Parametric Simulation Analysis of the Lifting and Dropping Adjusting Mechanism of the Transplanting Platform

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Abstract

The seedling upright degree of the transplanting is an important indicator of the operating performance of the seedling transplanting machine. Seedling upright degree was affected by many factors. The lifting and dropping of the planting platform is one of the important factors. In this paper, parametric optimization model was established by analyzing the kinematics characteristics of the lifting and dropping of the adjusting mechanism of small crop seedling transplanting machine to which adapt the operating characteristics of the hills and mountains of the South. Then it obtained the best agencies geometric parameters that improve seedling upright assisted by MATLAB simulation analysis. All this provides an important guarantee for improving the transplanting quality of the transplanting machine.

Keywords

Transplanting; Seedling; Parametric Optimiaztion; Simulation.

1. Introduction

In order to solve the problem that crop seedlings mechanized transplanting in the complex field terrain of the South, we have designed a small transplanting machine as shown in Figure 1.The transplanting machine is composed of two major parts by planting agency and planting platform. And the planting agency is installed in the planting platform. Different high ridge of field, different varieties of crop seedlings requires different planting depth. Planting depth requirements vary depending on the field ridge of high and need to adjust the height between the planting platform and the field ridge. Planting platform is lifted and dropped by the adjusting hydraulic mechanism. However, there is a certain height difference in the vertical direction between the front wheel supporting rod and the rear wheel supporting rod in the lifting and dropping process for the difference diameter and difference fitting angle between the two wheels, which leading the planting platform has a certain inclination that affecting the seedling upright of transplanting.

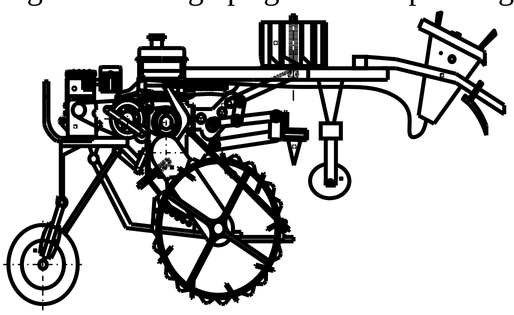


Fig.1 The small crop seedling transplanting machine

In this paper, parametric optimization model was established by analyzing the kinematics characteristics of the lifting and dropping of the adjusting mechanism of small crop seedling transplanting machine, targeting with the minimum height difference of the front and rear supporting rod and optimizing the parameter relationship of the rods member, so that the planting platform within the allowed lifting and dropping range, the height variety between the front and rear supporting rods are substantially equal, and to ensure that the planting platform tilt angle with the horizontal direction close to zero, while the impact on the planting angle reaches the minimum level.

2. Working Principle of the transplanting platform adjusting mechanism

The transplanting platform adjusting mechanism, as shown in Figure 2, lift or drop the platform by a driving force from the extension or contraction of the hydraulic cylinder, with chain driving wheels as a fulcrum, three-link strut ABED driven rod EF and two-link FGH to move so that lead the platform rise or fall of the chassis. The front wheel and the drive wheel on the same level ground and the radius R2 of the front wheel less than the radius R1 of the driver wheel considering its running performance and steering of convenience.

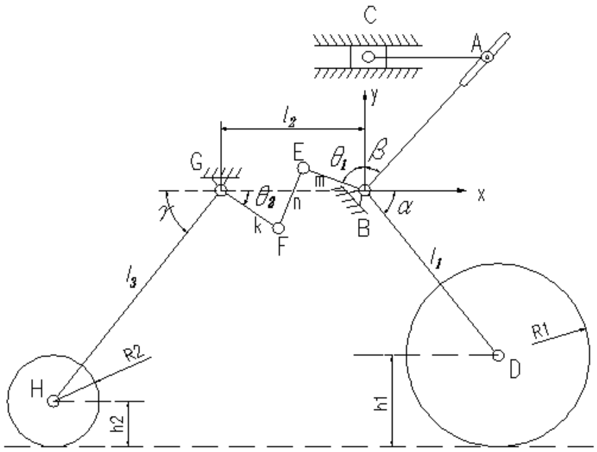


Fig.2 Structure principle of the transplanting platform adjusting mechanism

Dynamic equilibrium to be achieved in order to maintain the transplanting platform at the level during the lifting-dropping process, it is requirement that the height incremental of supporting rod HG of the front wheel equal to the height incremental of the sprocket box BD of the rear wheel. That mean $\Delta h_1/\Delta h_2=1$or$\Delta h_1-\Delta h_2=0$, otherwise the transplanting platform will in the tilted state affecting the degree of crop seedlings planted upright.

3. Parametric optimization design

3.1 Constraint conditions

According to the requirements of field work of the crop transplanting machine, the corresponding constraints of the adjusting mechanism is: (1) The distance between the lowest position of the transplanting platform and the field ground no less than 400mm. (2) Positions B and G at the same level and the designed space of two positions l_2=220mm. (3) Maximum height changes of the transplanting platform $\Delta h\in[150,200]$mm. (4) The maximum length of the hydraulic cylinder variety is 100mm, i.e. the right limit distance of cylinder AC is 100mm. (5) According the parts layout requirement, the space of BC is 270mm.

3.2 Mathemetic Model of the Mechanisim

As shown in figure 2, a Cartesian coordinate system XOY is establish as the origin of point B, with the rod HG and rod GF rigid connection, rotating around the point G, and with the rod BD AB, BE rigid connection, rotating around point B. Point B and point G are fixed on the platform. The rods of the adjusting mechanism respectively are: BD as l_1, BG as l_2, GH as l_3, BE as m, EF as n, GF as k, distance between point B and point C as l, the angle between the rod BD and horizontal line as α, the angle between the rod AB and the vertical line as β, the angle between the rod BE and the vertical line as θ_1, the angle between the rod GH and horizontal line as γ. Hydraulic cylinder move toward to the right, the incremental of its extrusion is vt at the moment t, the incremental of angle β is $\Delta\beta$. Based on the geometric relationship of the Cartesian coordinate system XOY established above, it can obtained follows:

$$\text{When } t=t_0,\ L_{AC}=l_b=vt_0,$$

$$\beta=\arctan(l_b/l)=\arctan(vt_0/l) \quad (1)$$

When $t=t_1= t_0+\Delta t$, $L_{AC}=l_b+v\Delta t$,

$\beta_1=\beta+\Delta\beta$, $\alpha_1=\alpha+\Delta\alpha$, so,

$$\Delta\beta=arctan\ ((l_b+v\Delta t,)/l)-\beta \tag{2}$$

Because the value domain of the angle θ_1 is $[0, \pi/2]$, the vector relationship between the geometry of the lever member can be obtained as follows:

$$\overrightarrow{BG}=\overrightarrow{BE}+\overrightarrow{EF}+\overrightarrow{FG} \tag{3}$$

$$n^2=(k\cos\theta_2-l_2+m\sin\theta_1)^2+(-k\sin\theta_2-m\cos\theta_1)^2 \tag{4}$$

$$\theta_2=\arcsin\frac{(n^2-l_2^2-k^2+m^2\sin\theta_1^2+2l_2m\sin\theta_1)}{2k\sqrt{(m\sin\theta_1-l_2)+m^2\cos^2\theta_1}}-\arctan\frac{(m\sin\theta_1-l_2)}{m\cos\theta_1} \tag{5}$$

As the height of lifting and dropping of the front wheel and the rear wheel, it can be obtained as follows:

$$l_3\sin\gamma+R_2=l_1\sin\alpha+R_1 \tag{6}$$

$$\Delta h_2=l_3\sin(\gamma+\Delta\gamma)-l_3\sin\gamma \tag{7}$$

$$\Delta h_1=l_1\sin(\alpha+\Delta\beta)-l_3\sin\alpha \tag{8}$$

$$\Delta x=l_1\cos\alpha-l_1\cos(\alpha+\Delta\beta) \tag{9}$$

And the optimizing object function is

$$Min\ \Delta h=\Delta h_1-\Delta h_2 \tag{10}$$

3.3 Initial prameters

According to the constraint condition, design the initial value of parameters of the mechanism members respectively are: Rod AC=70mm, l_1=600mm, l3=650mm, k=110mm, n=90mm, R_1= 300mm, R_2=180mm. So the range of θ_1 is obtained $43° \leq \theta_1 \leq 90°$ for the maximum position of the hydraulic cylinder and the angle of rotation which driven by the cylinder.

3.4 Optimization Methods And Processes

According to the constraint condition of the transplanting machine, the initial value for each supporting rod is given, the optimization model object calculated θ_2 and θ_1 of the relational expression of θ_1, respectively, the front wheels and the drive wheels are listed lifting and dropping height expressions. Then analysis the impact of difference θ_1 on the result of the expression$\Delta h_1/\Delta h_2$ orΔh_1-Δh_2 and verify the correctness and reliability of the final results through the optimization model. The flow chart of the optimization as shown in figure 3.

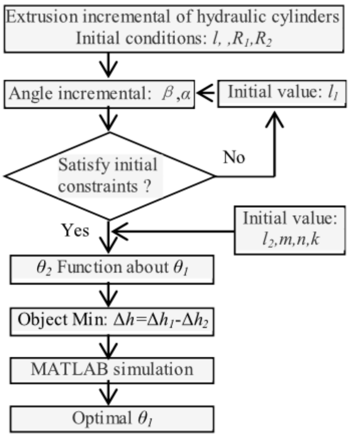


Fig.3 Flow chart of parametric optimization

4. The height difference MATLAB simulation analysis

MATLAB simulation analysis is one of useful optimizing methods. A certain MATLAB program is made out based on the methods and the mathematic model as mentioned above. As the constraint conditions and the initial conditions was input into the MATLAB program, the ratio of the lifting and dropping height increment of the rear wheel and the front wheel can be calculated in the moment of t (0 ~ 1) increased i.e. $\Delta h_1/\Delta h_2$ and the final result can be output by the plotting graph as which distribution shown in Figure 4. The more the ratio approaches 1, the better of levelness of the platform.

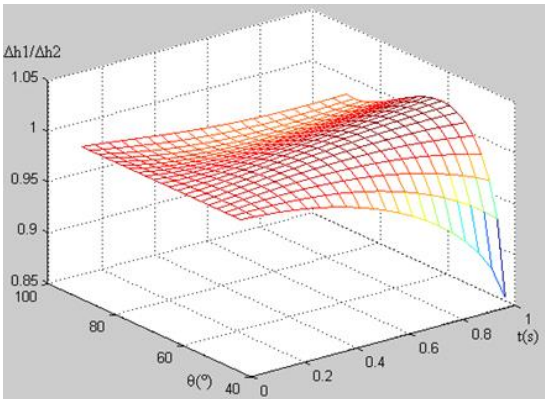


Fig.4 Ratio of the height difference of two wheels

As show in figure 4, the plotting surfaces of ratio and curves of $\Delta h_1/\Delta h_2$=1 intersect at two points. The object results of function Δh_1-Δh_2=0plotting graph as show in figure 5 below, which reflect the running stability of the transplanting platform.

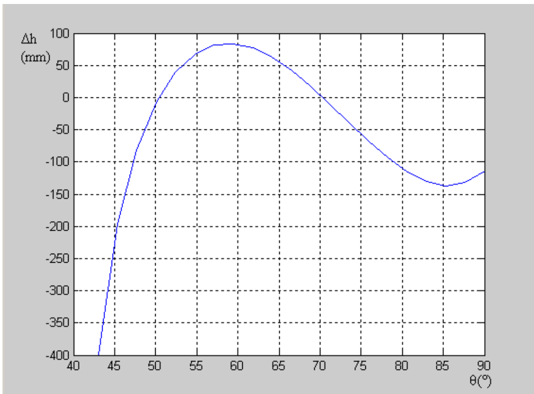
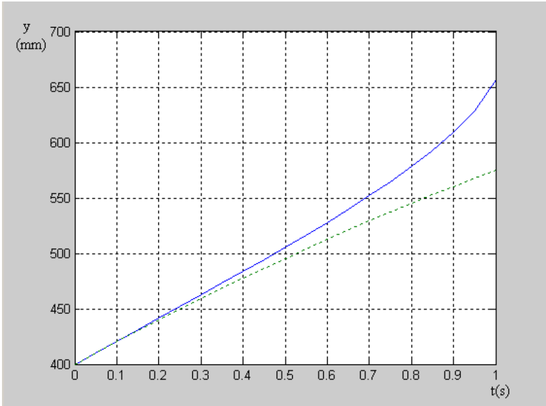


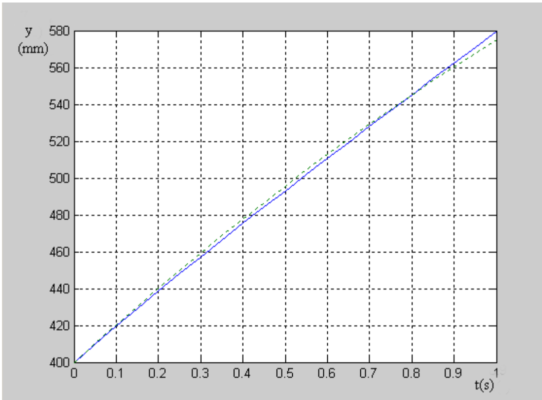
Fig.5 Distribution curve of the height difference

Within the time (t = 0 ~ 1), 43 ° <θ1 <50 °, the change rate of the distribution curve is relatively large, when θ1 value of 43 °, the height difference of accumulated and maximum up to 400mm, but in 50 ° <θ1 <90°, accumulated difference in height is relatively flat. Therefore, the target value reaches to the minimum when the θ1 equal to the two values: θ1=51° and θ1=70°.

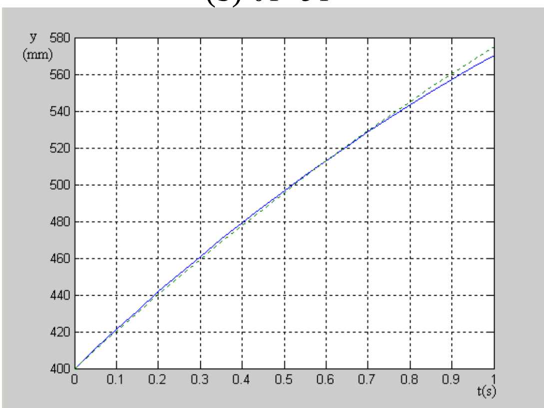
To show the changing trend of the lifting and dropping of the platform, the detail curve from the simulation is analyzed respectively when θ_1 value as the initial value and the optimum value. The plotting graph is show as figure 6 and wherein the solid and broken lines respectively represent the variation in height of the front and rear wheels.



θ1=43°



(b) θ1=51°



(c) θ1=71 °

Fig.6 Comparison of height difference of the two wheels when θ1 value vary

From the comparison in figure 4 above, whenθ_1=43 °, it is obviously that the difference in height of the front and rear wheels increasing especially after the planting platform lifted more than 470mm from the ground. The rear wheel (drive wheel) lifted 260mm when the hydraulic cylinder extruded 100mm while the front wheel lifted 260mm, which height difference is too large to cause the planting platform generates horizontal tilt that affect the transplanting quality.

When θ_1=51 °, lifting height of the platform in the range of 400~550mm, the two lines substantially coincide, i.e. the height difference between the front and rear wheels is very small, and substantially synchronous rising and dropping. When the hydraulic cylinder extruded 100mm, the height above the ground of the front wheel is 580mm whereas the rear is 578mm, the height difference only 2mm.

When θ_1=70 °, the height difference of the two wheels close to zero during the entire lifting process and the maximum height difference occurs at the point of the hydraulic cylinder extends to 100mm. The height above the ground of the front wheel is 570mm whereas the rear is 574mm, the height difference only 4mm.

From the simulation and analysis above, the independent variable of optimization θ_1 best value is 51 ° and 70 °, where guaranteed the transplanting platform remained level in the lifting and dropping process. The maximum height difference of the two wheels is 0.35mm while the maximum inclination is 0.074 ° by the verification of programming.

5. Conclusion

As the small crop seedlings transplanting machine composed with the front and rear wheels which different diameter and the supporting rods which different length to bearing the transplanting platform, the platform generate titillation during lifting and dropping, which will directly affect the upright of seedling planting. From the geometric modeling and MATLAB simulation analysis of the platform adjusting mechanism above, it is conclusion that the transplanting platform is keeping at the level and the stable running anywhere, in the precondition of satisfying the constraints, by rational design of link parameters and initial angle of correspondence mechanism members, which ensured the upright of transplanted seedlings.

Acknowledgements

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