.3964/j.issn.1000-0593.2007.10.028

[5] Liaocheng University. A Kind of soil breaking Mechanism of Garlic Harvester :CN202122720133.4[P]. 2022-03-18.

[6] Zhang Gaiping, He Xinhai, Bai Jinqi, He Xiaorong, Xu Jikuan, Hou Wucheng. Desktop clean fischer model design and implementation of the robot [J]. Journal of Chinese modern education equipment, 2019 (13) : 11-14. DOI: 10.13492 / j.carol carroll nki cmee. 2019.13.005.