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Bionic Study of Hydraulic Excavator Attachment

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Abstract
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. In order to optimize the excavator attachment, expand modern optimization design method. This paper puts forward the new idea of bionic optimization design, based on the basic theory of bionic research and technology. It described that the research profile of excavator attachment and the status for the parts of it. Finally, optimize the entire excavator attachment by bionic. Thus, it can improve the overall efficiency of the excavator.

Key words: Bionics; Excavator attachment; Optimization; Efficiency

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INTRODUCTION
Today hydraulic excavators are widely used in construction, mining, excavation, and forestry applications (Patel, *et al.*, 2011). Its diversity and convenient operating nature make it popular. It plays a very important role to raise labour productivity, to ensure the quality of the project. The power consumption and cutting force of excavator attachment is an important mining performance indicator. Study for excavator attachment has been subject to the concern of many scholars.

Bionics is a multidisciplinary science that searches in natural systems, principles and/or properties (structures, processes, functions, organizations and relations) and their mechanisms with the objective of applying them to create new products or solve existing technical problems in the already conceived products. This activity is part of the principle that the process of evolution occurred during millions of years in nature, resulted in the natural selection where only the survived species satisfactorily adapted to their intrinsic functions and to the environment. The methodology of the bionics allows the organization of basic stages that facilitates the course of the study, providing a logical way to act, assisting designers in the capitation of basic information for future projecting applications of products, enabling them in the search of eco-efficient solution (Junior, *et al.*, 2005).

Biomimetics offers enormous potential for inspiring new capabilities for exciting future technologies. Some of nature's capabilities can inspire new mechanisms, devices and robots (Bar-Cohen, 2006). It provides a new idea to improve the excavator working device.

1. RESEARCH PROFILE OF THE EXCAVATOR ATTACHMENT
Hydraulic excavators also called diggers. There are many variations in hydraulic excavators. They may be either crawler or rubber-tire-carrier-mounted, and there are many different operating attachments. With the options in types, attachments, and sizes of machines, there are differences in appropriate applications and therefore variations in

economical advantages (Gadhvi, *et al.,* 2010). Excavator digs, elevates, swings and dumps material by the action of its mechanism, which consists of boom, arm, bucket and hydraulic cylinders. Bucket is used for trenching, in the placement of pipe and other under-ground utilities, digging basements or water retention ponds, maintaining slopes and mass excavation (Patel, *et al*., 2011). Excavator working device (including the development of the boom, dipper stick, bucket), along with the change of materials, structures, processes, is derived form, after the early steel pipe finishing frame combination arm, steam power more primitive stage of the wire rope drive, after 100 years of development , the design of the excavator working device has been gradually mature. However, High efficiency and Low-power excavator attachment is required as the development of science and economy.

2. THE SITUATION FOR BIONICS RESEARCH

2.1 History of Bionics

The word of bionics was put forward originally by Jack Ellwood Steele, an America scholar.He combined the Latin words "bios", meaning the mode of live, with suffix "nick", meaning some character. It means that bionics is a system science simulating the biologic system, or possessing the characteristics of the biologic system, or resembling the biologic system.

Although the history of bionics could be traced back to many centuries ago, it is considered to all that the first symposium on bionics held in USA is the land mark for up-to-date bionics. Bionics simulates and transplants the special functions, which were observed, analyzed, studied and then understood, possessed by the biology in the nature into various engineering scopes for advancement of human society.

It is only 5 million years for human's development, but evolution of life has over 3.5 billion years history. Although, copying the creation from other human being is important, however, it has much more potential and opportunity in imitating the nature, and more possibility to promote the ability of original innovation (LU, 2004).

Today, as the rapid development of machinery, materials and information science, research and application of bionics at home and abroad have been a great deal of attention and vigorous development. Scientists are working with a large number of technical problems, which include the automatic control, energy conversion, information processing, mechanical models, and material composition of, to find inspiration to biological systems.

2.2 Significance of Bionics

Adapting ideas from biology can involve copying the complete appearance and function of specific creatures, as in toy manufacture where simplistic imitations are increasingly being incorporated to form electro mechanized toys such as dogs that walk and bark, frogs that swim, and many others. Flying was inspired by birds using human-developed capabilities, whereas the design and function of fins, which divers use, was copied from the legs of water creatures like seals. Once human flying became feasible, improvements in aircraft technology led to capabilities that far exceed any creature living on earth (Bar-Cohen, 2006).

Biological materials have capabilities that surpass those of man-made ones and these include silk, leather and wool that are widely used to make clothing (Carlson, *et al*., 2005). Further, biologically made structures have numerous advantages and the honeycomb is one such example. Bees create the honeycomb for its efficient packing configuration and, for its low weight and high strength; the same structure shape of the honeycomb is used to produce many aircraft parts. Generally, there is no evidence that the man-made structure was copied from nature. However, since it is a commonly known structure which was invented by nature many years before humans arrived, no patent can be granted in the 'patent court' of nature to the first human who produced the honeycomb configuration. Plants also offer ideas for imitation and they have evolved in various ways, with some that produced uncommon solutions to their special needs (Stahlberg, *et al*., 2005). In addition to their familiar characteristics, some plants exhibit actuation capabilities that we would expect from biological creatures. Such plants include mimosa and sensitive fern (monocle sensible) that bend their leaves when touched. There are also bug-eating plants with a leaf-derived trap that closes the 'door' locking unsuspecting bugs that enter the cage and become prey. The sunflower tracks the sun's direction throughout the day to maximize exposure to its light. Understanding the mechanism that drives this capability as locally controlled actuators offers potentially effective new motors.

3. RESEARCH OF THE BIONIC EXCAVATOR ATTACHMENT

The cutting forces of excavator attachment directly affect the efficiency of the machine. Biological exchange matter and energy and information with nature, it created them to adapt to ecological environmental systems. Many scientific and technical problems in the biosphere have been satisfactorily resolved. Certain animals, such as: the daily needs of the mice and voles mole cricket cock pangolin completed an important task is to mining capabilities of soil and other substances, is characterized by the formation of the active process of adaptation and soil dug dig enough developed. The curved shape of these animals claw toe bulldozing plate loader bucket and the

excavator bucket are certain similarities to the surface shape.

The cutting performance of the toe of a field mouse's claw, after inducting the concept of longitudinal/depth ratio, is analyzed with a FEM based on the observe and analysis about the geometric characteristics of animals' claw, and the basic laws and reasons for the superiority of mechanical performance during cutting process by animals' claw are surveyed, with which the reliable biologic information for the bionic design of cutting components is provided. Bionic excavator bucket which cutting performance was better than the ordinary bucket was designed by Guo Zhijun and Zhou Zhili (GUO, *et al*., 2007).

REN Luquan, CONG Qian, TONG Jin and CHEN Bingcong (2001) put forward Bionic electro-osmosis, a new method of reducing soil adhesion to soil-engaging components or parts of terrain machines, is presented. It is based on the anti-adhesion mechanism of the body surfaces of soil burrowing animals. The key feature of bionic electro-osmosis is to arrange a series of electric pole plates to create a non-smooth working surface. The static and dynamic effects of bionic electro-osmosis on the reduction of soil adhesion have been examined. The pole plates of the non-smooth surfaces with different dimensions used for bionic electro-osmosis have been designed and tested based on an experimental optimization method. The result showed that the adhesion of soil to a shovel was substantially reduced at a low electro-osmosis voltage. This technique shows promise for practical applications in reducing adhesion of soil against machine parts.

The mole cricket is a typical soil-dwelling insect which has excellent abilities of digging and excavation. Zhang Yan, by applying geometrical shape of the claw of mole cricket to a conventional scale of JL80 excavator bucket teeth, bionic excavator tooth was designed. The models of bionic teeth and JL80teeth were manufactured by using FDM-Dimension rapid molding system. The results of excavating test show that the resistance of bionic teeth 15 smaller than JL80 conventional teeth when the wedge angles are 90 and 60. The internal stress of tooth and soil was simulated and analyzed by using finite element method with ANSYS software. The simulating results are in consistent with the practical experimental results. According to the stress contour, we know that bionic tooth can change the stress concentration place from the tip of tooth to the surface of soil, which can disperse the stress of the soil in order to decrease the resistance of wedging. By analyzing and comparing the stress of JL80 and bionic tooth in wedging process, it is clear that the bionic tooth can decrease the wedge angle by not change the design of excavator machine and the working condition. The horizontal component of the total resistance acting in bionic tooth can be reduced by decreasing the wedge angle, which devote to the decreasing of wedge resistance (ZHANG, 2011).

4. FORELAND AND FRONTIER OF BIONIC EXCAVATION ATTACHMENT

Hydraulic excavator from the bodies of the boom, stick institutions, shovel mechanism composed of three parts, construction machinery is a multi-degree of freedom. These agencies often start, brake, change to the external load, and poor working conditions, shock and vibration, and higher design is required by the working device of the hydraulic excavator. In this study, typical excavator working device as a prototype, and our laboratory Dr. Zhang Yan thesis developed a bionic fighting gear research study mole cricket, typical excavator working device based on the simulation design and its corresponding virtual working device. Finally, the traditional mining and devices and bionic fighting tooth research to integrate design more energy saving, high efficiency and greater operational capacity excavator working device, thereby enhancing the performance of the whole excavator. The specific steps are as follows:

Part model-based 3D solid modeling software Pro/E and accurately build a hydraulic excavator, virtual assembly, and establish appropriate constraints, the dynamic simulation of excavator attachment.

Kinematic analysis in ADAMS to draw the trajectory of the hydraulic excavator bucket tooth tip, the largest excavator digging radius, maximum digging height, maximum digging depth of the basic performance parameters.

Analysis the dynamic force measurements, obtained the maximum force value of each hinge point in the boom, stick and other components of the excavator backhoe device at the hinge point, to more traditional excavator devices and bionic excavator attachment geometry, movement and dynamic characteristics, structural strength, and economic requirements.

To integrate the advantages of traditional excavator working device and the bionic excavator working device, to obtain the optimum parameters to design more energy-efficient environmental protection, high efficiency, and greater operational capacity excavator working device.

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