Structural Design and Performance Analysis of a Lengthened Working Device of Hydraulic Excavator Based on General Hydraulic Cylinder

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***Abstract*—Aiming at the problem of hydraulic cylinder design difficult, complex processing, we proposed a design method of lengthened of lengthening type working device of excavator based on general-purpose hydraulic cylinder by modifying the working device size and adjusting the hydraulic cylinder hinge point location. Its three-dimensional modeling is built by Pro/E. The dynamics simulation is finished by ADAMS which can verify whether the design scheme satisfy the requirements of excavation height, depth and get the most dangersous working state and the joint force in this state. Through the ADAMS dynamic simulation of the lengthened working device and prototype excavation test, research shows that the lengthened working device design can statisfy the complete machine working performance.**

Keywords-Lengthened working device; Hydraulic excavator; ADAMS simulation; dynamics simulation analysis

I. INTRODUCTION

Working device as the main actor of basic movements of hydraulic excavator, in the dual promotion of market and technology, the structure design is developing toward trend of diversity, in order to meet the needs of different specific work environment. INTERMAT construction machinery exhibition in 2012 April held in Paris of France, can be found in hydraulic excavator is moving in the direction of the development of multi function. That according to the specific needs design and manufacture a working device with a specific function. Such as Komatsu Komatsu PC350LC lengthened working device, greatly exceeded the ordinary working device operating range. Domestic manufacturers of excavators also have exhibited their products. However, China's production of hydraulic excavators used limited by its main parameters, the main job in the construction process parameters such as maximum digging radius, maximum digging height and depth can not meet the construction needs. To meet clean ditches, water conservancy construction, digging ramp, built underground engineering, demolition construction high-rise buildings and other specific needs, the study design with a wider range of operations that can be remote operation of a hydraulic excavator working device lengthened has important practical significance.

In view of the traditional design of lengthened working device of hydraulic cylinder design difficult, complex processing, can not satisfy the original machine parts commonality problem, we design a kind of lengthened working device to modify the standard working device size and adjust the hydraulic cylinder hinge point [1].

II. IMPROVEMENT PROGRAM AND DYNAMIC ANALYSIS

The lengthened working device design requirements as shown in Table 1:

TABLE I. THE LENGTHENED WORKING DEVICE DESIGN REQUIREMENTS

Parameters	Operating weight	Maximum digging height	Maximum digging radius	Maximum digging depth
CN150 lengthened	3000Kg	10460mm	12580mm	10060mm

Using Pro / E to its three-dimensional solid modeling, based on the ADAMS dynamics simulation verifies that the design could meet the requirements of mining depth, mining height index, and conduct the interference test by using full condition simulation [2-3]. Based on working device in 15 tons of standard type hydraulic excavator do several improvements, after analyzing and comparing, determine the optimal program. The holes of arm defined in Fig. 1 below.

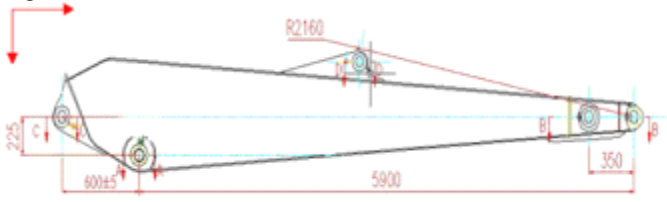

Figure 1. The diagram of lengthened arm

Carry out the ADAMS simulation, using the boom pivot as the origin. The boom pivot from the ground is 1m, away from the rotary center 1.2m. The improved programs are shown in Table 2.

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TABLE II. THE IMPROVED PROGRAMS OF LENGTHENED WORKING DEVICE

Program	Improvements	Maximum digging height	Maximum digging depth	Maximum digging radius
	Design Goals	10460 mm	10060 mm	12580 mm
1	**middle hole of arm right in 200mm Left hole up 225mm**	8837.6 mm	11164.6 mm	13444.6 mm
2	**middle hole of arm right in 100mm Cylinder stroke increased 100mm**	8783.7 mm	9294.7 mm	13554.7 mm
3	**Modified arm and bucket cylinder block Modified boom, arm,**	10504 mm	11557 mm	14240 mm

The lengthened working device was improved according to scheme three. According to the requirements of the gap, the boom cylinder mounting seat back and up, the safe distance for the cylinder set aside at least 30mm. Boom and the arm safety distance needs more than 40mm. Move bucket cylinder mounting seat, to ensure the safety of bucket and arm distance more than 40mm. For improved working device ADAMS kinematics simulation analysis, the largest excavator digging height is 10504mm, maximum digging depth is 11557mm, and maximum digging radius is 14240mm.

Program 3 maximum digging height, maximum digging depth of ADAMS kinematics simulation shown in Fig. 2, 3.

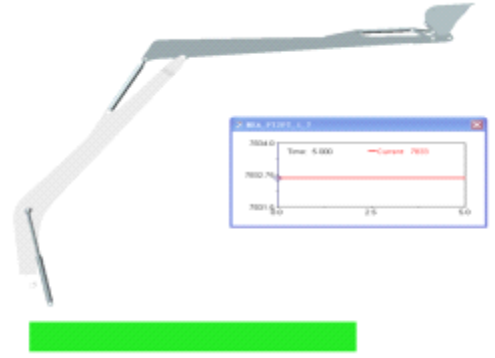

Figure 2. Maximum digging height of program 3

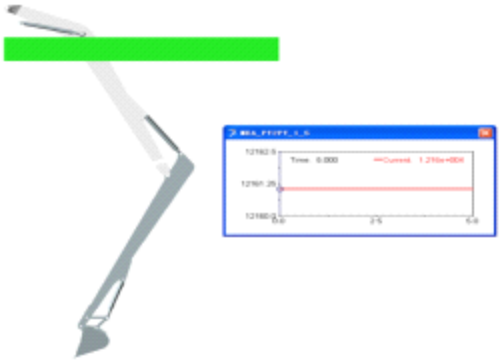

Figure 3. Maximum digging depth of program 3

Compared with the previous two programs, identify program three can meet the original design requirement. Therefore, the program three lengthened working device is best.

Boom weight of lengthened working device is 1187.10Kg, arm weight is 527.2Kg, and bucket weight is 249.55Kg. The weight of lengthened working device is 1964.35Kg. The bucket capacity is 0.3m^3 and soil weight is about 1000Kg, the total actual weight is less than 3000Kg. Therefore, the lengthened working device meets the weight requirements of the final model.

III. DYNAMICS SIMULATION ANALYSIS

Referencing standard dynamics simulation method, conduct dynamic simulation for the lengthened working device [4, 5]. Its external load force calculated as follows:

Tangential digging resistance: $W_1 = K_0 b h = 19KN$

Normal digging resistance: $W_2 = \Psi W_1 = 5.7KN$

The gravity of materials: $G = \rho V g = \gamma N = 4.5KN$

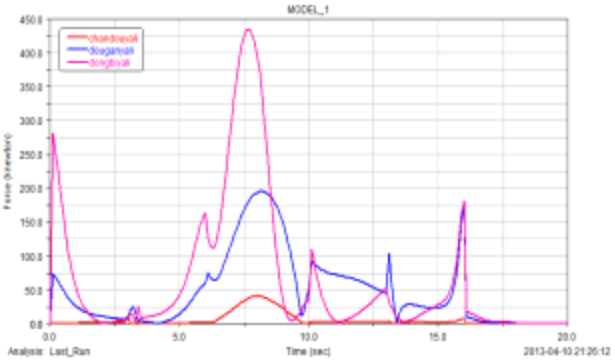

Figure 4. The pressure curve of hydraulic cylinders

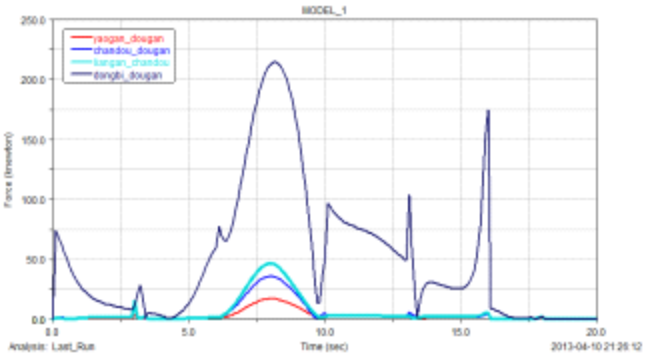

Figure 5. The stress curves of hinge points

Through dynamics simulation, the pressure curve of three hydraulic cylinders as shown in Fig. 4. The stress curves of boom and arm hinge point, arm and bucket, connecting rod and bucket as shown in Fig. 5.

As can be seen from the simulation diagram, the hinge point force and the hydraulic cylinder force are consistent with the actual working conditions. The maximum stress of hinge point occurs at 8.2s, and it similar with the most dangerous attitude theoretically. Take this attitude as the most dangerous, get the force of each hinge point on this attitude [6].

IV. DIGGING TEST OF EXCAVATOR

To verify the ADAMS dynamic simulation on hydraulic excavator is feasible and its accuracy, and further verify the lengthened working device can meet the work performance. For this paper, design the 15 tons lengthened hydraulic excavator digging test. For each hydraulic cylinder pressure and displacement data measurement, to obtain a test data curve. Then compared with the ADAMS dynamics simulation results, dynamic model of the verification is correct, and the most dangerous work attitude of the simulation is accurate.

Figure 6. Data acquisition interface

Figure 7. Digging test of excavator

By displacement sensors measure displacement of the hydraulic cylinder to achieve the purpose of indirect measure attitude of the working device. Based on the data acquisition, use Labview software development program as a data acquisition interface. As shown in Fig. 6. Through digging test and data acquisition, select the data of same dynamics simulation process from the collected data. The curve of corresponding pressure and displacement of the hydraulic cylinder can obtained.

Figure 8. Hydraulic cylinder displacement curve

Figure 9. Hydraulic cylinder pressure curve

From the experimental curve can be seen, the test curve and the dynamic simulation curves are consistent. When hydraulic cylinder pressure reach maximum, the displacements tested and simulated are basically the same as. It illustrates the most dangerous working attitude obtained from dynamic simulation is correct. It verified the method of the ADAMS dynamics modeling and simulation is feasible, and further validate the lengthened working device can meet job performance [7].

V. SUMMARY

1) The optimal design of lengthened working device was determined upon ADAMS kinematics simulation. The working device adopted a combined style which meets the common requirements of the 15 tons of standard hydraulic excavator key parts and easily process, repairs and replaces. Furthermore, it could achieve efficient use of resources.

2) The author got the most dangerous working state and the joint force in this state through the dynamics simulation analysis to the ADAMS simulation model of the lengthened working device and verified that it could meet the work performance.

3) The lengthened working device excavator test verified the feasibility and accuracy of the ADAMS dynamics simulation, and further validated it could meet the work performance.

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