

Electrically Powered Hydraulic Steering On Medium Duty Trucks

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ABSTRACT

Electrically Powered Hydraulic Steering (EPHS) has provided value in passenger car applications by reducing power consumption at engine idle, providing only the required power during high speed lane-keeping, and allowing engine-off operation of vehicles with alternative power sources. This work discusses the design modifications made to use EPHS for medium duty commercial vehicle applications. Configuration options along with communication and diagnostic interface are discussed. Bench tests show the steady-state performance of the system. Experiments are done on a medium duty truck with the EPHS as the sole source of steering power to determine the speed of steer at various vehicle speeds. Finally, the power consumption for the EPHS system is compared to a conventional engine driven pump.

INTRODUCTION

The conventional hydraulic system consists of an engine driven pump and an open center steering gear as shown in [Figure 1](#) [4]. The steering gear requires a specific flow through it. The engine driven pump is sized such that it provides the required flow at engine idle for static steering. But this results in approximately twice as much flow at highway cruising speeds which has to be bypassed to the reservoir resulting in loss of energy as heat into the system.

There has been a push towards energy independence in the past few years as a result of high oil prices. As a large proportion of oil is being used to power vehicles, efforts are being made to increase vehicle fuel economy. Hybrid vehicles which use two or more different sources of power are already on the market. These vehicles achieve the goals of greater fuel economy as well as decreased pollution. More recently, plug-in electric vehicles are being introduced into

the market. As a result of this development, gasoline/diesel engine, the tradition power source of the vehicle, has either been reduced in size or completely eliminated.

Most of the hybrid vehicle configurations rely on a battery to drive the vehicle and use different auxiliary power sources (engine, fuel-cell etc.) to maintain the battery state of charge. With regards to power steering this means the conventional engine driven pump used to provide flow to the steering gear may not be a feasible choice. An electric motor is necessary to run the pump using a battery and is an ideal source of power for power steering systems as it is capable of providing on-demand variable flow by controlling the speed of the motor and hence the pump. Variable displacement pumps provide a similar benefit for engine driven pumps.

An important difference between the engine driven pump and an electric motor driven pump is that whereas the engine driven pump has abundant power for all driving situations and is able to provide a constant flow to the steering gear, the electric motor powered by the typical 12V battery power supply in the vehicles has limited power. In case the electric motor is sized to provide less power than the maximum required in all steering situations because of cost, size, and energy storage considerations, there will be insufficient flow whenever the required steering power exceeds the motor power.

EPHS is already in production for passenger car applications [1]. As hybrid vehicles have also been introduced in medium and heavy duty truck markets [6,7,8,9], there are potential uses of EPHS for steering in different configurations [2,3,4]. Modifications have been made to the EPHS system to enable its use for medium duty truck applications such that the modified EPHS system can be used as the sole source of steering power. The well accepted norm for speed of steer for a highway vehicle is 1.5 hand-wheel turns per second for

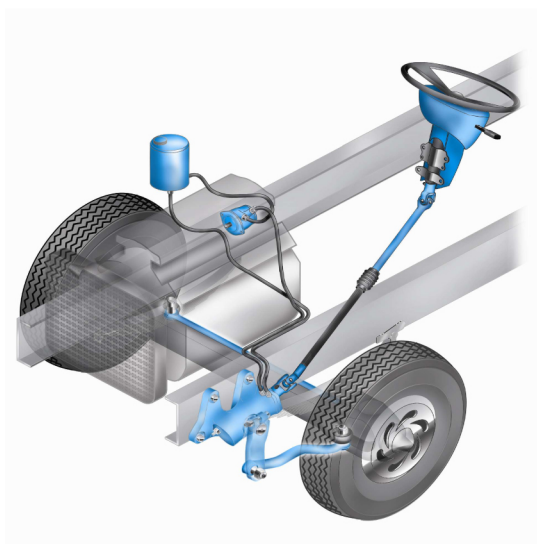


Figure 1. Conventional Steering System

avoidance maneuvers. This paper shows that although the speed of static steer is limited due to the high pressure developed during dry-park, it improves considerably as the tires start to roll because the steering pressure drops down significantly. Experiments done on a medium duty truck show the speed of steer at different vehicle speeds and relate it to pressure-flow characteristics of the EPHS system.

Figure 2 shows the architecture of the steering system studied in this paper. EPHS provides the flow which goes through the open center steering gear providing the output torque to steer the vehicle.

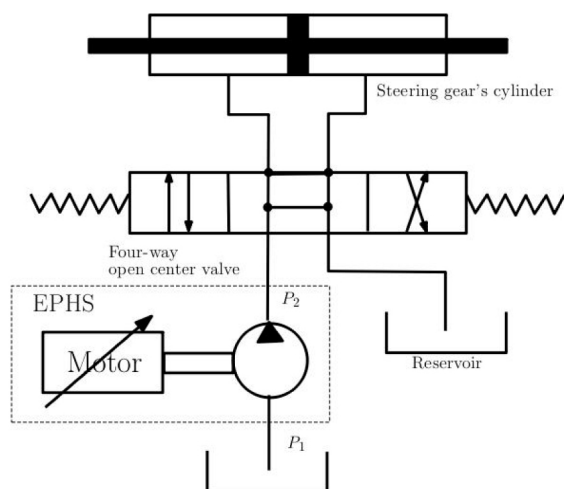
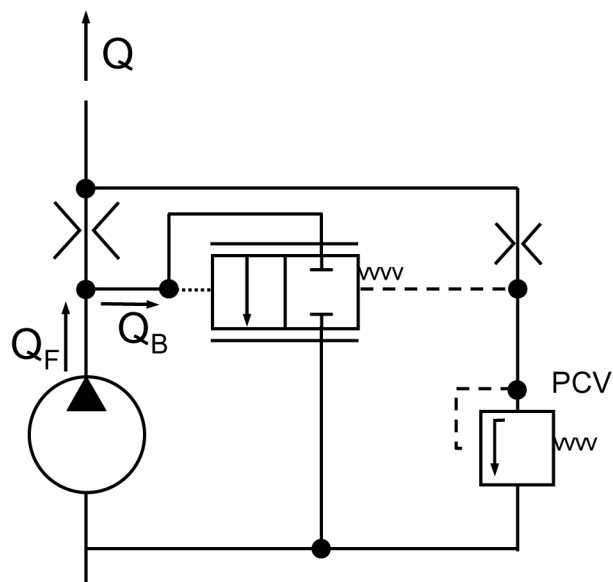


Figure 2. Proposed Architecture for steering a medium-duty truck



MODIFICATIONS TO PASSENGER CAR EPHS

The production passenger car 100C EPHS pumps [1] can provide up-to 1000W of output power with limits on maximum pressure and maximum flow. The maximum flow is 12 liters per minute (lpm) which corresponds to the maximum allowable motor/pump speed at no load. A relief valve built into the system limits the maximum allowable pressure to 120 bar.

For medium duty truck applications, the steering gears are usually rated at 150 bar pressure. The required pump flow for 1.5 hand-wheel turns per second steering wheel velocity varies from 8-10 lpm. To allow application for medium duty trucks, the motor control has been modified such that the EPHS system is able to operate up-to 150 bar pressure and provides a near constant flow of 8.3 lpm up-to 80 bar. The modified EPHS will henceforth be referred to as 100CV EPHS. Figure 3 shows the pressure-flow characteristic of the 100CV EPHS system.

The figure also shows the current drawn by the 100CV EPHS system at different pressures defining the input power of the system. It can be seen from the figure that for pressures above 80 bar, the input current to the system is constant, and the system operates in a power limited mode. With efficiency of approximately 65%, this results in the hyperbolic pressure flow curve for pressures above 80 bar. The maximum output power for the modified system is 1200W. Table 1 gives the specifications for the 100CV EPHS.

Table 1. 100CV EPHS Specifications

Specification	100CV
Maximum Pressure	150 bar ⁺⁸
Voltage (12V System)	13.5 V
Maximum/Standby Current	137A / 2A
Electrical Interface	V-bat, GND, CAN, Ignition
Hydraulic Return Port	Plug Connection 18mm ^{+/- 0.1}
Hydraulic Pressure Port	SAE 6 O-ring
Dimensions (D x L x W)	150 x 233 x 171mm

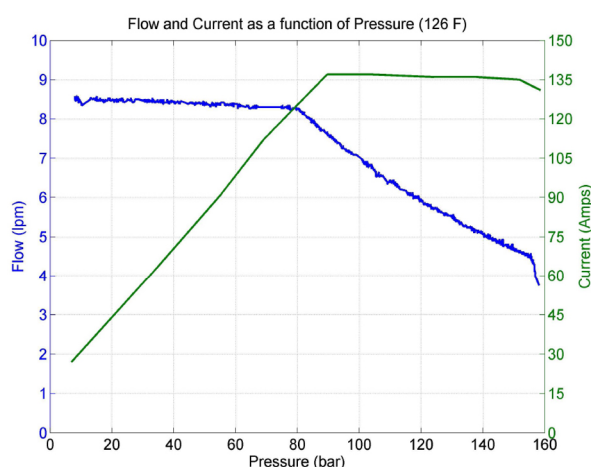


Figure 3. Variation of 100CV EPHS output flow and current consumption with pressure

SAE J1939 is the standard for communication and diagnostics among heavy vehicle components. The standard Vector CAN communication in the production EPHS has been modified to follow the SAE J1939 protocol. Functionality has been added to allow diagnostics in the field following the SAE J1939 standard. The pump flow can be varied as a function of vehicle speed and engine speed/steering rate via a 2D look-up table which is user configurable. The system can also be configured to turn-off on specific events to save power e.g. the pump can be turned off when the park brake is applied.

SPEED OF STEER EXPERIMENTS

As is evident from Figure 3, a single EPHS is able to achieve the maximum pressure required by a 150 bar steering gear. But due to limited power, the flow at 150 bar is reduced to approximately 5 lpm. Although power steering is still available during conditions of high pressure, the speed of steer is limited due to reduced flow. In this section, experimental results are presented for the speed of steer of a medium duty truck at different vehicle speeds.

Experimental data showing the variation of steering pressure with vehicle speed for a medium duty vehicle has been plotted in Figure 5. The figure shows the raw pressure with respect to the vehicle speed along with a curve fitted to approximate the maximum pressure at different vehicle speeds. It can be clearly seen from Figure 5 that the maximum pressure drops significantly as the vehicle speed increases. Above 25 kph, the steering pressure rarely goes above a 70 bar.

Figure 6 shows the FL-60 experimental vehicle used in the experiments. The front axle weight of the truck is 7900 lb. The Gross Vehicle Weight (GVW) is 23400 lb. The steering gear used is TAS40 with an output torque of 3214 Nm at the rated pressure of 150 bar and a required flow of 8.3 lpm to achieve 1.5 hand-wheel turns per second.

The steering pressure and speed of steer between a static and moving vehicle are compared in Figure 7. It can be clearly seen from the figure that the average pressure for a static



Figure 4. 100CV EPHS Unit