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Engine Motor Coupling for Parallel Hybrid Vehicle

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Abstract

In recent years there has been an immense increase of interest in hybrid vehicles over diesel or petrol vehicles given their low exhaust emission, lesser noise and lower fuel consumption. Hybrid vehicles have a bright future in India given the increase in pollution caused by the rapidly rising number of automobiles used by general public. A hybrid vehicle consist of two power sources i.e. 1) - engine 2)- battery(ultra-capacitor, super capacitor etc. can also be used as optional power resources). The motor and engine are generally coupled with a set of planetary gears which transfers the power output of motor and engine to the differential with some mechanical energy losses. This paper describes a new type of coupling system which can be used in hybrid cars while completely removing the necessity of using planetary gear sets and transfer of power can be done directly to the differential and then to the wheels and thereby eradicating mechanical energy losses caused by the planetary gear sets and at the same time saves the effort to design and fabricate them. The onboard charging system using Torsen Differential and engine will not only eliminate the necessity of availability of electric charging stations at various locations but also reduces the time spent for charging of batteries. The coupling system was designed in SolidWorks and simulations were done to verify the proposed concept. The calculations were done by choosing an average passenger car and the coupling system was designed accordingly. The simulation results verified that the proposed system could be easily used in hybrid cars.

Keywords *- Torsen Differential, Parallel Hybrid, Engine motor coupling*

I. INTRODUCTION

Fossil fuels which have been powering our vehicles since a century are getting depleted at a very fast rate. The need of the hour is to use an alternate sourceor method to run the automobiles. Electric cars have been a prominent discovery in today's fuel deficit world. Electricity can be produced from different sources such as solar energy, hydro energy, wind energy, nuclear energy. For a developing nation like India, bringing a sudden shift from of fossil fuels driven to electric driven automobile would not be effective because of thesmall number of the charging stations available and the amount of time required tocharge the batteries. There is a need of hybrid transition period between internal combustion engine vehicles and electric vehicle. This paper enlightens the application of Torsen differential for coupling of power output from engine and motor allowing the user to use either of them independently or both of them together. This model also provides an onboard charging system and kinetic energy recovery system to increase the efficiency.

II. COMPONENTS

2.1 Torque-Sensing (Torsen) differential

The Torsen differential, originally used as central differential in Audi Quattro B5, has been modified by placing two sprockets, one on each side to provide dual power input to drive the vehicle, one from the engine and one from the electric motor. In the heart of torsen differential lies specially shaped gear pair assembly. A Torsen works on the simple principle of worm gear- worm wheel; that is a spinning worm gear can rotate the wheel, but the rotating wheel cannot spin the worm gear.

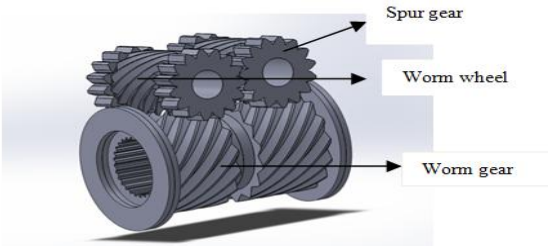


Figure 1. Worm-gear and worm wheel of Torsen differential

2.2Testvehicle

The test vehicle is a SAE Formula Student car with a kerb weight of 220 Kg. The configuration is designed to be rear engine-rear wheel drive with wheel base 1600mm and front and rear wheel track of 1100mm and 1000 mm respectively.

2.3 Engine KTM Duke 200

The engine used for the model is of KTM Duke. Specification of engine is mentioned in table 1.

Table 1. Specification of KTM Duke 200 Engine

Displaced Volume	199.5 cc
Bore	72 mm
Stroke	49 mm
Compression ratio	11.3.1
Transmission	6 speed, shifting claws
No. of valves	4 (Overhead Camshaft)
Average Km/l of gasoline	25

Figure 2. KTM Duke 200 Engine

2.4 Electric Motor Agni 95R

Agni 95R motor is chosen. It has a very high efficiency (theoretically 93%). The motor is used as motor generator to drive the vehicle in electric mode and to charge the batteries during the conventional engine mode. The specification of the Agni 95R motor is given in the table 2.

Table 2. Specification of Agni 95R

RPM / Volt	71
Max. Voltage	84
Max RPM	6000
Cont. Output Power	16KW @ 78V
Avg. Torque	5 N. m.

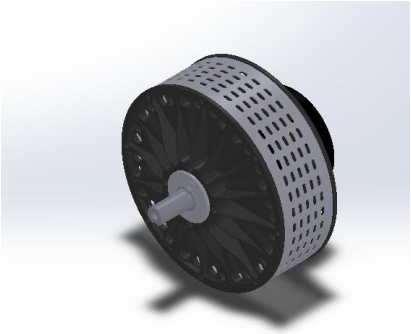


Figure 3. Agni 95R Motor

2.5 Battery and Battery Management System

The Battery used is a series arrangement of 26 Lithium ion LFP90AHA cells. These cells possess a wide working temperature range along with a high current discharge rate. Cell board SE100AHA provides value of all the cell parameters to the Battery Management System 2CN0000H. The BMS provides the status of Battery pack along with setting the charge and discharge limits. It also ensures the cooling of battery and signals at the loss of insulation.

Table 3. Specification of LFP90AHA cell

Nominal Capacity	90Ah
Operation Voltage	2.5V - 4.25V
Charge Current	<3CA
Discharge current	3CA - 20CA
Battery Life	3000 - 5000 cycles
Operating Temperature	-45 - 85°C

Figure 4. LFP90AHA cell

2.6 Motor Controller and Throttle paddle

A Kelly KEB48401X controller provides efficient and smooth response to the input provided by throttle paddle .It is programmable which allows ease in calibrating the motor with the engine. It ensures that motor's rpm is equal to that of engine's shaft to achieve maximum efficiency. It provides a current cutback, warning and shutdown on high temperature providing more safety to a motor system.Kelly throttle pedal operates at small voltages .Throttle input in the form of a PWM signal is generated depending on the angle to which pedal is being pressed. Using these signals the motor controller interprets the required rpm and provides required voltage to the motor.

Figure 5.A Kelly KEB48401X controller

Figure 6. Throttle pedal

III. Working of the system

Torsen differential is a unique and ingenious method of providing differential action while overcoming the traction difference problem. The internal component of Torsen is quite different from a conventional differential. It consists of a worm-gear worm-wheel arrangement. A pair of such gears is fitted with the case. Each end of the worm wheel are fitted with a meshing spur gear as shown in figure 1.

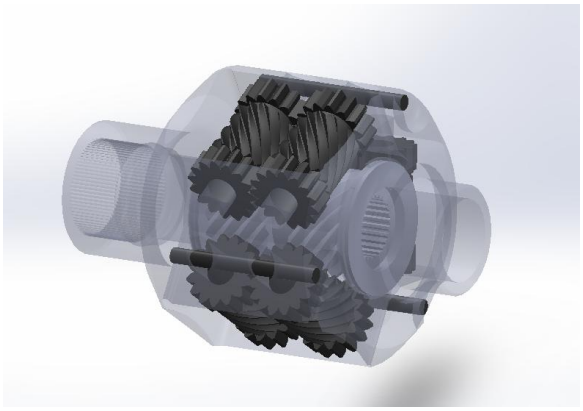


Figure 7. Torsen differential with transparent casing

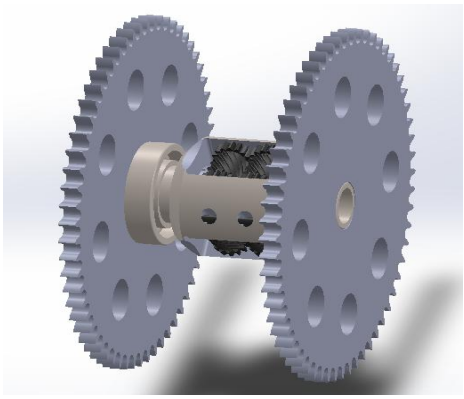


Figure 8. Modified Torsen Differential

For conventional single input configuration, while the vehicle is moving in a straight path, the worm wheel will push and turn the worm gears. So both the drive wheel will rotate at the same speed. In this condition the worm wheel do not spin on their own axis and the whole mechanism will move as a single solid unit. When the vehicle is negotiation a right turn, the left wheel need to rotate at a higher speed than the right wheel. The worm gear of the faster left axial will make the corresponding worm wheel spin on its own axis. On the other side, the slow right axial is turning the worm wheel in opposite direction. The meshing spur gear will ensure a perfect differential action (say +x % and -x %). When one the wheel looses traction while using conventional differential, the slippery wheel starts to rotate very rapidly and will draw the majority of the engines power. But if a Torsen differential is used, the speed change will make the worm wheel on the side of lower traction spin at its own axis. This will, in turn, spin the second worm wheel on the side of higher traction. But this worm wheel will not be able to turn the corresponding worm gear. As a result the whole mechanism gets locked and both the wheels turn together. This allows a large amount of torque to be transferred to a high traction wheel. Thus in Torsen, the locking action is instantaneous

The modified Torsen differential used consists of two sprockets one on each side of casing to provide input from engine and motor respectively. The sprockets are linked to engine and motor using 5/8 x 1/4" (520) O-Ring chain. The sprocket on the engine side of differential is mounted on a One way bearing fitted in such a way that the engine can be can give input to differential casing but casing cannot move engine drive shaft. The sprocket on the motor side of differential is fixed with the casing and power can be transmitted to and from the electric motor. Thus motor may act as generator if the sprocket is rotated by external torque. A common throttle pedal is in synchronization with motor controller and throttle system of engine is used to give input for acceleration to the vehicle.

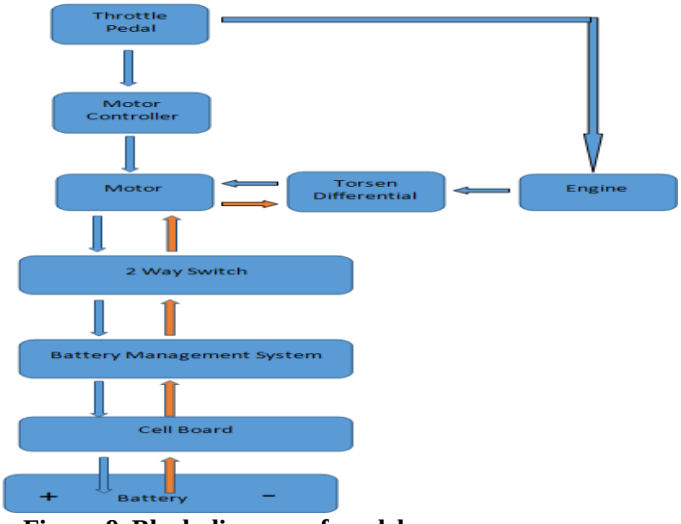


Figure 9. Block diagram of model

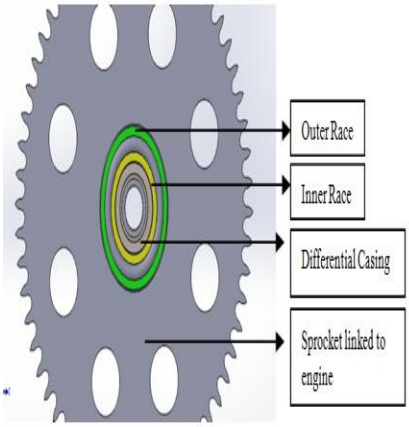
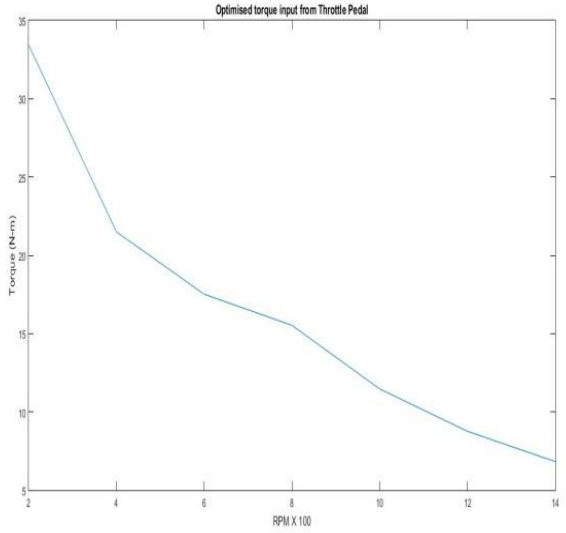


Figure 10. Side view of Torsen differential

3.1 Driving modes of the vehicle

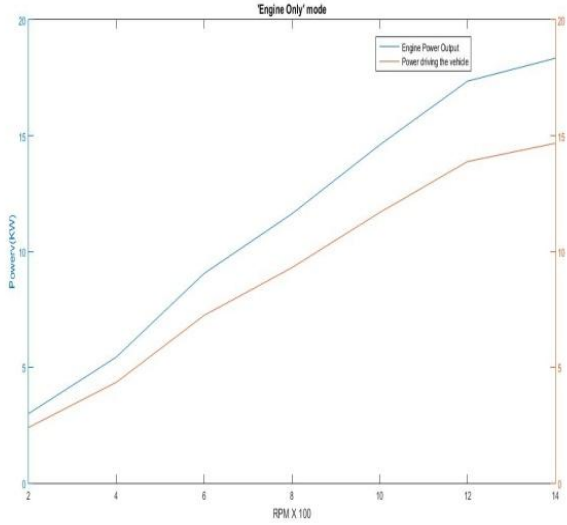
3.1.1 Motor only mode.



In this mode the power is drawn from the battery by motor to move the corresponding motor sprocket. The motor sprocket rotates the casing, which in turn rotates the worm gear of the differential. This is pure electric drive which gives silent with no harmful gases emission and full torque at all speed. From figure 10, we can see that the motor will rotate the inner race in clockwise direction. In this condition, the one way bearing is unlocked position and no power is transmitted to engine sprocket because the frictional torque between inner and outer race is not enough to move the outer race. The current is directly proportional to torque. Thus, the angular movement of throttle pedal is calibrated to corresponding signal to motor controller for required current or torque.

Figure 11. RPM and Torque in motor only mode.

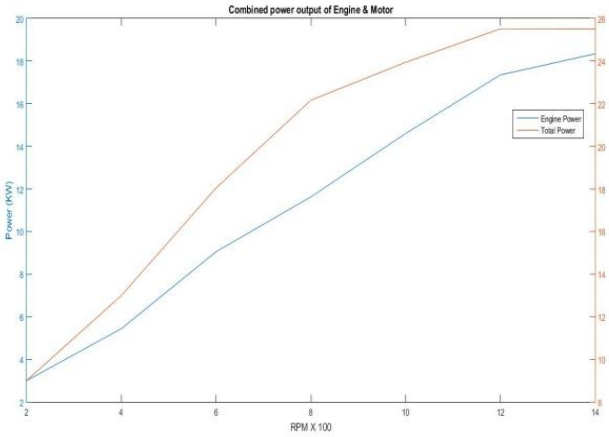
3.1.2 Engine only mode.



In this mode, the one way bearing is in locked position. Thus engine is rotating the sprocket in clockwise direction. The power is transferred to the casing via locked one way bearing. This input power is transmitted to the worm gear which drives the vehicle. Some amount of power output from engine is utilized to run the Agni 95R as electric generator. This produces electromotive force and can be stored in the battery. This constitutes an onboard charging system using internal combustion. Figure 12 shows that a small amount of total power output of engine is utilised by generator to charge the battery.

Figure 12. Power output in Engine only mode

3.1.3 Engine and motor mode.



The locked or unlocked state of the one way bearing depends upon the speed difference between motor and engine. It engine is at higher speed than motor, charging of battery takes place. The most optimized parameters of motor is fed to motor controller to get equal rpm from engine and motor for high performance condition. Thus both engine and motor will be used to drive the vehicle with combined power output

Figure 13. Total power output in engine only mode

IV. Benefits

4.1On board charging system

When the vehicle is running on engine only mode, the engine is driving the engine as well as providing torque to the motor. According to Faraday's laws of electromagnetic induction, whenever a conductor is placed in a varying magnetic field (OR a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. Agni 95R acts as a generator and charges the battery when shaft is driven by an external torque. Thus the overall fuel requirement of the vehicle and requirement of frequent charging stations reduces.

4.2 Kinetic Energy recovery system

Engine braking occurs when the retarding forces within an engine are used to slow a vehicle down, as opposed to using additional external braking mechanisms such as friction brakes or magnetic brakes. Every time the driver leaves the throttle pedal in order to slow down or stop the vehicle, the kinetic energy is transferred back from half shaft to Agni Motor. This kinetic energy is stored back to battery in the form potential. Thus, this system provides an electric motor equivalent of engine braking.

V. Conclusion

The model worked efficiently for in all three driving modes. Proven that inclusion of torsen differential for engine motor coupling will not only increase the efficiency but also the performance of the vehicle. Electricity is the green fuel. Use of electricity will reduce the harmful exhaust emission. It is a perfect balance of conventional internal combustion engine and budding electric power train.

