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Testing the Efficiency of Generator Hubs

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Testing the Efficiency of Generator Hubs

by Jan Heine (text) and Andreas Oehler (measurements and illustrations)

The idea of generator hubs has been popular since the 1940s.[1] Standard generators running on the tire tread or rim suffer from significant losses at the wheel/generator interface. In addition, they are unreliable in wet weather, because the generator wheel slips. Generator hubs offer a simple and reliable way to generate power for bicycle lights.

But only in recent years have efficient generator hubs become available. Currently, the most popular generator hubs are made by Schmidt Maschinenbau in Germany and by Shimano in Singapore. At the same time that generator hubs have been perfected, modern technology has reduced the losses of sidewall generators. The Lightspin "bottle" generator claimed greater efficiency than generator hubs, with the added advantage of no resistance when it is turned off. However, the problem of slipping rollers on wet tires remains.[2]

Methods

For these tests, the most popular models of generator hubs, as well as the Lightspin sidewall generator, were tested on the test apparatus of Schmidt Maschinenbau in Tübingen/Germany.[3, 4]

For each generator model, three brand-new generators were taken from standard production runs and run-in for at least 15 minutes. Then their resistance was measured, without a load and with a Schmidt E6 headlight (3W light bulb; Philips HPR64 6 volt 3 watt).[5] After these preliminary tests, hubs of the same model with higher and lower efficiency/losses were discounted as outliers, and the "average" hubs were tested in detail.[6]

Models tested

Dynosys Lightspin (model year 2004, no longer produced): sidewall generator; cost: $ 120;[7] weight: 280 g.[8]

Shimano HB-NX32 (2004): generator hub; $ 50; 729 g.[9]

Shimano DH-3N30 (2004, not imported to North America): generator hub; approx. $ 60; 872 g.

Shimano DH-3N70 (2004): generator hub; $ 100; 667 g (replaced by DH-3N71)

Shimano DH-3N71 (2005): generator hub; $ 90; 675 g.

Schmidt Maschinenbau SON28 (2005): generator hub; $ 209; 575 g.

Schmidt Maschinenbau SON20 (2005): generator hub, intended for small-wheeled bicycles, but used here in a 700C wheel; $ 209; 575 g.

Power output

All tested generators except the SON20 provide almost full light intensity starting at speeds of 10 km/h (6.2 mph) (Fig. 3). The Shimano DH-3N71 is the winner at low speeds, as it provides more power (and thus a brighter light). The SON20 – used here with a 700C wheel for which it was not designed – provides the least power at low speeds. At 20 km/h (12.4 mph), all tested generators provide at least the 6 volts needed to power a standard lighting system at full brightness.

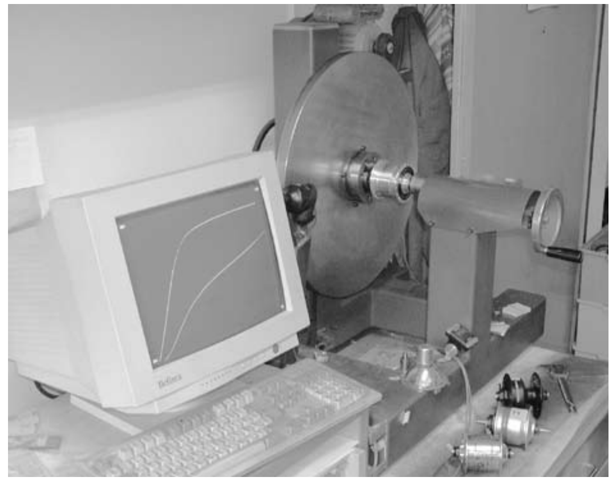

Fig. 1: The test apparatus at Schmidt Maschinenbau.

Nighttime resistance

When the light is turned on, the resistance of most generators tested increased (Fig. 4) – the exception is the Shimano HB-NX32, which becomes easier to turn at high speeds when switched on.

The Shimano DH-3N30 provides a major improvement over the HB-NX32: At all speeds, the resistance is less – in fact, it is less than the more expensive DH-3N71. The DH-3N71 does not live up to its advertising: Shimano claimed efficiency gains of 30% or more (and 70% less drag switched off) compared to its predecessor,[10] which would have put this hub generator far ahead of the SON. Instead, the new DH-3N71 has slightly higher drag at all speeds than the predecessor DH-3N70.

Overall, the SON28 still is the most efficient hub generator, but the Shimano DH-3N30 does not lag far behind. At very high speeds, it requires less power. The advantage of the SON20 over the SON28 (see sidebar on p. 27) is greatest at medium to high speeds.

Daytime losses

With the light turned off, the losses are lowest for the Lightspin (Fig. 5): With the generator not touching the wheel, only the drag of the front

Fig. 2: Modern generators (from l. to r.): Lightspin, Shimano DH-3N30, Shimano DH-3N71, SON28/20, SON XS (see sidebar on p. 29)

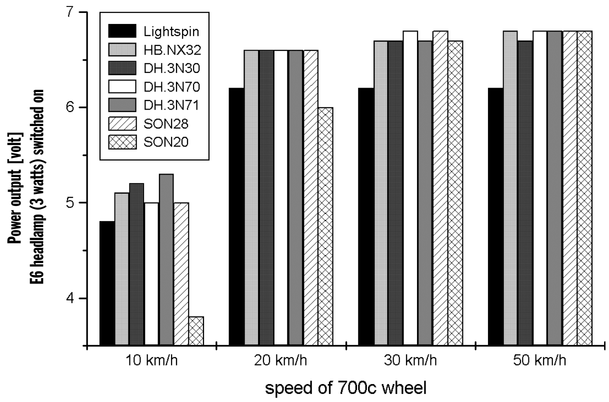

Fig. 3: Power output varies only at low speeds. The outputs are capped at 6.2 volts by the Lightspin and 6.8 volts by the E6 light on the other hubs. (10 km/h = 6.2 mph; 20 km/h = 12.4 mph, 30 km/h = 18.8 mph; 50 km/h = 31.3 mph)

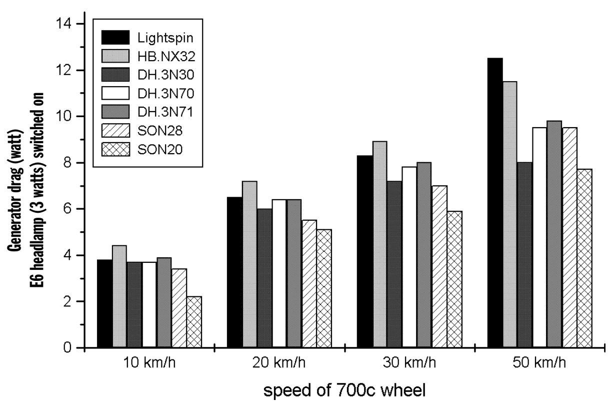

Fig. 4: Nighttime resistance (light on). SON20 is most efficient.

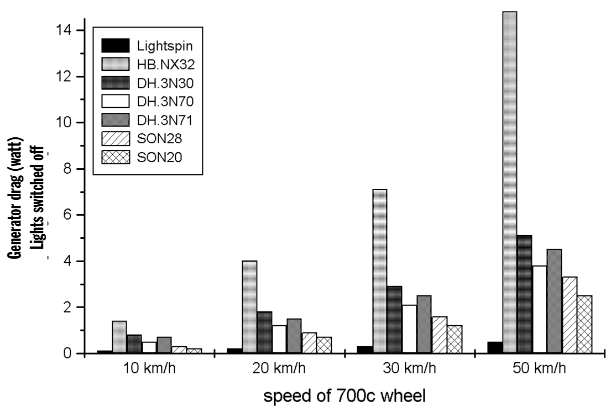

Fig. 5: Daytime resistance (light off) varies significantly between generators. Resistance for Lightspin is from a standard front hub.

Using small-wheel generator hubs with large wheels

Most bicycle lights are designed to comply with German laws, which requires lights to output 0.75 watt at 5 km/h (3 mph) and 2.70 watt at 15 km/h (9.4 mph). These laws were designed for German everyday cyclists traveling short distances at very low speeds, not avid riders. Many cyclists rarely travel slower than 15 km/h (9.4 mph), so they may decide that they do not need full light intensity at speeds below this value.

Using the SON20 with 700C or 650B wheels instead of the 20'' wheels for which it was designed, results in less power output, but also less resistance (see diagrams at left): The larger wheels rotate slower than the 20'' wheels for which the generator was designed.

The test results show that precious energy can be saved this way. For four years, I have used a SON20 with 700C and 650B wheels. On very steep uphills, the light begins to flicker. But at those very low speeds, I do not need as much light to see the road. For those riding in urban traffic on very steep roads, the SON28 may be preferable: Even at low speeds, cyclists remain visible to other traffic.

Starting in late 2005, the narrow SON-XS (for folding bikes with narrow forks) will be available for standard 100 mm dropout spacing. While the efficiency of this model is about 2% lower than that of the SON20, at 398 g it weighs 179 g less than the SON20. However, the narrow flange spacing (40 mm, instead of 58 mm for the standard SON) and the aluminum alloy axle (instead of stainless steel) result in weaker front wheels less appropriate for rough use.

hub remains. The Shimano HB-NX32 causes significant drag, especially at higher speeds, and really is not suitable for a performance bicycle. The newer DH-3N30, on the other hand, is a significant improvement, with a resistance that is comparable to more expensive generator hubs.

The new Shimano DH-3N71 has slightly higher resistance than its predecessor DH-3N70. During daytime running, the SON28 still provides significantly less resistance than other generator hubs. As expected, the losses of the SON20 with a 700C wheel are even lower, but at the price of reduced low-speed light output at night.

Conclusion

Lights powered by generator hubs offer reliable light under most conditions. The added resistance is measurable (Fig. 6), but its importance is easily overstated. It is greatest (in percent of overall power output) at low speed. At high speeds and on uphills, the added resistance becomes negligible compared to the overall power required to propel the bike.

If cost is no object, the SON28 provides the best product for most cyclists. It combines high efficiency with quality construction. Since 2002, the SON incorporates pressure-compensation seals that prevent problems when the bicycle is brought outside on a wet, cold day. (The relatively large interior air volume of the generator hub contracts as it cools, sucking moisture into hubs without the special seals.)[11]

The Shimano DH-3N71 is a good product, but offers slightly worse performance to its predecessor, the DH-3N70. Both are significantly heavier and less efficient than the SON. The cheaper DH-3N30 offers better performance, but is 200 g heavier. Because it also has inferior bearings and seals, the higher price of the more expensive Shimano hubs appears justified. The expected lifetime of the bearing cones in the inexpensive Shimano hub generators (HB-NX32, DH-3N30) appears to be on the order of 5000 km (3000 miles).[12] That said, the DH-3N30 offers surprisingly good performance for its price.

If it were not for the slippage problems in wet weather, the Lightspin would provide a good alternative to the hub generators. Its light weight (even including the weight of mounting hardware and front hub) and lack of daytime resistance are appealing for riders who only occasionally ride after dark. When the light is turned on, the Lightspin's resistance increases to values above that of the SON28 and the current Shimano hub generators. Perfect alignment of bottle generators is difficult to achieve and maintain, so the resistance may vary with use.

For performance cyclists, using the SON20, or the surprisingly light-weight SON-XS (see sidebar on p. 27), with a larger rim reduces both daytime and nighttime resistance, especially in the speed range from 25 to 35 km/h (15-22 mph). The downside is less light output at very low speeds.

One or two headlights?

At speeds above 25 km/h (16 mph), all generator hubs (except the SON20) can be used with dual headlights wired in series. Many American randonneurs like to use two headlights. While the resulting beam is impressively bright, I feel that the added weight, resistance and complication is not worthwhile. A single E6 headlight provided sufficient illumination even on our tandem during Paris-Brest-Paris at speeds of up to 70 km/h (44 mph) on unfamiliar, challenging roads.[14] Those strong enough to power two headlights on the flats benefit most from the reduced resistance of the SON20.

Disclaimers and Acknowledgements:

Andreas Oehler works at Schmidt Maschinenbau, manufacturers of the SON hubs and E6 lights. We thank Schmidt Maschinenbau for the use of their equipment. Shimano America Corporation did not return phone calls and e-mail requests with regards to this test.

This article was reviewed by Mark Vande Kamp and Jim Papadopoulos.

Notes:

1 Rebour, D., Paris-Brest-Paris...dans 3 ans. Le Cycle 9/25/1948, p. 9 and Pernot, Raymond, Autour de Paris-Brest-Paris et Retour, Le Cycliste 7/1949, p. 150.
2 http://www.pdeleuw.de/fahrrad/lightspin-e.html, status 5/9/2005.
3 The hub generators are attached to a 30 kg (66 lb.) flywheel and accelerated to 50 km/h (31.25 mph). The motor is disengaged and the flywheel/generator assembly coasts to a stop. The test setup is calibrated by measuring the speed over time (deceleration) of the flywheel alone as it coasts to a stop. Comparing this with the deceleration with the generator engaged allows calculating the power required to turn the hub at various speeds. To measure sidewall generators, a complete wheel (17 mm wide rim, Panaracer Pasela TG 32-622 tire, 6 bar/87 psi pressure) is attached to the flywheel and calibrated. The generator is oriented by eye to be perpendicular to the wheel's radius (5 mm distance tire/generator wheel when switched off).
4 A different test, where the hub shell was clamped in a lathe, and the resistance at various speeds on the axle was measured using a long lever and a laboratory scale, corroborates the test results. O. Schulz, Nabendynamos im Labortest, 2004, unpubl. manuscript for ProVelo.
5 Because light bulbs vary in their resistance, the drag of generators will vary slightly with different light bulbs.
6 The variability between samples of the same models was small, except for the drag (light on) of the Lightspin (10%, inconsistent interface tire/generator) and drag (light off) of the Shimano DH-3N71 (29%, probably bearings adjusted too tightly.)
7 Prices are approximate.
8 Weight does not include the front hub. A Campagnolo Record front hub (large flanges) weighs 180 g. Hardware to attach the generator to a bicycle weighs another 15-60 g.
9 All weights without quick releases/axle nuts.
10 http://cycle.shimano-eu.com/publish/content/cycle/seh/nl/en/news___info/news/extremely_light_rotation.html, status 5/12/2005.
11 To check whether your SON has the pressure-compensation seals, check for a tiny hole inside the axle, about 2 cm (1") from the end with the contacts.
12 http://de.geocities.com/hb_nx30/, status 5/12/2005. Includes overhaul instructions for HB-NX32. To check for loose cones on Shimano hub generators, concentrate on feeling axial play. Do not loosen the nuts on the connector side, as this could damage the internal wires and cause a short circuit. SON hub bearings are not adjustable.
13 Total power requirements (rounded) from http://www.analyticcycling.com/ForcesPower_Page.html (frontal area 0.52m², drag coeff. 0.5, air density 1.226 k/m³, rider/bike weight 90 kg, rolling resist. 0.005), status 5/9/2005. Several standard front hubs were measured, including Sachs Neos Cartridge and Shimano LX.
14 Haworth, J. and J. Heine, 2003: The fastest "Tandem Mixte" in Paris-Brest-Paris 2003. Vintage Bicycle Quarterly Vol. 2, No. 1, p. 1.

Speed	Power required for entire bicycle	Standard sealed front hub	SON28 (light off)	Speed reduction (light off)	SON28 (light on)	Speed reduction (light on)
10 km/h	15 W	0.1 W	+0.2 W (+1.3%)	-0.1 km/h	+3.3 W (+22%)	-1.6 km/h
20 km/h	50 W	0.2 W	+0.7 W (+1.4%)	-0.1 km/h	+5.3 W (+11%)	-1.1 km/h
30 km/h	130 W	0.3 W	+1.3 W (+1.0%)	-0.1 km/h	+6.7 W (+5.2%)	-0.7 km/h
50 km/h	500 W	0.5 W	+2.7 W (+0.5%)	-0.1 km/h	+9.0 W (+1.8%)	-0.36 km/h

Fig. 6: How much harder is it to pedal a bicycle with a hub generator?[13] Compared to a bike without hub generator, the table shows the additional power required to maintain the same speed, as well as speed reduction at the same power output – on level ground. Only the added nighttime resistance (light on) at low and medium speeds will slow the rider noticeably. At high speeds, the added resistance (light on) is less significant. On uphills, hub generator resistance is an even smaller percentage of the overall resistance. For example, climbing a 5% hill at 10 km/h requires about 140 W. In this situation, the 3.3 W consumed by the SON28 (light on) slow the rider by only 0.2km/h.