Large-scale corn header design with adjustable line spacing and lifting cylinder motion simulation

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Abstract. Existing large corn harvester headers have inflexible walking, fixed line spacing, and cannot be well applied to the harvesting requirements of different line spacings. Based on the existing header, the header is designed to be foldable and the line spacing is adjustable. The dynamics analysis software ADAMS was used to simulate the hydraulic cylinder of the lifting header. The results show that under uniform load, the connection between the hydraulic cylinder and the vehicle body and the connection between the hydraulic push rod and the conveying bridge are large, and the lifting speed is positively correlated with the force. The offset load has an influence on the force of the motion pair and has the greatest influence on the force between the hydraulic push rod and the transport bridge. When the strength check is performed, attention should be paid to ensure that the strength and life reach the design requirements.

1. Introduction
Due to the wide distribution of corn planting areas, there are differences in planting time, variety, method, plant spacing and row spacing, which have hindered the mechanized harvesting of corn. In particular, the spacing of corn is different, the line spacing can reach 300mm in dense areas, and the line spacing of 900mm in sparse areas [1-3].

The existing corn harvester headers are fixed in row spacing, and it is difficult to apply the requirements of different row spacing. The versatility of corn harvesters is worse, which is also the main reason for the low level of mechanization of corn harvest. According to statistics, the mechanized harvest of wheat in 2016 can reach more than 90%. The mechanized harvest level of corn is less than 70% [4-6]. The existing large-sized headers are inflexible, inconvenient to walk, and poor in applicability of the line spacing. In order to solve the problems existing in the existing harvester headers, the design scheme is aimed at large corn harvester headers. On the basis of the research, the design of the nine-row corn harvester header with collapsible header and adjustable row spacing not only meets the requirements of harvesting different row spacing corn, but also solves the inconvenience caused by the inflexible harvester header. The intelligent level of the header increases, and the structure of the header is complicated and the quality is increased. In order to ensure the stability of the maintenance header during operation, the ADAMS software is used to simulate the dynamics of the hydraulic cylinder supporting the header. The smooth operation of the harvester provides protection [7].
2. Structure design of the header

2.1 A subsection
In order to adapt to the problem of inconvenient walking caused by the existing large-sized header, as shown in Fig. 1, the existing large-sized header is physically redesigned on the basis of the existing structure, and the header is divided into three parts. They are the foldable part and the middle part of the two ends respectively. When harvesting small row spacing corn, the left and right ends are not opened and harvested directly. When harvesting medium-sized corn, the left-end folding section is opened, and the row of the picking rolls is adjusted to be harvested. When the large row spacing is harvested, the folding sections of the left and right ends are opened to realize the harvest of the large row spacing corn plants. Figure 2 shows the three-dimensional folding effect of the designed header. Figure 3 is a physical diagram of a manufacturing production header.

![Figure 1 Existing large header](image1)

![Figure 2 folding header three-dimensional](image2)

![Figure 3 folding header](image3)

2.2 The line spacing adjustment design of the picking roller
The overall width of the designed header is 4550mm, and the line spacing between the picking rolls can be adjusted in the range of 450-650mm. When harvesting in the field, first collect data from the field of the operation, then upload it to the PC, calculate the line spacing value to be adjusted through the PC, transfer the value to the PLC, control the flow of the hydraulic valve through the PLC and control the size of the line spacing. After completing the above steps, the operation can be performed, as shown in Fig. 4, which is a roadmap for line spacing control. The picking roller is in the middle position when the work is not performed. When the line spacing adjustment is required, the large hydraulic cylinder installed on the left side pushes all the picking rolls to the left side, and then the small picking rolls are pushed to the right by the small hydraulic cylinder. Figure 5 shows the installation positions of large and small hydraulic cylinders.

![Figure 4 line spacing adjustment route](image4)

![Figure 5 installation positions of large and small hydraulic cylinders](image5)
3. The simulation process of the header lifting cylinder

3.1 Introduction to ADAMS Software
ADAMS, Automatic Dynamic Analysis of Mechanical Systems, is a virtual prototyping software developed by Mechanical Dynamics Inc. [8]. The ADAMS software uses an interactive graphical environment and parts library, constraint library, and force library to create a fully parametric mechanical system geometry model. The solver uses the Lagrange equation method in multi-rigid system dynamics theory to establish system dynamics. Equations, static, kinematic and dynamic analysis of virtual mechanical systems, output displacement, velocity, acceleration and reaction force curves [9]. Simulation of ADAMS software can be used to predict mechanical system performance, range of motion, collision detection, peak loading, and calculation of input loads for finite elements [10-11].

3.2 Simulation steps
In this paper, a good model (shown in Figure 6) will be built by the 3D CAD software SolidWorks. The format output of x_t, after importing into ADAMS, the parts need to be named, and then the material properties are defined. The materials of the two lifting hydraulic cylinders defined in this paper are 45 steel, and the rest parts are HT200. The specific parameters of each material are shown in Table 1 and Table 2 shows. The hydraulic cylinder is also constrained by the rotation between the earth. The movement of the hydraulic cylinder and the push rod is constrained. The push rod and the rotation constraint of the conveying bridge. Transport the bridge and the fixed constraint of the header. Transports a fixed constraint between the bridge and the earth. Symmetrical component settings have the same constraints.

| Table 1 Material 45 steel specific parameters |
|-----------------------------------------------|
| name | density (kg/m³) | Elastic Modulus (N/m²) | Poisson’s ratio | tensile strength (MPa) |
| 45 # steel | 7850 | 2.05×10¹¹ | 0.285 | 600 |

| Table 2 Material HT200 specific parameters |
|---------------------------------------------|
| name | density (kg/m³) | Elastic Modulus (N/m²) | Poisson’s ratio | tensile strength (MPa) |
| HT200 | 7000 | 1.2×10¹¹ | 0.31 | 200 |

4. Simulation results and analysis

4.1 Uniform load
Under uniform load, the lifting speed is set to 0.1m/s, 0.15m/s, and 0.2m/s respectively. From the simulation results, as shown in Figures 7, 8, and 9, it can be seen that When the lifting speed is 0.1m/s, the maximum force of the rotating pair between the hydraulic push rod and the bridge is about 27750N,
the maximum force is about 28750N when the lifting speed is 0.15m/s, and the lifting speed is 0.2m/s. The maximum force is about 29250N. From the simulation results, it can be seen that there is a positive correlation between speed and force. When the lifting speed is set to 0.1m/s, the speed and acceleration results of the left and right hydraulic push rods are output (as shown in Figures 10, 11, 12, and 13). From the output results, it can be seen that Under the cloth load, there is no significant difference in the output results.

Simulate the output of three rotating side-effect forces, as shown in Figures 7, 14, and 15. Figure 14 shows the rotating pair between the hydraulic cylinder and the ground (that is, the same as the harvester body, the same below). The maximum force is about 27000N. Figure 15 shows the rotating pair between the bridge and the car body. It can be seen from the figure that the maximum force is about 21000N. It is not difficult to see the force output from the three motion pairs. The rotational side effect between the hydraulic cylinder and the rotating pair of the vehicle body and the hydraulic push rod and the conveying bridge is large, and attention should be paid to the strength calculation check to ensure that the strength of the component meets the use requirements.
4.2 Offset load

Due to the offset of the header load during the line spacing adjustment, in order to simulate the effect of the situation on the lifting hydraulic cylinder, the action load is set in the ADAMS, and the action point is carried out while ensuring that the overall acting load is constant. Offset. The results of each exercise pair are output as shown in Fig. 16 (a), (b), and (c). Comparing the corresponding side effects of motion (Fig. 7 and (a), Fig. 14 and (b), Fig. 15 and (c)), it can be seen that the curve under the bias load and the curve under the uniform load are not significant changes, but the force of each movement increased under the eccentric load condition, especially the force between the transmission bridge and the header increased greatly.

5. Conclusion

(1) On the basis of the existing large headers, the structure of the header has been improved. The design of the large header has improved the harvesting efficiency and adapted to the needs of the current social development. The left and right headers can be folded to increase the flexibility of the harvester. The free adjustment within a certain range of line spacing adapts to the harvesting requirements of different rows of corn plants. Improve the adaptability of the corn harvester and help to further promote mechanization.

(2) Using ADAMS to simulate the lifting header, the results show that the connecting force between the hydraulic cylinder and the vehicle body and the connecting part between the hydraulic push rod and the conveying bridge is large, and the lifting speed is positively correlated with the force.
(3) The offset load has an influence on the force of the motion pair and has the greatest influence on the force between the hydraulic push rod and the transport bridge.

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