Hexacopter Motor Parameter Selection

Gazebo: `gz::sim::systems::MulticopterMotorModel`

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Overview

This note sets the constants for the Gazebo motor plugin `gz::sim::systems::MulticopterMotorModel`. We use propeller coefficients to compute the thrust constant k_f and the moment constant m_c. We then limit the maximum speed by the motor/ESC current limit (safe operation), not by the no load RPM.

1 Reference Setup and Assumptions

- Motor: SunnySky X2216 (KV1250), sensorless BLDC
- Propeller: 11×5.7; we use APC 11×5.5 MR data as a close proxy
- Battery: 4S LiPo, nominal $V_{\text{bat}} = 14.800\,\text{V}$
- Air density: $\rho = 1.225\,\text{kg}\,\text{m}^{-3}$ (sea level)
- Prop data (hover / static): $C_T \approx 0.112$, $C_P \approx 0.042$
- Diameter: $D = 0.279\,\text{m}$ (11 in)
- ESC current limit used for "safe": 30.000 A (motor spec is 28–30 A)

2 Thrust Constant k_f (`motorConstant`)

The model in the plugin is $T = k_f\,\omega^2$. From prop theory,

$$k_f = \frac{C_T\,\rho\,D^4}{4\pi^2}.$$

With the values above, this gives

$$\boxed{k_f \approx 2.11 \times 10^{-5}\ \text{N}\,(\text{rad/s})^{-2}}.$$

3 Moment Constant m_c (`momentConstant`)

The yaw (reaction) torque can be written two equivalent ways,

$$\tau = k_m\,\omega^2 = m_c\,T, \quad \text{so} \quad m_c = \frac{k_m}{k_f}.$$

Using

$$k_m = \frac{C_P\,\rho\,D^5}{8\pi^3},$$

we obtain

$$k_m \approx 3.55 \times 10^{-7}\ \mathrm{N\,m\,(rad/s)^{-2}}, \qquad \boxed{m_c = \frac{k_m}{k_f} \approx 0.0168}.$$

(As implemented in the plugin, m_c multiplies thrust; numerically it behaves like a dimensionless ratio.)

4 Safe Maximum Rotational Speed

We cap speed where the motor hits its current (torque) limit with this prop, not at no load RPM.

Motor torque constant from KV:

$$K_t = \frac{60}{2\pi\, K_V} \approx 0.00764\ \mathrm{N\,m/A}.$$

At 30.000 A,

$$\tau_{\max} \approx K_t I \approx 0.229\ \mathrm{N\,m}.$$

Since $\tau = k_m \omega^2$,

$$\omega_{\max} = \sqrt{\frac{\tau_{\max}}{k_m}} = \sqrt{\frac{0.229}{3.55 \times 10^{-7}}} \approx \boxed{8.0 \times 10^2\ \mathrm{rad/s}} \quad (\approx 7{,}600\ \mathrm{RPM}).$$

5 Hover Sanity Check (per motor)

Using $T = k_f \omega^2$ and a hover thrust of about 5.100 N (for a 3.120 kg hexacopter),

$$\omega_{\mathrm{hover}} = \sqrt{\frac{T}{k_f}} \approx \sqrt{\frac{5.1}{2.11 \times 10^{-5}}} \approx 4.9 \times 10^2\ \mathrm{rad/s}\ (\approx 4{,}700\ \mathrm{RPM}),$$

which matches the prop data well.

6 Final Parameters (for `model.sdf`)

Parameter	Value	Unit	Basis
`maxRotVelocity`	800.000	rad/s	Current limit with 11×5.5/5.7 prop
`motorConstant` (k_f)	2.110×10^{-5}	$\mathrm{N\,(rad/s)^{-2}}$	From C_T
`momentConstant` (m_c)	0.017	(ratio)	From C_P/C_T
`timeConstantUp`	0.015	s	ESC + motor response
`timeConstantDown`	0.015	s	ESC + motor response

SDF Snippet (Gazebo Plugin)

```
<plugin filename="gz-sim-multicopter-motor-model-system"
        name="gz::sim::systems::MulticopterMotorModel">
  <motorConstant>2.11e-05</motorConstant>      <!-- kf: N/(rad/s)^2 -->
  <momentConstant>0.0168</momentConstant>      <!-- mc = km/kf -->
  <timeConstantUp>0.015</timeConstantUp>
  <timeConstantDown>0.015</timeConstantDown>
  <maxRotVelocity>800.0</maxRotVelocity>       <!-- rad/s, current-limited -->
</plugin>
```

References

[1] APC Propeller, *Performance Data (11×5.5 MR)*, available at `https://www.apcprop.com/files/PER3_11x55MR.dat`.

[2] SunnySky USA, *X2216 Brushless Motors*, available at `https://sunnyskyusa.com/products/sunnysky-x2216-brushless-motors`.