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Study on the application of fuzzy controller in hydrostatic transmission system of heavy earth moving machines

A simple hydrostatic transmission system (HST) mainly encompasses an engine (diesel or electric), a variable displacement hydraulic pump and a variable displacement hydraulic motor. By monitoring the rotational speed of the prime mover and administering the hydraulic components displacements, the final output speed of the HST is regulated. Conventionally, a PID controller has been utilized for the controlling of speed but it faces the drawback of causing fluctuation in the speed control system's dynamics when speed is being varied. The paper takes in account the application of fuzzy control in dealing with various issues related to off road vehicle's HST systems such as detecting slippage, speed control of motor, controlling accuracy and position, energy regeneration, etc.

Keywords: *Fuzzy controller; hydrostatic transmission system; earth moving; machines*

Introduction

Hydrostatic transmission system is an essential feature in the transmission of power related to the heavy moving machines like tractors, harvesters etc. because of its added advantage such as high power to weight ratio, steeple speed and better control. But they do suffer from some serious issues like low efficiency and non-linear behaviour. There are situations where the conventional linear feedback controller has some pitfalls, e.g. conditions in need of complete precision of speed and response like slipping of wheels of off load vehicles. Hence, the new strategy called adaptive sliding fuzzy logic controller has been practiced which takes care of the irregularities of the conventional system. It works excellently in continuously fluctuating conditions with precise control of speed and consequently solving issues such as wheel slippage and regenerating braking energy. The next section brings into light the work done by various researches in context of fuzzy logic with respect to hydrostatic transmission system of heavy duty vehicles.

Njabeleke et al [1] analyzed the pertinence of self organizing fuzzy logic for regulating the speed of a hydraulic motor used in HST systems. The self organizing fuzzy logic controller has similar features with respect to standard fuzzy logic controller enabling non-requirement of any mathematical model. It adjusts the fuzzy rules spontaneously online and acclimatizes itself to the continuously varying process feature which is the prime concern in hydrostatic speed control where the model relies heavily on the running speed. The advantages of self organizing fuzzy logic over linear control have been listed also.

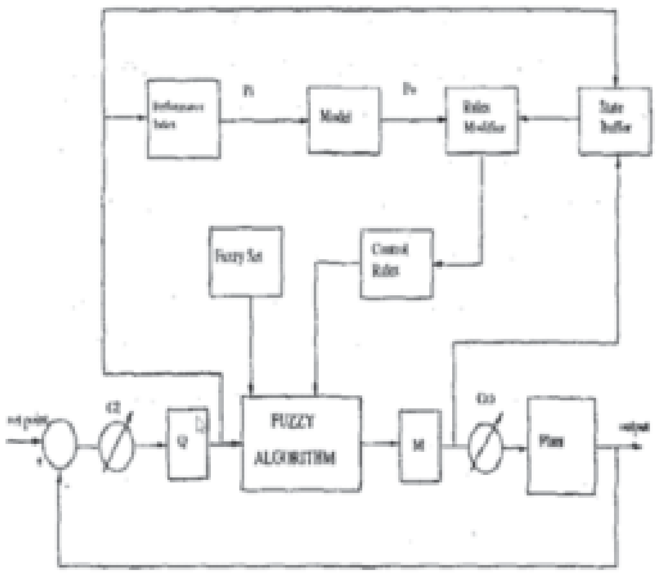

Fig.1 Block diagram for self organizing fuzzy logic control system

Hasemann and Kansiila [2] devised a novel method for forbidding slippage associated with hydrostatic power transmission in case of heavy earth moving machines. Loss of traction and surface damage were the two significant issues affecting the wheel slippage and hence having severe impact on the smooth functioning of the hydrostatic power transmission in heavy duty vehicles. Essentially there exists two levels of control: a kernel control which furnishes a primary functionality and the other one advanced control for superior control were employed for accomplishing the objective which in turn depend heavily on robustness and fault tolerance of the vehicle. Finally the developed adopted fuzzy logic control

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approach was put forward to monitor the factors affecting wheel slippage and consequently stopping it.

The expressions for torque come out as follows:

$$T_i = T_{wheel\_1} = T_{wheel\_2} = T_{wheel\_n} \quad ... ... (1)$$

$$T_{wheel\_n} = T_{surf} + T_b \quad ... ... (2)$$

where, T_{surf} is the surface friction coefficient torque and T_b is the brake torque.

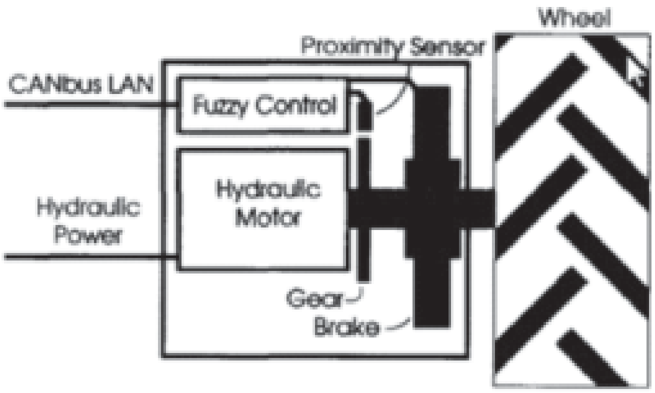

Fig.2 Mechatronic wheel motor

Do et al [3] evolved an adaptive fuzzy sliding mode controller for controlling the velocity of secondary controlled hydrostatic transmission system (SC-HST) to deal with the non-linearities which are usually associated with SC-HST. The non-linear features consists of dead zone input in secondary controlled unit and self blocking of the swash plate as well as disruption load in normal working conditions such as wind load and rough load which affects the velocity control of the entire system and cannot be handled by traditional linear controllers. Hence to match with these irregularities, the developed adaptive fuzzy sliding mode controller comes handy in dealing with these issues and finally controlling velocity. They concluded after conducting experiments that the developed controller works excellently in terms of controlling the velocity of the SC-HST.

The actual output flow rate and input torque of the pump

$$Q_i = \propto \omega D_{\max} \eta_{vp} \quad ... ... 3$$

$$T_i = \propto \Delta D_{\max} \eta_{tp} \quad ... ... 4$$

where, $\propto$, $\omega, D_{\max}$, Δp, η_{vp}, η_{tp} are displacement ratio, pump angular speed, maximum displacement, pressure difference between two ports, volumetric efficiency and mechanical efficiency of pump mode, respectively.

The dynamic equation of the flywheel FW is obtained by applying Newton's second law, as:

$$T_m = J\dot{\omega} + C\omega + T_{ext} \quad ... ... 5$$

where T_m is the torque generated by the hydraulic motor, J is inertial moment of the flywheel FW, C is viscous friction coefficient of FW, ω is the velocity of FW, T_{ext} is external torque which is braking torque in this study.

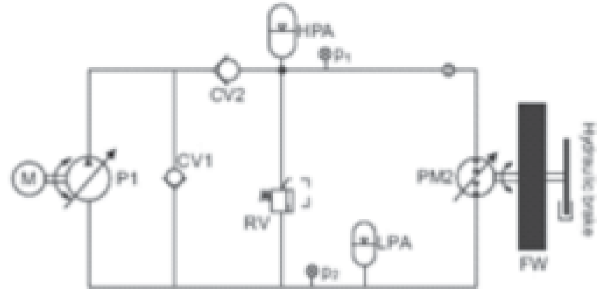

Fig.3 Schematic diagram of the proposed SC-HST

Schulte [4] focused on the significance of the role of Takagi-Sugeno fuzzy systems to depict the non-linear behaviour of the HST system. Based on the physical interpretation, a generalized non-linear space model of the HST system was devised which consisted of a variable displacement pump and a variable displacement motor. A Takagi-Sugeno fuzzy system was evolved from the existing proposed non-linear space model. Finally with the help of some functions and calculations, weighting functions were obtained from the non-linear terms.

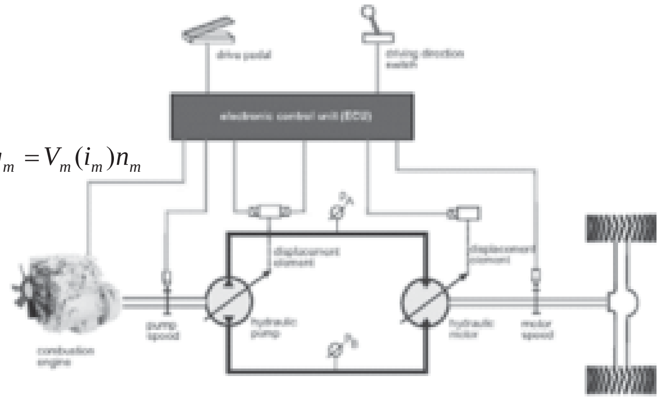

Fig.4 Electro-hydraulic hydrostatic transmission in off-road vehicles

The oil flow produced by the pump is proportional to its rotational speed n_p

$$q_p = V_p (ip) n_p \quad ... ... 6$$

where, V_p (i_p) is the specific volume of the pump per revolution, itself depends on the input current to the servovalve, n_p is the turning speed of the combustion engine.

The volume flow through the motor is given by:

$$q_m = V_m (i_m) n_m \quad ... ... 7$$

where, v_m (i_m) is the specific volume of the motor and is the variable turning speed. The specific volume v_m (i_m) depends on the input current to the servovalve.

The power of the ideal hydraulic motor is described by:

$$P = (p_A - p_B) q_m \quad ... ... 8$$

where, p_A and p_B are the pressure on the two sides of motor.

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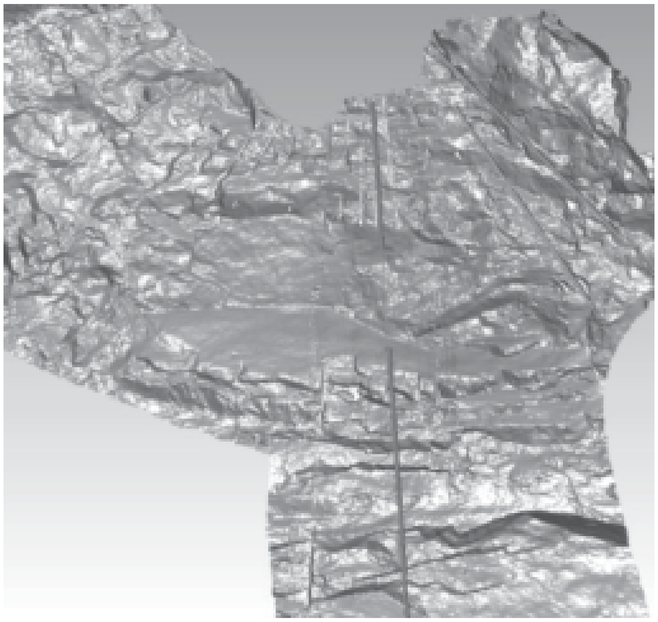

Fig.33 Excavated stope and drilling actual

From the examples below, the design can be tested against the actual.

Drilling actuals, sockets and barrels can easily be identified and compared against design.

Conclusion

As can be seen from the laser scanning examples above, has only touched the surface of all the possibilities.

There is geological and geotechnical mapping fields that can be explored. With the extensive number of new software packages that support laser scanning, this can surely enhance every technical discipline on a mine.

Due to the nature of obtaining data in a remote manner, safety to personnel is greatly enhanced. Inaccessible places that was previously estimated, can now be documented with great accuracy.

Data can now be shared, from a virtual tour inspecting scanning images, to survey, geology, mechanical, electrical, geotechnical, design engineers.

STUDY ON THE APPLICATION OF FUZZY CONTROLLER IN HYDROSTATIC TRANSMISSION SYSTEM OF HEAVY EARTH MOVING MACHINES

(Continued from page 160)

Nevala et al [5] proposed a resilient anti-slip system for the HST system which was employed in forest tractor. CANbus and fuzzy control were the tools which helped in achieving the aim of developing an energy efficient system. The prime concern was to discover the fault i.e. wheel slippage instantly so that necessary measures could be taken to minimize wear on the surface of the wheels. The applied methodology could work significantly well in case of mechanical transmissions and its prime idea of measuring technique can do wonders in specialized fields. The test result was found to be matching with theoretical assumptions which justify the proposed analytical approach.

Conclusion

This paper throws light on the various applications and modifications of the fuzzy logic controller to solve the real time issues related to the hydrostatic transmission of the off road vehicles which are employed in difficult terrain. The off road vehicles are subjected to wear, wheel slippage, various wind load and other non-linearities such as uncontrolled speed which makes their task even more cumbersome. Due to these above situations, the cost of operating the vehicle also goes up as there is significant loss of fuel too. Hence, the need of the hour is to develop an adaptive fuzzy logic controller which can adjusts itself according to the vehicle dynamics and operating conditions and which would come handy in solving the faults associated with the heavy machines.

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