Design Based on Changing the Bucket of Small Hydraulic Excavator to Clamp Brick Machine

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Abstract. Small hydraulic excavators have the characteristics of multi-function and wide application range. It is an important mechanical equipment widely used in mechanized construction. It can not only be used for excavation of earth and stone, but also plays an irreplaceable role in various engineering constructions. Moreover, through the replacement of working devices, it can also be used for various operations such as lifting, loading, grabbing, piling, and drilling. This article takes a small excavator as an example. By disassembling the original bucket, the newly designed brick clamping mechanism is installed in the position of the bucket, so as to realize the purpose of clamping or moving bricks and increase the scope of use of the original excavator.

Keywords. Excavator, Brick Clamping Machine, Hydraulic System.

1. Introduction
The grand western development program China has made various projects in full swing, which has led to the development of China’s construction machinery field. According to data in 2019, there are currently 6.9 to 7.47 million construction machinery in China, of which the number of excavators is 1.5 to 1.68 million [1], accounting for about one-sixth of the construction machinery. The idleness of such a number of excavators will cause great Waste of resources, and the cost of an excavator is relatively high, and its price is about hundreds of thousands. Therefore, while improving the efficiency of the excavator, its economic benefits should also be maximized to increase the speed of cost recovery and improve work efficiency. It is to equip it with some other attachments to make it suitable for more work scenarios. The more work you do, the higher the economic benefits generated by the excavator.

Since the western region of China is dominated by plateaus and mountainous areas, it is inevitable to open mountains, dig canals, and drill rock during the various infrastructure constructions. When these tasks are completed, the excavator will be left idle until the end of the project. To maximize the utilization rate of excavators, and the rugged roads, ordinary construction machinery is difficult to walk on the rugged roads, which causes difficulties in transporting construction materials, such as bricks, square wood and blocks, etc. Not only slows down the progress of the project, but also wastes precious time. Although, there is a machine specifically for clamping bricks on the market-the brick clamping machine, which is only suitable for the brick making industry, construction field, and
transportation field, and cannot work effectively in areas with complex terrain. In order to solve this problem, we can transform the idle excavator and design a brick clamp as a replaceable attachment of the excavator, so as to increase the utilization rate of the excavator, reduce the cost of the project, and improve the excavator's performance. Realize one machine with multiple uses and one machine with multiple fields.

2. Current Status of Existing Excavators and Brick Clamps

2.1. Current Status of Excavator Technology
Small excavators are mainly used for urban civil construction and general residential renovation work. A large number of environmental protection and energy-saving technologies are used on small excavators to make small excavators have lower noise and better emission control; a large number of humanized design techniques are used to make the operation easier. Maintenance is more convenient [2]. The superior performance, technical indicators and economic indicators of small hydraulic excavators have made many countries in the world, especially industrially developed countries, vigorously develop small excavators.

At present, the development of small excavators focuses on the improvement of power and transmission systems to achieve high efficiency and energy saving; the scope of application continues to expand, the cost is continuously reduced, and the development of standardization and modularization is developed to improve the reliability of parts and accessories, thereby ensuring the whole machine reliability; electronic computer monitoring and control, mechatronics technology improves the mechanical performance of excavators, reduces noise, reduces downtime and waits for work, and improves adaptability, making excavators more widely used.

2.2. The Current Situation of the Use of Special Brick Clamping Machines
In the traditional industry, bricks need to be stacked and handled many times before they are actually used in the construction industry. In this process, manual handling is the main method, which not only has low work efficiency, but also increases the damage rate of bricks. Therefore, the market a special machine for clamping bricks has appeared. This machine is only limited to levelling the road or operating in the field; the other is in the form of attachments and needs to be used in conjunction with a forklift. This type of machine is light and small, but this brick clamping machine is restricted by forklifts [3], and its work efficiency is low. The restriction of forklifts means that the machine cannot be widely promoted.

In view of the existing problems of these two brick clamping machines and excavators, the design of a brick clamping machine with low cost, wide application range and stable walking on rugged roads has become a hot topic in the field of construction machinery. Looking at the future of small excavators, there are the following trends: by disassembling the original bucket, installing the newly designed attachments (brick clamping mechanism) on the small excavator, so that the small excavator is transformed into a brick clamping and brick conveying clamp. Machine, improve the scope of use of the original excavator, and become a multi-functional machine. At present, the transformation of small excavators is widely used in hydraulic engineering, transportation, construction and mining and other mechanical constructions. It plays a very important role in reducing engineering costs, rational use of resources, and improving labor productivity.

3. Ideas for Designing Brick Attachments of Small Hydraulic Excavators

3.1. Choose the Model and Parameters of the Excavator
This article selects the mini excavator produced by Guangxi Xuvol Construction Machinery Equipment Co., Ltd., Model: WY17U, and the drive hydraulic motor has a displacement of 10 ml per revolution (cm³/r); there are three pumps with a flow rate of 12/12/6 ml each rotation (cm³/r), engine (hydraulic motor, pump) speed 1600–1800 rpm, maximum pressure oil 16 Mpa.
3.2. Design of Mechanical Structure

Place the bricks in a flat stack. The number of bricks to be clamped is large and heavy, which requires a large clamping force. In order to facilitate the comparison and determination of the plan, this paper designs three clamping mechanisms as shown in figure 1 (a)

![Clamping Mechanism](image)

**Figure 1.** Clamping Mechanism.

The picture shows the two-way hydraulic cylinder structure. The piston rods on both sides push two fingers respectively to realize the opening and closing clamping functions. When the pressure oil is passed into the rod cavity of the hydraulic cylinder, the hydraulic rod retracts to realize the clamp opening without rod. The clamp can realize the clamping function when the pressure oil is passed into one side of the cavity, but the hydraulic cylinder is complicated and difficult to manufacture; the figure uses two hydraulic cylinders, each driving a finger to realize the clamping and releasing functions, but the two hydraulic cylinders are The cost of a hydraulic cylinder is high and it is difficult to synchronize; the figure uses a hydraulic cylinder to drive the fingers on the other side through the linkage mechanism to ensure the synchronization of the claws. The structure is simple, the cost is low, and it is easy to control. Therefore, this article adopts the figure 1 (c) as scheme. Due to the large size error of the bricks, in order to ensure that the bricks are not easy to fall off during the clamping process, we set a spring structure on the contact side of the fixture and the bricks, so that each brick can be clamped.

It can be seen from figure 1(c) that the single-cylinder drive ensures stable performance, safe work, and economical benefits, and ensures that the left and right jaws can output the combined force at the same time and complete the grasping synchronously. The brick clamping machine consists of a support, left and right jaws, connecting rods, hydraulic cylinders, etc. The right jaw and the left jaw are connected by a connecting rod. When the right jaw is driven by the piston rod, the left jaw moves synchronously due to the connecting rod connection, thus Ensure that the two claws open and close at the same time. From the research and analysis of the original excavator model parameters, it is possible to determine the relative size of each hinged hole of the brick clamp, and to design the maximum opening and closing range and determine the outline length of the left and right jaws.

4. Design and Calculation

4.1. Force Analysis and Calculation

Assuming the size of the standard red bricks to be clamped is 240 mm×115 mm×90 mm, each layer of bricks is 3×3, 9 blocks in total, 4 layers in total, then 36 bricks can be clamped each time, and then the bricks are clamped once. The block size is: length 720 mm width 345 mm height 360 mm. According to the "Machine Design Manual", the density of the bricks is (1.4~2.2)×103 Kg/m^3, take 2.0×103 Kg/m^3, and calculate the weight of each clamped brick (0.72 m×0.345 m×0.36 m) ×2.0×103=178.848 Kg, the final weight of the brick is 180 Kg by taking an integer. For the sake of
safety, the final weight needs to be multiplied by a safety factor of 1.3, that is, 180×1.3=234 Kg, that is, the weight of the brick to be clamped is 2340 N, so that G in figure 1 is equal to 2340N. The brick clamping machine needs to clamp the bricks smoothly, and the friction force Ff formed between the clamp and the bricks must be greater than or equal to the weight of the bricks, that is, Ff≥G. Ff is 1.5 G, and 1.5×2340=3510 N, that is, Ff=3510 N. According to the mechanical design manual, the static friction observation force between the brick and the steel is 0.2, then the clamping force F = friction force ÷ friction coefficient, that is: F = 3510 ÷ 0.2 = 17550 N, as shown in figure 1 (c) The F force is 17550 N. According to the lever balance principle, the formula \(F×a=F′×b\) is listed. According to the size of the one-time clamping brick, take a=b=500 mm, then the piston rod thrust \(F′\) is equal to 17550 N.

4.2. Calculation and Selection of Clamping Hydraulic Cylinder
From the "Hydraulic and Pneumatic Technology" [4] page 20 (2-1), the formula \(F′=P×πD^2/4\), \(D\) is the inner diameter of the hydraulic cylinder, and \(p\) is equal to the pressure oil provided by the excavator, which is 16Mpa. Substituting the provided thrust \(F′=17550\text{N}\), \(D=37.4\) can be obtained. Since 16Mpa is the maximum pressure oil provided by the hydraulic excavator, we can appropriately choose a larger hydraulic cylinder and take the hydraulic cylinder with an inner diameter of 50mm. Take the standard hydraulic cylinder parameters from "Hydraulic Technology Practical Manual" [5]: Hydraulic cylinder model HGS-50, inner diameter 50mm, outer diameter 60mm, rod diameter 28mm, pressure 16Mpa, stroke 150mm.

4.3. Design the Rotating Mechanism
It is necessary to adjust a certain angle when clamping bricks. For this reason, we need to design a rotating mechanism for the brick clamping machine. When rotating, we must prevent the brick clamping machine from reversing due to gravity. The rotation mechanism we designed is also Must have self-locking function. Therefore, a worm gear mechanism with self-locking function is used to realize the rotation function. The worm is driven by a hydraulic motor to drive the worm wheel to rotate to realize the rotation function of the brick clamp.

4.4. Selection of Hydraulic Motor
It is known that the weight of the bricks to be clamped is \(G=2340\) (N), the weight of the clamping machine is \(G′=5000\) (N), and the diameter of the supporting worm gear bearing is 100 mm. At this time, the total pressure on the bearing is \(G + G′= 7340\) (N). The friction torque acting on the bearing is found from the "Machine Design Manual", that is, the friction torque that the worm gear needs to overcome when rotating \(T=(G + G′)×\text{bearing diameter} 100=734000\) (N·mm) Suppose the worm gear ratio \(i=20\), and the safety factor is 1.3, the worm gear torque \(T2=1.3×Tsrc=1.3×734000=954200\) (N·mm), and the worm torque \(T1=T2/i=954200/20=47710\) (N·mm)=47.71 (N·m). The worm is connected with the hydraulic motor, so the torque that the hydraulic motor needs to provide is the worm torque \(T1\), and the hydraulic motor can be selected according to the worm torque 47.71 (N·m). Check "Hydraulic Cylinder" and select the hydraulic motor parameters as follows [6-10]: Hydraulic motor model: BMR-50, speed: 730rpm, torque: 89 (N·m), shaft diameter: 25mm, shaft length: 40mm.

5. How to Install Attachments
5.1. The Basic Composition of the Brick Clamping Machine
The basic composition of the brick clamping machine is shown in figure 2. 1 is the hydraulic rotary joint mounting plate, 2 is the horse-drawn head connecting the brick clamp and the excavator, 3 is the solenoid valve control group, 4 is the hydraulic motor, 5 is the worm gear reducer, and 6 is the rotation of the claw of the brick clamp table, 7 is a hydraulic cylinder for clamping, 8 is a connecting rod, 9 is a splint that is a gripping claw, 10 is an elastic assembly for fixing the top of the elastic splint, and 11 is an elastic splint.
5.2. Installation Method of Excavator Attachment
The basic principle is: do not change the structure of the original hydraulic excavator, just install the brick clamp we designed on its front arm, connect its spare oil pipe, and operate the clamp through the control rocker in the cab which will be clamping, rotating, placing and other actions of the brick machine. There is no need to disassemble the arm of the excavator when the brick clamp is needed, and the original attachments of the excavator are directly disassembled, and the horse head of the brick clamp is connected with the original installation hole on the arm of the excavator, and the oil supply pipe of the bucket cylinder is used. The road is connected to the oil supply to control the opening and closing of the brick clamp. The original hydraulic system of the excavator can be used directly to meet the power needs of the brick clamp, and the supporting hydraulic control valve group, working pipeline and auxiliary hydraulic components can be added to realize all the functions of the brick clamp.

6. Control System Design
The opening, closing and rotating actions of the brick clamp are all completed by the pressure oil provided by the excavator. The control principle diagram is shown in figure 3, and the hydraulic component control buttons are shown in table 1.

Table 1. Hydraulic System Control.

| Control object | Three-position eight-way reversing valve | Hydraulic motor control valve | Hydraulic cylinder control valve |
|----------------|------------------------------------------|-------------------------------|--------------------------------|
| Buttons        | Buttons SB1 (left), SB2 (right)         | SB3 (left), SB4 (right)       | SB5 (left), SB6 (right)        |
7. Modification Considerations
There is no need to disassemble the big and forearm, just install the attachment at the front end of the forearm, replace the bucket with the attachment, and connect the pin of the original bucket of the excavator with the horsehead of the brick holder. The oil supply pipeline of the bucket cylinder is connected to supply oil to control the opening and closing of the brick holding clamp. The original hydraulic system of the excavator can be directly used to meet the power needs of the brick holding conveyor. The additional hydraulic pressure is the control valve combination and the working pipeline and the attached hydraulic components complete the function of clamping and transporting bricks.

8. Concluding Remarks
Excavator is a kind of construction machinery that is more commonly used, but its use has a certain intermit entity, which is related to the progress of the project. Therefore, designing a brick clamping machine at the excavator bucket position is to transform the excavator into a brick clamping conveyor. On the basis of not changing the performance of the excavator and not damaging the structure of the excavator, the attachments of the excavator are improved. In order to enrich, the use time of the excavator is increased, and the equipment investment is saved at the same time.
According to the different weight of loading and unloading bricks, you can choose the appropriate tonnage excavator to cooperate with the brick clamping machine, and you can get the brick clamping conveyor of different tonnage. The brick-clamping transporter only needs one excavator driver to operate in the cab to complete the entire work process of clamping, transferring and placing bricks, saving labor costs and reducing labor intensity. The attachment of the excavator is changed to a brick clamping machine, which not only reduces the high brick damage rate and poor labor environment in the traditional brick moving method, but also greatly reduces the labor cost input, improves the efficiency of brick moving, and reduces the idle rate of excavators. After the excavator is equipped with attachments to form a brick clamping machine, it has a wider application range and a cheaper price than the brick clamping machine currently on the market. The forearm part of the excavator can swing up and down, crawler walking and other functions have certain advantages in some places with higher or uneven terrain. It can also adapt to complex placement methods and operating methods. It can be placed in stacks and rows. It overcomes the shortcomings of general mechanical equipment that it is difficult to adapt to many complex placement methods. The brick clamping machine designed in this paper provides an effective guarantee for the infrastructure construction in the mountainous area.

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