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Mechanical coupling for Parallel Hybrid Drivetrain

Karni Singh Chauhan, Anurag Arora, Sahil Uppal, Umang Grover, Niranjan Lumpatki

Automobile Engineering, SRM Institute of Science & Technology, Kattankulathur
Mechanical Engineering, SRM Institute of Science & Technology, Kattankulathur
Automobile Engineering, SRM Institute of Science & Technology, Kattankulathur
Mechanical Engineering, SRM Institute of Science & Technology, Kattankulathur
Mechanical Engineering, SRM Institute of Science & Technology, Kattankulathur

Abstract- *In present-day scenario, the increasing demand for fuel efficient and less pollutant vehicles have stimulated the development of hybrid and electric vehicles. These vehicle platforms often incorporate drivetrains which utilize multiple power sources (prime movers like the internal combustion engine, and electric motor) for vehicle propulsion in an effort to increase fuel mileage and reduce emissions. This leads to an evolution in coupling design and has new challenges in drivetrain design. Coupling the two prime movers which have fundamentally different characteristics makes it even more challenging. While the electric motor has quite a linear output, then engine is not quite so.*

Results from this research include the fundamental torque and rpm relationships that exist in a multiple-input, single-output power transmission device. These results were deduced from a practical working in a Formula student car that incorporated two separate power inputs into a planetary differential which combined to produce a single output.

Keywords- *Hybrid Vehicle, Drivetrain, Parallel Hybrid, Differential, Mechanical Coupling*

I. INTRODUCTION

Fossil fuels which have been powering our vehicles for over a century. The time has come to look at alternate sources of energy, due to depletion of fossil fuel reserves, and more importantly to help reduce emissions. Electric vehicles are the future of the automotive industry, which allows for production of energy from renewable energy sources. A transitional niche between the internal combustion engines, and electric vehicles is occupied by hybrid vehicles, which bridges the gap between the two [1]. It combines the reliability of the internal combustion engine, with the efficiency of an electric motor. 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 the limited number of the charging stations and the also amount of time required to charge the batteries.

In our research, we have elucidated on the working of a new type of a mechanical coupling, to be used as parallel hybrid coupling between an internal combustion engine and an electric motor. This coupling allows for the transmission of power from both the prime movers individually, or collectively.

II. COMPONENTS

2.1 Test Vehicle

The mechanical coupling was tested on a Formula Student vehicle made by *Hybrutos Racing*, from SRM Institute of Science & Technology, Kattankulathur. The prime movers used by the vehicle are:-

1. KTM Duke 200 Engine
2. Agni 95R PMDC Motor

2.2 Engine: KTM Duke 200

The engine used for the model is of KTM Duke 200. The Specifications of the engine are mentioned in table 1.

Table 1. Specification of KTM Duke 200 Engine

Displacement volume	199.5 cc
Bore	72mm
Stroke	49mm
Max Power	25.1 PS
Max Torque	19.2 Nm
Compression Ratio	11.3:1

Figure 1. KTM Duke 200 Engine

2.3 Electric Motor: Agni 95R

Agni 95R is a PMDC (Permanent Magnet DC) motor, which was used in the test vehcle. Technical specifications are mentioned in table 2

Table 2. Specifications for Agni 95R

RPM/Volt	71
Torque/Amps	0.1344
Max Rpm (66V)	4686 RPM
Max Torque	53 Nm

Figure 2. Agni 95R

2.4 Battery and Battery Management System

The Battery used is a series arrangement of 20 Lithium ion WB-LYP40AHA cells. These cells possess a wide working temperature range along with a high current discharge rate. 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. Specifications for WB-LYP40AHA

Minimum Voltage	2.5 V
Maximum Discharge Current (Continuous)	3C
Operating Temperature	-45°C to 85°C
Energy Density	75Wh/kg

Figure 3. WB-LYP40AHA

2.5 Mechanical Coupling

The powertrain comprises of a custom designed mechanical coupling, referred to as the *Reverse Differential Action Powertrain Coupling* (RDAPC). The RDAPC comprises of a custom designed casing made of AL 6061- T6, housing a set of custom manufactured, carburized differential bevel gears made of EN 353 steel. The mechanical coupling consists of 4 bevel gears; 2 spider gears and 2 side gears. The casing is splined externally at the left end which is used to transmit the motion to a sprocket (splined internally) which proves as the final drive input.

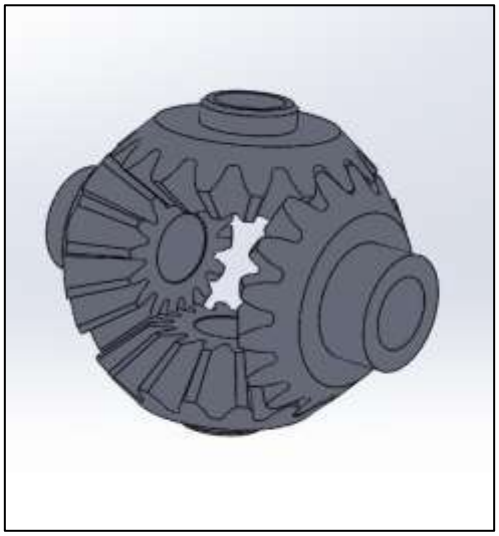

Figure 4. Gear arrangement

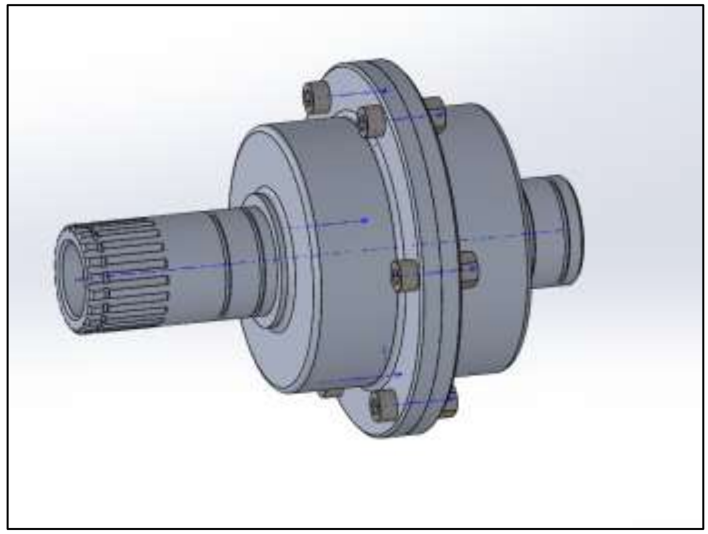

Figure 5. RDAPC Casing

III. WORKING

The mechanical coupling helps effectively transfer power from either prime mover to the differential. The output from the electric motor and internal combustion engine are coupled at the RDAPC. The RDAPC comprises of a differential type planetary gear system, which provides efficient torque addition. The mechanical coupling consists of 4 bevel gears; 2 spider gears and 2 side gears. There are thrust washers between each gear and the casing, which help resolving axial forces, and keep gears aligned on the shaft. The side gears allow for input from either prime mover, while the spider gears are attached to the casing via a pin, on which they are allowed to rotate freely. The spider gears link both side gears with each other, and allow for the power transmission from either prime mover to the casing via the pin. The casing is splined externally at the left end which is used to transmit the motion to a sprocket (splined internally) which proves as the final drive input. The coupling is capable of taking input from either prime mover either individually, or collectively.

There are two one-way clutches used in the powertrain. Each one-way clutch in the powertrain is used as a backstopping clutch, instead of freewheel bearing. During the only Electric mode, to prevent the engine shaft from rotating in the reverse direction, the first One-way clutch is coupled to the engine side input shaft. Likewise, in only Combustion mode, another One-way clutch is used on the motor side input shaft, restricting the reverse rotation of the motor.

The sprocket attached to the RDAPC transfers torque to the TORSEN Differential (Final Drive) through a chain drive.

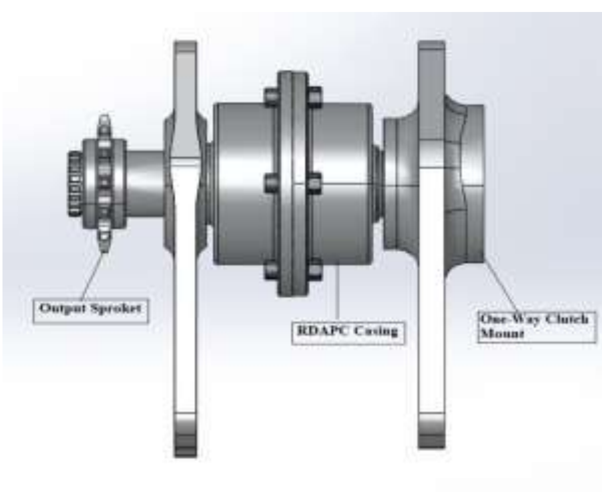

Figure 6. Assembled Coupling (Front View)

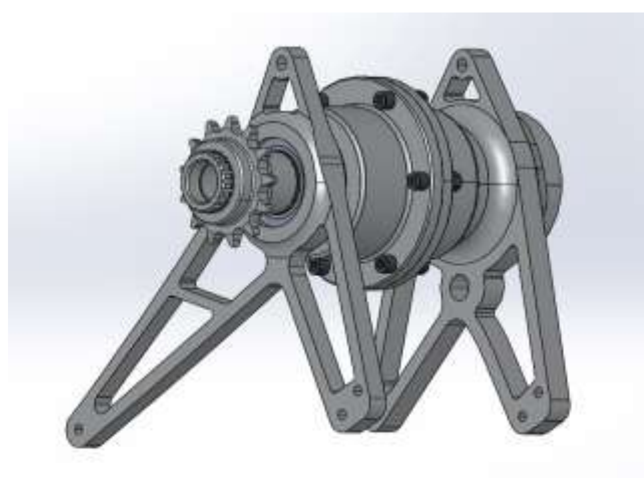

Figure 7. Assembled Coupling (Isometric View)

3.1 Operating Modes of the Vehicle

3.1.1 Only Electric Motor Mode

During only electric mode, only the motor powers the vehicle through the coupling. In order to reduce power loss, the one-way clutch installed on the engine side input shaft does not allow for the reverse rotation of the shaft, and ensures power transmission to the wheels via the differential.

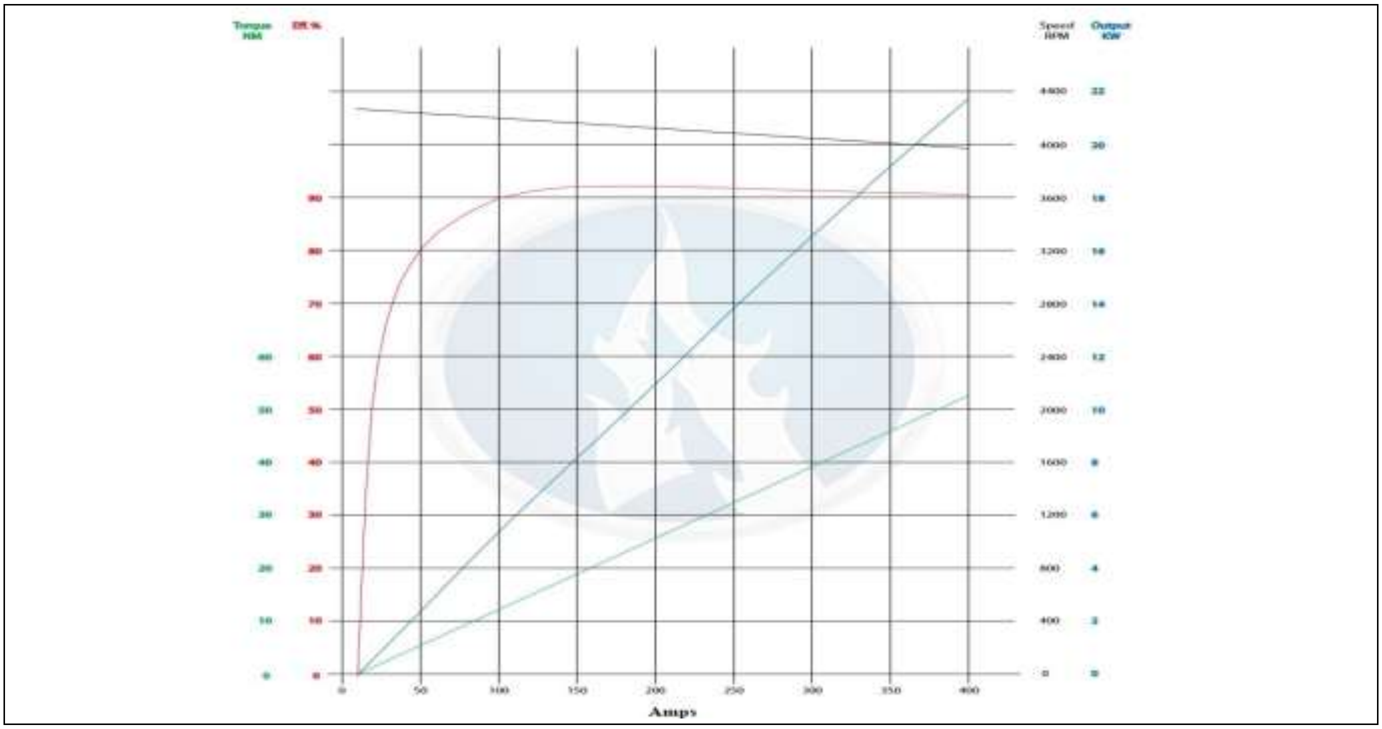

Figure 8. Agni 95R Output Characteristics

3.2 Only Internal Combustion Engine Mode

During the only internal combustion engine mode, only the engine powers the vehicle via the coupling. In order to reduce power loss, the one-way clutch installed on the motor side input shaft does not allow for the reverse rotation of the shaft, and ensures power transmission to the wheels via the differential.

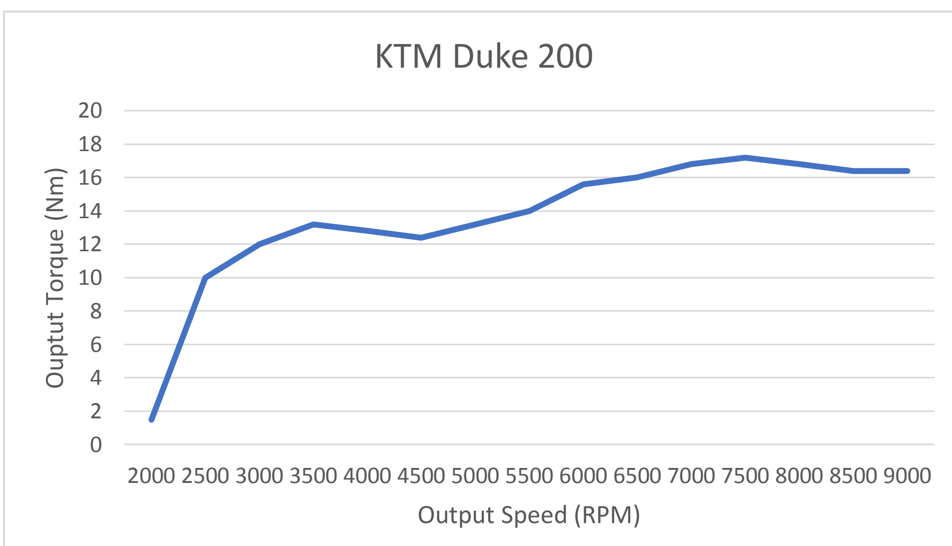

Figure 9. Engine Torque v/s Speed Characteristics

3.3 Hybrid Mode

In the Hybrid mode, the coupling takes input from both the electric motor, and the internal combustion engine simultaneously. The output speed and torque characteristics are according to principle of conservation of power [3] ie.

$$(Tm*Rm) + (Te*Re) = (To*Ro)$$

Where,

Tm = Motor Torque

Rm = Motor RPM

Te = Engine Torque

Re = Engine RPM

To = Output Torque

Ro = Output RPM

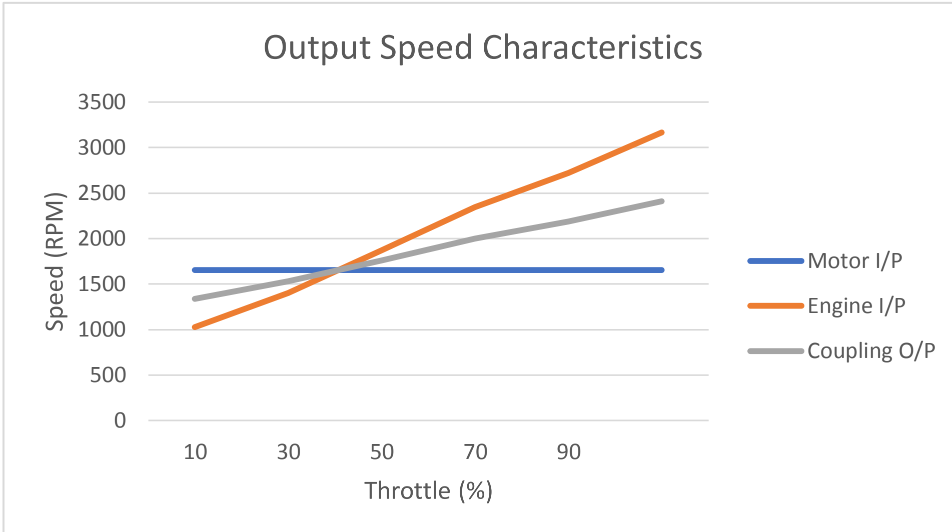

Figure 10. Coupling Output Speed Characteristics

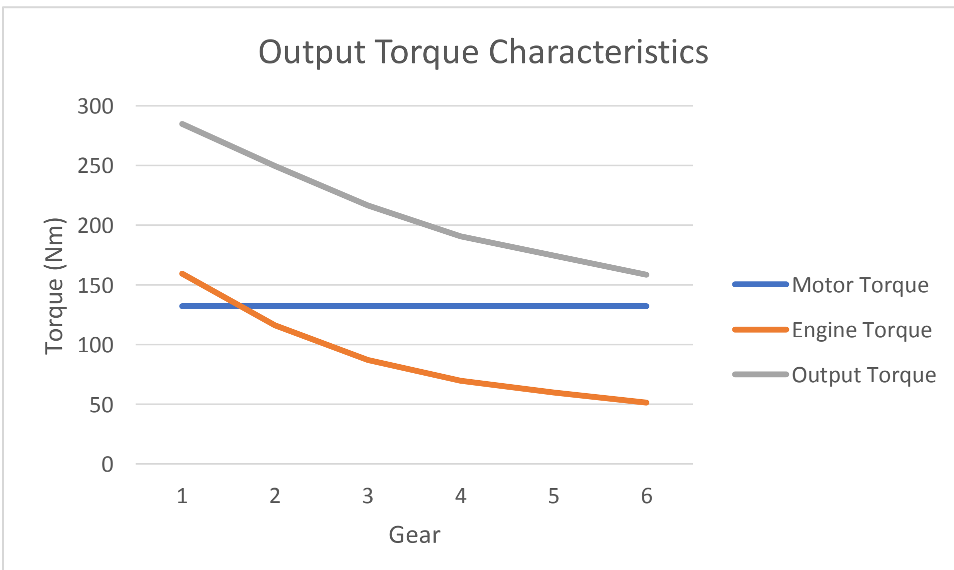

Figure 11. Coupling Output Torque Characteristics

The data for this graph was derived from trigger wheels installed on both prime mover outputs, and using a proximity sensor to obtain the RPM of either of the prime movers real-time. On the engine, the trigger wheel is mounted on the output shaft, while on the motor, the trigger wheel is mounted on the primary reduction gear, so as to have the RPM input at the RDAPC.

IV. ADVANTAGES

The drivetrain allows for inputs from both prime movers ie. the internal combustion engine, and the electric motor simultaneously, as well as individually. This allows for greater flexibility in choosing drive modes, and has a potential to achieve greater performance, and fuel efficiency than a conventional hybrid setup. This drivetrain setup also improves the overall mechanical efficiency, and compactness of the setup, instead of a chain setup.

V. CONCLUSION

The mechanical coupling worked efficiently in all three driving modes, proving the wide range of operation of the coupling. The coupling is capable of not only increase the efficiency, but also the performance of the vehicle. This coupling thereby gives a scope to hybrid vehicles, which can combine the efficiency of the electric motor with the accessibility of the internal combustion engine.

VI. REFERENCES

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