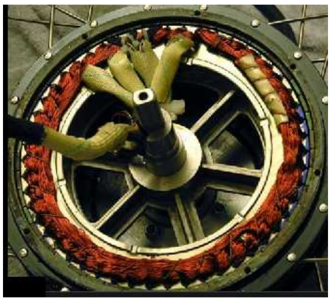
DAQs to be used:

- Inertial tests: **SP1** is useful for most cases when testing an e-bike as the power uses to be low (normally below 5 KW)

- Braked tests: **SP1+, SP5 and SP6** can control the brake and implement several test modes like ramp, steady rpm, and inverted braked test.

E-bikes

- **Hub motors** (motor in the wheel): there are two types: direct drive and geared:
  - **Direct Drive:** ratio is only the **tire_to_roller ratio** = roller diameter / tire diameter as the motor speed = wheel speed, for instance for a 26" wheel on a 320 mm roller ratio is about 0.5 (320 / 660 = 0.484)



  - **Geared motors:** as the motor has a planetary gearbox inside, the total ratio = **gearbox ratio * tire_to_roller** ratio (see above)

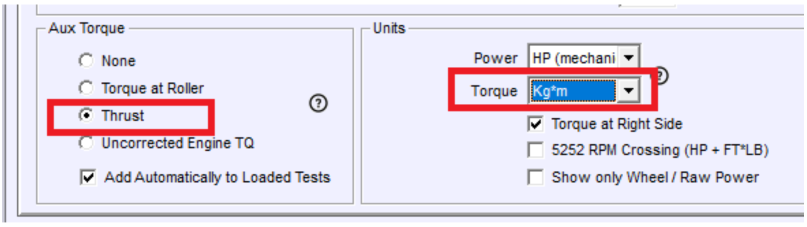
- **Mid-drive motors** (motor in the pedals) ratio changes with the bike gearing, so it normally has to be calculated manually with respect the pedals RPM. If there is access to the **controller telemetry** it could be acquired by the software.

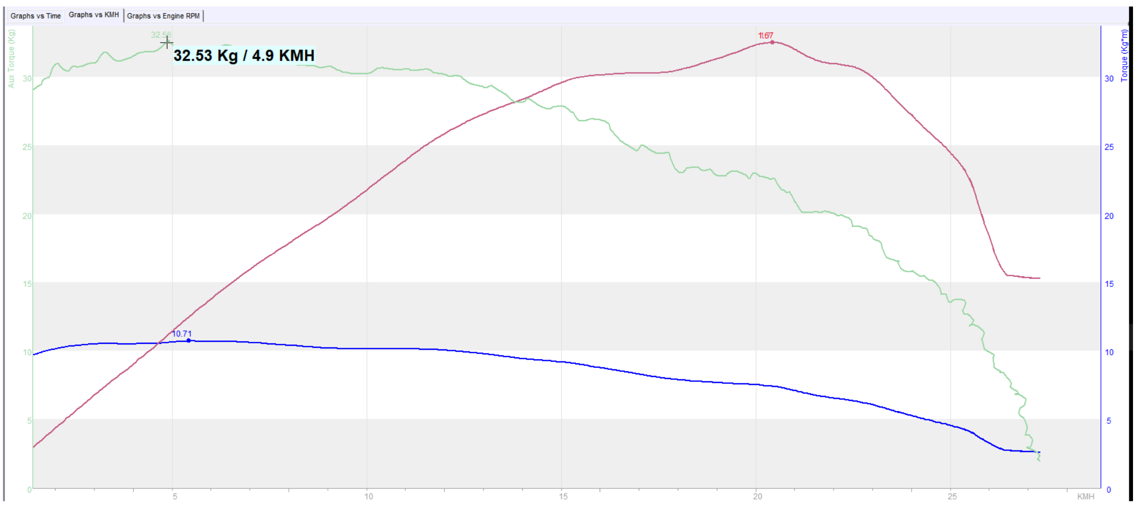
<u>Telemetry / data acquisition</u>

- Sportdyno Software can acquire:
    - **CAN** (broadcast),
    - **CANopen** (query-reply protocol),
    - **VESC** Controller telemetry (CAN or serial),
    - **Cyclone-TW** protocol (used in their bluetooth controller),
    - in general any **serial** (documented) protocol could be added

<u>Data to be measured and calculated:</u>

- For **single gear vehicles** (normally with hub motors) an important measurement is the linear **THRUST** (in Kg or N) as it determines the **climbing capacity** of the vehicle, while for mid-drives as they normally use the gears it is expected that the user can choose low or high gears depending on the slope. Climbing capacity percentage is the thrust force / vehicle + drive weight (aprox)

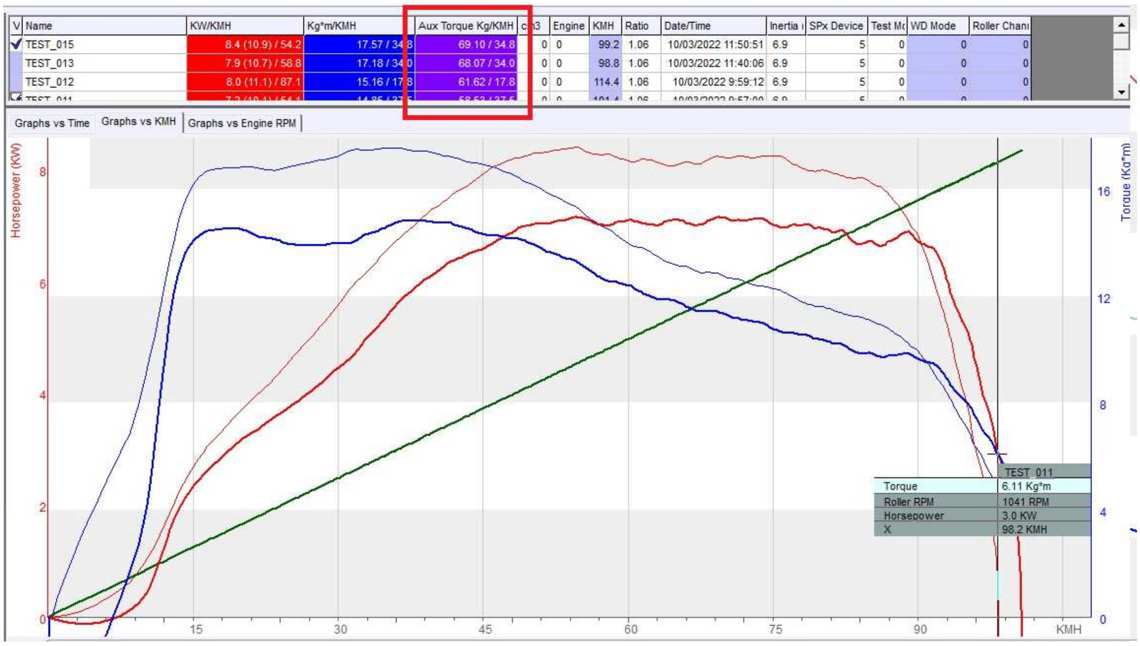




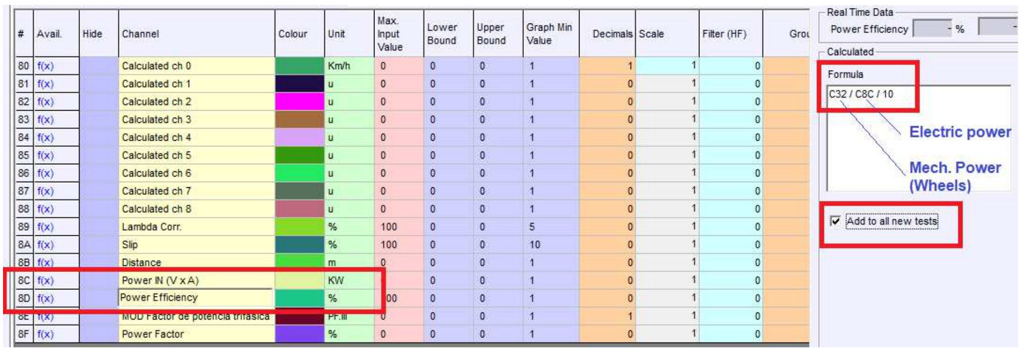
This test on a **MXUs 1.5 KW Direct Drive Hub Motor** shows:

- 1.67 HP (aprox 1.2 KW, friction losses were not recorded) (red)
- 105 Nm torque at wheel (as wheel to roller ratio 0.75 was applied)
- **32.5 Kg** of thrust (green), for an ebike of 30-40 and a driver of 80 kg it gives **approx** 32,5 / 120 = 27% of climbing capacity (but these motors get hot very fast)

This other test is from a **8 KW scooter** also with a small wheel (more torque) and **Direct Drive Hub Motor**, it gives aprox 68 kg of thrust and about 100-110 top speed. Roller and wheel had a similar diameter (500 mm), resulting ratio was 1.06.



- **EFFICIENCY** is also an important value to measure. For this measurement it is necessary to access to the voltage and battery current from the controller. They could be measured by analogue means but it is more accurate if the controller provides these values.
  - **Efficiency = mechanical power / electrical power** (electrical power = battery voltage * battery current). Controller efficiency is normally not measured, controller + motor are considered a "black box"

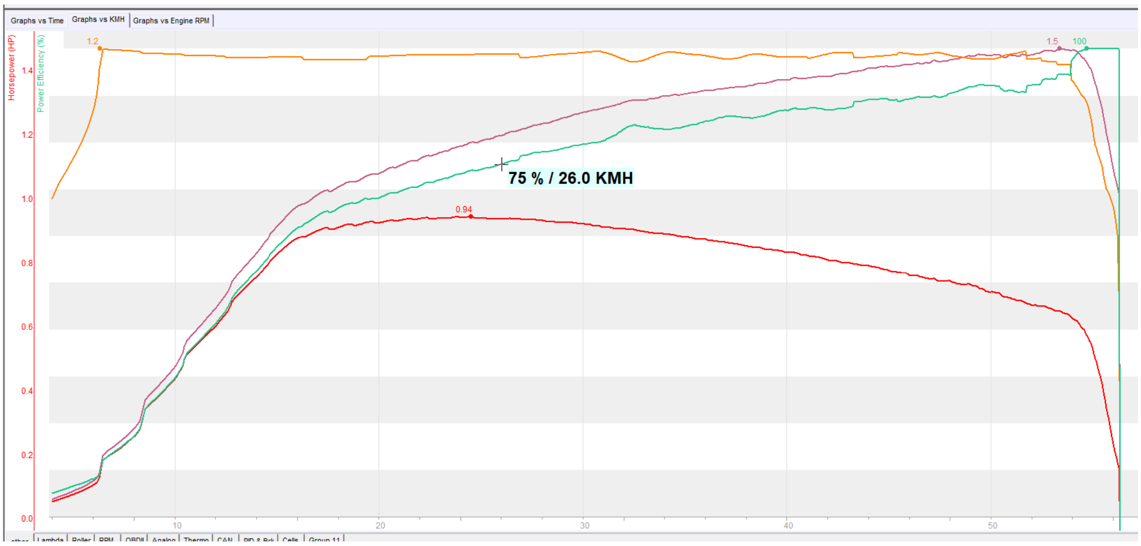


  - (motor) Efficiency can be measured considering tire friction or only wheel power.

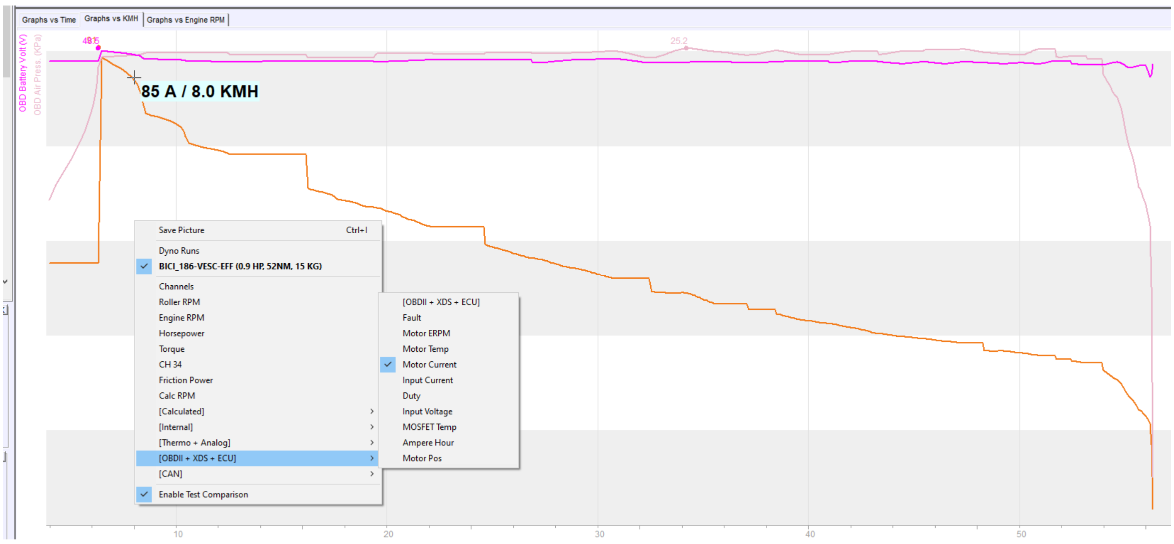
For instance hub motors when used with big tires, specially with high speed configurations have LOWER efficiency than mid-drives (despite all the gearing inside the mid-drive)

The following test measures the efficiency from a MXUs 1.5 KW Direct Drive Hub Motor:

- **Input Power:** It shows a flat graph (orange) at 1.2 KW as the battery voltage (50V) is quite stable and input current is limited by the controller (25A in this case).
- **Power graphs:** red graph is the **wheel power** (0.94 HP), while the violet graph is the estimated **motor power** (1.5 KW) as the tire has high losses at higher speeds
- **Efficiency:** green line is obtained from **MOTOR power** / **input power**. As it can be seen it is only 75% at aprox ½ of the top speed (26 kmh for a top speed of 55 kmh). Values over 45 or 50 kmh are not realistic, indeed in the last section (54-56 kmh) the formula is clamped to 100%. For a more accurate calculation at this area a steady test should be performed instead, but considering the tire losses.



The next graph shows the **battery voltage** (47V light pink) **and battery current** (25A violet), and also the **Motor Current** (orange) obtained through the serial line of a VESC Controller. It can be seen how the battery current is limited to 25A while the **motor current starts at 90A**, but decreases as speed increases to keep the constant 1.2 KW input.



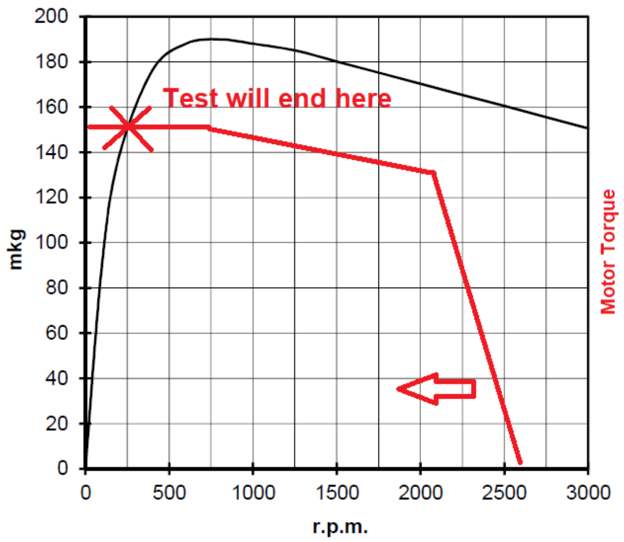
- For **E-Motorcycles** (also called ebikes) it is also interesting to measure the **braking / regenerative capacity**. Then an **electric motor** has to be connected to the roller to be able to drag the wheel and put energy back into the motor and then into the battery. This requires a SP1+/SP5/SP6 (with load cell input) and a special configuration so both positive (braking) and negative torque (dragging the wheel) are measured by the load cell and the software

Testing Power and Torque in E-Vehicles

As E-vehicles can start from 0 RPM and 0 speed, it is recommended to set a low starting speed value to ease the test process, specially for **ramp mode**, but always using a speed in which the torque can be handled by dyno (say 40-50 kmh), as most vehicles will have huge torque values at lower speeds. This may not be an issue with low power vehicles, but with cars with more than 300 HP torque could be too high at low speeds like 10 or 20 km/h.

Although inertial tests could be performed from 0 kmh, there will be always a torque peak in the transition from 0 to some speed and if the vehicle has a huge power tires can slip.

It is also possible to perform an “inverted” test using an increasing brake ramp from top speed until the vehicle stops, but this can be more “intensive” and the total test time is unknown as each vehicle will require a final braking value until all torque is cancelled. Note: eddy current brakes cannot provide braking torque at 0 rpm, thus the test should end at a low speed (20-25 km/h in the example below, for a 500 mm roller), but will be never 0.



Braking torque according to rotational speed

Torque: as in general it is difficult to know the internal motor speed, we cannot get the actual motor torque. It is easier to measure tire’s torque (tire to roller ratio), or better measuring the linear thrust (N or Kg).
But if actual motor speed (telemetry), or actual motor + tire to roller ratio are known the resulting ratio can be setup manually to get the calculated motor speed and thus the motor torque.