Design of vehicle gearbox

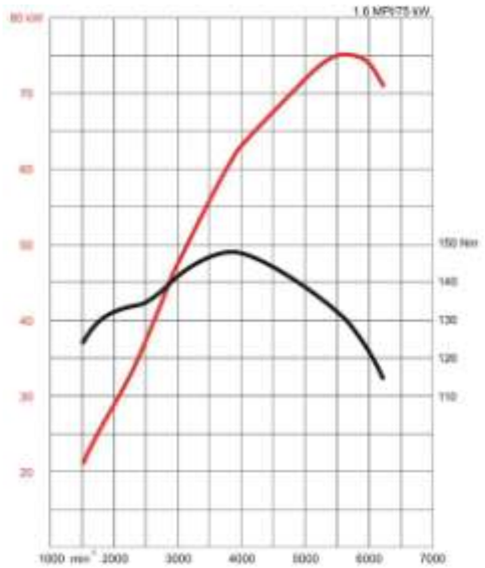
Example

Determine the gear ratios of each gear and car. Consider the number of gears z = 6, and for the maximum gear ratio, consider stage $i_{VI} = 1$.

Define:

$P = 75$ kW Maximum power
$n_{Pmax} = 5600$ rpm Engine revolutions at maximum engine power
$M_{max} = 148$ N.m Maximum torque
$n_{Mmax} = 3800$ rpm Engine revolutions at maximum engine torque
$\mu = 0{,}8$ coefficient of adhesion
$\eta_c = 0{,}9$ overall mechanical efficiency (clutch, gearbox, gearbox, bearings, ...)

When calculating the gear ratios, we consider the torque speed characteristic for the maximum fuel supply to the engine.



The maximum vehicle speed will be v_{max} = 190 km / h When calculating the minimum speed v_{min}, consider that the maximum adhesive force must be transmitted at maximum engine power.
We calculate the maximum adhesive force as

$$F_{k\max} = m \cdot g \cdot \mu = 1450 \cdot 9{,}81 \cdot 0{,}8 = 11380 \text{ [N]}$$

Then power is applied:

$$P = \frac{F_{k\max} \cdot r_d \cdot v_{\min}}{\eta_c \cdot r_v}$$

$$v_{\min} = \frac{P \cdot \eta_c \cdot r_v}{F_{k\max} \cdot r_d} = \frac{75000 \cdot 0{,}9 \cdot 0{,}285}{11380 \cdot 0{,}3} = 5{,}635\,[\text{m/s}]$$

$$v_{\min} = 5{,}635 \cdot 3{,}6 = 20{,}286\ [\text{km/h}]$$

Vehicle control range (expresses the ratio of maximum and minimum speed):

$$R = \frac{v_{\max}}{v_{\min}} = \frac{190}{20{,}286} = 9{,}366$$

Engine control range (speed ratio at maximum power to speed at maximum torque):

$$R_M = \frac{n_{P\max}}{n_{M\max}} = \frac{5600}{3800} = 1{,}474$$

Then the required control range of the gearbox (ratio of maximum and minimum gear ratio of the gearbox) will be:

$$R_i = \frac{R}{R_M} = \frac{9{,}366}{1{,}474} = 6{,}354$$

With an even distribution of gears, the following gears should apply:

$$q = \frac{i_n}{i_{n+1}}$$

Applies to the control range of the gear unit:

$$R_i = \frac{i_I}{i_z} = \frac{i_z \cdot q^{z-1}}{i_z}$$

when:

- i_I 1st gear ratio
- i_z Maximum gear ratio

It will apply to the quotient:

$$q^{z-1} = R_i$$

$$q = \sqrt[z-1]{R_i} = \sqrt[5]{6{,}354} = 1{,}447$$

furthermore, the condition must be met:

$$q \le q_{\max} = \mathrm{R_M}$$

$$1{,}447 < 1{,}474$$

If this were not the case, we would have to change the minimum or maximum speed or increase the number of gears so that the condition is met.

Vehicle propulsion systems

Part: **9**

Applies to the maximum vehicle speed:

$$\frac{\omega_{P\max} \cdot r_v}{i_{VI} \cdot i_r} = v_{\max}$$

when:

i_r Permanent transmission (gearbox transmission)

then:

$$i_r = \frac{\omega_{P\max} \cdot r_v}{i_{VI} \cdot v_{\max}} = \frac{\frac{2 \cdot \pi \cdot n_{P\max}}{60} \cdot r_v}{1 \cdot v_{\max}} = \frac{2 \cdot \pi \cdot 5600 \cdot 0{,}285}{60 \cdot 1 \cdot \frac{190}{3{,}6}} = 3{,}167$$

We can now calculate the individual gear ratios of the gearbox:

$$i_{VI} = 1$$

$$i_V = i_{VI} \cdot q = 1 \cdot 1{,}4475 = 1{,}448$$

$$i_{IV} = i_V \cdot q = I_{VI} \cdot q^2 = 1 \cdot 1{,}4475^2 = 2{,}095$$

$$i_{III} = i_{IV} \cdot q = I_{VI} \cdot q^3 = 1 \cdot 1{,}4475^3 = 3{,}033$$

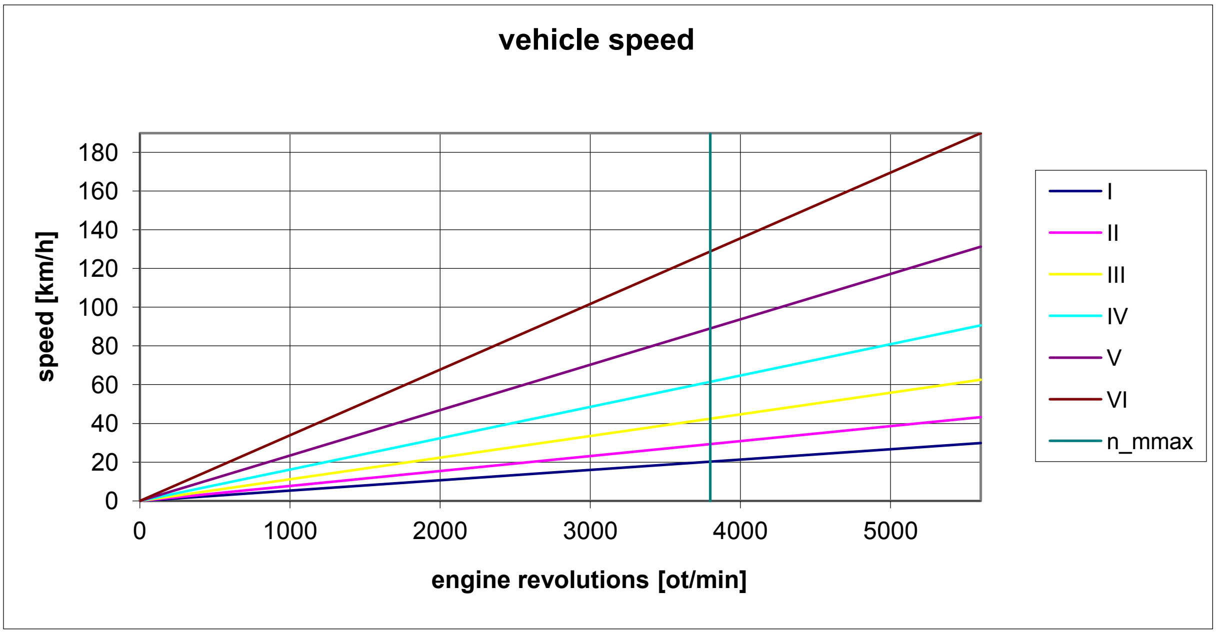
$$i_{II} = i_{III} \cdot q = I_{VI} \cdot q^4 = 1 \cdot 1{,}4475^4 = 4{,}390$$

$$i_I = i_{II} \cdot q = I_{VI} \cdot q^5 = 1 \cdot 1{,}4475^5 = 6{,}355$$

These are theoretical values. When designing the gearbox, it is necessary to select such a number of gear teeth that the actual values are as close as possible to the theoretical ones.

Graphical representation of the speed dependence on the engine speed and the engaged gear.

Saw diagram.

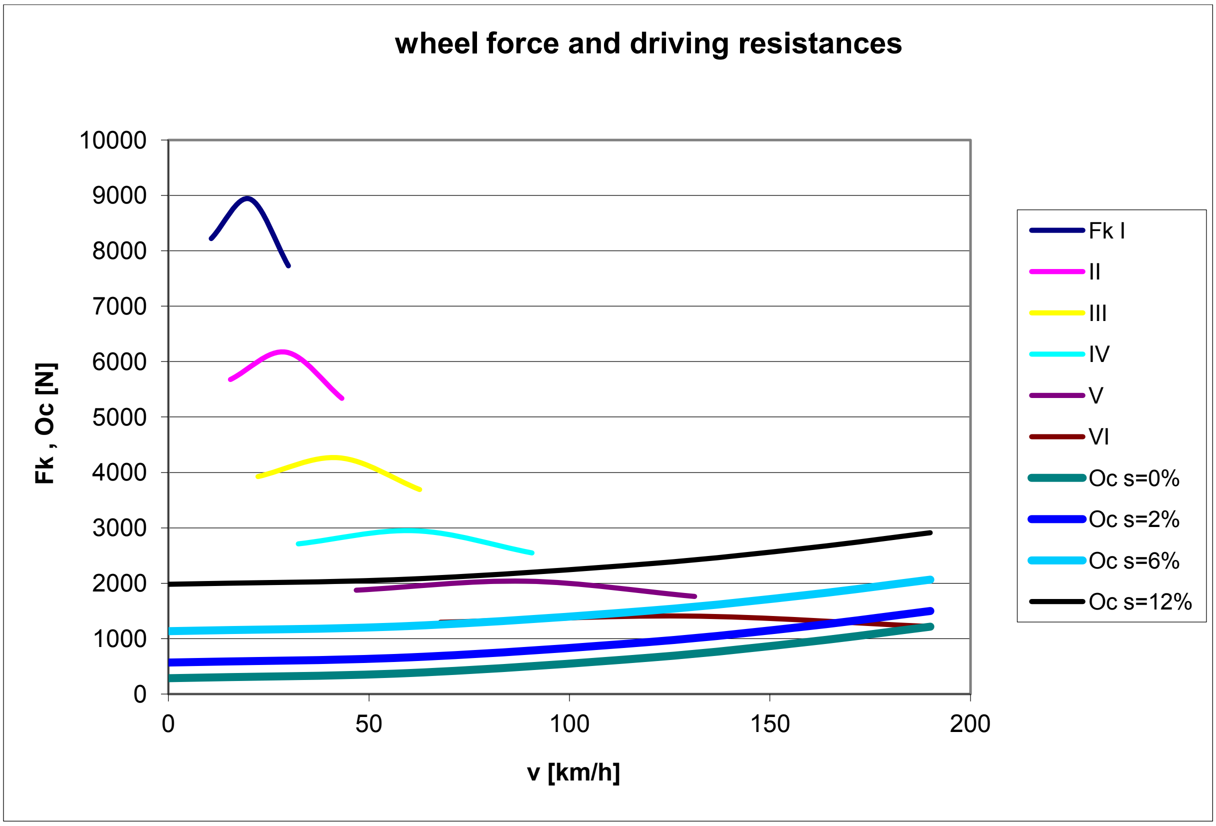


$$v = \omega_k \cdot r_v = \frac{\omega_m \cdot r_v}{i_c}$$

Graphical representation of the magnitude of the wheel force and the total running resistance at the vehicle speed and gear engaged.

We substitute the torque from the torque speed characteristic of the motor and the speed from the saw diagram. (only values for 2000, 3800 and 5600 rpm were used)

$$F_k = \frac{M_m \cdot i_p \cdot i_r \cdot \eta_c}{r_d}$$



The engine power reserve (the difference between the maximum driving force and the running resistances) can be used for acceleration or as traction at a given constant speed and incline.