Automation in Construction 92 (2018) 286–296

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Review

Review of hybrid electric systems for construction machinery

Xiangyu He[a,*], Ying Jiang[b]

[a] College of Automobile and Mechanical Engineering, Changsha University of Science and Technology, Changsha, Hunan 410004, China
[b] Art Crafts Industrial Design Center of Hunan Province, Changsha University of Science and Technology, Changsha, Hunan 410004, China

ARTICLE INFO

Keywords:
Energy-saving
Hybrid electric system
Construction machinery
Energy recovery
Control strategy

ABSTRACT

A large amount of construction machinery results in an enormous waste of energy and is a serious source of air pollution. Increasing fuel efficiency or using cleaner energy has become the most fundamental methods to solve this problem. First, this paper briefly introduces hybrid electric system (HES) structures. Second, HES for several types of construction machinery are comprehensively discussed and compared. Third, energy-saving control strategies for construction machinery are analysed in detail. Finally, the prospects and challenges of HES research for construction machinery are presented.

1. Introduction

Construction machinery has been widely used in earthwork construction, concrete pouring, paving and heavy lifting. Common types of construction machinery are shown in Fig. 1. However, construction machinery has low energy efficiency and high pollution production. A large amount of construction machinery yields a massive waste of energy and is a serious source of air pollution [1,2]. In the past two decades, the most fundamental methods for achieving energy conservation and emission reduction targets are increasing fuel efficiency or using cleaner energy [3–6].

Researchers have conducted numerous energy-saving studies based on HES in typical vehicles, which provides a new way for energy conservation and emission reduction of construction machinery. Construction machinery and typical vehicles have large differences in structure, load, weight range, transmission and energy consumption, etc. Table 1 shows the differences between construction machinery and vehicles. The main differences can be described as follows:

(1) There are many types of construction machinery. Therefore, we need to change the chassis [7] and working device according to the different construction environments, which leads to a complex transmission structure.
(2) Construction machinery must still rely on a hydraulic system to drive the working devices. Using a standard excavator as an example, the boom, arm, bucket, swing and travels are driven by corresponding cylinders or hydraulic motors (HM), and pressure, flow and direction are controlled with multi-way valves, as shown in Fig. 2. The hydraulic system makes the research of HES more complicated.
(3) The load of construction machinery varies drastically during the working process [9,10]. The output power of a 20-ton hydraulic excavator is shown in Fig. 3. In a short period of time (80 s), the power fluctuation is very severe and the power varies from 0 kW to 120 kW.
(4) The weight of different types of construction machinery varies greatly. Using an excavator as an example, the minimum weight of a mini-excavator is only 1.5 tons [11], while the weight of a mine excavator can exceed 6400 tons [12].
(5) The energy consumption characteristics of construction machinery are more complex. The energy consumption law and energy-saving control strategy of HES for construction machinery have higher requirements.

From above discussion, we can know that construction machinery has unique characteristics. The HES research results of typical vehicles cannot be directly applied to construction machinery. Therefore, HES structures and energy-saving strategies for construction machinery must be determined to improve energy efficiency and reduce pollution emission [9,10,13–15].

This paper is organized as follows. Section 2 introduces HES structures. Section 3 discusses and compares the HES of different types of construction machinery. Section 4 describes some energy-saving control strategies. Finally, Section 5 presents the prospects and challenges of HES for construction machinery.

* Corresponding author.
E-mail address: hexiangyu@csust.edu.cn (X. He).

https://doi.org/10.1016/j.autcon.2018.04.005
Received 2 September 2017; Received in revised form 4 March 2018; Accepted 14 April 2018

Fig. 1. Construction machinery.

Table 1
Difference between construction machinery and vehicle.

	Construction machinery	Vehicle
Chassis	Crawler Wheel Walking-pedrail	Wheel
Transmission	Hydraulic Mechanical	Mechanical
Weight	Big difference	Relatively small difference
Load	Big fluctuating	Smooth
Fuel economy	Poor	Good
Emission	High	

2. HES structures

HES structures can be divided into internal combustion engine (ICE), pure electric, series, parallel, series-parallel, etc. [4]. Table 2 is a comparison of HES structures. In addition to the ICE structure and pure electric structure, the remaining structures can be considered HES. Generally, an HES should consist of no more than two power systems and should contain a power system with a reversible energy flow to achieve energy recovery. This combination can improve energy efficiency and reduce emissions, thus saving fuel and providing environmental protection.

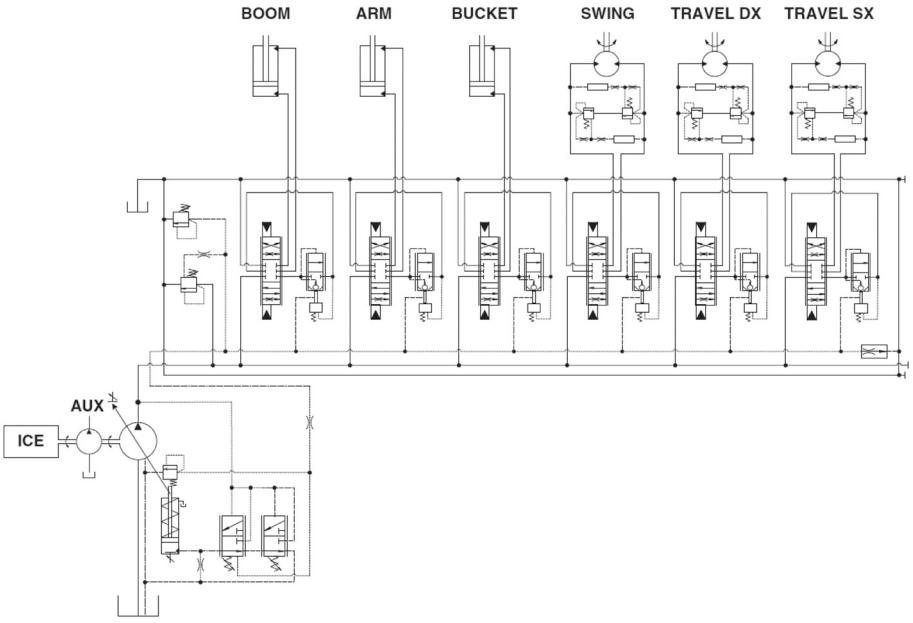

Fig. 2. Schematic of a standard excavator hydraulic circuit [8].