Applied Mechanics and Materials
ISSN: 1662-7482, Vols. 592-594, pp 2244-2248
doi:10.4028/www.scientific.net/AMM.592-594.2244

Submitted: 2014-04-23
Revised: 2014-05-07
Accepted: 2014-05-18
Online: 2014-07-15

Study of energy recycling in electro-hydraulic system

J. Das[a*], Santosh K. Mishra[b], Ajit Kumar[c], N. Kumar[d], Sujit. K[e], R. Paswan[f]

Department of Mining Machinery Engineering, ISM, Dhanbad-826004, India
[a]jayanta_mech_engg@yahoo.co.in, [b]apsantoshmishra@gmail.com, [c]ajit.ism185@gmail.com,
[d]niranjan_jgec05@yahoo.co.in,[e]sujitkr0084@gmail.com,[f]ramarit_paswan@rediffmail.com

Keywords- hybrid excavator; potential energy recovery; arm; energy saving

Abstract

Environmental and energy issues demand the construction equipment industry to develop more efficient and energy saving machines as they have done to the automotive industry in the last decade. This energy of traditional excavator is lost in the form of heat energy. Heavy earth moving equipments such as excavators, loaders and forklift trucks have unique power train mechanism, thus the focus on important issues like efficiency improvement or energy savings holds great value. Hence, the need of the hour is to develop machinery which can match the necessities and challenges of the ever evolving industry in terms of energy saving management. In this context, hybrid excavators have been ushered in currently. Here system translates the arm/boom/buck's potential energy into electrical energy and then the electrical energy is stored in a storage device. It develops a set of energy management strategy to make the recoverable energy usage efficiently. The advancements in the field of heavy machineries holds key in future of hybrid excavators.

Introduction

Energy conservation is important for hydraulic excavator in heavy machinery industries. The energy utilization ratio is only 20% for traditional hydraulic excavator. Hydraulic excavators work under poor condition and consume huge amount of fuel, so the research of saving energy will bring a huge economic benefit. Based on the current hydraulic excavators energy saving procedures, improving the equipment working conditions, hydraulic system structure and power matching of engine-hydraulic pump have the energy saving potential of hydraulic excavator. The development of hybrid technology that has already been applied in automobiles and with the same effect if it is incorporated in heavy machineries, then it will be the start of new era in the energy saving of construction machineries.

Weidong et al. [1] formulated a set of energy saving strategy to make the recoverable energy recycling efficiently. This energy of traditional excavator dissipates in the form of heat energy. Researching on this system acts as a stepping stone in solving the ever growing global problem of energy crisis.

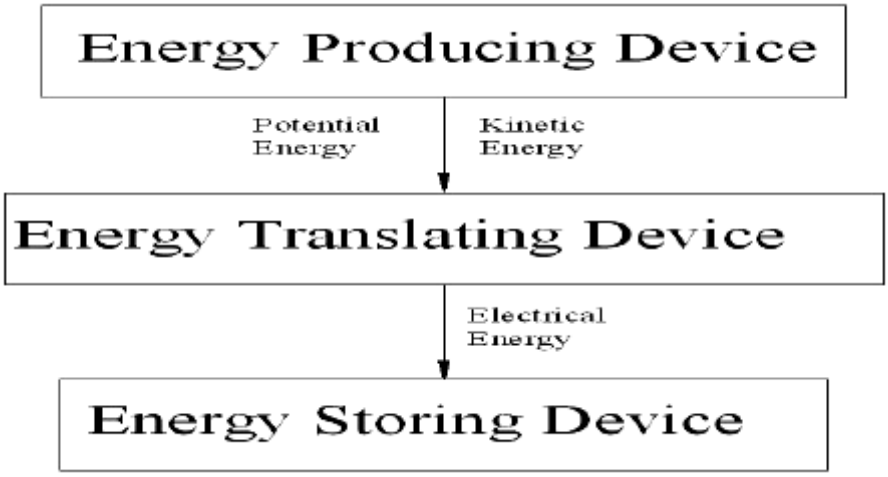

Figure 1. Overall design of energy recovery system used in hydraulic machinery

This system comprises producing energy, transporting energy, storage energy and energy management units. This energy includes the potential of working device, the kinetic energy of the turning body and braking. The part of transporting role is to transmute energy in order to channelize and depot effectively.

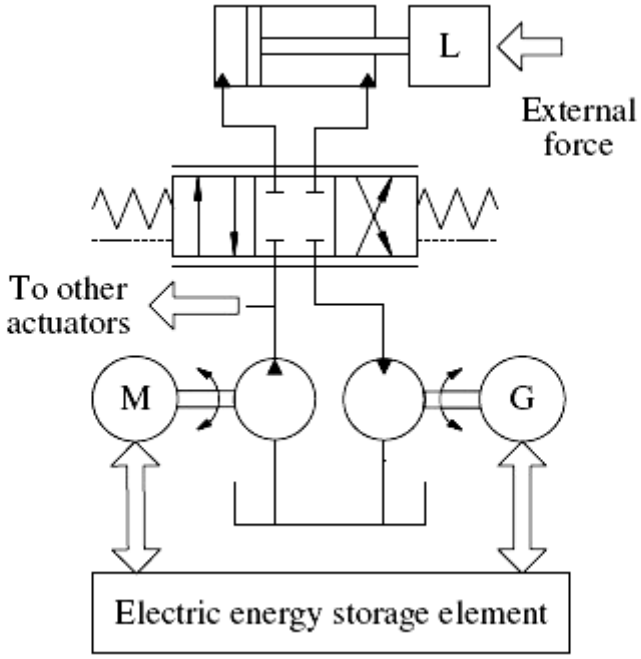

Figure 2. Schematic of proposed energy-saving hydraulic system.

Tao Wang and Qingfeng Wang [2] studied a novel energy-saving hydraulic system, where a regeneration unit comprising of a hydraulic motor and an electric generator is used instead of a conventional pressure compensator. Thus hydraulic energy can be regenerated rather than dissipated in the compensator while load compensation function can be realized by adapting the electromagnetic torque of the generator to the loaded pressure. The experimental results show that expected control performance and significant energy saving can be obtained. As shown in Fig. 2, the dynamics of the piston of the single-rod hydraulic cylinder can be expressed as

$$m_c \frac{dv_c}{dt} = F_l + P_2 A_2 - P_1 A_1 - f_c - B_c v_c \qquad (1)$$

where m_c is the equivalent mass of the load, v_c is the velocity of the piston, F_l is the external force, P_1 and P_2 are the pressures in the large and small chamber of the single-rod cylinder, respectively, A_1 and A_2 denote the corresponding working areas, F_c is the coulomb friction force, and B_c is the combined coefficient of damping and viscous friction forces on the load and the rod. The value of v_c is the differential of the piston displacementx_c.

The flow equations of the two chambers of the cylinder are given by

$$\frac{V_1}{\beta_e}\frac{dP_1}{dt} = A_1 v_c - Q_1 - C_{ci}(P_1 - P_2) - C_{ce1}(P_1 - P_r) \quad (2)$$

$$\frac{V_2}{\beta_e}\frac{dP_2}{dt} = Q_2 - A_2 v_c + C_{ci}(P_1 - P_2) - C_{ce2}(P_2 - P_r) \quad (3)$$

where V_1 and V_2 are the volumes of the two chambers of the cylinder, β_e is the effective bulk modulus of hydraulic oil, $Q_1$and Q_2 are the flow rates of the two chambers, C_{ci} is the internal leakage coefficient of the cylinder, C_{ce1} and C_{ce2} are the external leakage coefficients of the two chambers, and P_r is the tank pressure.

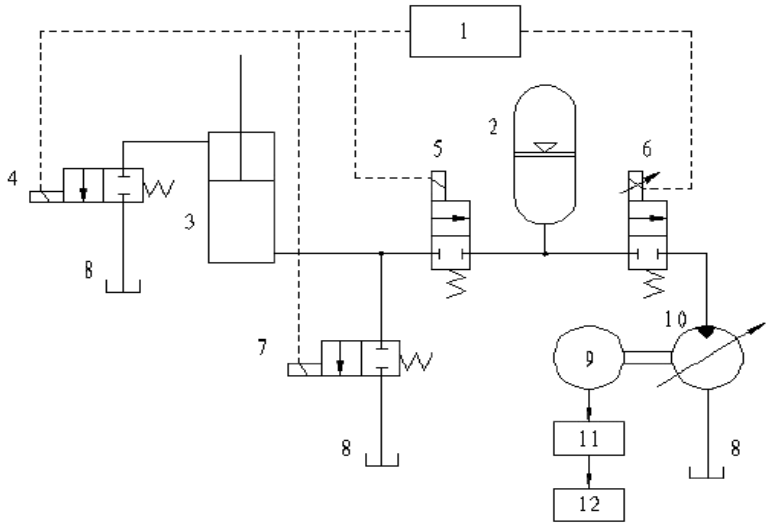

Figure 3. Hydraulic excavator boom potential recovery system

1- controller, 2- accumulator, 3- hydraulic cylinder, 4- two-position two-port electromagnetic valve, 5 - two-position two-port electromagnetic valve, 6- two-position two-port proportional valve, 7- two-position two-port electromagnetic valve. 8- oil tank, 9- generator.10 - hydraulic motor,11- inverter, 12 - storage battery

Zhang et al. [3] devised a hydraulic excavator boom potential recovery system based on accumulator-hydraulic motor-generator. The accumulator of the system stores potential energy from construction of boom hydraulic cylinder through energy recovery. Then the generator generates electricity by driving the hydraulic motor using the energy saved in the accumulator. Research showed that the system was able to save energy by improving the efficiency of hydraulic excavator boom potential recovery.

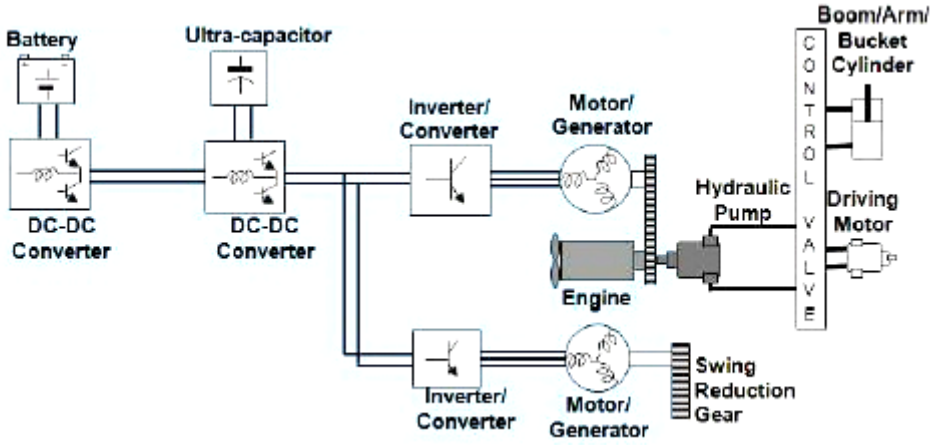

Figure 4. Structure of compound hybrid system

Yearn Jo et al. [4] focused on the importance of hybridization of heavy equipments with a eye on its economical value and current technical issues. They demonstrated various examples of hybrid power trains. The concern shown by them on energy and environmental issues can act as path defining issue in the advancement and development of hybrid excavators.

Chen Mingdong and Zhao Dingxuan [5] suggested a closed circuit boom energy recovery system to decrease the installed power and energy consumption in hydraulic excavators. The energy saving principle was discussed using the accumulator for hydraulic counter weight; the mathematical models of hydraulic system were established based on its working principle. Theoretical analysis and simulation results proved that boom energy-saving system with closed circuit runs steadily with considerable power minimization in hydraulic excavators. Force balance equation of Hydraulic cylinder piston is given by:

$$Mv' = F + P_2A_2 - P_1A_1 - F_f - B_cv_c \qquad (4)$$

where ,M is the mass of hydraulic cylinder piston, v and v' are velocity and acceleration of hydraulic cylinder piston.

Continuity equation of Hydraulic cylinder piston is given as:

$$\frac{Q_1}{A_1} = \frac{Q_2}{A_2} \qquad (5)$$

Summary

In this paper the work done by various authors on electro-hydraulic excavators have been studied have been studied. The work done by various authors are as follows. Weidong et al. [1] compared 16T hybrid wheeled excavators with traditional excavators in test and observed that the hybrid excavator's efficiency is improved. Tao Wang and Qingfeng Wang [2] used are generation unit is used to take the place of a conventional pressure compensator to save energy. Zhang et al. [3] examined that theoretical analysis and simulation research show that the energy saving function of accumulator matches the motor rotate speed and generator. Yearn Jo et al. [4] focused on the importance of hybridization of heavy equipments with an eye on its economical value and current technical issues. Chen Mingdong and Zhao Dingxuan [5] demonstrated that the boom closed circuit energy recovery system of hydraulic excavators can reduce damage to hydraulic component and system noise can be reduced for its better application value in engineering field.

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