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# An Energy Matching Method for Hydraulic Press Group Based on Operation Load Profile

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**Abstract**

To improve the energy efficiency and reduce the energy consumption of hydraulic press, a partitioned control method for grouped hydraulic presses is proposed. A drive system composed of several motor-pumps is the only drive system to provide energy for all hydraulic presses in a group, which is partitioned into several drive zones according to the load profiles. Each drive zone with installed power matching the needed power of an operation is employed by grouped hydraulic presses in the same operation. Different drive zones provide energy for each hydraulic press in the order of operations, which obtains great energy-saving effect.


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*Keywords:* energy saving; hydraulic system; power matching; energy efficiency; drive system

## 1. Introduction

Hydraulic system gains its popularity over industrial manufacturing especially in metal forming process for its safety and convenient control. However, the energy inefficiency is the major drawback of hydraulic system. Its efficiency ranges from 6% to 40% which leads to the huge waste of energy [1]. For these reasons, increased attention has been paid in recent years to the energy saving of hydraulic systems.

A perusal of the current literature reveals a number of developments in this direction. A first group seeks to address this issue from the perspective of improving the regenerating efficiency of hydraulic system. Triet Hung Ho et al. [2] purposed a new Energy Regenerate System (ERS) which was based on a closed-loop hydrostatic transmission and used a hydraulic accumulator as the energy storage system fabricated in a novel configuration to recover the kinetic energy without any reversion of the fluid flow. Experimental results indicated that the round trip recovery efficiency varied from 22% to 59%. Lin and Wang [3, 4] studied the traditional energy regeneration system in hybrid hydraulic excavator and purposed a new ERS with a hydraulic accumulator where the kinetic energy could be converted into both electric and hydraulic energy. Experimental results showed that 45% or more kinetic energy could be recovered compared with the traditional ERS.

Another line of work underlined the significant potential for improving the energy utilization efficiency. Tatiana A et al. [5-7] utilized electric servo drives in the control of hydraulic lifting systems directly by an electric-servomotor-driven hydraulic machine. Servomotors directly drive and control lifting system of a forklift which means no energy would be wasted on valves and control wires. Hence its efficiency has been improved. Electro-hydraulic load sensing control strategy has been applied in low-priced drive system by Darko Lovrec et al. [8]. In this strategy, speed-controlled induction motor to dynamically adjust its speed to output the corresponding energy according to the load condition of hydraulic system, which reduced the energy loss caused by power mismatch. Experimental study fulfilled the expectation of lower energy loss and higher efficiency.

Summarizing the findings of the above discussions, it can be claimed that these methods have made great achievements


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in terms of energy saving for hydraulic system. Nevertheless, there is still some obstacles which impede further improvement of energy efficiency:

- The mismatch between the required power of hydraulic system and the output power of motor-pumps
- The long idle time of drive system which accounts for the characteristics of the forming process
- The insufficiency of energy saving methods for grouped machines

This balance of this paper consists of four sections. The drawbacks in energy saving of traditional hydraulic system was analyzed in section 2. And the energy matching method was purposed in the following section. A case study was considered in section 4 with providing the appliance of the energy matching method to a group of hydraulic presses for sheet metal forming. Finally, the paper presents a summary and conclusions.

## 2. Energy consumption of traditional hydraulic system

Generally idle stage (I), fast falling stage (FF), press stage (P), pressure maintaining stage (PM) and returning stage (R) are included in a typical forming process. The power needed of hydraulic press in various forming stage was shown in Fig. 1. In traditional hydraulic drive system, the input power was designed to meet the power requirement of press stage which owns the largest demanded power, but the time length of press stage is much shorter in comparison to the whole working process, leading to the waste of energy and low energy efficiency of hydraulic system. The consumed energy and efficiency of hydraulic system could be calculated by the following equations.

$$E_1 = P_{\max} T_{sum} \quad (1)$$

$$\eta_1 = \frac{\int_0^{T_{sum}} P(t)\,dt}{E_1} \quad (2)$$

Where,
$P_{\max}$ is the maximum power required in a forming process,
$T_{\text{sum}}$ is the total time of whole forming cycle.

In traditional forming process, there exists an idle stage which is set to complete auxiliary works, for example loading and unloading work pieces. In this stage, the motors in the drive system are still running without providing energy to the hydraulic press. The proportion of idle stage in the whole forming cycle was shown in Fig. 2, idle stage occupies a considerable part of the whole forming cycle.

As mentioned above, the installed power is designed to meet the maximum power requirement of hydraulic press which leads to the mismatch between the required power of hydraulic system and the output power of motor-pumps. And, a long idle time means that drive system stays idle which causes much more energy wasted. The problems described above lead to the high energy consumption and low energy efficiency of hydraulic press.

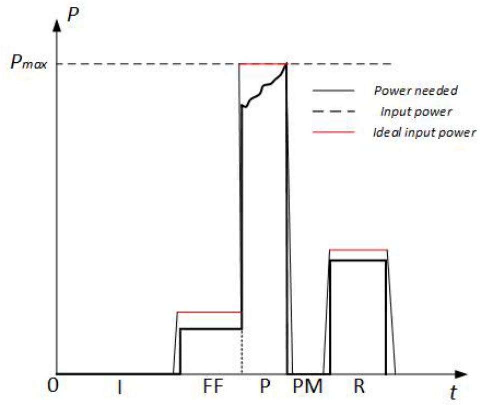


Fig. 1. Power requirement in a forming process.

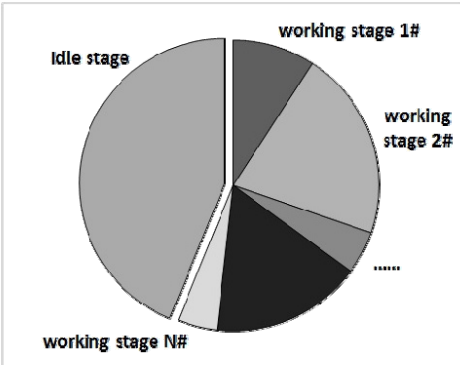


Fig. 2. Distribution of working stage and idle stage.

## 3. Energy matching method

In order to solve the mismatch and long idle time problem above, an energy matching method for single hydraulic press was purposed. According to the load characteristic of hydraulic press in a typical forming process, the whole working cycle could be partitioned into several working stages. In order to match the input power and the demanded power of the corresponding working stages, the drive system of the hydraulic press is partitioned into several drive zones with different installed power. The relation between drive system and hydraulic press is shown in Fig. 3. The drive system is divided into $N$ drive zones according to the number of working stages of hydraulic press in a working cycle. The output power $P_i$ of each drive zone matches with the required power of hydraulic press working in the corresponding working stage.

When hydraulic press runs in working stage 1#, the corresponding drive zone 1# in drive system will be activated and supply energy to the press. When working stage 1# is over, drive zone 1# will be deactivated and drive zone 2# will be activated to serve hydraulic press when it is at working stage 2#. Each drive zone only works when hydraulic are in the corresponding working stage, and stays unloading at the other time of the whole cycle. When working stage N# is