Study on Design of Working Device and Hydraulic System of Hydraulic Excavator Based on Computer Aided Technology

WenJing Hu*, Zheng Meng
Dalian ocean university, China, 116011

*Corresponding author e-mail: 22150997@qq.com

Abstract. This paper expounds the importance of hydraulic excavators in urbanization and infrastructure construction, and reviews the history of the emergence and development of hydraulic excavators. Based on the computer aided technology and the working process of the hydraulic system in the practical application, the paper expounds the principles to be followed in the design, so as to realize the design and research of the working device and the hydraulic system of the excavator.

Keywords: Hydraulic Excavator, Working Device, Hydraulic System, Computer Aided Technology

1. Introduction

Excavator first started in the United States, in the process of large-scale development in the western United States, the main power source is steam engine, imitation of human function, large-scale mining for mines[1]. Compared with the most widely used shovels and transport machinery in land development, excavators not only have a narrow application range in the early stage of development, but also have complex devices, large range of movement and high requirements for free coordination of structures, so the development of excavators in a certain period of time is relatively slow[2]. Later, the transmission technology has been greatly developed, and the rapid development of hydraulic transmission technology has brought unprecedented opportunities for the development of excavators. Many drawbacks of the traditional transmission technology have provided the technical basis for the emergence of hydraulic excavators and brought a breakthrough revolution for excavators[3]. At the same time, the era of urbanization has opened, engineering construction has produced new changes, the construction situation has been changed, excavator has a new and more important use, its application scope is a vast land. Up to now, the process of urbanization in China is still advancing, and the infrastructure construction is constantly improving, in which the role of hydraulic excavator is irreplaceable[4]. In the era of numerous projects, huge scale of projects and open architectural design, hydraulic excavators also need to follow the pace of science and technology and the times, constantly
adapt to new requirements and meet new needs.

2 Principles of hydraulic excavator

The so-called excavator in modern mainly refers to hydraulic excavator, mechanical excavator has been very rare[5]. Hydraulic technology is the technical basis of excavator, which in turn greatly promotes the development of hydraulic technology because of the high demand of excavator for hydraulic technology. Hydraulic system is the most complex hydraulic system of construction machinery, and many advanced technology of hydraulic transmission is embodied in excavator. Advanced hydraulic excavators are known as civil manipulators and are the representatives of construction robots[6]. According to the structure and working characteristics of hydraulic excavator, combined with the basic action requirements of the whole machine, the principle and characteristics of the new load flow independent distribution system pressure compensation control are analyzed. The hydraulic system of excavator is comprehensively analyzed, and the working principle of each subsystem is analyzed, and the data change of each component under the action of LUDV system under the action of the prototype test is obtained, and the specific analysis is made for different working conditions and different action mechanisms, so as to provide reference for the related structure and system analysis design of such products. The hydraulic device oil supply system form of the excavator is shown in Figure 1.

![Diagram](image_url)

(a) Sight oil feed

(b) Closed oil supply

Figure 1. Oil supply for hydraulic excavator
3. Design principles for hydraulic excavator working device

In doing anything, it involves methodology. Similarly, there are certain principles and requirements in carrying out structural design. Because the hydraulic excavator often starts frequently, brakes, changes direction, the external load changes greatly, the working condition is bad, often bears the vibration and the shock, therefore has the high design request to the working device.

3.1. Scope of operations and transport requirements

When designing the working device, the geometric size should satisfy the distribution characteristic of reasonable excavation force besides convenient transportation, so that the excavator can realize the maximum excavation force in the main excavation area. In the main excavation area, the excavator is excavated in the way of excavating below the ground, from bottom to top, moving to the fuselage, in this way, the loading efficiency is high, the cycle time is short, easy to unload, the driver has good field of vision, high productivity and safety.

3.2. Mechanical stability

The stability of the whole machine is closely related to the design of the working device, so the designed working device should be satisfied that the excavator should not be tipped when working and parking, and so on.

3.3. Meet structural strength requirements

The structural strength requirement is to design the working device, so the working device should be subjected to the stress distribution and deformation law of each part of the structure under various stress conditions, so as to ensure that the designed working device should have sufficient strength.

3.4. Environmental economic requirements

The design of the working device should not neglect the economic cost because of the simple pursuit of technical performance while meeting the requirements of use.

4. Hydraulic excavator hydraulic system working process

To understand and design the hydraulic system of the excavator, we must first analyze the working process of the hydraulic excavator and understand the operation requirements of the excavator. It is necessary to master the flow rate, force and power requirements of each hydraulic action element. The compound action requirements of the hydraulic action element to cooperate with each other and the flow distribution and power distribution of the oil pump to the oil supply of each hydraulic component of the same action when working together. The excavator hydraulic system is shown in Figure 2.
4.1. Spadework

Usually the bucket hydraulic cylinder or bucket rod hydraulic cylinders are separately excavated, or the two are combined to dig. In the process of excavation, the bucket and bucket rod have compound action, when necessary with arm movement. In this case, the bucket rod retracts and the moving arm lifts, hoping that the bucket rod and the moving arm shall be supplied by separate pumps to ensure independence and non-interference with each other. In order to improve the cutting speed, the double-pump combined flow is generally used when the bucket rod is used. The following is a three-pump system to illustrate the combined action excavation, oil pump flow distribution and split-flow oil connection oil supply situation. When the oil pressure of the bucket rod is close to the pressure of the relief valve, the oil of the original overflow is used for the bucket effectively; when the bucket rod and the moving arm are combined, because the moving arm only plays the role of adjusting the position, mainly the bucket rod is excavated, so the bucket rod is used for preferential confluence and double pump oil supply. When the moving arm, bucket rod and bucket are combined, each pump of the three pump system is better supplied with a single hydraulic action element in order to prevent interference with each other when supplying oil with the pump. It is possible to interfere with each other with the compound action of double pump system, so it is necessary to use throttling and other measures to distribute the flow rate, and its flow distribution requirement is the same as that of three pump system. For effective vertical excavation, pressure oil is provided to the rotary motor to produce the rotary force and keep the bucket close to the side wall for cutting. Therefore, the rotary and bucket rods are required to supply oil together. Rotary and bucket rod shrink at the same time, by the same pump oil supply, the use of rotary priority oil, or the oil flow to the low pressure, making it difficult to
dig close to the side arm. A variable throttle valve is arranged on the end return line of the piston rod of the bucket rod. The opening size and throttling degree of the valve are controlled by the rotary leading pressure. If the rotary leading pressure is large and the throttle is large, the return oil pressure of the bucket cylinder is increased, and the oil supply pressure of the pump is increased. When it is possible to meet stones and roots in the excavation process, it is necessary to increase the excavation force for a short time. In the excavation operation, the external resistance of the excavator mainly comes from the excavation resistance, which is decomposed in the tangential direction and normal direction to write F1, F2, respectively. The former is perpendicular to the tip of the tooth, while the latter is tangent to the tip of the tooth.

\[
F_1 = k_0 wd \quad (1)
\]
\[
F_2 = \varphi F_1 \quad (2)
\]

Among them, \(k_0\) is mining specific resistance, \(w\) is mining depth, \(\varphi\) is mining resistance coefficient.

4.2. Gyration

Because of the large inertia, the oil pressure will rise very high, and it is possible to overflow from the relief valve. However, because the lift pressure of the arm is high, the one-way valve is closed most of the time, and the left pump is only for rotary and bucket rods. The rotary motion generally needs less flow, so it is advisable to use a smaller flow pump. If it is driven by a large flow pump, the moment of inertia is very large and the power loss is large in the process of starting and braking.

4.3. Unload

When turning to the unloading position, the turntable brakes, adjusts the unloading radius and unloading height with the bucket rod, and unloads with the bucket cylinder. In order to adjust the unloading position, also need to move the arm to match the action. When unloading, mainly bucket rod and bucket composite action, between the movement arms.

4.4. Ture back

At the end of unloading, the turntable rotates backwards, while the arm cylinder and bucket rod cylinder cooperate with each other to put the empty bucket to the new excavation point. This working condition is rotary, moving arm and bucket rod compound action. Because the drop of the moving arm has the effect of gravity, the pressure is low, the variable pump flow rate is large and the drop is fast, so the oil supply condition of this working condition is that one pump has the full flow rate for turning, the other pump has most of the oil supply arm, and a small part of the oil is throttled through the bucket rod. The oil supply of oil pump is small when the engine is low speed. In order to prevent the moving arm from falling rapidly because of gravity and the suction phenomenon of the moving arm oil cylinder, the oil of the moving arm cylinder without rod cavity can be supplied to the rod cavity by gravity.

5. Conclusion
This paper analyzes the importance of hydraulic excavator in engineering construction, describes the working process of each device of hydraulic excavator, discusses the design principle of the working device, and provides the basis for the design optimization of the working device of hydraulic excavator.

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