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An improved energy matching method to utilize the potential energy of large-sized hydraulic press at multi-system level

Lei Li[a]*, Haihong Huang[a], Xinyu Li[a], Zhifeng Liu[a]

[a]*School of Mechanical Engineering, Hefei University of Technology, Hefei 230009, China*

* Corresponding author. Tel.: +86-156-0969-7105. *E-mail address:* hfut_lilei@hotmail.com

Abstract

Large energy loss caused by mismatching and wasted potential energy, is a prominent problem for large-sized hydraulic press. The mismatch problem can be solved at the multi-system level of hydraulic press, where a drive system consisting of several drive zones provides energy to hydraulic presses according to the load profiles. Based on the multi-drive to multi-press system, we added a peer to peer mode, where the potential energy of the slider can be utilized mutually among these presses by combining the chambers of hydraulic cylinders. In this improved multi-system method, the number of drive zones can be reduced by combining operations and the matching degree is further improved. Meanwhile, the scheduling scheme needs to be redesigned according to the enhanced constraints of duration of each operation, which shows better energy-saving effect.

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Keywords: Energy matching; large-sized hydraulic press; multi-system; Combining; potential energy;

1. Introduction

Hydraulic presses with advantages of high power to mass ratio and high load capability, are widely employed in various forming processes. To meet the demand of large forming force, large-sized hydraulic press (Fig. 1) with installed power up to hundreds kilowatts is a common occurrence

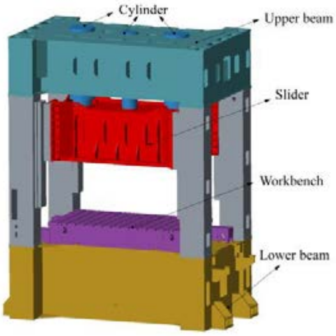

Fig. 1. Physical structure of hydraulic presses

Unfortunately, they suffer from significant drawback that large energy loss occurs during energy conversion, especially the large-sized one. Only 7% of the energy consumption is converted to the forming energy in each forming process as shown in Fig. 2[1].

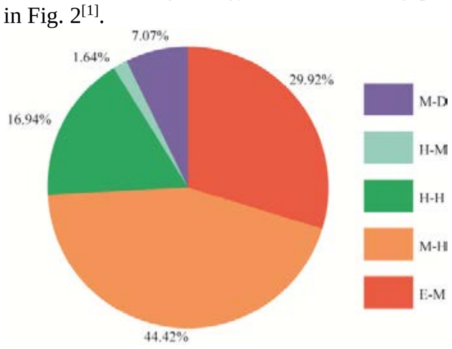

Fig. 2. Energy consumption of each energy conversion unit in a forming process (E-M, electrical- mechanical energy unit; M-H, mechanical-hydraulic energy unit; H-H, hydraulic-hydraulic energy unit; H-M, hydraulic-mechanical energy unit; M-D, mechanical-deformation energy unit)

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With this energy flow, several operations are performed in a forming process as shown in Fig. 3.As the demanded power of each operation with different velocity varies and the installed power of a hydraulic press is designed to meet the maximum one, the mismatch between the installed power and the demanded power then occurs, which leads to low energy efficiency. Furthermore, drive system stays idle during a long waiting time(WT) to load and unload work piece, which causes much more energy loss.

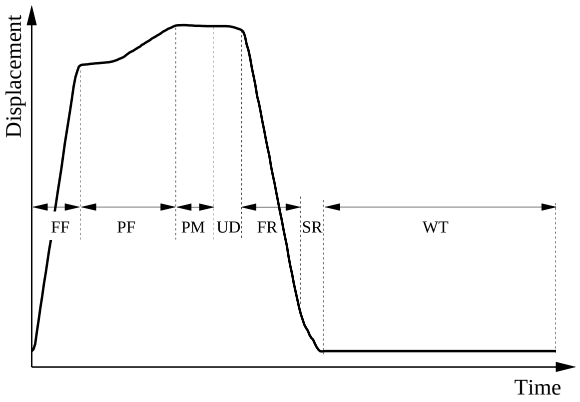

Fig. 3. Displacement of the slider changes with operations in a forming process (Firstly, the slider moves downward to approach the workpiece with a high speed (FF operation) from the initial position, then forms workpiece with a lower speed (PF operation) and keeps high pressure (PM operation) in the cylinder for a while. After that, releasing the pressure (UD operation) is needed. At last, the slider moves upward with high speed (FR operation) and then continues moving to the original position with lower speed (SR operation).)

To solve this problem, a widely used system is the volume control electrohydraulic system driven directly by various kinds of variable-speed motors, such as variable-frequency motor[2, 3] and servo motors[4]. The control of pressure, flow and direction of working liquid is achieved by controlling rotation speed[5].And considerable research has developed adaptive control approaches to satisfy control performance for the servo motor direct drive volume control system[6-10]. However, these methods increase the complexity of control and do not reduce installed power of hydraulic systems.

Therefore, an energy-saving method for hydraulic press group has been developed to reduce the average installed power of each hydraulic press [11-15], where a single drive system composed of several motor-pumps, is partitioned into several drive zones corresponding to load profiles. The system is used to supply power to several hydraulic presses with approximately same installed power. As a result, the mismatch between the installed power of the drive system and demanded power of hydraulic presses was eliminated by sharing drive zones with different installed power in order and the significant energy-saving potential is shown in Fig. 4[16].

After the mismatch has been solved, the wasted potential energy of the slider become more prominent. The mass of the slider is considerable compared to that of the whole equipment. Therefore, plenty of energy has been wasted in the reciprocating movement of the slider in forming processes. It is noticeable that the potential energy of the slider wasted in the downward movement during FF operation and the energy consumption used to move the slider upward during FR and SR operation account for about 20% of the whole energy consumption as shown in Fig. 4.

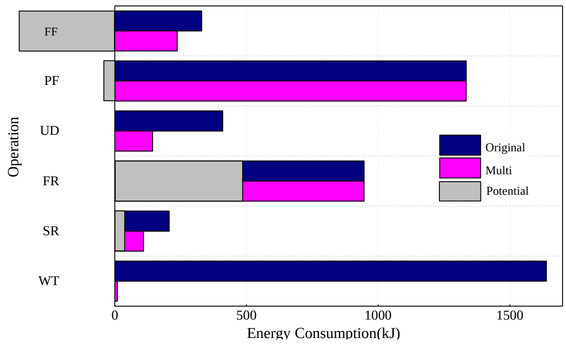

Fig. 4. The energy consumption and potential energy variation of each operation in a forming process ("Original" is for the hydraulic press with original hydraulic press, "Multi" is for a hydraulic press in a group with multi-drive and "Potential" is for the potential energy change.)

Therefore, some regeneration methods have been proposed by using accumulator to recover the kinematic energy or a flywheel to store the inertia energy[17, 18]. The potential energy of the vertically moving load can be harvested and returned to the hydraulic drive systems[19-23]. Generally, the traditional energy recovery methods could be divided into two parts: energy recovery process and energy reuse process as shown in Fig. 5.

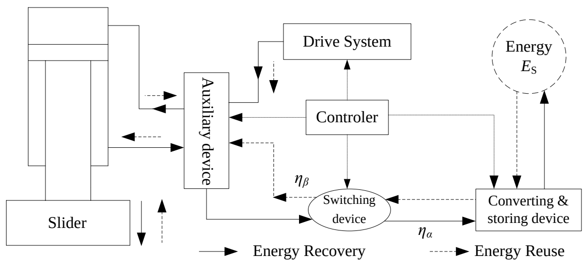

Fig. 5. Energy recovery and reuse process in the traditional regeneration methods

In the recovery process, using converting and storing device, the gravity potential energy of the slider would be recovered and transferred into other forms of energy such as the kinetic energy of flywheel, the potential energy of accumulator and the electrical energy of the super capacitor or the battery. And energy conversion of this process could be expressed as Equation (1).

$$\int_{t_1}^{t_2} F \frac{\partial H}{\partial t} dt \eta_\alpha = E_S \quad (1)$$

where, t_1- t_2 is the duration of the recovery process. F is the resultant force, which is the gravity of the slider during FF operation; H is the displacement of the slider. E_S is the recovered energy, and η_α is the energy efficiency in the