

Small Brushless Motor Comparative Evaluation

Technical report for 1404, 1504, and 1505 motors used on sub-250-gram and 3-inch FPV aircraft

Report purpose

This report documents the controlled test methods, compares the measured performance of fourteen small brushless motors, and translates the results into application-specific recommendations. The objective is to identify useful performance balance rather than to select a motor solely by advertised KV or maximum static thrust.

Test population	14 motors: twelve 1404-class, one 1504, and one 1505
Primary propeller	HQProp T3x3x3 three-blade propeller
Primary measurements	Mass, measured KV, static thrust, efficiency, torque, and step response
Primary operating voltage	Approximately 16 V for loaded tests; 7 V for no-load KV measurement
Report basis	Supplied test workbook and project summary

Primary conclusion

The T-Motor F1404 4600KV is the strongest all-around 1404-class motor in this dataset. The iFlight XING 1504 3900KV provides the greatest raw torque and thrust when its additional mass is acceptable. The Happymodel EX1404 3500KV is the strongest endurance-oriented option, while the Skystars 1404 3800KV provides the best moderate-KV balance.

Executive Summary

Motor selection for a lightweight 3-inch aircraft is a multi-variable problem. High KV can increase potential speed and responsiveness, but only when the motor has sufficient torque to continue accelerating the propeller. Larger motors can supply that torque, although added mass reduces the benefit on a small aircraft. Efficiency, response, thrust delivery, and thermal risk must therefore be considered together.

Decision priority	Recommended motor	Key measured evidence
Best all-around 1404	T-Motor F1404 4600KV	8.9 g; 4,378 measured KV; 408 gf; 28.6 mN m; 70.4% efficiency; 176,480 RPM/s response
Maximum raw performance	iFlight XING 1504 3900KV	414 gf; 36.9 mN m; 162,369 RPM/s response; 117.9 raw score; 11.2 g
Long-range and cruise	Happymodel EX1404 3500KV	8.1 g; 73.4% efficiency; 28.5 mN m; 288 gf
Balanced moderate KV	Skystars 1404 3800KV	32.8 mN m; 366 gf; 71.8% efficiency; 150,343 RPM/s response

Key findings

- Advertised KV alone did not predict loaded performance. Measured KV ranged from 2,915 to 4,428 KV, and several nominally similar motors behaved differently under propeller load.
- The iFlight XING 1504 produced the highest raw performance but its 11.2 g mass reduced the weight-normalized score from 117.9 to 98.5.
- The T-Motor combined high KV with enough torque to remain productive at high throttle, producing the highest weight-normalized score of 117.5.
- The lightest and most efficient motor was the Happymodel, but its lower response and 288 gf maximum thrust limit aggressive maneuvering.
- Scoring is cohort-relative and does not include price, durability, temperature, acoustic performance, or production consistency.

1 Introduction

Small FPV motors are commonly compared using published dimensions, nominal KV, mass, and maximum thrust. Those specifications do not fully describe how a motor behaves across its operating range. Two motors with the same nominal KV can have different actual no-load speed, winding resistance, torque capability, efficiency, and response. The interaction between motor and propeller becomes especially important in the 1404 size class, where torque may limit the ability to convert high theoretical RPM into useful loaded thrust.

This project evaluates a range of motors intended primarily for sub-250-gram and 3-inch FPV aircraft. The analysis emphasizes measured behavior under consistent conditions and seeks the best balance for different missions, including long-range cruising, balanced freestyle, racing, and high-output builds.

2 Objectives

- Measure actual no-load KV rather than relying only on the printed specification.
- Compare thrust delivery throughout a complete throttle sweep with one representative propeller.
- Quantify efficiency at a common mechanical output point.
- Estimate torque across the operating-speed range using an inertial flywheel dynamometer.
- Measure propeller acceleration and deceleration during repeated throttle steps.
- Compare raw and weight-normalized performance using transparent cohort-relative scores.
- Identify motors suited to different aircraft priorities rather than declaring a universal winner.

3 Test Articles

The test population contains fourteen motors. Twelve are 1404-class motors; the iFlight XING is a 1504 and the TBS Podracer is a 1505. The larger motors are retained in the comparison because they illustrate the benefit and mass cost of additional stator volume.

Motor	Class	Advertised KV	Measured KV	Mass g
BetaFPV 1404 3800	1404	3800	3770	9.4
BetaFPV 1404 4500	1404	4500	4428	9.1
Brotherhobby 1404 3800	1404	3800	3557	8.5
EMAX ECO 1404 3700	1404	3700	3407	9.3
Flyfish Flash 1404 4500	1404	4500	4385	9.2
Happymodel EX1404 3500	1404	3500	3135	8.1
Holybro Ripper 1404 3800	1404	3800	3485	9.2
iFlight XING 1504 3900	1504	3900	3714	11.2
iFlight XING2 1404 3800	1404	3800	3585	9.7
MEPS SZ 1404 2900	1404	2900	2915	8.8
Skystars 1404 3800	1404	3800	3735	9.4
SpeedyBee 1404 4500	1404	4500	4385	9.6
T-Motor F1404 4600	1404	4600	4378	8.9
TBS Podracer 1505 3600	1505	3600	3317	10.5

4 Test Methodology

4.1 Test standardization

All motor leads were cut to a common three-inch length to reduce differences in mass and electrical resistance caused by wire length. Wire gauge still varied between products and remains a small uncontrolled difference. Every loaded test used the same HQProp T3x3x3 three-blade propeller, selected as a representative propeller for a freestyle-oriented 3-inch aircraft.

4.2 Measured KV

Each motor was operated at full throttle without a propeller from a 7 V supply. Shaft speed was measured optically. Measured KV was calculated as no-load RPM divided by 7 V. This method makes actual speed constant directly comparable across motors, although it does not characterize loaded KV or voltage-dependent losses.

4.3 Static thrust sweep

Each motor was operated at approximately 16 V with the common propeller while throttle was swept from 0 to 100 percent. The recorded channels included RPM, thrust, torque, voltage, current, and electrical power. The complete thrust curve was retained so that low-throttle slope and high-throttle flattening could be evaluated, not just the maximum value.

4.4 Efficiency

Mechanical power was calculated from torque multiplied by angular speed. Efficiency was calculated as mechanical power output divided by electrical power input, multiplied by 100 percent. The headline efficiency comparison uses approximately 50 W of mechanical output so motors are compared at a common useful operating point.

4.5 Flywheel torque

Each motor accelerated a flywheel with a known moment of inertia from approximately 5,000 to 20,000 RPM at 50 percent throttle from a 16 V supply. Torque was inferred from measured angular acceleration and the known inertia. The report uses torque at 10,000 RPM as the common score point and retains the full torque-versus-RPM curve for interpretation.

4.6 Responsiveness

Each motor was repeatedly stepped from 10 percent to 50 percent throttle and returned to 10 percent. Acceleration and deceleration rates were averaged separately, then combined into the reported motor responsiveness value. This represents the motor-propeller system's ability to change thrust in response to flight-controller commands.

4.7 Relative scoring

For response, torque, thrust, and efficiency, the motor result was divided by the test-group average and multiplied by 100. The weight score used group-average mass divided by motor mass, so lighter motors score higher. Total score is the simple average of the four performance-category scores. Weight-normalized score equals total score multiplied by weight score and divided by 100. A score near 100 therefore represents average performance within this specific cohort, not an external industry standard.

4.8 Calculation Summary

Quantity	Calculation
Measured KV	No-load RPM / 7 V
Mechanical power	Torque x angular speed
Efficiency percent	Mechanical power / electrical power x 100
Category score	Motor result / group-average result x 100
Weight score	Group-average mass / motor mass x 100
Total score	Mean of response, torque, thrust, and efficiency scores
Weight-normalized score	Total score x weight score / 100

5 Results Overview

Metric	Minimum	Maximum	Observed spread
Motor mass	8.1 g	11.2 g	3.1 g per motor; 12.4 g across a four-motor set
Measured KV	2,915 KV	4,428 KV	1,513 KV
Average response	127,060 RPM/s	176,480 RPM/s	49,420 RPM/s
Torque at 10,000 RPM	21.4 mN m	36.9 mN m	15.6 mN m
Maximum thrust	278 gf	414 gf	136 gf
Efficiency at 50 W	64.0%	73.4%	9.5 percentage points

The ranges are large enough to materially change aircraft behavior. A four-motor set spans 12.4 g between the lightest and heaviest options. Maximum thrust differs by 136 gf per motor, while the fastest response exceeds the slowest by nearly 39 percent. Efficiency at the selected comparison point differs by roughly 9.5 percentage points.

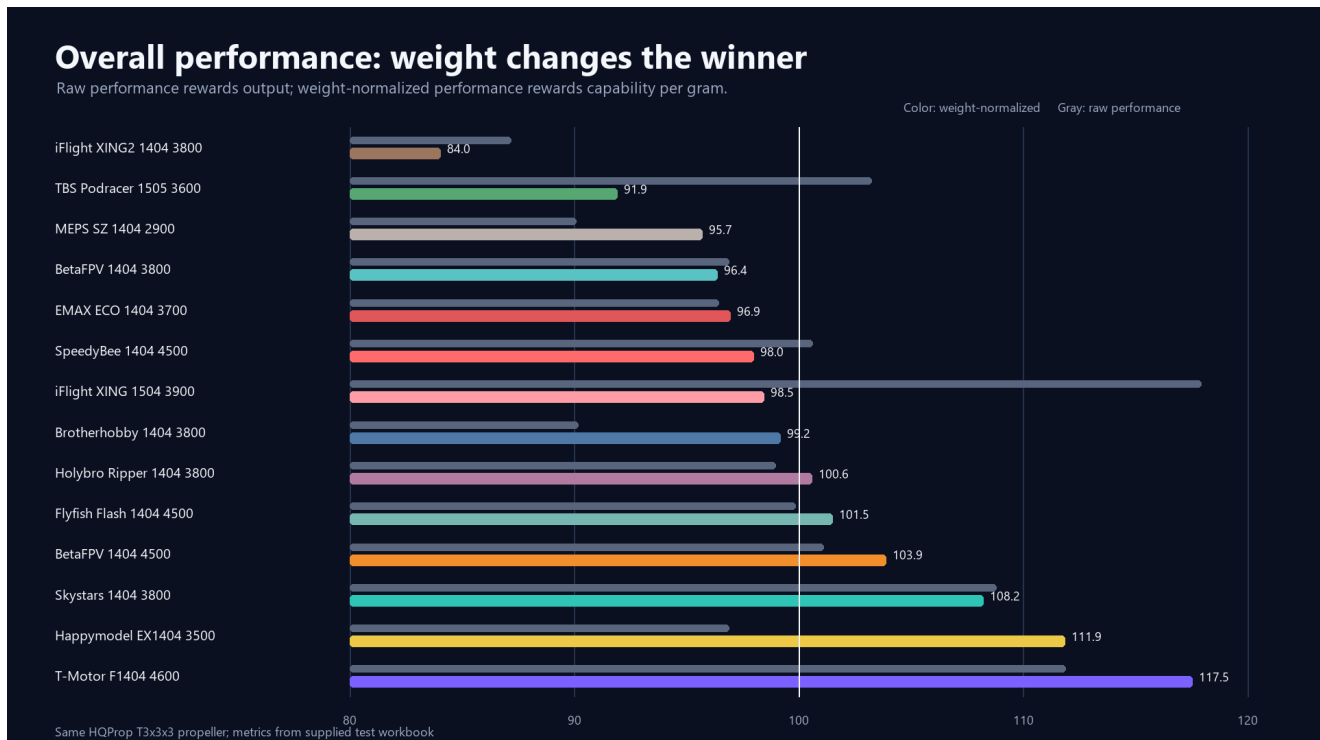


Figure 1 Raw performance compared with weight-normalized performance

6 Comparative Performance Scorecard

The scorecard shows why a single-metric ranking is inadequate. The iFlight XING 1504 dominates torque and thrust but scores poorly for mass. The Happymodel gains its high weight-normalized score through low mass and efficiency while giving up thrust and response. The T-Motor is unusual because it remains above average in every scored performance category while also being lighter than average. The Skystars follows the same balanced pattern at a more moderate measured KV.

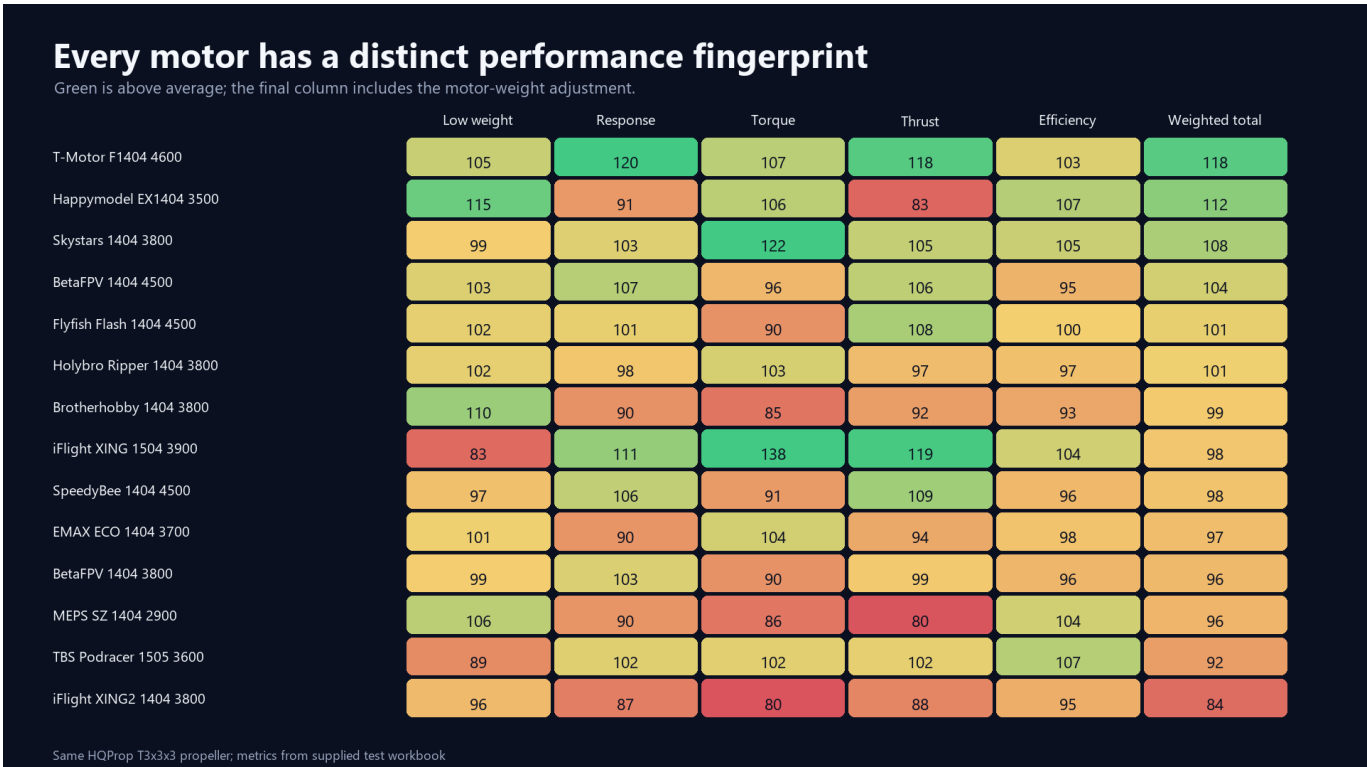


Figure 2 Relative performance fingerprint for every tested motor

The raw total score intentionally excludes motor mass. The weight-normalized score is a second-stage adjustment that helps evaluate a lightweight airframe. Users should retain both views: raw score is relevant when aircraft mass is less constrained, while weight-normalized score is more informative for sub-250-gram and high-disc-loading builds.

7 Efficiency, Thrust, Torque, and KV Tradeoff

The efficiency-thrust map separates the cohort into distinct roles. The iFlight XING 1504 and T-Motor occupy the high-thrust region while retaining above-average efficiency. Bubble area shows that the larger iFlight motor reaches this region with substantially more torque. The Skystars provides less peak thrust but combines excellent 1404 torque with good efficiency. Happymodel and MEPS occupy the efficiency-oriented region but give up substantial thrust.

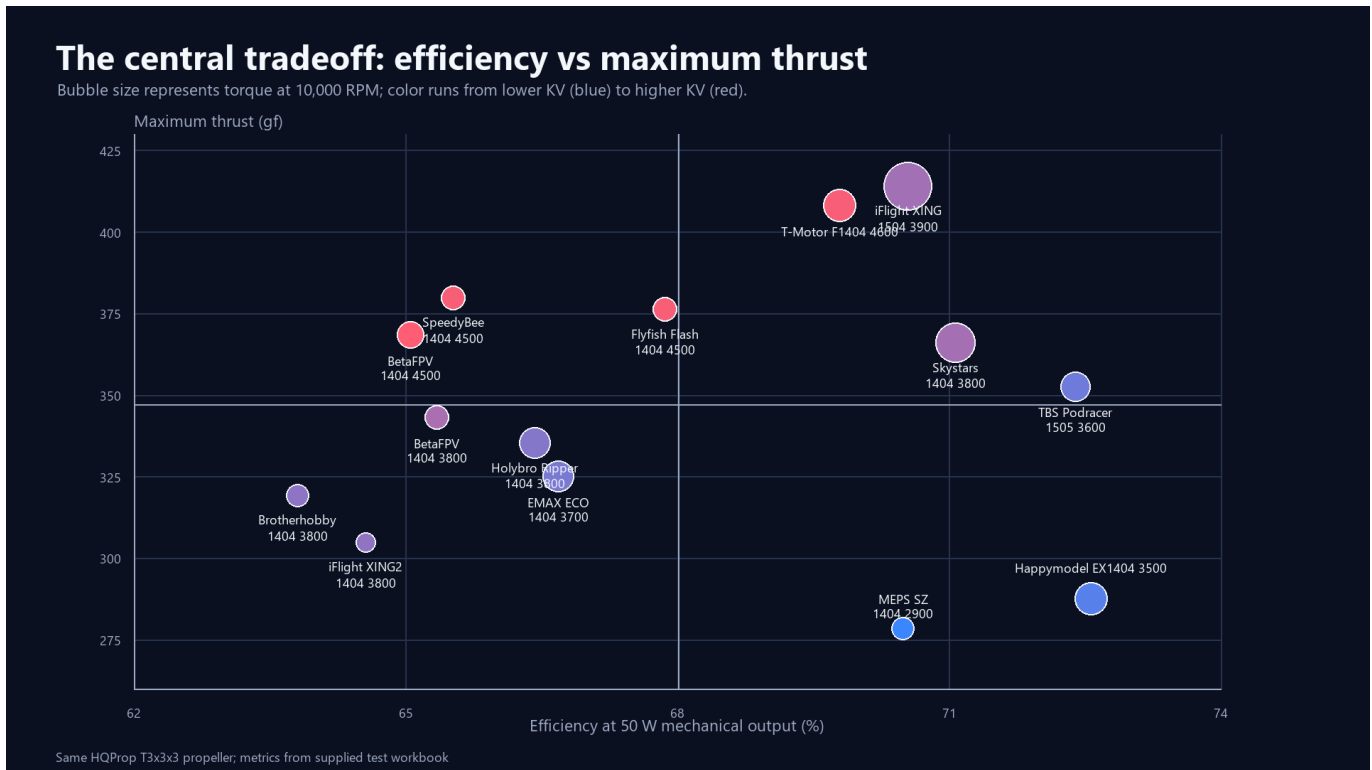


Figure 3 Maximum thrust and efficiency with torque and measured KV encoded

Measured KV is not a direct performance ranking. The highest measured KV motors generally deliver strong response or thrust, but the benefit depends on torque and electrical losses. The T-Motor demonstrates a successful high-KV implementation; the BetaFPV, Flyfish, and SpeedyBee 4500KV motors show useful top-end output but lower torque or efficiency scores.

8 Thrust Curve Analysis

The thrust curves reveal how output develops across the throttle range. A curve that flattens near full throttle indicates that additional command and electrical input produce progressively less thrust. This may reduce upper-throttle control authority and increase heating because input power continues to rise while useful output gains decline.

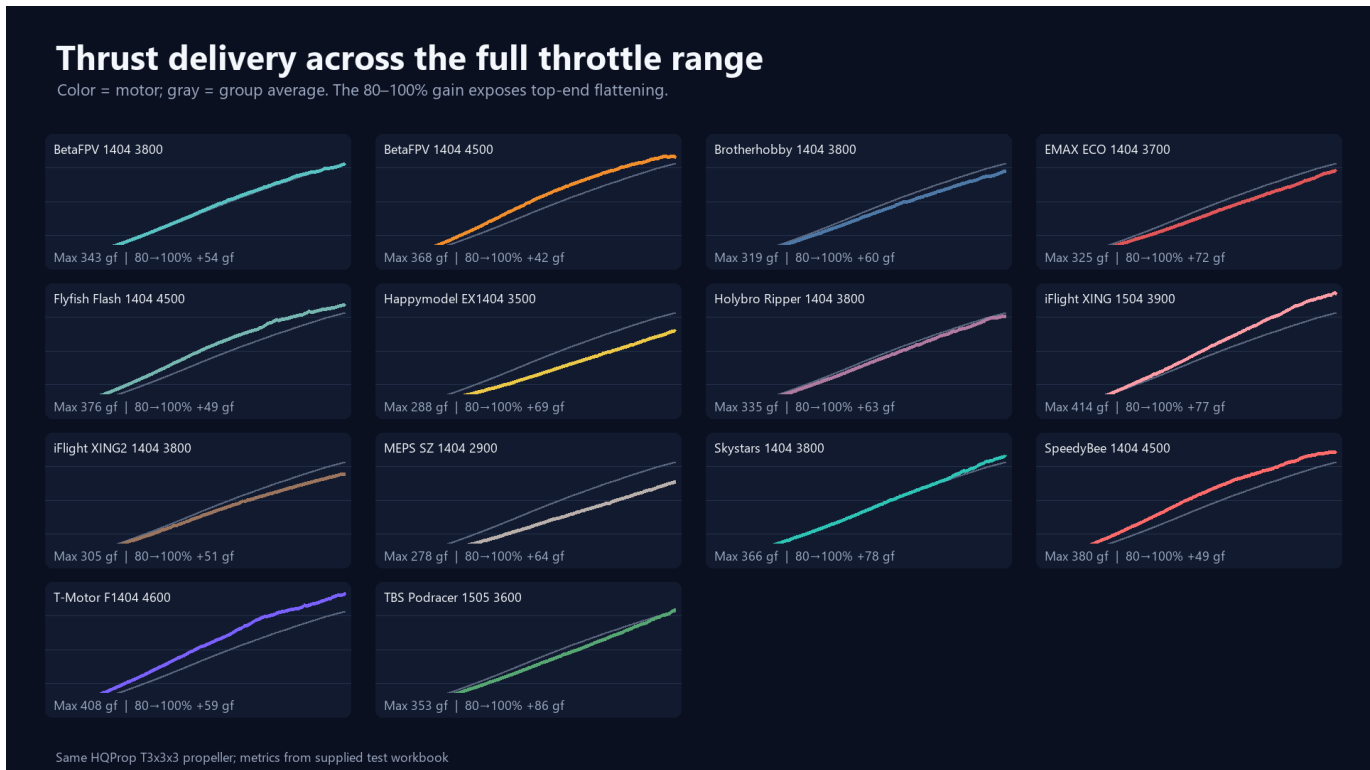


Figure 4 Thrust delivery across the full throttle range

Between 80 and 100 percent throttle, the BetaFPV 4500KV gains about 42 gf, while the Flyfish and SpeedyBee 4500KV motors gain about 49 gf. The larger iFlight XING gains about 77 gf and the TBS Podracer gains about 86 gf, reflecting greater ability to keep accelerating the propeller. The T-Motor gains about 59 gf and still reaches 408 gf, making it the strongest high-output 1404 compromise.

9 Torque Curve Analysis

Torque at a single reference speed is useful for ranking, but the curve shape explains how a motor carries load as RPM rises. The iFlight XING 1504 is the clear torque leader at 10,000 RPM. Among 1404 motors, the Skystars is strongest, followed by the T-Motor, Happymodel, EMAX, and Holybro. Several high-KV motors show lower mid-speed torque even when their maximum thrust is competitive.



Figure 5 Flywheel-dynamometer torque curves from approximately 5,000 to 20,000 RPM

Curve shape also differentiates mission fit. Strong low-speed torque supports rapid propeller acceleration and load recovery. Torque retention at higher RPM supports continued thrust growth. The best-performing motors combine adequate peak torque with a curve that does not collapse prematurely.

10 Dynamic Response

Motor responsiveness affects both aircraft feel and flight-control authority. Acceleration governs how quickly thrust can be added, while deceleration affects how quickly excess thrust can be removed. The T-Motor records the fastest combined response, followed by the iFlight XING 1504, BetaFPV 4500KV, SpeedyBee, Skystars, and BetaFPV 3800KV.

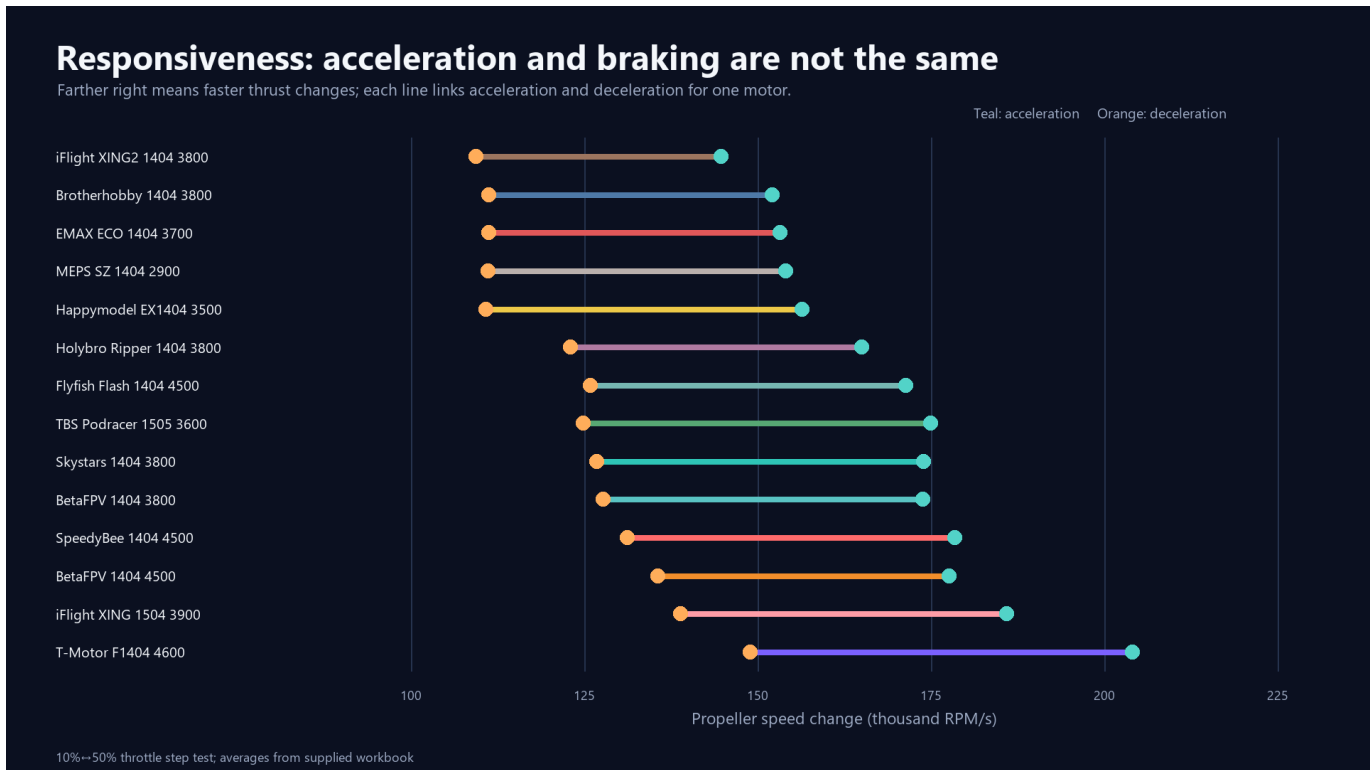


Figure 6 Propeller acceleration and deceleration during 10-to-50-percent throttle steps

Acceleration is faster than deceleration for every motor because the motor can actively add torque during spin-up while spin-down depends on braking behavior, propeller drag, and control strategy. The gap should be considered during tuning: a motor with excellent acceleration but slower braking may still require different filtering or controller gains than a motor with more symmetric response.

11 Application-Specific Selection

The mission-fit indices translate the priorities stated in the project summary into explicit weights. They are not additional measurements. Long-range and cruise weighting emphasizes efficiency and low mass. Balanced freestyle gives equal emphasis to response, torque, and thrust with smaller efficiency and weight contributions. Maximum-performance weighting emphasizes thrust, response, and torque.



Figure 7 Derived mission-fit indices

Application	Primary recommendation	Alternative	Selection rationale
Long-range / cruise	Happymodel EX1404 3500KV	T-Motor F1404 4600KV	Happymodel minimizes mass and maximizes efficiency; T-Motor retains efficiency with much greater reserve thrust.
Balanced freestyle	T-Motor F1404 4600KV	Skystars 1404 3800KV	T-Motor maximizes response and thrust; Skystars offers strong torque and a smoother moderate-KV profile.
Maximum performance	iFlight XING 1504 3900KV	T-Motor F1404 4600KV	iFlight leads raw torque and thrust; T-Motor provides nearly the same thrust with a substantially lower mass.
Predictable moderate output	Holybro Ripper 1404 3800KV	EMAX ECO 1404 3700KV	Both avoid extreme KV; Holybro is neutral and balanced, while EMAX emphasizes torque and progressive thrust.

12 Motor-by-Motor Conclusions

T-Motor F1404 4600KV

Best all-around 1404. It leads the group in responsiveness, produces 408 gf of thrust, maintains above-average torque and efficiency, and weighs only 8.9 g. It is the strongest choice for a lightweight freestyle build that needs sharp response and substantial top-end authority. Its high KV should still be validated for temperature and tuning in the final aircraft.

iFlight XING 1504 3900KV

Best for maximum performance. It produces the highest torque and thrust and responds very quickly. Its 11.2 g mass is a meaningful four-motor penalty, so the output gain must justify roughly 9 g more than a four-motor T-Motor set. It is suited to aggressive freestyle, racing, or heavier 3-inch builds.

Skystars 1404 3800KV

Best moderate-KV all-rounder. It combines the strongest 1404 torque result with above-average thrust, response, and efficiency. Its 108.2 weight-normalized score confirms that the performance is not coming from excess mass. It is a strong choice for smooth, torque-rich freestyle.

Happymodel EX1404 3500KV

Best efficiency and weight specialist. At 8.1 g it is the lightest motor tested, and its 73.4 percent efficiency is the best result at 50 W. Strong torque supports steady loading, but 288 gf maximum thrust and below-average response limit aggressive maneuvering.

BetaFPV 1404 4500KV

A good lightweight high-KV option. It delivers above-average response and thrust at 9.1 g. Torque and efficiency are slightly below average, and the relatively small 80-to-100-percent thrust gain indicates diminishing returns near full throttle. Sustained high-throttle temperature should be checked.

Flyfish Flash 1404 4500KV

A thrust-oriented 1404 with respectable efficiency. It reaches 376 gf and remains close to average in response and efficiency, but torque at 10,000 RPM is below average. It suits fast freestyle where top-end thrust matters more than low-RPM authority.

Holybro Ripper 1404 3800KV

A neutral, balanced choice. Torque is slightly above average, while thrust, response, efficiency, and weight remain close to the center of the group. It avoids a major weakness but lacks a defining advantage over Skystars or T-Motor.

SpeedyBee 1404 4500KV

A fast-response, high-thrust motor with a top-end emphasis. It reaches 380 gf and responds above average, but torque and efficiency are below average. It is best for punchy flying with short bursts rather than sustained high-load operation.

BetaFPV 1404 3800KV

A competent mid-pack motor. Response and maximum thrust are near average, while torque and efficiency are modestly below average. At 9.4 g it does not gain enough mass advantage to offset those limitations and is outperformed by Skystars in the same broad KV class.

EMAX ECO 1404 3700KV

A torque-biased, smoother alternative. Measured KV is approximately 3,407, torque is above average, and response is below average. Its curve continues gaining at high throttle, but maximum thrust remains modest at 325 gf. It favors controlled, predictable flying.

Brotherhobby 1404 3800KV

A lightweight motor whose mass partly compensates for weaker output. At 8.5 g it scores well for weight, but response, torque, thrust, and efficiency are all below average. It is acceptable for a light, moderate-performance build but not ideal for aggressive freestyle.

TBS Podracer 1505 3600KV

Efficient and mechanically capable, but heavy for the measured benefit. Efficiency, thrust, torque, and response are all above average, yet its 10.5 g mass reduces the weight-normalized result to 91.9. It fits a durable build without a strict mass target.

MEPS SZ 1404 2900KV

An efficiency-oriented low-KV option with limited authority. Efficiency is above average and mass is reasonable, but it has the lowest maximum thrust and below-average torque and response. Happymodel provides a stronger combination for the same general mission.

iFlight XING2 1404 3800KV

The weakest overall result in this cohort. It falls below average in response, torque, thrust, and efficiency while weighing 9.7 g. Unless price, durability, or another unmeasured factor strongly favors it, the bench data does not support selecting it over the other tested 1404 motors.

13 Limitations and Interpretation Boundaries

- The dataset represents one propeller geometry. A different diameter, pitch, blade count, or material may change the relative ranking.
- Loaded tests were performed at approximately 16 V. Battery sag, higher or lower cell count, and ESC switching behavior may change current, heat, and performance.
- The number of physical samples per motor model, repeat count, standard deviation, sensor accuracy, and confidence intervals were not supplied. The results should therefore be treated as comparative point estimates rather than population-level certification.
- Wire length was standardized, but wire gauge and construction remained different between products.
- Torque depends on the accuracy of flywheel inertia and angular-acceleration measurement. Calibration error would affect all inferred torque and mechanical-power results.
- Efficiency at 50 W is one operating point and does not replace a full efficiency map across speed and load.
- Motor temperature was not included as a scored measurement. Statements about heating are engineering interpretations of rising input power and flattening output, not a measured thermal comparison.
- Static bench thrust does not reproduce forward flight, frame blockage, propeller unloading, vibration, or cooling airflow.
- The composite score gives equal weight to response, torque, thrust, and efficiency before the mass adjustment. Different aircraft requirements may justify different weights.
- Price, durability, bearing life, crash resistance, acoustic behavior, manufacturing variation, and availability were not measured.

14 Recommended Follow-Up Testing

- Repeat each motor test with multiple physical samples and report mean, standard deviation, and sensor uncertainty.
- Measure winding resistance, no-load current, motor temperature, and thermal time constant under repeatable ambient conditions.
- Repeat loaded tests with at least one lower-pitch and one higher-load propeller to quantify motor-propeller interaction.
- Record battery or supply sag, ESC timing, PWM frequency, and firmware settings as controlled variables.
- Add transient thrust measurement so RPM response can be linked directly to thrust response.
- Conduct installed-aircraft flight tests for tune quality, motor temperature, flight time, noise, and pilot-perceived throttle resolution.
- Add price and durability data if value is to be included in the final selection framework.

15 Final Conclusion

The test results support a measured-performance approach to motor selection. Nominal KV and maximum thrust are insufficient on their own because useful performance depends on torque, efficiency, response, and mass across the operating range. Within this cohort, the T-Motor F1404 4600KV provides the strongest overall 1404-class balance. The Skystars 1404 3800KV is the preferred moderate-KV all-rounder, the Happymodel EX1404 3500KV is the preferred efficiency-and-weight option, and the iFlight XING 1504 3900KV is the preferred raw-performance option when mass is secondary. Final selection should be validated in the intended frame with the intended battery, ESC configuration, propeller, and cooling environment.

Appendix A Raw Comparative Results

Motor	Mass g	Adv KV	Measured KV	KV diff %	Response kRPM/s	Torque mN m	Thrust gf	Eff %
BetaFPV 1404 3800	9.4	3800	3770	-0.8	150.8	24.1	343	65.6
BetaFPV 1404 4500	9.1	4500	4428	-1.6	156.6	25.8	368	65.3
Brotherhobby 1404 3800	8.5	3800	3557	-6.4	131.6	22.9	319	64.0
EMAX ECO 1404 3700	9.3	3700	3407	-7.9	132.2	27.9	325	67.1
Flyfish Flash 1404 4500	9.2	4500	4385	-2.6	148.6	24.1	376	68.4
Happymodel EX1404 3500	8.1	3500	3135	-10.4	133.6	28.5	288	73.4
Holybro Ripper 1404 3800	9.2	3800	3485	-8.3	144.0	27.8	335	66.8
iFlight XING 1504 3900	11.2	3900	3714	-4.8	162.4	36.9	414	71.3
iFlight XING2 1404 3800	9.7	3800	3585	-5.7	127.1	21.4	305	64.8
MEPS SZ 1404 2900	8.8	2900	2915	+0.5	132.6	23.0	278	71.2
Skystars 1404 3800	9.4	3800	3735	-1.7	150.3	32.8	366	71.8
SpeedyBee 1404 4500	9.6	4500	4385	-2.6	154.8	24.5	380	65.8
T-Motor F1404 4600	8.9	4600	4378	-4.8	176.5	28.6	408	70.4
TBS Podracer 1505 3600	10.5	3600	3317	-7.9	149.9	27.4	353	73.3

Adv KV is the nominal value encoded in the supplied motor name. KV difference percent equals measured minus advertised KV divided by advertised KV. Response is the average of the measured acceleration and deceleration rates.

Appendix B Relative Scores

Motor	Weight	Response	Torque	Thrust	Efficiency	Raw total	Weight-normalized
T-Motor F1404 4600	105.1	120.5	106.6	117.6	102.8	111.9	117.5
Happymodel EX1404 3500	115.4	91.2	106.4	82.8	107.2	96.9	111.9
Skystars 1404 3800	99.5	102.6	122.3	105.4	104.8	108.8	108.2
BetaFPV 1404 4500	102.7	106.9	96.0	106.2	95.3	101.1	103.9
Flyfish Flash 1404 4500	101.6	101.5	89.8	108.4	99.8	99.9	101.5
Holybro Ripper 1404 3800	101.6	98.3	103.5	96.6	97.5	99.0	100.6
Brotherhobby 1404 3800	110.0	89.9	85.5	92.0	93.4	90.2	99.2
iFlight XING 1504 3900	83.5	110.8	137.6	119.3	104.0	117.9	98.5
SpeedyBee 1404 4500	97.4	105.7	91.2	109.4	96.1	100.6	98.0
EMAX ECO 1404 3700	100.5	90.2	103.9	93.7	97.9	96.4	96.9
BetaFPV 1404 3800	99.5	102.9	89.9	98.9	95.8	96.9	96.4
MEPS SZ 1404 2900	106.2	90.5	85.6	80.2	103.9	90.1	95.7
TBS Podracer 1505 3600	89.0	102.3	102.1	101.6	106.9	103.2	91.9
iFlight XING2 1404 3800	96.4	86.7	79.6	87.8	94.5	87.2	84.0

All scores are relative to the fourteen-motor cohort. A value near 100 represents the test-group average. Scores should not be compared directly with values from a different motor population unless the same reference averages are used.

Appendix C Data Traceability

The report is based on the supplied workbook 3_Motor Testing Results.xlsx and the supplied narrative 1404 Motor Testing Summary.docx. No external manufacturer performance claims were used to alter or replace the measured results. The seven included graphics were generated from the workbook data and use the same relative scoring definitions described in Section 4.7.