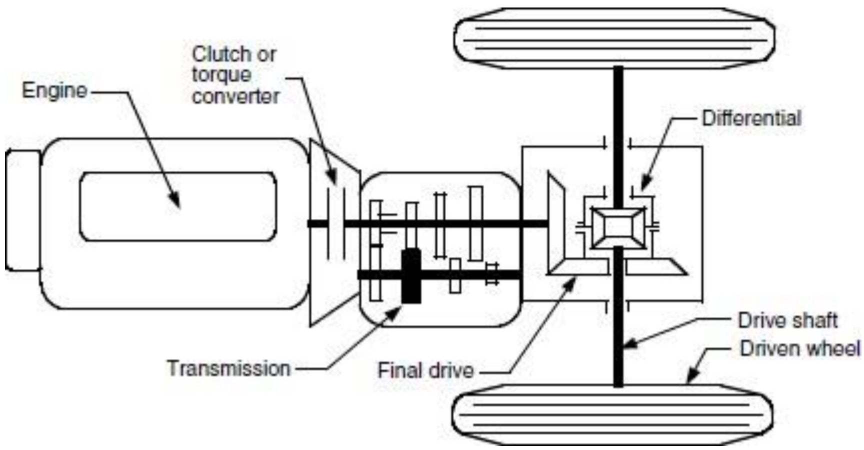
1.3 VEHICLE POWER SOURCE CHARACTERIZATION:

An automotive power train, as shown in Figure, consists of a power plant (engine or electric motor), a clutch in manual transmission or a torque converter in automatic transmission, a gearbox (transmission), final drive,



Differential, drive shaft, and driven wheels. The torque and rotating speed of the power plant output shaft are transmitted to the drive wheels through the clutch or torque converter, gearbox, final drive, differential, and drive shaft.

The clutch is used in manual transmission to couple the gearbox to or decouple it from the power plant. The torque converter in automatic transmission is a hydrodynamic device, functioning as the clutch in manual transmission with a continuously variable gear ratio.

The gearbox supplies a few gear ratios from its input shaft to its output shaft for the power plant torque– speed profile to match the requirements of the load.

The final drive is usually a pair of gears that supply a further speed reduction and distribute the torque to each wheel through the differential. The torque on the driven wheels, transmitted from the power plant, is expressed as

$$T_w = i_g i_0 \eta_t T_p \qquad \text{……………...eq1}$$

where *ig* is the gear ratio of the transmission defined as *ig_Nin/Nout* (*Nin* —input rotating speed, *Nout* — output rotating speed), *i*0 is the gear ratio of the final drive, η*t* is the efficiency of the driveline from the power plant to the driven wheels, and *Tp* is the torque output from the power plant. The tractive effort on the driven wheels, as shown in Figure 1.6, can be expressed as

$$F_t = \frac{T_w}{r_d}$$ eq2

Substituting (eq1) into (eq2) yields the following result

$$F_t = \frac{T_p i_g i_0 \eta_t}{r_d}$$ eq3

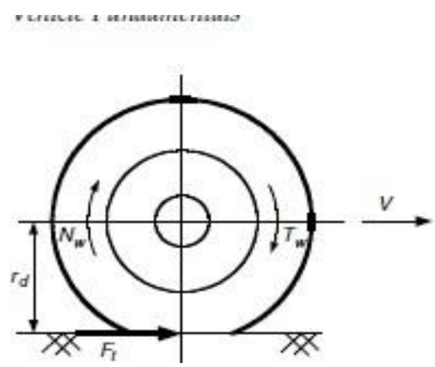


Figure 1.2 Tractive effort and torque on a driven wheel

The friction in the gear teeth and the friction in the bearings create losses in mechanical gear transmission. The following are representative values of the mechanical efficiency of various components:

Clutch: 99%

Each pair of gears: 95–97%

Bearing and joint: 98–99%

The total mechanical efficiency of the transmission between the engine output shaft and drive wheels or sprocket is the product of the efficiencies of all the components in the driveline. As a first approximation, the following average values of the overall mechanical efficiency of a manual gear-shift transmission may be used:

Direct gear: 90%

Other gear: 85%

Transmission with a very high reduction ratio: 75–80%

The rotating speed (rpm) of the driven wheel can be expressed as

$$N_w = \frac{N_p}{i_g i_0}, \qquad \text{..........................eq4}$$

where *Np* is the output rotating speed (rpm). The translational speed of thewheelcenter (vehicle speed) can be expressed as

$$V = \frac{\pi N_w r_d}{30} \text{(m/s)}. \qquad \text{..........................eq5}$$

Substituting (eq4) into (eq5) yields

$$V = \frac{\pi N_p r_d}{30 i_g i_0} \text{(m/s)} \qquad \text{.....................eq6}$$

1.2.1 VEHICLE POWER PLANT AND TRANSMISSION CHARACTERISTICS:

There are two limiting factors to the maximum tractive effort of a vehicle. One is the maximum tractive effort that the tire–ground contact can support and the other is the tractive effort that the power plant torque with given driveline gear ratios can provide. The smaller of these two factors will determine the performance potential of the vehicle. For on-road vehicles, the performance is usually limited by the second factor. In order to predict the overall performance of a vehicle, its power plant and transmission characteristics must be taken into consideration.

1.2.2 POWER PLANT CHARACTERISTICS:

For vehicular applications, the ideal performance characteristic of a power plant is the constant power output over the full speed range. Consequently, the torque varies with speed hyperbolically as shown in Figure. At low speeds, the torque is constrained to be constant so as not to be over the maximaimited by the adhesion between the tire–ground contact areas. This constant power characteristic will provide the vehicle with a high tractive effort at low speed, where demands for acceleration, drawbar pull, or grade climbing capability are high.

Since the internal combustion engine and electric motor are the most commonly used power plants for automotive vehicles to date, it is appropriate to review the basic features of the characteristics that are essential to predicating vehicle performance and driveline design.

Representative characteristics of a gasoline engine in full throttle and an electric motor at full load are shown in Figure 1.3and Figure 1.4, respectively.

The internal combustion engine usually has torque–speed characteristics far from the ideal performance characteristic required by traction. It starts operating smoothly at idle speed.

Good combustion quality and maximum engine torque are reached at an intermediate engine speed. As the speed increases further, the mean effective pressure decreases because of the growing losses in the air- induction manifold and a decline in engine torque.

Power output, however, increases to its maximum at a certain high speed. Beyond this point, the engine torque decreases more rapidly with increasing speed. This results in the decline of engine power output. In vehicular applications, the maximum permissible

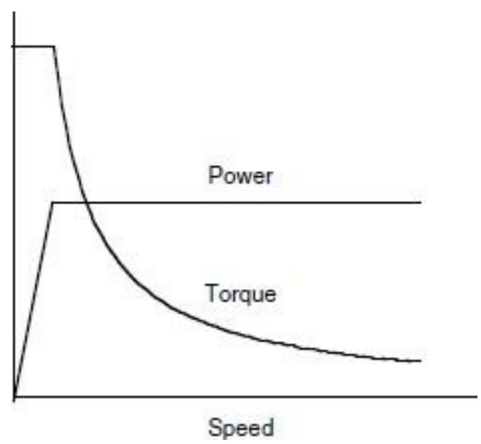


Figure 1.3 Ideal performance characteristics for avehicle traction power plant

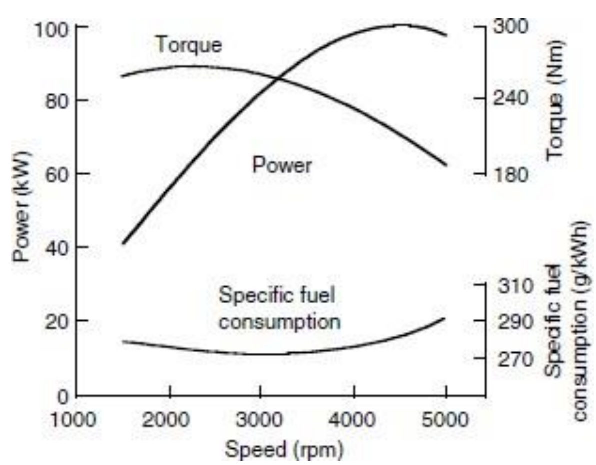


Figure1.4 Typical performance characteristics of gasoline engines

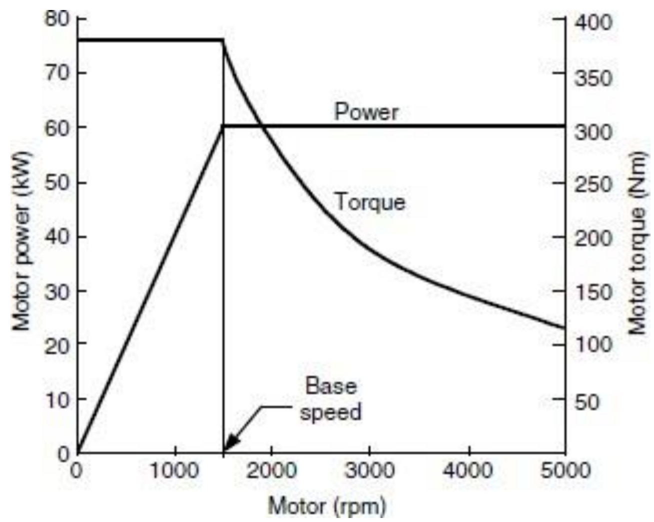


Figure1.5 Typical performance characteristics of electric motors for traction

Speed of the engine is usually set just a little above the speed of the maximum power output. The internal combustion engine has a relatively flat torque–speed profile (compared with an ideal one), as shown in Figure1.5. Consequently, a multi gear transmission is usually employed to modify it, as shown in Figure 1.5. Electric motors, however, usually have a speed–torque characteristic that is much closer to the ideal, as shown in Figure 1.5. Generally, the electric motor starts from zero speed. As it increases to its base speed, the voltage increases to its rated value while the flux remains constant. Beyond the base speed, the

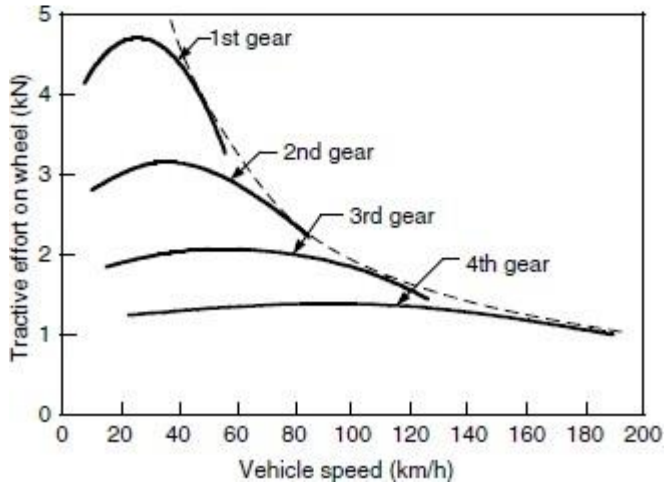


Figure 1.6 Tractive effort of internal combustion engine and a multigear transmission vehicle vs. vehicle speed

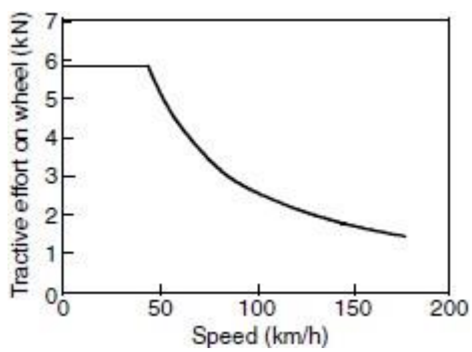


Figure1.7 Tractive effort of a single-gear electric vehicle vs. vehicle speed

Voltage remains constant and the flux is weakened. This results in constant output power while the torque declines hyperbolically with speed. Since the speed–torque profile of an electric motor is close to the ideal, a single-gear or double-gear transmission is usually employed, as shown in Figure 1.7.