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Design and development of secondary controlled industrial palm kernel nut vegetable oil expeller plant for energy saving and recuperation

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Abstract

This paper presents an experimental work on energy saving and recuperation in secondary controlled industrial palm nut vegetable oil plant. It employs the hydrostatic constant pressure rail principle to accomplish crushing, pressing and filtering operations. The seed crushing and oil expelling operations are based on pressure differential between the fed seeds and discharged mash resulting in an oil recovery efficiency of 97.1%, energy saving of 53.48 KW during cylinder retraction and the reduction in barrel temperature from 203 to 187 °C which was effected through cooling pipes. The plant consists of an oil expeller, a filter press, and a conveyor unit and works on a single feed, single stage compression principle with a throughput capacity of 30 kg/h and effective capacity of 16 kg/h. The plant mathematical model is derived and simulation on flow through hydraulic transformer performed using SIMULINK. The experimental results not only agree with theoretical analysis but also appears to be very efficient in energy saving and recuperation.

Keywords: Secondary control; Energy saving; Constant pressure rail; Hydraulic accumulator; Screw press; Oil extraction

1. Introduction

A hydrostatic constant or common pressure rail (CPR) transmission is a secondary controlled system that consists of the following main parts: high and low pressure lines through which power are supplied to various system loads. These two lines also separate loads from power sources which in turn reduce load–source interaction while pressure compensated variable and fixed displacement pumps maintain high and low pressures in the high and low pressure lines, respectively. Besides, the fixed displacement pump (charge pump) compliments oil supply to the (CPR) as a result of leakages. Others include, a hydraulic transformer (HT) which serves as the pressure converter transforming the system pressure and flow to the requirement of both the linear and rotary loads of the plant. The transformer, which is a hydraulic component, is used to drive a linearized load in a constant pressure rail CPR system without throttle losses. The classic concept (HT) unlike the modern hydraulic transformer was used in the past as a hydraulic amplifier. In 1996, a new concept (HT) called the Innas hydraulic transformer was developed by Innas BV. This transformer was further improved through the development of a new distribution pair by Zhejiang University in China. This new (HT) has solved the problem of adjusting the valve plate of narrow angle range of Innas hydraulic transformer (IHT) to a broader angle range resulting in throttle loss reduction, higher efficiency and energy saving. The accumulators maintain the system constant pressure, pressure peak shaving as well as energy recuperation (Okoye et al., 2005). Hydrostatic CPR transmission offers the possibility to connect several hydraulic drives to a

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CPR an increase in efficiency (Vael George, Achten, and Fu). It operates at a constant pressure and reaches the prescribed torque and speed by matching the volume displaced per stroke. The described structure of the power source which can be called a hydraulic power unit (HPU) (Okoye et al., 2005) could be compared with an electricity grid whose voltage is kept at a predefined level. In an electricity grid, different electrical appliances are connected to the same voltage line and loads are independent of the power source. Similarly, all loads connected to the hydraulic (CPR) system are also independent of the power source because all loads are controlled from the same (CPR) as shown in (Fig. 1).

In addition, its control structure is practically identical with the control structure of an electrical (DC) machine. The swivel angle feedback of a hydrostatic axial piston unit corresponds to the current feedback of the (DC) electric machine while its speed feedback is the same with that of (DC) electric machine (Wusthof, 1996). An hydraulic power unit is employed to drive the industrial palm kernel vegetable oil plant due to its power peak shaving, energy recuperation, non-throttle losses, and load independency among others. It is new in the vegetable oil processing industry. There are several different steps and methods used for processing vegetable oils. The quality, flavor, and nutritional content of oils vary according to the processes used. Oil can be extracted from different seeds and nuts for both industrial and domestic application as shown in Fig. 2.

There are eight major processes in the production methods of vegetable oils which are carried out in a series of individual steps. These include extraction, refining, bleaching, and deodorization. Additional processes for specific products include winterization, hydrogenation, texturing, and fractional crystallization (McGraw-Hill Encyclopedia of Science and Technology, 1987). For the purpose of this study, the processing methods used are getting the nuts, cleaning and preconditioning, pressing, cake bagging, and crude oil filtration. Specifically, there are three basic methods of extracting vegetable oil from nuts/seeds, grains beans or olive. These include (1) hydraulic press, (2) expeller pressed, and (3) solvent extraction. Expeller press, which is the one described in this paper, uses a screw or continuous press with a constantly rotating worm shaft which squeezes out oil through the barrel under constant pressure as well as discharging the cake at the choke end of the barrel. The oil processed through this method has to be refined with further processing, such as filtration and deodorization, among others before being considered edible. According to Mrema and McNuity (1985), mechanical pressing, unlike solvent extraction, is the most popular method of oil processing in the world because it yields a chemical free protein-rich meal that is simple in construction and easy to operate and maintain. However, the conventional mechanical screw presses are relatively inefficient, leaving about 8–14% of the available oil in the cake (SriKantha, 1980). In addition, industrial oil press plants driven by electric motor alone consume much energy and therefore high electric bills to the companies. Moreover, oil expeller machines are characterized by much thermal effect on the machine barrel because of the friction between the worm teeth (the helix) and the barrel resulting in the arbitrary expansion and wear of the machine barrel and shaft, respectively, which easily render them out of use after a short time. There are also problems of driving different loads of an industrial expeller plant with many electric motors which result in the high cost of the equipment. Finally, most existing automated systems of mechanical oil expeller plants are not effective and efficient hence cannot aggressively increase and improve the output capacity of the plant. Some researchers have tried to improve the efficiency of the oil extraction machine. Most of these researchers focused on the optimization of process variables such as applied pressure, pressing temperature, and the moisture conditioning of the fed samples (Ohlson, 1992) while others concentrated on various physical treatments such as size reduction, cracking, de-hulling, thermal

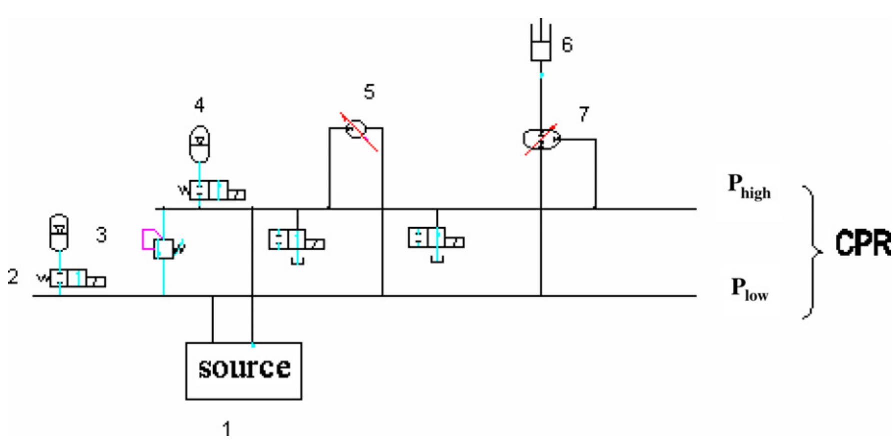

Fig. 1. CPR transmission system. (1) Power source, (2) 2/2 directional control valve, (3) relieve valve, (4) hydraulic accumulator, (5) hydraulic motor, (6) hydraulic cylinder, and (7) hydraulic transformer.