Hybrid Transmission for Mobile Robot

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This paper presents proposed designs of parallel hybrid transmissions with only one electric motor/generator (MG) and without any rotating clutches. The proposed motor/generator integrated hybrid transmission serves to regulate the engine's effective gear ratio (engine rotational velocity versus vehicle velocity) by mixing the engine and electric motor powers through a power controlling device. The proposed design provides some of the benefits and flexibility of a power-split design but using conventional available components in a simpler mechanical layout that makes the design compact, mechanically simple, and operationally flexible. Three commonly used transmission gear sets are used for this purpose; Simpson, Ravigneaux, and Type-6206 gear sets. With an electronic control unit, eight major modes of operation including a regenerative braking capability are shown to be feasible in the proposed hybrid transmission; one electric motor mode, two engine modes, two engine/charge modes, and two power modes. Continuously variable transmission (CVT) capability is provided with the second engine/charge mode and with the second power mode. The second power mode can be further subdivided into three hybrid submodes that correspond to the direct drive, underdrive, and overdrive of a conventional automatic transmission. The feasibility of the proposed hybrid transmission is demonstrated with a numerical example employing conventional Ravigneaux gear train. The kinematics, static torque, and power flow relations for all operation modes are analyzed in detail. [DOI: 10.1115/1.4005590]

1 Introduction and Literature Review

A hybrid system combines two motive power sources, such as an internal combustion engine and an electric motor, to achieve efficient driving performance.

A hybrid electric vehicle (HEV) or mobile robot achieves fuel economy, and improved performance by combining a smaller than normal engine with electric motor(s) and an energy storage system (ESS). The engine is smaller in displacement, or downsized, so that the average loads that the vehicle has to meet during acceleration and highway driving are closer to the engine's higher efficiency operating zones, represented in Fig. 1 by higher efficiency percentages [1].

A HEV uses the electric motors and ESS to average the load on the engine, to achieve an efficient use of fuel. One or two electric motors are used in a variety of ways, depending on how they are connected to the vehicle power train [2]. Motors can provide a positive torque to drive the vehicle alone in the forward or reverse direction, or assist the engine during acceleration. One way to increase the average load and decrease fuel use is to shut off the engine when the vehicle load is small. Commonly this is referred to as engine idle stop, but the engine can sometimes be kept off for light accelerations and low cruising velocities.

Peak power demands on the engine, such as a hard acceleration, can be lowered by using the motors to supply some of the additional power required, and discharge the batteries.

Under conditions in which motors demand negative torque, they operate as generators to recharge the batteries. This negative torque can be met

(1) through the engine, or
(2) by converting the vehicle's kinetic energy into electric energy, referred to as regenerative braking.

By acting as a generator, the electric motor increases the average load on the engine.

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Numerous HEV configurations have been proposed. John Miller's book [3] is a good resource for more information about hybrid vehicles and hybrid systems. In the present work, only HEVs with epicyclic-type power trains will be considered.

Figure 2 shows an epicyclic gear mechanism employing the Ravigneaux gear set as the ratio change gear train. Rotating and band clutches are denoted by C and B, respectively.

Typically, the clutching sequences for the transmission include a first gear for starting, a second or third gear for passing, an overdrive for fuel economy at road speeds and a reverse [4]. Table 1 shows the clutching sequence for the transmission shown in Fig. 2, where an X*i* indicates that the corresponding clutch is activated on the *i*th link for that gear.

Tsai and Schultz [5] proposed an improved design of the novel parallel hybrid transmission introduced earlier by Tsai et al. [6,7]. The proposed design provides the transmission the functional appearance of a conventional 4-speed ratio change automatic transmission. The design needs a motor/generator unit with a conventional automatic transmission to function; therefore, it requires more complicated controllers and extra electronics hardware than with other hybrids.

Tsai [8] proposed an innovative approach using just one internal combustion engine, one electric motor/generator, and a power regulating gearbox that can provide a vehicle with six different operating modes including a regenerative braking capability.

Toyota hybrid system (THS) [2], which is a series/parallel hybrid, contains a power split devise that splits power into two paths. In one path, the power from the engine is directly transmitted to the vehicle's wheels. In the other path (electrical path), the power from the engine is converted into electricity by a generator to drive an electric motor or to charge the battery. Since the engine is the primary converter on the vehicle, the direct fuel to engine to wheels path is the most efficient energy path on the vehicle.

THS posses many favorable characteristics; however, the potential disadvantages of THS design include the need for two electrical motors and a constant split of the engine power. Also, the simultaneous dual motor operation requires sophisticated control systems and intricate custom fabrication [1].