Vehicle Dynamics: Theory and Application

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Cap. 4 – Driveline Dynamics

Power and torque performance curves

The maximum attainable power P_e of an internal combustion engine is a function of the engine angular velocity ω_e. This function must be determined experimentally, however, the function $P_e = P_e(\omega_e)$, which is called the *power performance function*, can be estimated by a third-order polynomial

$$\begin{aligned} P_e &= \sum_{i=1}^{3} P_i \omega_e^i \\ &= P_1 \omega_e + P_2 \omega_e^2 + P_3 \omega_e^3. \end{aligned} \tag{4.1}$$

The driving torque of the engine T_e is the torque that provides P_e

$$\begin{aligned} T_e &= \frac{P_e}{\omega_e} \\ &= P_1 + P_2 \omega_e + P_3 \omega_e^2. \end{aligned} \tag{4.11}$$

Power and torque performance curves

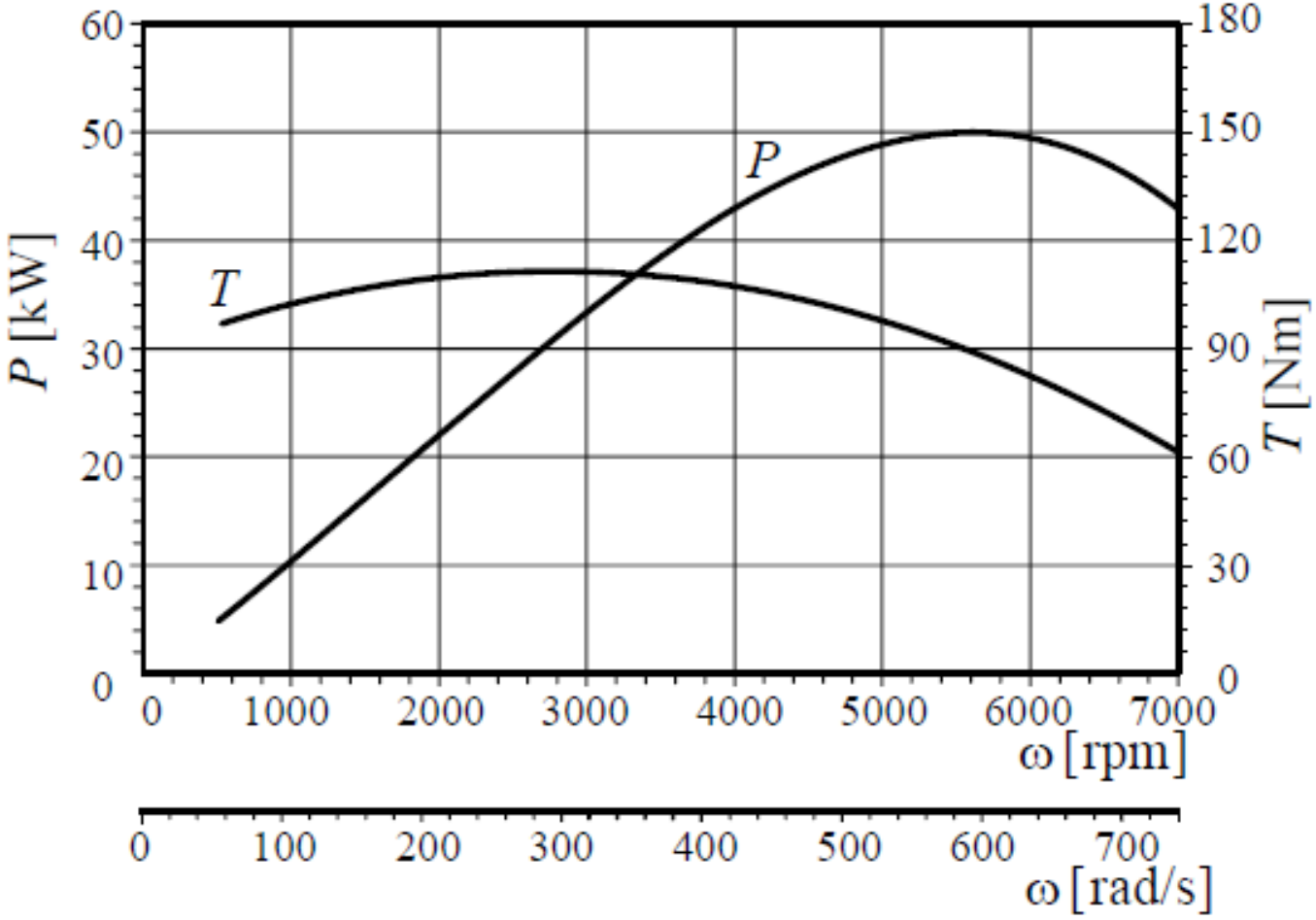
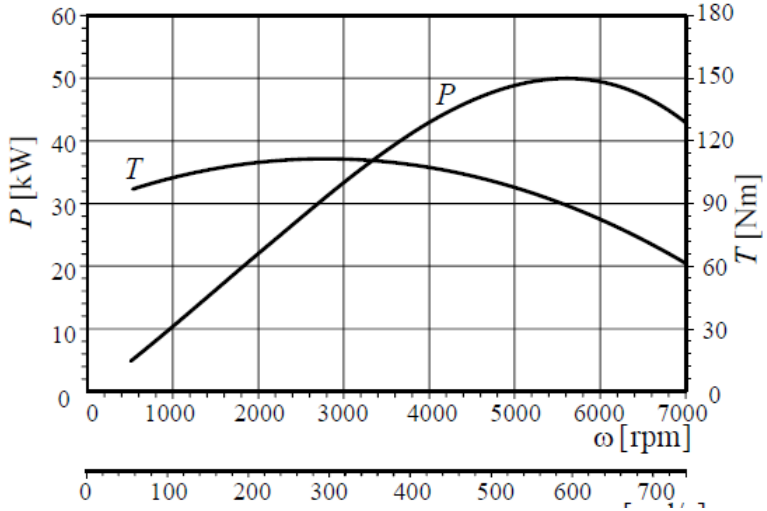


FIGURE 4.1. A sample of power and torque performances for a spark ignition engine.

Power and torque performance curves



If we use ω_M to indicate the angular velocity, measured in $[\mathrm{rad/s}]$, at which the engine power reaches the maximum value P_M, measured in $[\mathrm{W} = \mathrm{N\,m/s}]$, then for spark ignition engines we use

$$P_1 = \frac{P_M}{\omega_M} \tag{4.2}$$

$$P_2 = \frac{P_M}{\omega_M^2} \tag{4.3}$$

$$P_3 = -\frac{P_M}{\omega_M^3}. \tag{4.4}$$

Power and torque performance curves

For indirect injection Diesel engines we use

$$P_1 = 0.6\frac{P_M}{\omega_M} \tag{4.5}$$

$$P_2 = 1.4\frac{P_M}{\omega_M^2} \tag{4.6}$$

$$P_3 = -\frac{P_M}{\omega_M^3} \tag{4.7}$$

and for direct injection Diesel engines we use

$$P_1 = 0.87\frac{P_M}{\omega_M} \tag{4.8}$$

$$P_2 = 1.13\frac{P_M}{\omega_M^2} \tag{4.9}$$

$$P_3 = -\frac{P_M}{\omega_M^3}. \tag{4.10}$$

Power and torque performance curves

Example 120 *Porsche* 911^{TM} *and Corvette* $Z06^{TM}$ *engines.*

A model of Porsche 911 *turbo has a flat-6 cylinder, twin-turbo engine with* $3596\,\mathrm{cm}^3 \approx 220\,\mathrm{in}^3$ *total displacement. The engine provides a maximum power* $P_M = 353\,\mathrm{kW} \approx 480\,\mathrm{hp}$ *at* $\omega_M = 6000\,\mathrm{rpm} \approx 628\,\mathrm{rad/s}$, *and a maximum torque* $T_M = 620\,\mathrm{N\,m} \approx 457\,\mathrm{lb\,ft}$ *at* $\omega_e = 5000\,\mathrm{rpm} \approx 523\,\mathrm{rad/s}$. *The car weighs around* $1585\,\mathrm{kg} \approx 3494\,\mathrm{lb}$ *and can move from* 0 *to* $96\,\mathrm{km/h} \approx 60\,\mathrm{mi/h}$ *in* 3.7 s. *Porsche* 911 *has a top speed of* $310\,\mathrm{km/h} \approx 193\,\mathrm{mi/h}$.

Power and torque performance curves

The power performance equation for the Porsche 911 engine has the coefficients

$$P_1 = \frac{P_M}{\omega_M} = \frac{353000}{628} = 562.1\,\mathrm{W\,s} \tag{4.12}$$

$$P_2 = \frac{P_M}{\omega_M^2} = \frac{353000}{628^2} = 0.89507\,\mathrm{W\,s^2} \tag{4.13}$$

$$P_3 = -\frac{P_M}{\omega_M^3} = -\frac{353000}{628^3} = -1.4253 \times 10^{-3}\,\mathrm{W\,s^3} \tag{4.14}$$

and, its power performance function is

$$P_e = 562.1\,\omega_e + 0.89507\,\omega_e^2 - 1.4253 \times 10^{-3}\,\omega_e^3. \tag{4.15}$$

Power and torque performance curves

A model of Corvette Z06 uses a V8 engine with $6997\,\mathrm{cm}^3 \approx 427\,\mathrm{in}^3$ *total displacement. The engine provides a maximum power* $P_M = 377\,\mathrm{kW} \approx 512\,\mathrm{hp}$ *at* $\omega_M = 6300\,\mathrm{rpm} \approx 660\,\mathrm{rad/s}$, *and a maximum torque* $T_M = 637\,\mathrm{N\,m} \approx 470\,\mathrm{lb\,ft}$ *at* $\omega_e = 4800\,\mathrm{rpm} \approx 502\,\mathrm{rad/s}$. *The Corvette weighs around* $1418\,\mathrm{kg} \approx 3126\,\mathrm{lb}$ *and can move from* 0 *to* $100\,\mathrm{km/h} \approx 62\,\mathrm{mi/h}$ *in* $3.9\,\mathrm{s}$ *in first gear. Its top speed is* $320\,\mathrm{km/h} \approx 198\,\mathrm{mi/h}$.

Power and torque performance curves

The power performance equation for the engine of Corvette Z06 has the coefficients

$$P_1 = \frac{P_M}{\omega_M} = \frac{377000}{660} = 571.2\,\mathrm{W\,s} \tag{4.16}$$

$$P_2 = \frac{P_M}{\omega_M^2} = \frac{377000}{660^2} = 0.86547\,\mathrm{W\,s^2} \tag{4.17}$$

$$P_3 = -\frac{P_M}{\omega_M^3} = -\frac{377000}{660^3} = -1.3113 \times 10^{-3}\,\mathrm{W\,s^3} \tag{4.18}$$

and, its power performance function is

$$P_e = 571.2\,\omega_e + 0.86547\,\omega_e^2 - 1.3113 \times 10^{-3}\,\omega_e^3. \tag{4.19}$$

Power and torque performance curves

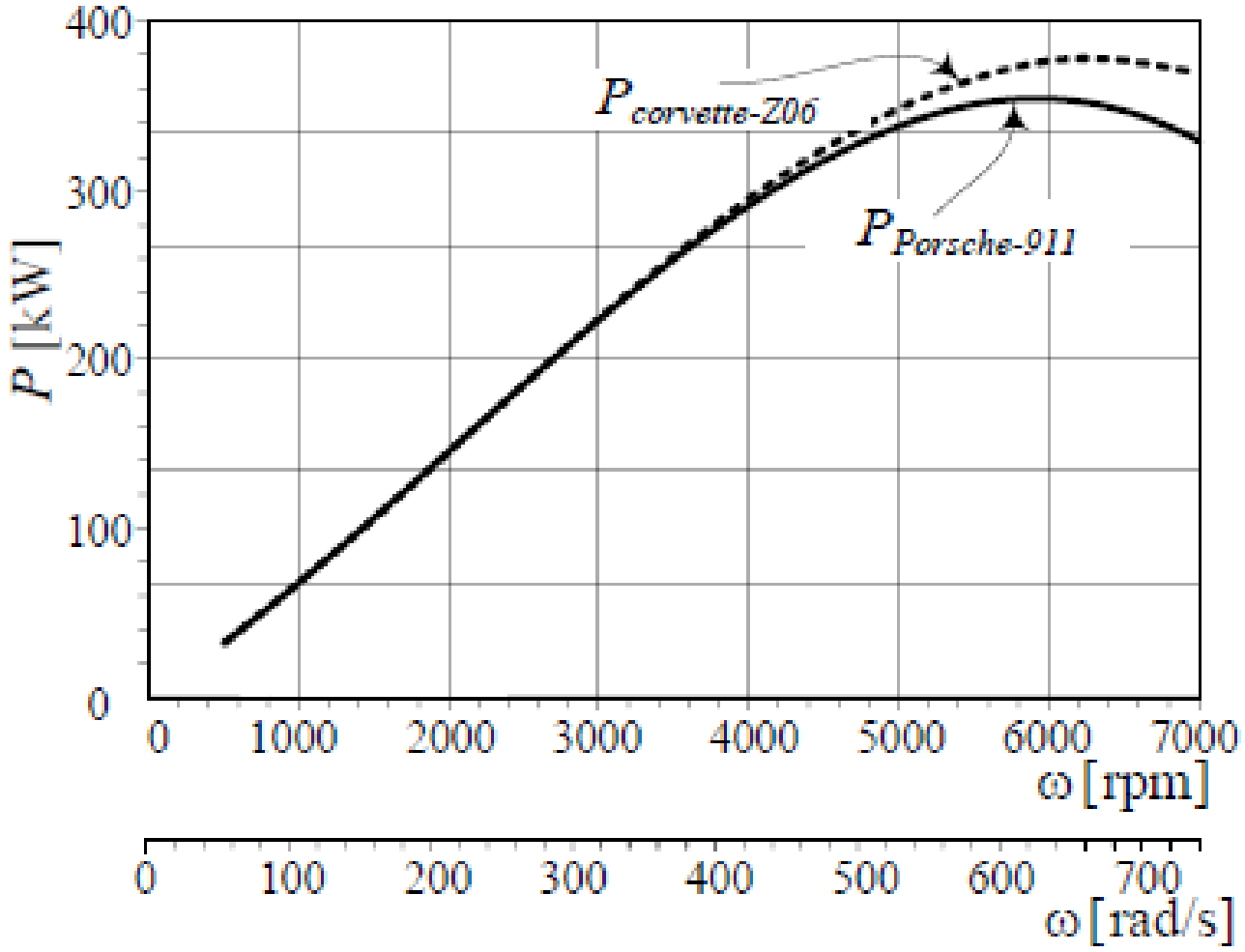


FIGURE 4.2. Power performance curves for the Porsche 911 and Corvette $Z06$.