

# The Research on Power System of Hydraulic Hybrid Garbage Truck

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## Abstract

The series-parallel hydraulic hybrid vehicle can combine the advantages of series and parallel hydraulic hybrid vehicle. Theoretically, it enables the transmission of the vehicle to achieve optimal working conditions. Under the AMESim-Simulink/Stateflow co-simulation platform, the drive system and the controller of the series-parallel hydraulic hybrid garbage truck have been modeled. According to real-time vehicle traveling condition, the accumulator pressure case and the change of requested torque, the vehicle can be real-time switched under the different hydraulic hybrid modes. In this paper, the special working condition of the garbage truck was simulated and analyzed. The results show that: the series-parallel hydraulic hybrid vehicle can not only meet the requirements of the braking and dynamic of the vehicle, but also improve the fuel economy of the vehicle.

## Keywords

Series-Parallel; Hydraulic Hybrid Garbage Truck; Amesim-Simulink/Stateflow; The Fuel Economy.

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## 1. Introduction

Characteristics of urban garbage truck driving conditions: fixed route, low speed, long idle time, start and stop frequently [1]. This has resulted in garbage truck's poor fuel consumption and emissions. First of all, this paper describes the development status and trend of hydraulic hybrid vehicles both at home and abroad, analyzes the advantages and disadvantages of different forms of hybrid system structure, and defines a structure scheme for a hybrid hydraulic hybrid system suitable for urban waste trucks [2]. Then, this paper analyzes the typical driving conditions of the hybrid hydraulic hybrid garbage truck and various driving working modes. In order to improve the fuel economy of the vehicle, this paper designs an energy control strategy based on the logic threshold, and realizes the switching between the working modes. Finally, the main components of the hybrid hydraulic hybrid waste truck are selected and matched with the parameters, including engine, variable pump/motor, accumulator, transmission and so on. Based on the AMESim and Simulink/Stateflow joint simulation platform, the hybrid model, the engine model, the transmission model, the vehicle model and the hydraulic drive system were established in the AMESim software and the energy Control strategy model was established in the Stateflow software. The simulation and analysis of the economic and dynamical characteristics of the hydraulic hybrid vehicle are carried out by using the Simulink-based operator. And analyzes and compares the fuel economy's improvement of the hybrid hydraulic hybrid waste trucks and traditional garbage trucks. If the driving condition of the garbage truck is only considered, the fuel economy of the hybrid garbage truck is 30.5% higher than that of the traditional garbage truck.

## 2. Hydraulic hybrid garbage truck configuration mode

Hydraulic hybrid power is divided into series, combined and mixed with hydraulic hybrid. Tandem hydraulic hybrid is combined with the engine, hydraulic pump, accumulator, hydraulic pump/motor, etc. Parallel hydraulic hybrid on the basis of the traditional vehicle transmission mechanism, increase a set of hydraulic drive, including accumulator, plunger pump/motor, etc. [3]. The engine is the main power source, the plunger pump/motor as the auxiliary power source. Mixed type hydraulic hybrid systems is combining tandem and parallel hydraulic hybrid device, can make the two driving devices in series, can also be under a state of parallel [4]. Mixed type hybrid drive mode diversity, plunger pump/motor drive alone, engine drive alone, plunger pump/motor and engine output power after coupling the common drive, engine stamping and driver, etc. According to the relative position between two kinds of powerplant and transmission, it is divided into preposition and rear [5]. In this paper, the power of the engine and the power of the plunger pump/motor are synthesized and the transmission is sent to the drive bridge. This kind of power plant combination method is high and relatively stable when plunger pump/motor recovery braking energy, and the recovery effect is good. Although the hybrid structure and control process are more complex, it can maximize the target of low fuel consumption and low emission. The structure of the hybrid hydraulic hybrid vehicle is shown in figure 1.

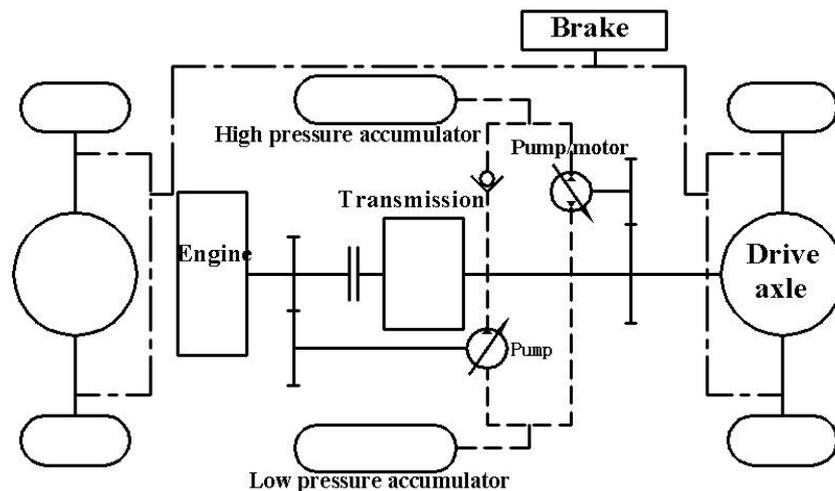


Fig. 1 The diagram of series-parallel hydraulic hybrid garbage truck

## 3. Model analysis of hybrid garbage truck

Mixed type of hydraulic hybrid vehicle energy control strategy goal is to make the vehicle dynamics and the brake is not affected under the premise of let the braking energy recycling as much as possible, the engine work in the best fuel economy of the area, realize the request of low energy and low emission [6]. This paper adopts an energy control strategy based on the logic gate value, which is simple, high reliability, fast operation and wide application. To the vehicle's fuel economy as objective function, using curve fitting method of fitting out a best torque curve of engine, as a basis to judge the state of the engine fuel.

The work pattern is as follows: 1) when the vehicle starts, if  $p > p_0$ , the plunger pump/motor drive and turn off the engine. When  $p < p_0$ , the engine starts stamping, plunger pump/motor drive. 2) when the vehicles moving, how the engine and piston pump/motor drive, the vehicle demand torque and engine torque curve best relative size to decide. If  $T_{req} < T_e$ , and  $p > p_0$ , the plunger pump/motor drive; If  $T_{req} < T_e$ , and  $p < p_0$ , the engine drives and ramps; When  $T_{req} > T_e$ , the engine is driven by the plunger pump/motor. 3) when the vehicle brakes, the plunger pump/motor braking can be recovered if the  $0 < br < 0.5$ . When  $br$  is greater than 0.5, the plunger pump/motor is combined with the brake. (accumulator pressure  $P$ , piston pump/motor minimum working pressure  $p_0$ , corresponding to the demand in front of the transmission torque  $T_{req}$ , best engine torque curve  $T_e$ , normalization of the

brake pedal instruction br.) In the hybrid vehicle power output, the use of vehicle demand based on the torque control strategy, so that the engine with the transmission gear changes, always work in the efficient area. In the case of hybrid vehicle braking, the control strategy based on normalized brake pedal instruction is adopted. The method of braking energy distribution is simple and reliable, and the recovery efficiency is high. In this paper, the control strategy is modeled in Stateflow. The concrete model is shown in Fig 2.

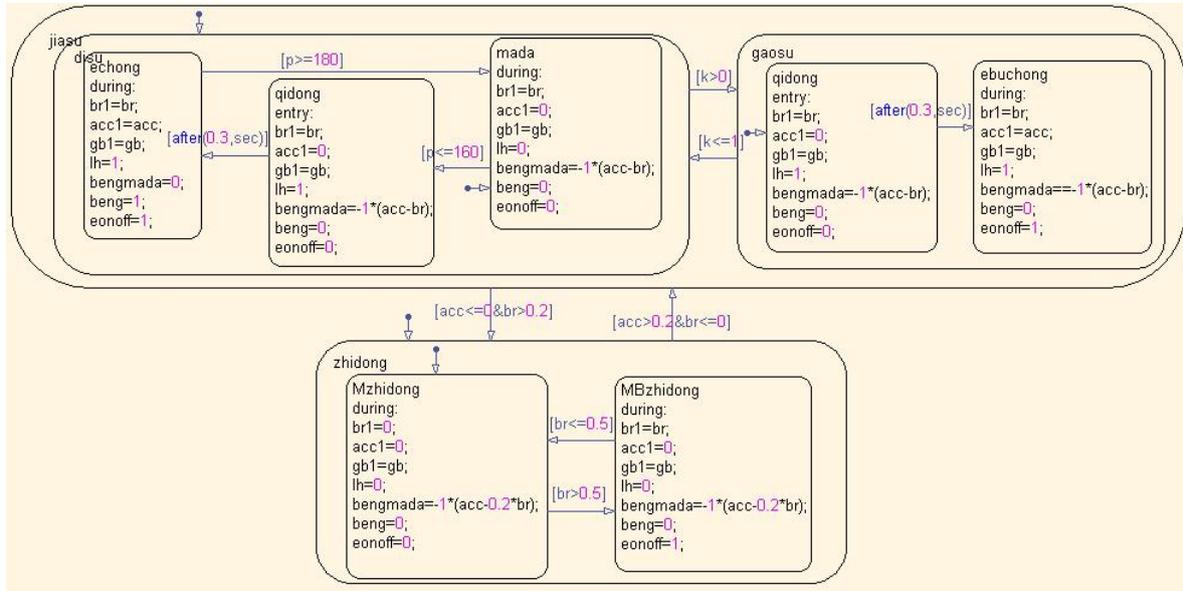


Fig. 2 The simulation model of Control the policy

#### 4. The driving conditions of urban garbage truck

City garbage truck compared to other vehicles, often traveling in the community, the distance between adjacent garbage delivery point is relatively close, with frequent start and stop, long time low speed driving characteristics, cannot use the conventional city vehicle condition diagram as a study mix Power source for power waste trucks [7]. To this end, this paper will be collected by the US Environmental Protection Agency of the city garbage truck operating conditions as a data source, respectively, garbage collection conditions and garbage transport conditions for analysis. The typical working conditions of the city garbage truck in the collection of garbage are shown in Fig 3. Its characteristics are: low speed, start and stop frequently, the average hourly start and stop about 100 times [8].

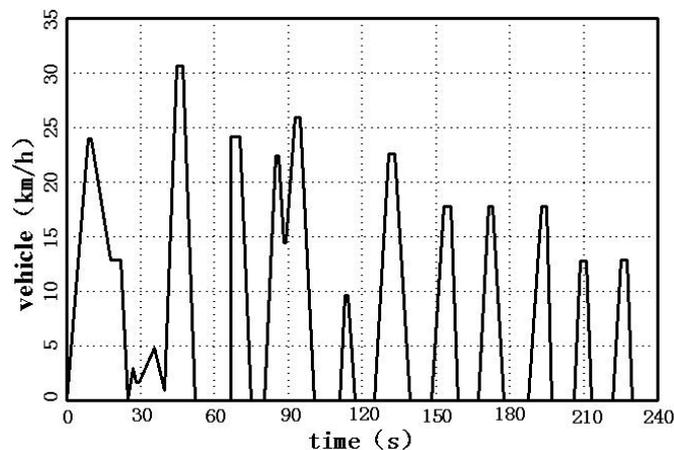


Fig.3 The driving conditions of urban garbage truck

### 5. Simulation Analysis of Hybrid Hydraulic Hybrid Garbage Truck

First, simulate the typical driving conditions of the garbage collection process, use AMESim's "Table Editor" tool to draw the problem diagram and add it to the task model. Then, according to the actual situation, the simulation model parameters are set. Click the "Start" button in the Stateflow software. After the simulation, you can view the simulation results of each model in AMESim. Figure 4 shows the changes in the pressure of the high-pressure accumulator, as shown in Figure 5; the change of the new variable pump/motor displacement ratio, as shown in Figure 6; the new variable Pump/motor efficiency changes, as shown in Figure 7; hybrid hydraulic hybrid waste truck and the traditional city garbage truck fuel consumption comparison chart, as shown in Figure 8. Through the simulation can be drawn: hybrid hydraulic hybrid garbage truck in the collection of garbage during the journey, the vast majority of time for the variable pump/motor-driven vehicles to meet the vehicle's acceleration performance and braking performance requirements, variable pump / The efficiency of the motor in most cases is about 90%, the braking energy recovery effect is obvious.

Compared with the transmission vehicle, this kind of hybrid hydraulic hybrid vehicle has improved a lot of fuel economy. Through the adjustment of the energy control strategy, the recovery of the braking energy has been fully realized, and the combustion efficiency of the engine is improved, As far as possible in the efficient area, this part of the regulation and control in the fuel economy increased by 30.5%.

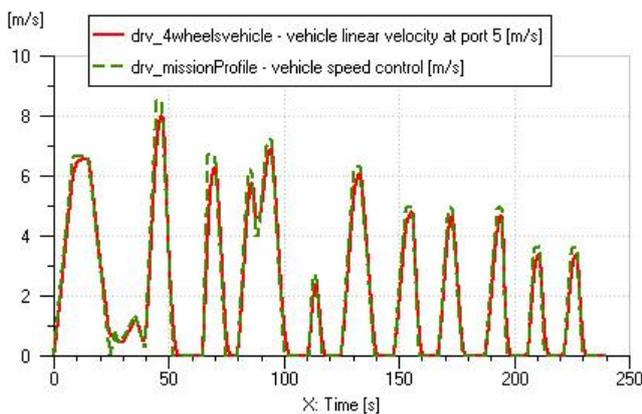


Fig.4 Simulation of vehicle speed

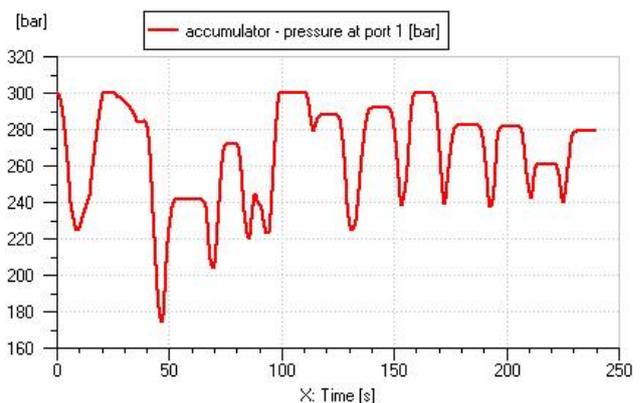


Fig.5 The pressure diagram of the accumulator

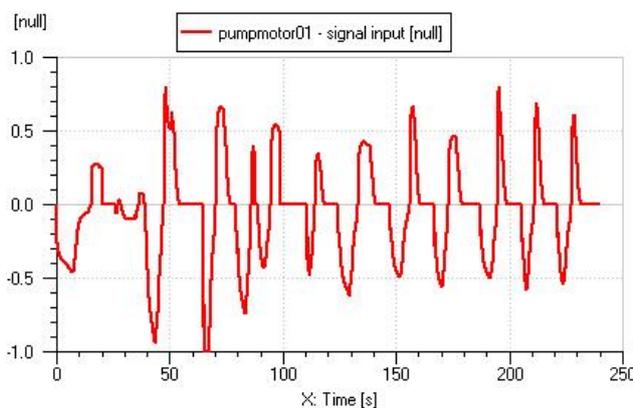


Fig.6 Pump/motor displacement ratio

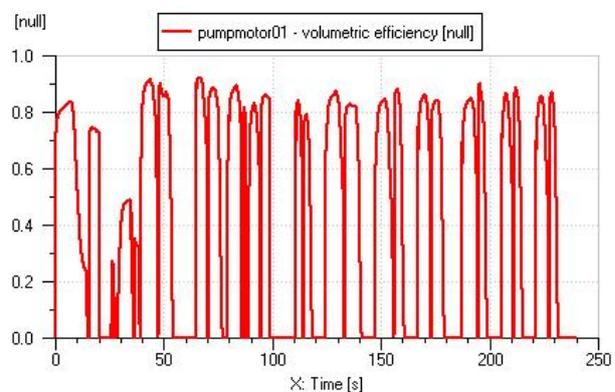


Fig.7 Pump / motor efficiency

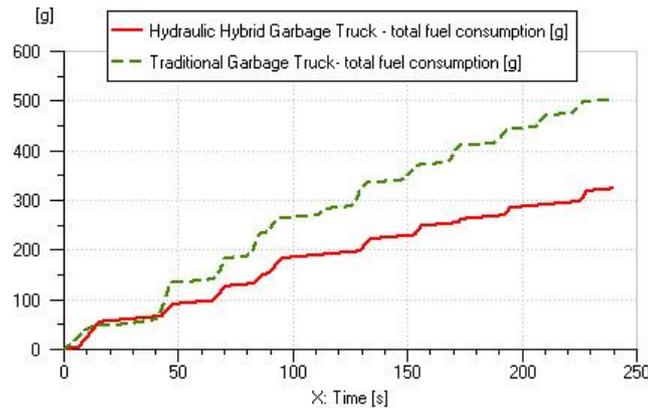


Fig.8 Vehicle fuel consumption

## 6. Summary

In this paper, AMESim-Simulink/Stateflow joint simulation method is used to simulate and analyze a hybrid hydraulic hybrid garbage truck under specific circulation conditions. The conclusion is as follows: 1) The combination of such hybrid powertrain is feasible, which can guarantee the vehicle power requirement and improve the fuel economy of the vehicle effectively. 2) Based on the logic threshold of the energy control strategy, it can be reasonable to coordinate the two power drive devices to work. 3) The hybrid vehicle with the transmission can ensure that the engine is operating within a better fuel economy.

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