CSCanada
Energy Science and Technology
Vol. 3, No. 2, 2012, pp. 93-97
DOI:10.3968/j.est.1923847920120302.386

ISSN 1923-8460[PRINT]
ISSN 1923-8479[ONLINE]
www.cscanada.net
www.cscanada.org

Review for Development of Hydraulic Excavator Attachment

YANG Cheng[a]; HUANG Kui[b]; LI Yinwu[a],*; WANG Jingchun[a]; ZHOU Meng[a]

[a]Key Laboratory of Bionic Engineering (Jilin University), Ministry of Education, Changchun, 130022, P. R. China.
[b]Computer Science and Technology College, Changchun University, Changchun, 130025, P. R. China.
*Corresponding author.

Supported by Research Fund for the Doctoral Program of Higher Education of China, No. 20110061120050, the Open Foundation of Key Laboratory of Bionic Engineering, Ministry of Education,Jilin University. NO.K201005 and National “985 project” of Jilin University.

Received 12 March 2012; accepted 15 May 2012

Yang, C., Huang, K., Li, Y. W., Wang, J. C., & Zhou, M. (2012). Review for Development of Hydraulic Excavator Attachment. *Energy Science and Technology*, *3*(2), 93-97. Available from: URL: http://www.cscanada.net/index.php/est/article/view/10.3968/j.est.1923847920120302.386
DOI: http://dx.doi.org/10.3968/j.est.1923847920120302.386

Abstract

The hydraulic excavators are widely used in construction, mining, excavation, and forestry applications. Its diversity and convenient operability make it popular. The performance of hydraulic excavator is depending on its performance of the backhoe front attachment. This paper focuses on the research work of excavator attachment, which mainly includes those aspects, such as the kinematic analysis, dynamic analysis, structural analysis, trajectory planning and control, fatigue life analysis and structural optimization design. and the development trends of excavator attachment,in the near future,are forecasted.

Key words: Excavator; Attachment; Development

INTRODUCTION

In the current tight economic environment, improving productivity in civil engineering construction works is vital. Due to its versatility and operability, hydraulic excavator currently dominates construction equipment fleets operating at most civil engineering work sites .Among the tasks performed by hydraulic excavators ,level digging or flat surface finishing work such as preparing housing foundations, reclamation of paddy fields, and pipe laying, account for a large percentage of required work (Haga et al., 2001). Hydraulic excavator consists of three main parts: undercarriage, upper structure and front attachment the upper structure rotates on the undercarriage. Accordingly, the performance of hydraulic excavator is depending on its performance of the backhoe front attachment. The backhoe front attachment of a hydraulic excavator consists of three major parts: boom, arm, and bucket (Bhaveshkumar et al., 2011). The research work and the development trends of excavator attachment are summarized.

1. THE DEVELOPMENT OF EXCAVATORS

Excavator was born in 1838, under steam, the arm operation rely on cable operations, to walk by wheel. With the development of technology and machine was becoming larger, walking mechanism was changed gradually for lower grounding pressure track for walking mechanism. Hydraulic excavator firstly developed by Carlo and Mario Bruneri in 1948. In 1961, the new Mitsubishi Heavy Industries introduced production technology, it was produced the first Japanese hydraulic excavator by Hitachi in 1965. From then on, hydraulic excavator with its convenient operation performance rapidly replaced traditional mechanical excavator (Jiang, 2011). At that time, hydraulic excavator already had those fundamental work parts: boom, arm, and bucket. When the local such a kind of mechanical parts instead of the hands of labor partly, it reduced the labor intensity of the workers. However, lag in hydraulic technology and complex operations hindered the development of the hydraulic excavator. Rapid developments of the hydraulic technology in aircraft and machine tool bring the progress of the hydraulic excavator, the volume and transmission system of hydraulic excavator became simply and directly. Up to now, hydraulic excavator has become the main type of machine with the machine, hydraulic and electrical engineering technology (Wang, 2001; Li, 2006; Zhang et al., 2006; Wang et al., 2002).

2. RESEARCH STATUS FOR EXCAVATOR ATTACHMENT

The developments of excavator attachment were accompanied by the development of the materials, structures, processes, and the transmission form. In the experience of the early steel pipe finishing frame combination arm, steam power, cable transmission of the original stage, the excavator working device had been designed to mature. At present, the research of excavator attachment is mainly concentrated in the kinematic analysis, dynamic analysis, structural analysis, trajectory planning and control, fatigue life analysis and structural optimization design at home and abroad.

2.1 Kinematic Analysis of the Excavator Attachment

Kinematic analysis for excavator working device can determine the scope of the excavator mining, and understanding of mining for performance, the kinematic equations can be established to determine the mining track, for the formulation of a strategy of trajectory planning. Research in the field is more and better research, theory is more mature.

The solid model of SLWY-60 excavator was constituted by Zhang Wobo and Yang Junfeng (2008), and the work and motion state model of the excavator was build based on UG and transmitted into ADAMS. The sizes and positions of work devices were parametric. Simulation model for work state was established by means of defining different joints and motion driving. And dynamic simulation for the excavator was carried out. Typical work conditions of the excavator were simulated. The work conditions of the excavator were simulated exactly in the virtual situation, it was determined that the performance parameters of the excavator’s maximum digging height, depth, and maximum digging radius ,and the work state was analyzed. Compare of the simulation results and work results, the simulation value and real value matched well. The study could early tested product performance and shortened the design cycle and reduced the major design errors possibilities in the development.

A numerical vibration analysis of the excavator model was presented by G. Wszołek (2004). This model with a discrete distribution of the parameters, shown in three working positions, was attracted to kinematic and dynamic excitations. The analysis was made in GRAFSIM program, which was intended and prepared for projecting and analyzing 2D and 3D mechanical systems with linear couplings. The program works on the basis that the algorithm transforms matrix hybrid graph model structures into block diagrams structures. The time and frequency responsed from the examined mechanical system were presented.

2.2 Dynamic Analysis of the Excavator Attachment

A flexible multi-body system power for the excavation process of the hydraulic excavator was presented by Imanishi and Etsujiro (2003), it was obtained that excavator working process of the deformation characteristics of the device, and it verified the dynamics simulation for the excavator design and effectiveness of the performance analysis for the whole machine.

Zygmunt Towarek (2003) discussed that the dynamics of a spatial model of a single-bucket excavator on a caterpillar chassis, the strain of the soil foundation is being taken into consideration. It has been assumed that the excavator is resting on a soil foundation expressed as a Kelvin–Voight viscoelastic body carrying loads distributed on the surface of interaction of the caterpillar and the ground. The excavator was treated as a system of appropriately inter-connected rigid solids, in which individual masses corresponded to the basic component elements of the excavator. For the dynamic description Lagrange second-order equations had been used. The generalized coordinates assumed enable one to make a dynamic analysis of working movements of the excavator during excavation for any position of the jib with respect to the chassis and any combination of movements of the bucket and the arm. The system of differential equations had been solved numerically, for numerical data corresponding to a single-bucket excavator of its bucket capacity of 1:10 m3. As was mentioned, excavators on a caterpillar chassis moved during operation, making a new working cycle in a place where the soil foundation was disturbed. The modulus of such a soil foundation is several times.

2.3 Structural Finite Element Analysis of the Excavator Attachment

Structural finite element analysis could help designers to understand the components of the stress and strain information to identify the weak links.

Comparative analysis the intensity of the excavator boom of the finite element method was conducted by Shi Qinglu and Jin Yideng (2009). The analysis results shown that local stresses of the boom were relatively higher under offset loads and transverse loads; no matter there are offset loads and transverse loads or not, there were higher stresses at some parts under the two work conditions, which was one of the main causes resulting in the boom breakage. Therefore, these parts should be paid attention to in structure design and manufacturing processes.

Finite element analysis is an important part of the overall design process, serving to verify or validate a design prior to its manufacture. Because finite element analysis is a simulation tool, the actual design is idealized, with the quality of the idealization dependent on the skill and experience of the analyst. Naresh N. Oza (2006) carried out the FEA and optimization of Earth moving attachment as backhoe. Accuracy of results was dependent on choice of elements, number of nodes, selection of proper material, boundary conditions, applied loads and expertise of the researcher. Finite Element Analysis were Creation of geometry and its cleanup, specify material and element properties, meshing of geometry in into nodes and elements, apply the loads and boundary conditions, and finally carried out the solution and post processing results. After getting the results, interprets the results and do required corrective steps on it to fulfill the requirement of the problem. They had done the EFA of the boom, arm and bucket by following the standard practice of analysis and carry out the solution for stress and deflection analysis; finally the results were compared with the results obtained from the MathCAD. Optimization for weight was also carried by them and reduces the weight of arm from 180 Kg to 154 Kg and stresses reduced from 386 MPa to 263 MPa. The weight of the bucket was reduced from 165 Kg to 156 Kg, and the developed stresses were within the limit.

Hydraulic excavator structure model in virtue of ANSYS was analyzed by Yang Xianping (2005), the natural frequency and the model of vibration were studied, to assess its dynamic characteristics by modal analysis results and found that the connecting shaft at the modes was easily to produce abrupt, modify the sensitive parts of the stiffness and improve the dynamic characteristics of the body structure, thereby enhancing the performance of the hydraulic excavator.

2.4 Trajectory Planning and Control of the Excavator Attachment

Trajectory planning for hydraulic excavating is good for improving mining efficiency and adapting to special conditions.

The excavation arm of a large hydraulic mining shovel, which having a multi-loop kinematic form was conducted by HallA and MeAree (2004). They described an iterative algorithm which allowing the position of the bucket to be tracked from measurements of the linear actuator extensions. The important characteristic of this algorithm was numerically well-behaved when the linkage was closed to singular configurations. While they focus on a specific device, the algorithm was easily adapted to other multi-loop linkages.

Controls intelligently of the position and tracking of working arms of the excavator to ensure accurate work, high efficiency and low energy consumption of the excavator was established by Pi Jun and Yao Bin (2005). The measure position cylinder and pilot service driving valve were used to availably control and drive the hydraulic valves of three working arms in the wiggling. A series of fundamental formulae, which describe the controlling theory, were derived HallA and MeAree (2004).

He Jilin and Liu Pengfei (2008) designed Trajectory controller prototype based on incremental theory of trajectory controlling, to verify the accuracy of the controlling, virtual reality software is developed based on open graphics library. Trajectory controller and virtual reality software composed hardware-in-loop simulation environment. In this environment, model mining tracked to set the level to go straight the line of action, adjusted the control parameters to achieve good control effect and finally proved that the motion controller prototype system could be expected to control requirements job.

2.5 Fatigue Life Analysis of the Excavator Attachment

Predict the fatigue life of the excavator working device could not only improve the product at the design stage, but also to provide guidance to service equipment during the repair and maintenance.

The bucket rod of hydraulic excavator simplify was analyzed by Su Meng and Zhang Wanshan (2006). Two kinds of fighting mode of bucket rod, fatigue fracture and brittleness fracture were taken out. Factors leading to the two fractures, Mainly includes three aspects: (1) Material defects and cracks on the stick, sectional dimension for Stick was large, and contained impurities, defects were more and more; and large-size components in high-stress state of the grain more easy to form a more fatigue cracks. From the fracture, stick, the main reason for cracking, was the formation of stick fracture obvious crack initiation source, slag, and undercut, not penetration. (2) Loads were withstanded by stick, and the defects near the crack tip would be produced stress concentration, it would be determined by the material the degree of sensitivity of the defect. (3) Achieve adequate levels of stress which produced fracture was the third reason, from stress concentration caused sub-analysis, structural design management, production and manufacturing process was inappropriate and poor assembly quality was made into a stress concentration, resulting in large additional stress and residual stress directly reasons. It was helpful for the maintenance and service of the excavator attachment.

The choice of materials for excavator working device was also very important, it was related to the fatigue life of the excavator working device. Abrasive wear produced the premature failure of many components of the extraction machinery in the mining industry with considerable economic costs. Fernández (2001) tested the abrasive wear resistance of several cast irons alloyed with different elements. Laboratory tests based on the ASTM G105-89 standard were compared to tests carried out under real working conditions of excavator teeth in mines. The experimental results had shown an acceptable correspondence between laboratory and field tests. To complete the laboratory research, hardness and microhardness measurements and optical micrographs were performed to identify the mechanism of wear. As a result of the experimental work, an economic evaluation of materials was also performed.

Aluminum alloy was substituted for steel alloy in the components of the arm by Luigi Solazzi (2010). The purpose was lightened components and increased the load capacity of the bucket, and so it was possible to increase the excavator productivity per hour. He tested many different load conditions have been studied numerically on the original excavator in order to estimate a safety factor and the deformability or flexibility of each component. These parameters had been used in order to design a new arm. Although it would spend a lot, but it was the economic value created far more than it costs. The price increased about € 2.500–3.000 and this aspect could be adjusted if we consider that the productivity per hour increased about 35%.

2.6 Optimizing the Structure Design of the Excavator Attachment

Purpose of structural optimization is to improve the efficiency and performance of the excavator.

Cevdet Can Uzer (2008) performed a finite element analysis by using a modified commercial program of OPTIBOOM software in 2008. The model parameter generation, model creation, analysis data collection and data evaluation phases were done by the Python and Delphi based computer codes. A global heuristic search strategy such as genetic algorithm was chosen to search different boom models and select an optimum. Evolutionary structural optimization method was used for removing inefficient material from the structure by using the predefined criteria. Optimum solutions of boom of HMK360 LC excavator was carried out. Initial design of the boom was 5% heavier than the final design and maximum stress was 10% higher than the Von Mises design stress criterion. Maximum stress was limited by predetermined global maximum stress value and weight was decreased 4.6% of the initial design. Actually obtained result was not the best one but it was one of the good results which was satisfying design criteria and aimed mass.

Pan Yuan and Cheng Hongtao (2009) established backhoe work device of the class virtual prototype mode base on ADAMS. The minimum target of which bucket and arm and boom oil cylinder of working pressure based on virtual prototyping technology and generalized reduced gradient method. It effectively reduced the fuel tank force, so that the body was more reasonable. This optimization was not 3 institutions separately, but in working condition, the optimization of the whole machine to avoid the three institutions separately from the limitations of the simulation. Considered the impact of one institution to another institution for the overall optimization ring, optimizing of the organization effectively reduced the cylinder force.

By using 2D finite element method, Guo Zhijun (2007) analyzed and compared to ordinary excavator bucket and bionic excavator bucket soil contact model the soil displacement difference, comparison results shown that, bionic excavator bucket cutting performance theoretically superior to the ordinary hydraulic excavator bucket cutting performance.

CONCLUSION

Here a review carried out on the excavator attachment is divided in two partly namely the development of excavators and research status for excavator attachment. In the first part of review, we talk about the development of the excavator mainly. Firstly, the history of it is introduced from the first excavator to new type of the excavator .Then we discussed the development of the aspects of shape and volume, structural components, power, walking installations for the excavator at this stage time. We can see that the excavator technology is improving with the rapid development of science and technology.

In the second part of review, Excavator working device as the flexibility to complete the work of excavators overall process reliability and energy saving and environmental protection one of the important indicators of the most important object of study, has long been the great concern of the domestic and foreign enterprises and academics. As can be seen from the above discussion, the development trends of excavator attachment, in the age of knowledge, mainly comprise:

(1) Improve the excavators reliability and efficiency, reduce production costs, to the development of intensive and efficient direction;
(2) Fully utilizing the virtual prototyping technology to reduce development costs;
(3) Application of technologies and materials in order to improve efficiency and save energy;
(4) Active use of microelectronic technology, chip technology to speed up the process of hydraulic excavator intelligent and mechatronics;
(5) Optimize the structure of the various components, improve reliability, and efficiency;
(6) Improve the efficiency of the excavator working device, by Bionics. Bionics is a discipline with the obvious characteristics of interdisciplinary science and technology. It provides new ideas, new original management and new methods for the science and technology innovation.

REFERENCES

[1] Patel, P. B., & Prajapati, J.M. (2011). Soil-Tool Interaction as a Review for Digging Operation of Mini Hydraulic

Excavator. *International Journal of Engineering Science and Technology, 3*(2), 894-901.

[2] Uzer, C. C. (2008). *Shape Optimization of an Excavator Boom by Using Genetic Algorithm* (Master of science dissertation thesis). The Graduate School of Natural and Applied Sciences of Middle East Technical University.

[3] Fernández, J.E. (2001). Materials Selection to Excavator Teeth in Mining Industry. *Wear*, *250*, 11-18.

[4] Guo, Z. J., Deng, Z. Q., & Chen, H. Y. (2007). Two-Dimensional FEA of Bionic Excavator Bucket-Soil on the Interacting Problem. *Construction Machinery*, (3), 74-77.

[5] Haga, M., Hiroshi, W., & Fujishima, K. (2001). Digging Control System for Hydraulic Excavator. *Mechatronics, 11*(6), 665-676.

[6] Hall, A.S., & MeAree, P.R. (2004). Robust Bucket Position Tracking for a Large Hydraulic Excavator. *Meehanism and Machine Theory, 40*(1), l-16.

[7] He, J. L., Liu, P. F., Peng, C., & He, Q. H. (2008). The Hardware-in-Loop Simulation Research About Trajectory Control on Hydraulic Excavator. *Journal of Huazhong University of Science and Technology (Nature Science Edition)*, *36*(S1), 19-22.

[8] Zhang, W. B., Yang, J. F., Wang, J. M., & Zhang, Q. (2008). Simulation and Application on Work and Motion State of Excavator. *Transactions of the Chinese Society of Agricultural Engineering*, *24*(2), 149-151.

[9] Jiang, Y. D. (2011). Development and Technology Trends of Excavator. *Construction Machinery,* (6), 43-44.

[10] Li, Y. R. (2006). New Technologies, New Structure and Development Trends of the Foreign Construction Machinery. *Mechanical Manufacturing and Automation*, (5), 8-10.

[11] Solazzi, L. (2010). Design of Aluminium Boom and Arm for an Excavator. *Journal of Terramechanics*, *47* (4), 201-207.

[12] Nareshkumar, N. O. (2006). *Finite Element Analysis and Optimization of an Earthmoving Equipment Attachment–Backhoe* (M. tech Dissertation Thesis*)*. Nirma University, Institute of Technology, Ahmedabad.

[13] Pan, Y., Cheng, H. T. & Jiang, D. Y. (2009).Design and Optimize Base on ADAMS for Excavator Working Device Simulation. *Coal Mining Machinery*, *30*(3), 15-17.

[14] Pi, J., & Yao, B. (2005). Study on Tracking Intelligent Control of Working Arms of the Excavator. *Journal of Jimei University Natural Science*, *10*(1), 67-70.

[15] Shi, Q. L., Zhang, F. S., & Lian, J. Y. (2009) .Comparison Analysis for Boom Strength of Excavators. *Construction Machinery and Equipment, 40*(7), 40-43.

[16] Su, M., & Zhang, W. S. (2006). Fracture Analysis of Hydraulic Excavator Working Mechnism. *Coal Mine Machinery*, *27* (6), 975-976.

[17] Wang, G. B. (2001) .The Development Trend of the Foreign Construction Machinery. *Machinery & Electrical New Products Guide,* (1-2), 160-162.

[18] Wang, J., & Wang, S. (2002) .The Development of the Walking Excavator. *Construction Mechanization,* (6), 17-18.

[19] Wszołek, G. (2004), Vibration Analysis of the Excavator Model in GRAFSIM Program on the Basis of a Block Diagram Method. *Journal of Materials Processing Technology, 157–158*, 268–273.

[20] Yang, X. P., & Liu, S. D. (2005). Analysis on Structural Dynamic Characteristics of Hydraulic Shovel. *Machine Tool & Hydraulics,* (11), 87-88.

[21] Zhang, H., & Zhang, J. (2006). Ramble on Development of Mini Excavator Abroad. *Construction Mechanization,* (9), 10-13.

[22] Zhang, W.B., Yang, J.F., Wang, J.M., & Zhang, Q. (2008). Simulation and Application on Work and Motion State of Excavator. *Transactions of the Chinese Society of Agricultural Engineering, 24*(2), 149-151.

[23] Towarek, Z. (2003). Dynamics of a Single-Bucket Excavator on a Deformable Soil Foundation During the Digging of Ground. *International Journal of Mechanical Sciences, 45*(6-7), 1053-1076.

