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Fuzzy logic control for a parallel hybrid hydraulic excavator using genetic algorithm

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ABSTRACT

In this paper, fuzzy logic control is put forward in a parallel hybrid hydraulic excavator for the purposes of better energy distribution and higher fuel economy. A mathematical model of parallel hybrid hydraulic excavator is presented in detail, and the parameters of components and overall system are listed and analyzed. The fuzzy logic controller is then designed to cope with energy distribution and management. To achieve better equivalent fuel consumption, genetic algorithm is implemented to fine-tune the membership functions. The control effects are compared between different control strategies, e.g. rule-based control and fine-tuned fuzzy logic control. The results indicate that hybrids with the proposed strategy can improve fuel economy for the excavator without sacrificing any system performance.

1. Introduction

Currently institutes, colleges and companies around the world are working in the field of energy saving and emissions reduction so as to find efficient solutions to increase fuel economy for excavators. Until now, several potential ways have been developed in the field, e.g. constant power control, all power control, cross sensing control, negative flux control, load sensing control, load-pump power matching control et al., while it is still necessary to find some other ways to meet higher standard emission criterion and more economical fuel consumption for excavators.

Hybrid technology might be one of the possible ways to get a better fuel economy in excavators. After all, the successful implement in vehicle (so called hybrid electric vehicle) showed that the hybrids would be capable of increasing fuel economy and diminishing emissions for a new generation of vehicles. So to study a hybrid hydraulic excavator should be a promising and encouraged direction in the near future. The differences between vehicles and excavators excluding different system configurations are listed below. (1) The pattern of working conditions is quite different; moreover an excavator's working condition is heavy, repeatedly changeable and regularly periodic while a vehicle's is comparatively stable. (2) The amount of working duration is totally different, and especially for excavators usually it would be operated for at least 20 h per day, so it has a stronger fuel economy impact on the hybrid hydraulic excavator compared to the hybrid electric vehicle. Similarly, we could classify hybrid excavators into three main types in terms of different system configurations: (1) series hybrid excavators, (2) parallel hybrid excavators and (3) power-split hybrid excavators. In essential, all types of hybrid excavators are supposed to have three key components in their powertrain architectures. One is existing power source, and it used to be one internal combustion engine (ICE), e.g. gasoline engine (DI) and diesel engine (CI).The other one is called added power source. Usually one or two motors are introduced to cooperate with the engine to drive the final shaft, and the motor(s) have both motor and generation functions. The remaining one is energy storage unit (ESU) that is used to receive excessive energy from the engine in charge mode or drive the motor in discharge mode.

Studies on hybrid hydraulic excavators could be traced back to the early 21st. K.K. Yoshiyu et al. introduced hybrid conception into construction machinery in order to increase system efficiency in 2001 [1]. Matsubara M developed one hybrid system for construction machine in 2001 and also a series of patents in the related field were registered during the period of 2001–2004 in U.S.A., Japan and Europe [2–6]. In 2003 M. Kagoshima et al. gave a description about the development of hybrid excavators [7] and N. Takao et al. developed a power simulation model for a series hybrid excavator that showed 40% fuel reduction in comparisons with conventional excavators in 2004 [8]. Q.F. Wang et al. did simulation research and evaluated energy saving effect in parallel hybrid excavators in 2005, and also presented the way to recover potential energy from excavators [9,11,12]. In 2008, rule-based control strategy for parallel hybrid hydraulic excavators was put forward by Q. Xiao et al. that chose required torque at the pumps and state of charge (SOC) of the battery as the signals to switch engine's working points [14]. D.Y. Wang et Al. presented performance analysis of hydraulic excavator powertrain hybridization that showed that the system could take the advantage of hybrid configuration in terms of cost, fuel economy and performance [10,13]. Despite the aforementioned efforts in the field, few papers concentrate on advanced control in hybrid excavators although control strategy and energy distribution are the primary concern here. Compared with the rule-based control in PHHE, i.e. single working point control, dynamical working point control

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