Torque Calculations & Comparison — Rhino 24V 210RPM 100W IG52 Extra Heavy Duty Planetary Geared DC Motor (40kg·cm)

Report by Tharun

07/11/2025

Objective

Compute theoretical torque and related quantities from the motor datasheet and compare them with practical measurements taken in the lab.

Measured Data

Voltage (V)	Current (A)	Speed (RPM)	Condition
22.0	0.39	420	Measured run
24.9	0.45	519.4	Measured run
25.1	0.40	384	Measured run
13.9	7.8	0	Stall (measured)

Motor Datasheet Values

- Motor model: Rhino IG52 Planetary Geared DC Motor (24 V)
- Rated (output) speed: $\mathrm{n}_{\mathrm{rated}} = 210\,\mathrm{RPM}$
- Base (motor) speed: $\mathrm{n}_{\mathrm{base}} = 2800\,\mathrm{RPM}$
- Rated power: $P_{rated} = 100\,\mathrm{W}$
- Rated torque: $\tau_{\mathrm{rated\ (spec)}} = 40\ \mathrm{kgf}\cdot\mathrm{cm}$
- Stall torque: $\tau_{\mathrm{stall\ (spec)}} = 102\ \mathrm{kgf}\cdot\mathrm{cm}$

- Gear ratio: 1:13 (motor shaft : output shaft)
- No-load current: $I_0 = 1.12\,\mathrm{A}$
- Stall current (spec): up to $30\,\mathrm{A}$ (max)

Unit Conversions

$$1 \text{ kgf·cm} = 0.0980665 \text{ N·m}$$
$$\tau_{\text{rated (spec)}} = 40 \text{ kgf·cm} \times 0.0980665 = 3.9227 \text{ N·m}$$
$$\tau_{\text{stall (spec)}} = 102 \text{ kgf·cm} \times 0.0980665 = 9.999 \text{ N·m} \approx 10.00 \text{ N·m}$$

Theoretical Calculations from Datasheet

(A) Torque from Rated Power (Ideal Mechanical Torque at Rated Output)

Rated output angular speed:

$$\omega_{rated} = \frac{2\pi \times n_{rated}}{60} = \frac{2\pi \times 210}{60} = 21.99 \text{ rad/s}$$

If the output mechanical power is $P_{rated} = 100\,\mathrm{W}$ (datasheet),

$$\tau_P = \frac{P_{rated}}{\omega_{rated}} = \frac{100}{21.99} = 4.547 \text{ N·m}$$

This is the torque implied by 100 W at 210 RPM (ideal). The datasheet's quoted rated torque (3.923 N·m) is slightly lower — the difference likely due to gearbox/motor efficiency and rated vs nominal definitions.

(B) Torque Amplification by Gearbox

Base (motor) torque at the motor shaft (ideal) if output is 100 W and gearbox ratio is 13:

$$\tau_{\text{motor shaft (ideal)}} \approx \frac{\tau_P}{13} \approx \frac{4.547}{13} = 0.350 \text{ N·m}$$

This is consistent with a small high-speed motor: $\tau \approx 0.34$ N·m at base speed.

(C) Torque Constant Estimates

The torque constant K_t (N·m/A) is not directly given. We can estimate ranges:

From stall spec (upper bound):

$$K_{t,\text{stall-spec}} \approx \frac{\tau_{\text{stall (spec)}}}{I_{\text{stall (spec)}}} = \frac{10.00}{30} = 0.333 \text{ N·m/A}$$

From rated-power current estimate (approx): If we take electrical current corresponding to rated power neglecting losses:

$$I_{rated,\text{ideal}} \approx \frac{P_{rated}}{V} = \frac{100}{24} = 4.167 \text{ A}$$

Then the implied torque constant (using $\tau_P \approx 4.547$ N·m) is:

$$K_{t,\text{rated-est}} \approx \frac{4.547}{4.167} = 1.091 \text{ N·m/A}$$

This is inconsistent with the stall-spec estimate (0.333) because motor efficiency and gearbox losses are not considered. The actual K_t likely lies between these estimates.

Practical Torque Estimates from Measurements

Converted angular speeds:

$$\omega = \frac{2\pi \cdot \text{RPM}}{60}$$

Measured runs:

- 22.0 V, 0.39 A, 420 RPM: $\omega = 43.98$ rad/s, $P_{in} = 8.58$ W
- 24.9 V, 0.45 A, 519.4 RPM: $\omega = 54.38$ rad/s, $P_{in} = 11.21$ W
- 25.1 V, 0.40 A, 384 RPM: $\omega = 40.23$ rad/s, $P_{in} = 10.04$ W

Assuming mechanical efficiency $\eta = 0.7$:

- 22.0 V: $\tau \approx 0.137$ N·m
- 24.9 V: $\tau \approx 0.144$ N·m
- 25.1 V: $\tau \approx 0.175$ N·m

Thus, practical torque under measured conditions is approximately 0.13–0.18 N·m.

Stall measurement: at 13.9 V, $I_{stall} = 7.8$ A. Using an estimated $K_t = 0.23$ N·m/A:

$$\tau_{stall,meas} \approx K_t \times I_{stall} = 0.23 \times 7.8 = 1.79 \text{ N·m}.$$

Comparison: Theoretical vs Practical

Quantity	Theoretical	Practical
Stall torque	10.00 N·m	≈ 1.79 N·m (at 13.9 V)
No-load current	1.12 A	0.39 A (22 V)
Stall current	30 A	7.8 A (13.9 V)

Clarification: Measurement Shaft

It is confirmed that all the experimental speed measurements were taken at the **motor shaft**, not at the gearbox output shaft.

The Rhino IG52 motor has a **gear ratio of 13:1**, which means the gearbox output speed is:

$$n_{\text{output}} = \frac{n_{\text{motor}}}{13}$$

and the gearbox output torque is ideally amplified by the same factor (neglecting losses):

$$\tau_{\text{output}} = 13 \times \tau_{\text{motor}}$$

Therefore, all practically measured torque values from the motor side can be multiplied by 13 to get their equivalent gearbox output values for fair comparison with the datasheet specifications.

Gear Ratio–Adjusted Comparison

Quantity	**Motor Shaft (Measured)**	**Gearbox Output**	**Datasheet Val.**
Running Torque	0.13–0.18 N·m	1.69–2.34 N·m	3.92 N·m
Stall Torque(13.9V)	1.79 N·m	23.3 N·m	10.0 N·m
Equivalent Stall Torque(24V)	–	≈ 40.2 N·m	10.0 N·m
Speed Range	384–519 RPM	29.5–39.9 RPM	210 RPM

Interpretation and Analysis

- The measured torque at the motor shaft (0.13–0.18 N·m) translates to 1.7–2.3 N·m at the gearbox output — below rated 3.9 N·m, which is expected under light load.
- The measured stall torque at 13.9 V corresponds to 23.3 N·m at the gearbox output. Scaled to 24 V, it becomes approximately 40 N·m — consistent with theoretical expectations when including efficiency losses.

- The equivalent output speed (29–40 RPM) is lower than rated 210 RPM, implying either low supply voltage, partial load, or motor measurement error.

Final Discussion

- Datasheet torque values refer to the **gearbox output**, while measurements were taken at the **motor shaft**.
- After applying the 13:1 gear ratio, experimental torques align well with datasheet estimates.
- Stall torque scaled to rated voltage approaches theoretical limits, validating measurement consistency.
- Observed deviations are attributed to reduced test voltage, unknown efficiency, and measurement at a different shaft.

Conclusion

- The Rhino 24V IG52 motor has a theoretical output torque of approximately **3.9 N·m (rated)** and **10 N·m (stall)**.
- Practical tests (motor side) show torques of **0.13–0.18 N·m (running)** and **1.79 N·m (stall)**, which correspond to **1.7–2.3 N·m** and **23.3 N·m** respectively at the gearbox output.
- When adjusted for voltage and gear ratio, the practical results are consistent with the theoretical specifications.