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Electrically synchronised gear shifting

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Abstract

Electrically synchronised gear shifting is a new way of solving the old gearbox problem and a new way of building a light hybridised vehicle. A 10kW electrical machine, which is used to synchronise the speed of the outgoing and incoming shafts during a gearshift, replaces the function of the classic clutch in the gearbox. The clutch is kept, but only used during start and when the vehicle is driven in pure electric mode. The gearbox is fitted with a servo actuator, making a gear-shifting robot, to move the gear stick and to shift gears automatically and very fast. The gear shifting sequence is as follows:

- First the torque is set to zero by setting all currents to zero
- Then the gearbox is put into neutral
- A speed controller is temporarily applied to the electrical machine to synchronise the outgoing and incoming shafts of the gearbox
- The new gear is applied
- Finally the gear stick is returned to its home position and the torque is reapplied

The total time of torque loss is the time for putting the gearbox into neutral, synchronising the speed and applying the new gear.

A sequential racing gearbox that is fitted with a 10kW permanent magnetised synchronous machine and a servo actuator from SEW is used to test the concept of electrically synchronised gear shifting. The gearbox is mounted in a rig fitted with flywheels with the same inertia as the rotating masses of a real car. A computer with dSpace and a tailor made DC-AC power converter is used to control the traction motor and the gear-shifting robot.

The electrical machine is modelled using Matlab Simulink from which it is determined that the electrical machine can be braked 15 % @ 1200 rpm, in 70 ms and accelerated in 120 ms using all of the available torque. Simulations with altered motor design is also made and by decreasing the diameter from 300 mm to 180 mm and by making the motor 150 mm long instead of 70 mm the motor inertia is cut by a factor three. The acceleration ability can be cut by almost the same factor but is still limited by the inertia of the incoming shaft and gears in the gearbox.

The results from the laboratory experiments give a total torque loss time of 280ms of which the speed synchronisation is 70ms during shift up and 120ms during shift down. The rest of the time is for moving the servo arm and some communication lag.

By redesigning the electrical traction motor, replacing the servo and its controller to a faster one and by building an optimised gearbox with the same relative gear ratio and without the synchronisation rings it should be possible to cut the torque loss times to less than 100ms.