Robot Requirement

$M = 21\ kg$

$v = 4\ m/s$

$a = 2\ m/s^2$

Terrain = flat surface

Environment = indoor

wheel radius $(r) = 60\ mm = 0.06$

$g = 9.81\ m/s^2$ (gravitational acceleration)

$\mu_s = 0.8$ (road coefficient of static friction)

Force necessary to reach specs.

$F = m \cdot a + m \cdot \mu_s \cdot g$

$F = 21 \cdot 2 + 21 \cdot 0.8 \cdot 9.81$

$F = 206.81\ N$

Stall Torque

$T_{stall} = r \cdot F = 0.06 \cdot 206.81 = 12.41\ N \cdot m$

Angular velocity with no load

$\omega_{no\text{-}load} = \frac{v}{r} = \frac{2}{0.06} = 33.33\ rad/s$

$RPM = \frac{v}{r} \cdot \frac{1}{2\pi} \cdot \frac{60s}{1min} = 319\ rev/min$

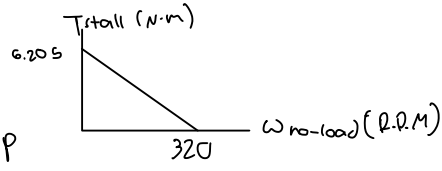
For Robotics is often recommended to use a F.S. (factor of Safety) of 2. This ensures that the motor can handle overloads or unexpected resistance.

$T_{stall}\text{-per-wheel} = 6.205\ N \cdot m$

$T_{max} = T_{stall} \cdot F.S. = 24.82\ N \cdot m$

$\omega_{max} = \omega_{noload} = 33.3\ rad/s \approx 320\ r.p.m.$

Motor Torque-Speed Curve



Motor Power

$P_m = \frac{T_{max}}{4} \cdot \omega_{max} = 206.6 = 207\ W = 0.28\ hp$

Voltage based on speed

$E_b(t) = k_b \cdot \frac{d\Phi(t)}{dt}$

$E_b(t) = k_b \cdot \omega_r$

$E_a = k_b \cdot \omega_{no\text{-}load}$

$\frac{k_t}{R_a} = \frac{T_{stall}}{E_a}$

$E_b(t)$: Back EMF (Back electromotive force)

k_b: EMF constant

ω_r: angular speed required.

The electrical constants of the motor $\frac{k_t}{R_a}$ and k_b, can be found from a dynamometer test of the motor, which would yield T_{stall} and $\omega_{no\text{-}load}$ for a given E_a.

$$e_a(t) = \frac{R_a}{K_t} T_m(t) + K_b \omega_m(t)$$

$$N = \frac{T_m}{T_F} = \frac{0.63}{6.21} = 0.101 = 0.10$$

$$N = 1:10 \text{ or } \frac{1}{10}$$

For safety reasons we will use a gear ratio of 1:12

where:
- T_F = final torque
- T_m = motor torque
- N = Gear ratio

Type of motor

Model: Maxon EC-i 40 Brushless DC Motor

- T_m = 0.63 N·m
- $\omega_{no\text{-}load}$ = 12000 RPM
- Mass ≈ 0.5 kg
- Nominal voltage = 24 V or 48 V
- Diameter: 40mm
- Length: 50mm
- η (efficiency) ~ 89 %

Reduction Gearbox

Model: GPX32 Planetary Gearhead

- N = 1:12
- ω_{max} = 500 RPM
- Mass = 0.8 kg
- Diameter: 32 mm
- Length: 43 mm
- Output shaft: 8mm
- Integrated encoder. 10mm

The motor can be purchase with the reduction gearbox, both are from the same manufacturer, allowing a better integration of the power train.