Dynamic AWD Hybrid System (DAHS) w/ APTU

-The Advanced APTU All Wheel Driving Hybrid Powertrain-

FRIENDLY PATENTED

Introduction

Giant Lion Know-How Co. Ltd. has developed a hybrid power train architecture aimed at the use in SUVs, small trucks and logistic vehicles. The Dynamic All-Wheel Drive Hybrid System (DAHS) is a four-wheel drive combined hybrid power train which incorporates a wide range of hybrid functionality while maintaining a simple layout. It has been designed as a system that is easy to manufacture and to assemble and uses reliable, low-cost components that are readily available off the shelf. A sophisticated operating strategy utilizes the implemented hybrid functions and realizes a significant mileage improvement. This article gives an overview over the system layout of the DAHS including its components and will describe the different available driving modes. In order to assess the performance and the fuel consumption behavior and to optimize the operating strategy, a simulation study of the DAHS has been carried out.

System Layout

A hybrid system consists of two different energy converters and storage systems. In this case, an internal combustion engine has been coupled with an electric machine. The main goal is to avoid those regions of operation in which the internal combus-tion engine shows a very poor efficiency. Especially under part load conditions it is not advisable to use the internal combustion engine for propulsion – the electric machine offers a much higher efficiency. A power train layout has to be designed in a way that both machines can be operated and combined in a highly efficient manner. The DAHS system as described below provides the opportunities to achieve that goal.

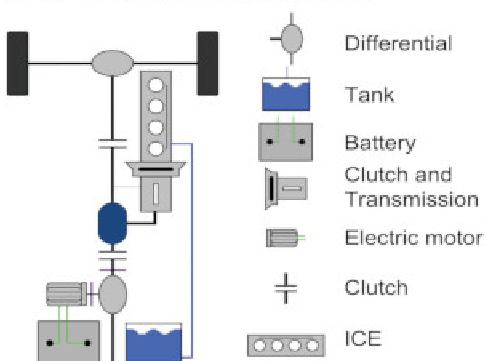

Fig1. DAHS powertrain configuration

The internal combustion engine is connected to a conventional automatic gearbox and can be de-coupled from the rest of the power train with the help of a friction clutch. An intermediate transmis-sion distributes the power to the rear and the front axle which both can be disconnected with two addi-tional friction clutches. The electric motor is being attached through a differential gear, realizing a speed addition of both the electric motor and the internal combustion engine. Friction brakes on two of the three terminals of the differential in combination with the clutches in the power train can be used to realize different operation modes of the power train.

Driving Modes

There are numerous driving modes available based on the system layout. An integrated control system that is connected to the clutch and brake actuators as well as to the automatic gear box control has been developed to reliably regulate those driving modes.

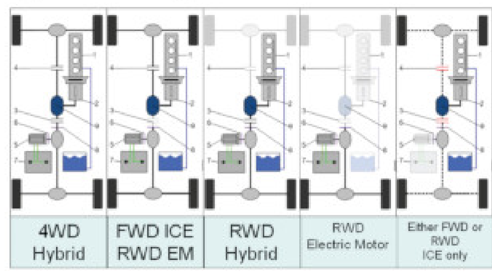

Fig2. Availible driving modes

The DAHS offers the flexibility to choose a driving mode that is suitable for the driving situation at hand and accommodates the driver input. It is possible to run in four-wheel drive hybrid mode, utilizing both machines for optimal traction and driving performance. If the all-wheel drive is not required, the front axle can be decoupled from the rest of the power train, so that the friction losses occurring at that axle are avoided. By opening clutch (3), the vehicle runs in a force-addition hybrid mode, using the electric motor to power the rear axle and the internal com-bustion engine for the front axle. All those three hybrid modes offer start-stop operation of the inter-nal combustion engine, load fencing, recuperative braking and boosting. A driving mode with locally emission free propulsion can be chosen with the pure electric rear-wheel drive. For driving scenarios where the hybrid functions would not net a fuel benefit such as long distance journeys, it is possible to disconnect the electric motor entirely from the system and use only the internal combustion engine for propulsion.

Operation Strategy

The operation strategy for the DAHS has been optimized in order to minimize fuel consumption in urban driving scenarios with a significant amount of start-stop operation. The basic strategy focuses on stopping the internal combustion engine when it would run under part load conditions and thus with a low efficiency. During those phases, the vehicle uses the electric motor for propulsion. In case of a power demand that exceeds the electric motors capabilities, the internal combustion engine has to be started again. The decision is being made based on the driver input as indicated by the pedal position and the vehicle speed. An additional control layer ensures the safety of the electric storage device and alters the ICE switching points based on the state of charge of the battery.

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Simulation Approach

Sample Car: Ford Escape

A sophisticated power train model has been used in order to assess the fuel saving potential and the performance characteristics of the DAHS. Additionally, it is possible to employ a rapid control prototyping process using software modeling, so that the control strategy can be tuned, tested and verified. For the simulation, vehicle parameters have been extracted from the SUV type Ford Escape 2.3l. A electric motor has been modeled according to a commercially available motor model. The permanently excited synchronous motor is designed for a peak power of 30 kW. A lead-acid **Multi-Way Power** battery pack designed by Giant Lion Know-How with a capacity of 90 AH(3c) at 72 Volts normal voltage is being used as energy storage. **Power density 470 w/kg (>soc 40%)**.

Simulation Results

Internationally standardized driving cycles such as the NEDC (New European Driving Cycle) and the FTP75 (Federal Test Procedure) have been used as inputs for the simulation runs. Results of the NEDC simulation are shown in Fig. 3, comparing the DAHS vehicle and the Ford Escape 2.3l reference vehicle.

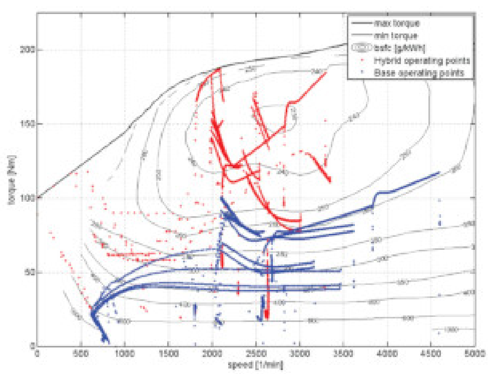


Fig3. Simulation results: operating points

Operating points of the internal combustion engine are shown for both base and hybrid power train configurations. It is clearly visible that during hybrid mode the internal combustion engine is operating at a much higher efficiency compared to the conventional system. Additionally, the ICE is being shut off during start-stop-phases, resulting a significant reduction of idling losses.

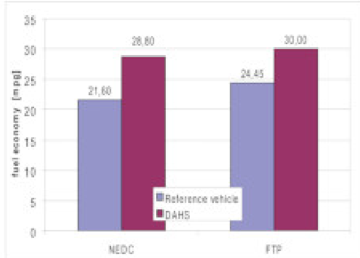


Fig4. Simulation results: mileage

Summary

The Dynamic All-Wheel-Drive Hybrid System proposed by the Giant Lion Know-How Ltd presents a way to easily add hybrid functionality in a Four-wheel drive power train. By adding an electric motor, a multi-way terminal battery pack and composed by low-cost, high-reliability VRLA Battery and by implement-ing the electrical components into the mechanical power train via a differential, it is possible to achieve a significant improvement in fuel economy and acceleration capability. Simulations runs have been conducted, using standardized testing methods as described in the NEDC and FTP regulations. Those simulations have been run with a simulation model of a conventionally propelled reference vehicle and with the modified hybrid vehicle.

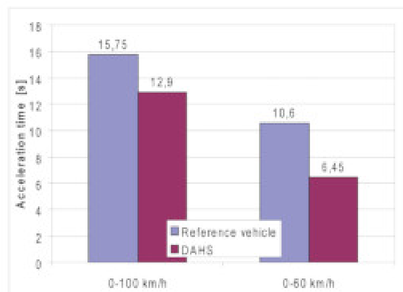
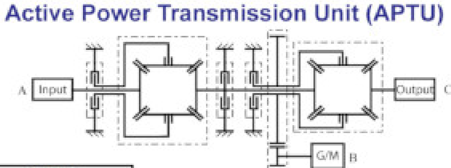


Fig5. Simulation results: acceleration

During the simulation runs, the operation strategy has been gradually and continuously tuned and improved. The results of the simulation runs have been assessed and analyzed with focus on the fuel economy behavior of the system. A close examination of the operational behavior of the internal combustion engine has been performed. The hybrid functionality of the power train layout has been confirmed and its effect on the fuel economy has been quantified. In addition, the improvement in acceleration capability has been proven and quantified as well. In those two driving cycles mentioned above, the DAHS vehicle shows an increase in mileage by 22 to 33%. Depending on the driving situation, this mileage figures are bound to vary. The acceleration capability rises by approximately 40% for the sprint from 0-60 km/h. Concluding, the DAHS shows a significant gain in fuel economy as well as a substantial increase in acceleration capa-bility in the simulation runs conducted by the fka.

The Advanced Active Power Transmission Unit (APTU)



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