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Motion Analysis for the Working Device of Loader Based on SolidWorks Motion

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***Abstract* — The motion of new type of reversing-six-connecting-rod mechanism was analyzed and a new method that can improve design efficiency was adopted to design the working device of loader. The three-dimensional software SolidWorks was applied to build the simplified mechanism model, the motion simulation was conducted using the Motion analysis function of the software to add drives that met the project needs. Through the Motion analysis, the motion characteristics of working devices and the load carrying force changing cures of the hydro-cylinder is achieved, which could provide theoretical foundation for the future designation of the loader's working devices.**

***Keywords* — Reversing - six - connecting - rod Mechanism, Working Device, Wheel Loader, SolidWorks, Motion Analysis.**

I. Introduction

Working device is the most important part in a loader. The rationality of the design directly affects the productivity, workload and motion characteristic of the loader [1]. The work cycle of a loader mainly includes insert, shovel, lifting, discharging and release. So the design requirements of the working device are pretty strict, which is demanding working mechanism's translational and automatic flat. Because of the requirement of further improvement of the loader's performance and the complexity of inversed six-bar linkage. The dynamic analysis of its working devices is also very important obviously.

Solid Works is the often used to design 3D model. Solid Works Motion is one of important plug-in in Solid Works to carry out the simulation analysis, and it has been strongly supported by ADAMS, as the Solid Works to carry out the simulation analysis of the plug-in, and it has been got more and more favours of designers by its simple and convenient method. Solid Works Motion is a virtual prototype simulation tool by using the computer to simulate the kinematics and dynamic of mechanism. It can achieve the comprehensive analysis of the kinematics and dynamics simulation by setting the interface. Motion parameters can be obtained by Solid Works Motion, including the reaction force, angular displacement, angular velocity, linear displacement and so on. It can be outputted with different kinds of expression forms such as animation, tables, graph, etc [2].

II. Setting Basic Parameters And Model Of Working Device

The working device of loader is a symmetric reverse six bar linkage, consists of two of the four bar linkage by articulated. It is mainly composed of front frame, movable arm, rocker arm, connecting rod, bucket, lifting oil cylinder and tilting oil cylinder. The upper hinged four link mechanism is composed of a front frame, a movable arm, a tilting oil cylinder and a upper part of rocker arm; The under hinged four link mechanism is composed of a bucket, a movable arm and a connecting rod and a lower part of the rocker arm, which constitute the six linkage mechanism of the working device. The basic parameters of the working device mainly include:

Bucket capacity: 1.1m^3
Rated load: 2T
Unloading angle: 46°
Maximum unloading height: 3266mm
Minimum unloading distance: 925mm

Each component of the working device of the loader is analyzed clearly. Parts of the work device are created and set up material properties to Q235 by SolidWorks. According to the relationship between the components, the parts are assembled with the constraint conditions, such as the hinge and the coaxial in SolidWorks assembly. Assembly model is shown in figure 1. The holistic movement of a loader's working device is produced by the corresponding hinged point by assembly to complete each other.

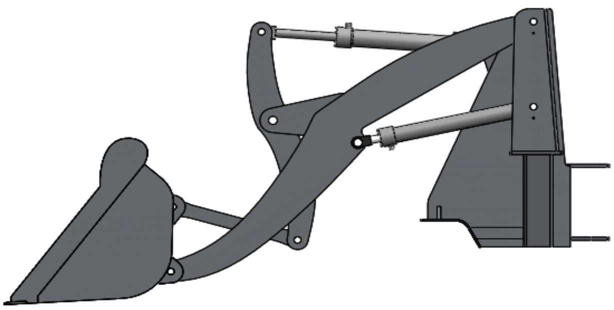

Fig.1. Three-dimensional working equipment of loader assembly model

III. Setting Simulation Conditions

A. Adding Constraints

Opening the plug-in in the toolbar and checking the SolidWorks Motion, witching to the interface motion and choosing the Motion analysis. Constraints that the hinge and the same axis that are selected when assembling the parts will be automatically converted into corresponding constraint pair such as rotating vice and cylindrical deputy vice. In addition, adding corresponding constraint relation according to the practical operation of working device [3]-[4].

B. Adding Driver

In motion analysis, lifting cylinder and t tilting cylinder of loader working device are defined as linear motor, its movement displacement line as shown in figure 2. Setting the example of time for 20s, 0~3s for inserting process, 3s~6s for picking process, 6s~11.5s for lifting process, 11.5s~14.5s for unloading process, 14.5s~20s for dropping process, and setting the number of frames per second to 30. Observing movement of loader working device, ensure that the motion relationship is correct.

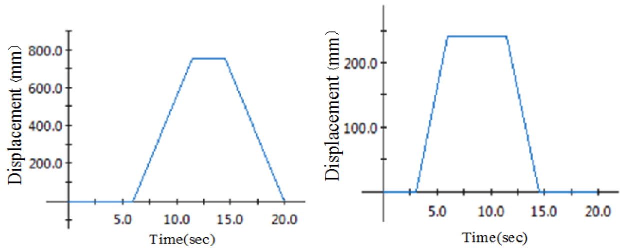

Fig.2. The curves of displacement for lifting cylinder and tilting cylinder

C. Adding Gravity

For fully analyze the stress of the loader working device in the actual work condition changes, Gravity is added in the Y axis direction of the negative and input value 9.81m·s^{-2}. At the same time, working device of its own gravity is automatically added to the Motion analysis.

D. Adding Force

In the case of considering the quality of the loader working device, load force is added to the bucket in the process of different jobs [5] .Insert resistance, rise of resistance and material of gravity is added to the bucket respectively, as shown in figure 3. In the insertion process, insertion resistance is added as shown in Figure 4 for the cross section of bucket teeth, placing close key code in 3s. In the process of removing, rise of resistance is added as shown in Figure 5 for the bucket bottom of the bucket and placing open in 3s, closing in 6s. At the beginning of the 2s, the gravity direction is perpendicular to the ground material is added as shown in Figure 6 for the bucket, until the working condition of unloading completed at the end of the 14.5s.

Through the above analysis, the full set is getting for the work device to calculating.

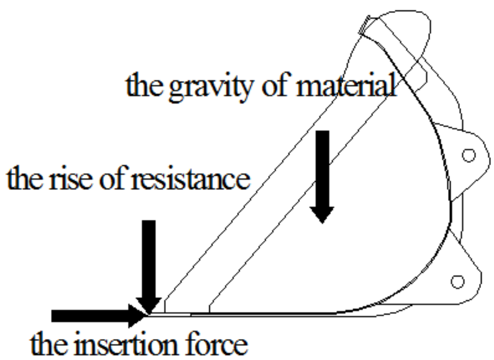

Fig.3. Force loading location

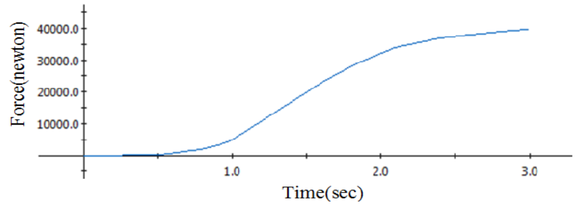

Fig.4. The insertion force changing with time

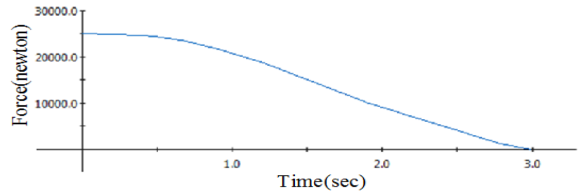

Fig.5.The rise of resistance changing with time

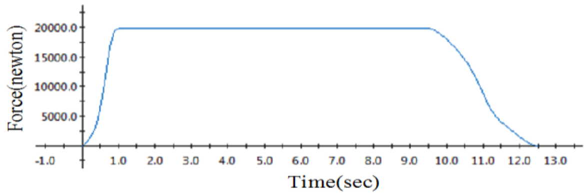

Fig.6. Material of gravity changing with time

IV. Kinematics Simulation And Analysis

Basing on the kinematics of tooling equipment of loader, this paper mainly verifies and analyzes the lifting translation, automatic leveling and included angle between main components for the working device. Bucket Angle change curve as shown in figure 7 and connect with bucket hinge connecting rod axis Angle change curve as shown in figure 8 was obtained.

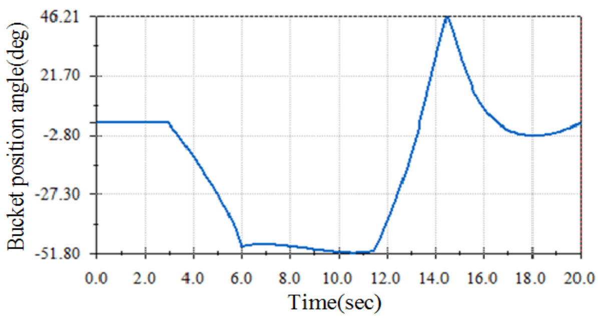

Fig.7. The bucket position angle changing curve

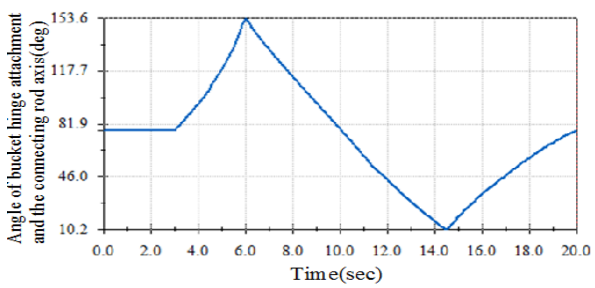

Fig.8. The changing angle of bucket hinge attachment and the connecting rod axis

A. Analysis of Lifting Translation of the Bucket

The lifting translation is an important standard to testing the translational movement performance of the working device of loader. The working process of the loader is very strict for the lifting translation. So, it is very necessary to analyzing the lifting translation of bucket. In order to avoid the material falling in the bucket, the bucket was required to do the approximate translational motion in the process of lifting the bucket material that from the lowest position is raised to the maximum unloading height [6]. The bucket position change as little as possible and the bucket angle less than ±10°. In the process of simulation, the stroke of the tilting oil cylinder is kept unchanged, so that the lifting oil cylinder is rising at a uniform speed. In the simulation results, the angular displacement of bucket position is measured, the approximate straight line segments in figure 7 is shown in the 6s~11.5s is obtained. From this analysis we can know, the mechanism can ensure that the bucket is translation in the lift at the beginning and end. During the course of the movement, the bucket angle changes did not exceed 1° in each position. The lifting translation of the mechanism is very reasonable.

B. Analysis of Automatic Leveling of the Bucket

The automatic leveling is an important standard to testing the vertical movement performance of the working device of loader. The realization of automatic leveling can reduce the time of the working device in the movement process and reduce the operation process. When the bucket is in the highest position of unloading, displacement of the tilting cylinder remains unchanged, the stroke of the lifting cylinder is reduced from the maximum displacement to the minimum distance. The automatic leveling of the agency's performance can be detected by changing the angle between the horizontal and the bottom of the bucket. Figure 8 shows the curve between 14.5s~20s, an angle between the bucket bottom surface and the bottom surface is 46.21° after the completion of the discharge bucket. It meets the minimum discharge angle of more than 45°, indicating that the mechanism can be unloaded in any working conditions [7]-[8]. When the bucket falls to the lowest position, the included angle (insertion angle) between the bottom surface of the bucket and the ground is 2.21°. The bucket returns to the original location. The mechanism meets the requirements of the angle between the bucket bottom plate and the ground is 2°~5°, reduces the resistance when inserted into the bucket. Through the verification, the mechanism can realize the automatic leveling of the bucket.

C. Analysis of the Change in Angle Between the Connecting Rod and Bucket Hinge Connection Axis

The same plane connection between the upper and lower hinge point is the hinge connection of the bucket. The line plays an important role in the design of the working device. In the design of the working device, the angle between the axis of the connecting rod and bucket hinge connection is high requirements, to ensure the corner is correct. At the same time, the requirements of dynamics should be paid attention, to prevent the phenomenon of movement of various organizations to be destroyed. The change of the angle between the axis of the connecting rod and bucket hinge connection in the whole operation process can be obtained from figure 8. In the insert condition, the angle between the axis of the connecting rod and bucket hinge connection is 77.5°. It enables the mechanism to obtain a larger transmission angle and the power factor. In the shovel loading condition, the included angle between the two is less than 170°, which avoids the occurrence of the phenomenon of the self locking mechanism during the movement of the mechanism. At the highest level of unloading conditions, the angle is 10.2°, and the transmission angle is the smallest. The overall analysis shows that the design of the mechanism is reasonable.

V. DYNAMICS SIMULATION AND ANALYSIS

In the process of design and analysis of the loader working device, not only the kinematics state should be considered, but also the stress situation of each hydraulic cylinder should be analyzed clearly. In fact, the kinematic analysis of the loader working device does not take into account the self gravity. But, the self gravity of the working device is very large, which occupies a large part of the load, and it is obviously not accurate to analyze the force performance of the hydraulic cylinder ignoring the effects of self gravity. When the kinetic analysis is carried out, it is needed to add gravity to the Motion analysis [9]. It was loaded on the bucket material load of 2 tons, to complete the simulation of working device.

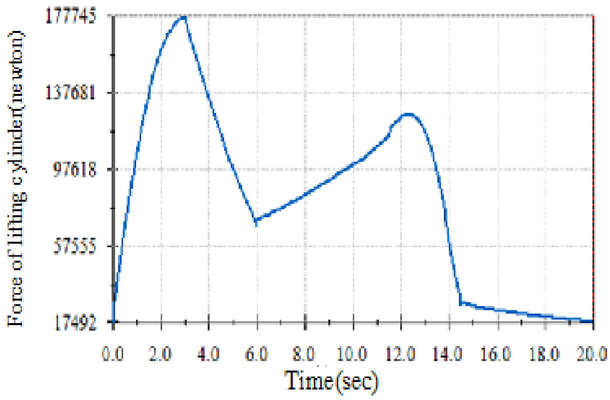

Fig.9. The changing force of lifting cylinder

A. Analysis of the Force of the Lifting Cylinder

Lifting cylinder is an indispensable part of the working device to achieve the movement of the maximum unloading position from the insert condition. Through the simulation, it is shown that the stress change curve of the lifting cylinder is shown in Figure 9. Simulation results show: In the process of insertion, the lifting force increases with the increase of the material [10], the force to reach the maximum of 177745N in the shovel. Along with the bucket scoop, the lifting cylinder force decreased gradually. In the lifting process, the lifting force of the cylinder increased steadily which affected by the bucket lifting of translation. When discharging, the force of the lifting cylinder decreases with the decrease of the material. In the leveling process, the lifting cylinder is only affected by the gravity of the working device and is gradually reduced to 17492N.

The force variation of the lifting oil cylinder is in line with the actual situation.

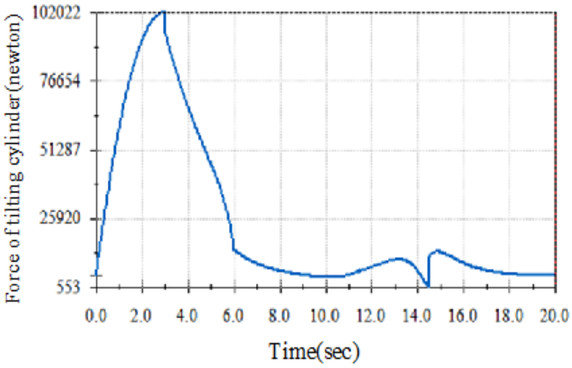

Fig.10. The changing force of tilting cylinder

B. Analysis of the Force of the Tilting Cylinder

Tilting cylinder is the main component of the bucket to completing the flipping. Through the simulation, it is shown that the stress change curve of the tilting cylinder is shown in Figure 10. Simulation results show: In the course of the shovel, with the increase of the material, the thrust of the tipping bucket is gradually increased to the maximum value 102022N. At the time of the shovel, the force moment of the bucket cylinder is reduced. The bucket cylinder is forced to reverse, but the force value is still very large. This is determined by the characteristics of the six bar linkage. In the lifting process, the displacement of the bucket cylinder remains unchanged. The change range of the bucket cylinder is very small, under the influence of lifting mechanism of translation. During unloading, the stroke of the tilting cylinder is gradually reduced under the thrust of hydraulic oil, but the stress has increased. After unloading, the gravity of the bucket increases the force of the tilting cylinder force. In the process of automatic leveling, the stroke of the tilting cylinder remains unchanged. With the lifting oil cylinder displacement decreases, the force of the tilting cylinder is gradually reduced. Through the analysis, the change of the force of the tilting cylinder is in line with the actual situation.

VI. CONCLUSION

Through the motion simulation and analysis of the loader working devices, the following conclusions are drawn:

1) The 3D models of the loader's working devices are established and assembled in SolidWorks, through the dynamics simulation analysis with SolidWorks Motion, simulation results can be achieved easily and quickly.
2) Through the simulation, the working mechanism's lifting translation and automatic leveling could satisfy the design requirements, and the maximum stress value of the lifting cylinder and tilting cylinder is figured. It provides a theoretical basis for the selection of the cylinder.

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