Prospects for in-hub gearbox front wheel drive cycles

By Stephen Nurse

Abstract

Front wheel drive cycles have existed since the Michaux bicycles of the 1860s, and gearboxes for their front hubs were developed before 1900. Since then, cycle transmission has been dominated by chain driven, rear wheel drive bicycles. But since 2000 hub gearbox cycles are being revived by keen inventors using advancing technology. This paper shows the uses, current developments and potential of front hub gearbox cycles (hubcycles), emphasises the technology with diagrams and speculates on an electrical hub.

Hub History

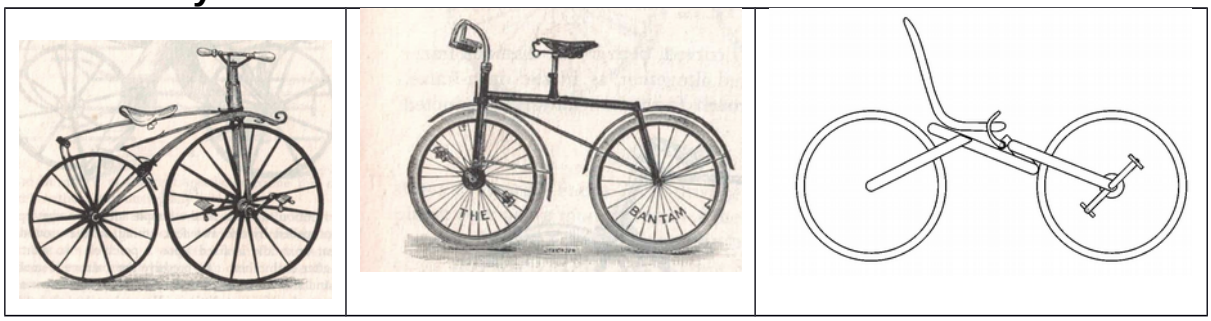

Figure 1: Michaux, Bantam and Kretschmer hubcycles (Michaux, Bantam from Sharp 1896, Authors sketch after Kretschmer 2000)

Front wheel drive cycles were the first pedalled bicycles, so have existed since the Michaux boneshakers of the 1860s. Back then, these were just bicycles but today we would call them moving bottom bracket front wheel drives. Gearboxes for hubs of these cycles started with the 1890s Bantam safety cycles and their fixed 2.75 ratio gearbox (Sharp 1896, 158). Although there were 1980s hubcycle patents (Garnet 2020a), wide gear range hubcycles were more widely publicised in articles by Thomas Kretschmer (1999, 2000), and John Stegmann (2002).

Kretschmer proposed a hub gearbox with a wide range, multiplying pedal rotations in the front wheel in a range from 1 to 4.5 (Figure 5). He prompted further development on two sides: hubcycle gearboxes and hubcycles themselves. Stegmann had been influenced by hand and foot driven hubcycles at International Human Powered Vehicle Association races in the USA, where he witnessed first-hand the benefits of streamlining. He proposed “The Hub”, a hubcycle with a small fairing on the front fork and modular options for load carrying and full fairings.

Proof of concept

Joakim Nilsson (2016 and Stackexchange 2012) and Kervelo (Le Borgne 2016) have both converted Pinion P18 bicycle gearboxes for hubcycles. These provided the wide range gearing Kretschmer imagined, multiplying pedal rotation between 0.55 to 3.5 times. With the large 700C - 28” wheel required to ensure foot clearance on recumbents, this produces developments from 1.23 to 7.79 m - 15.4” to 98” wheel diameter (Pinion website).

Figure 2: Kervelo Pinion hubcycle at Spezi, photo courtesy Kim Aargaard, @bicycle_only

These Pinion conversions produced recumbent hubcycles from Nilsson, and Kervelo bikes, trikes, electric bikes, and leaning trikes. Nilsson reported gears 8 to 18 as usable, indicating that there are seven useless low gears. This can be understood by using my tilting trike (20” wheel, 52 tooth ring driving 11 to 40 cluster, 2.1 to 7.5m development) as a benchmark. Like some hubcycles my trike is front wheel drive with little weight on the front wheel. On steep hills, the front wheel slips irrespective of the gear used (Nurse 2019a). With several unusable gears, Nilsson’s Pinion conversion can be called proof of concept rather than an ultimate product.

Gearbox development

Despite successful prototypes and numerous cycle design concepts, hubcycle gearboxes and cycles are hard to obtain. Here are some actual and potential gearbox developments.

Pinion are a successful gearbox manufacturer and the P18 converted by Nilsson and Kervelo is their model with the most gears. Possibly a simpler, lighter Pinion P1.9XR gearbox would make a better hubcycle conversion. Its highest gearing is lower (pedal rotation multiplied by 0.55 to 3.2) than the P18’s but that could be compensated for with slightly shorter cranks. OEMs such as Velomo already convert Pinions for use on the booms of their own and other recumbents (Velomo 2020), and other manufacturers could take up the challenge of making Pinion hubcycle gearboxes.

Mike Lecka in the USA has a Kervelo Pinion recumbent hubcycle bike, runs a custom cycle shop (https://velosrus.com) and is developing the Velotilt, a tilting, fixed bottom bracket front wheel drive, delta velomobile (Recumbents.com Velotilt forum 2020). He is making and documenting extensive changes to the Kervelo bike, including adapting its Pinion gearbox to other cycle forms. He sees the gearbox as being “great in penny farthing, uni-cycle, kervelo, velotilt, my 4 wheeler velomobile” (Recumbents.com Kervelo Forum 2019). The velomobile and Velotilt don’t use the Pinion in its hubcycle form.

Kervelo has progressed from using Pinion gearboxes to making prototype “Kernel” hubcycle gearboxes from scratch. They have shown lowracer recumbent- and bicycle- versions of cycles using their Kernel gearboxes at Spezi.

Their Kernel models are a 7 speed with 1.11 to 2.7 pedal rate multiplication and a 12 speed with 0.66 to 3.57 multiplication (Kervelo website). Passgenau Gmbh, a tooling manufacturer in Hambrücken, Germany, was due to show a Kernel based, front drive, rear steer bamboo trike at Spezi 2020 before the exhibition was cancelled due to Covid-19. However the trike appeared on the Spezi website (Passgenau 2020). Up till now, Kernel gearboxes and bikes including them have not been advertised for sale.

Russian Engineer Boris Frolov has made and written about his own hubcycle and hubcycle gearbox which includes variator technologies similar to Fallbrook's Nu Vinci hub. According to the report, one variator has a greater than 90% efficiency, costs 350 Euro, weighs 2kg and multiplies pedal speed between 1 and 4 times! (Bandanschik 2011)

Canadian designer Jeremy Garnet has championed hubcycles and published "Ergonomics of Direct-Drive Recumbent Bicycles" (Garnet 2008) which Joakim Nilsson used as a guide to building his proof of concept machine. He has also built a 4 speed bevel planetary gearbox prototype with pedal to wheel speed ratios from 1 to 3.27 (Garnet 2020). He is designing and prototyping an 8 speed hubcycle gearbox prototype with a stacked planet gear configuration. I emailed Jeremy about this gearbox and he replied "The highest ratio of my planned 8-speed hub is 3.83. For a 700C - 28" front wheel this translates to about 107 gear inches or 8.6 meters of development. The lowest gear is direct: 1:1." As well as gearboxes, Jeremy has built recumbent bike hubcycles.

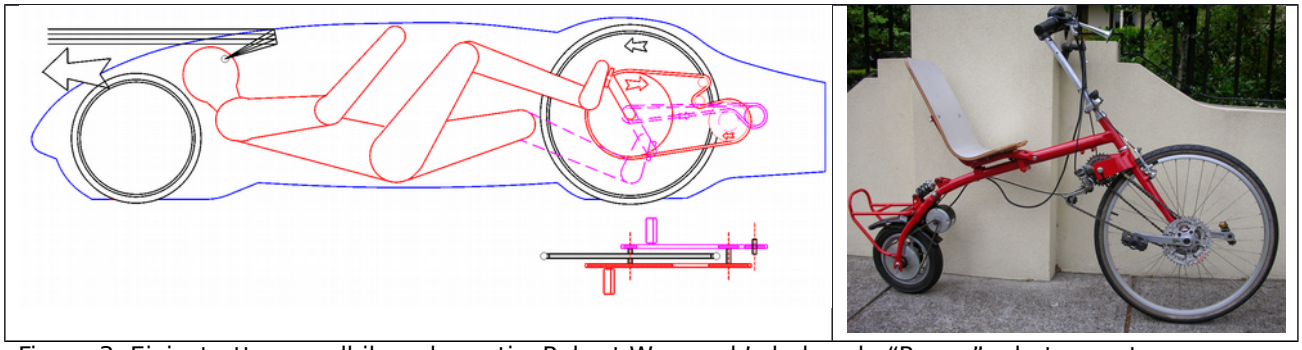

Figure 3: Eiviestretto speedbike schematic, Robert Waryszak's hubcycle "Penny", photo courtesy Robert Waryszak.

Lack of hubcycle gearboxes has not stopped designers building hubcycles. Combinations of existing cycle chain, hub gear, derailleur and clutch parts can make cycle drives with the same functional configuration as hubcycles. One transmission of this type is in the record breaking Eiviestretto speedbike which has a two chain hubcycle drivetrain and reverses rotation direction (Russospeedbike.com 2020). My friend Robert Waryszack has made a Penny Farthing type hubcycle with in-and-out-chains which I have ridden (Waryszak 2014). Commercial vehicles of this type are proposed by Bellcycles (open source plans and kit, http://bellcycles.com) and Trivek (https://www.facebook.com/Trivek-1575543719412380).

Covering this sort of chain transmission in a fairing or velomobile shell removes some disadvantages and brings it closer to the characteristics of hubcycle gearboxes:

- Inside a shell, chains are protected from grit and water

- Access hatches in the shell could ensure access for maintenance is not an issue
- Inside a shell, chains and cogs remain aerodynamic.

However the moving bottom bracket configuration of hubcycles may not suit velomobiles. John Stegmann proposed solving this issue by using stretchable fabric instead of rigid material for fairings.

Lastly, an electronic hubcycle could be used for series hybrid cycles, - that is cycles where the rider generates electricity by pedalling, and all motion force is from an electric motor. An example series hybrid cycle is the Bike2, (http://bike2.dk) and integrated hub units such as made by Zehus (http://www.zehus.it) could be used in such systems. A series hybrid hubcycle hub could handle generation, power delivery, and braking regeneration. In addition to regeneration and pedalling, further power inputs could include solar and mains charging and this sort of cycle could also be used for battery charging and power generation (Nurse 2018 and 2019b).

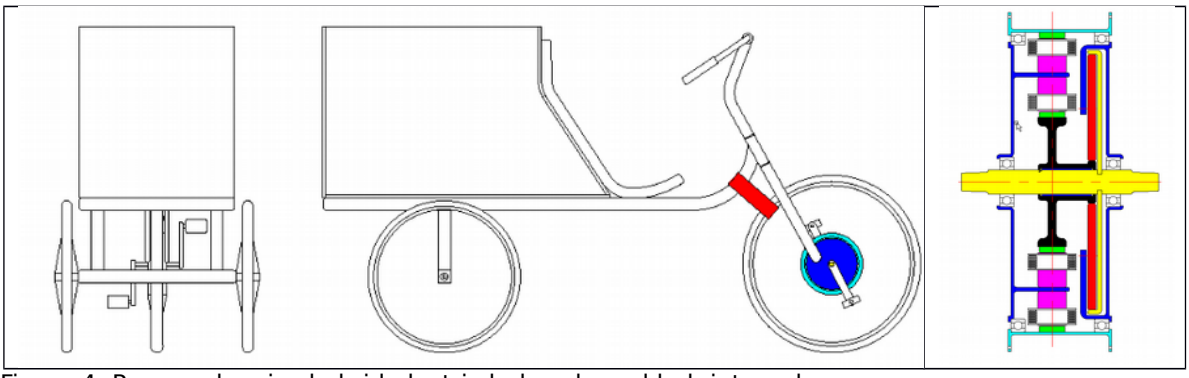

Figure 4: Proposed series hybrid electric hubcycle and hub internals.

Wheel Sizes

Except for internal ratios, front hub gearboxes' only adjustments for wheel development is wheel diameter and pedal crank length, whereas Pinion gearboxes in standard bicycle crank position have optional speed change via the final chain and sprocket drive. Notes on different wheel sizes (Nurse 2019a) follow.

28" - 700C large wheels are best for high speed hubcycles. The bottom bracket height is 356mm meaning the rider can be laid back and aerodynamic, and still have shoe clearance to the ground. However it is still worth considering what pedal crank length and cleat position might be used to improve heel clearance. In personal correspondence, Jeremy Garnet (2020b) wrote:

"My own experience with direct-drive confirms your comments about heel clearance: there is no problem at all with a 700C wheel. In my original sketches of 1989, I had thought a larger wheel would be required, but by the time I made my first direct-drive recumbent in 2003, I had found out that the very successful Easy Racer Tour Easy recumbent bike had a 13 inch high bottom bracket and a similar height of seat to what I was going to use, so, since a 700C wheel would give me a bit more than 13 inches, I thought it would be OK, and it was. I agree, though, that with wheels smaller than 700C, heel clearance might be a problem unless the seating was more upright."

20” small wheels could be best used for load carrying and unicycling. To avoid clipping heels on the ground during cornering, the riders leg position needs to be more vertical. This position makes the rider more visible in traffic and puts more weight on the driving wheel making slipping less likely on hills or with loads. Due to the more upright, bluff position, aerodynamic efficiency can be lost. Trisled have already made a modular front wheel drive cargo trike but this uses a moving bottom bracket transmission in an upright cycle setup (Trisled 2020).

Efficiency

Unlike bicycles using Rohloff and standard Pinion hubs, hubcycles don't have to deal with chain or belt drive inefficiency or deterioration due to mud, grit or rust. This means real world hub efficiencies will remain close to laboratory measurements. Multispeed hubcycle transmissions can be at least 90% efficient (Denham 2017) based on Pinion gearbox tests in standard bicycle setups with chain. There are several competing or prototype hubcycle technologies so efficiencies would vary.

Applications

Unicycles seem to be a sufficient application on their own for a wide range multispeed hub (Figure 6). Multispeed hubs for unicycles must lock out the clutch allowing freewheeling because backpedalling is part of unicycle balancing. Bruce Dawson (2012) is a fan of hub geared unicycles, owned several of them and believes in their speed advantages. Meanwhile, the only commercial geared unicycle hub, by Krisholm and Schlumpf, offers 2 speeds and was widely available but is out of stock at the time of writing (Krisholm 2021).

Velomobiles: David Hembrow runs the Dutch Bike Bits website and has documented the gear inches which suits his riding in a Sinner Mango velomobile in his blog (Hembrow 2012). He writes, *“I have a Tiagra double compact chainset (50 and 39 teeth), and a 9 speed 105 cassette (11-28). This is combined with a 26 tooth sprocket on the left side of the mid-drive driving the second chain and the standard 18 tooth sprocket on the rear wheel. Fitted with a 47 mm rear tyre, the wheel diameter is not far at all from 20 inches. Using the traditional British / American "gear inches" system, this combination gives a range of gearing from a low of 39 / 28 * 26 / 18 * 20 = 40 inches to a high of 130 inches. Converting to the European metres of development figure, this is a range of approximately 3.2 m to 10.5 m. Either way of looking at it, I find this to be an adequate range of gears. Riding up a 1:10 slope with a touring load the low gear is just adequate, while I never spin-out in the high gear unless I'm going downhill at speed. By then it is in any case time to stop pedalling. By fitting different gearing components it is possible to change these ratios quite a lot.”*

If one of the hubcycle gearboxes (Velotegra 2nd prototype) were to be used in the Mango with a maximum sized standard wheel (29”) the gear inches range would be 29” to 111” and developments 2.3 to 8.86m, below those of David Hembrow’s Mango. However with a 8.7m development at 80 rpm, the speed is 8.86m / rev * 80 rev / min * 60 min / hour = 42542 m / hour or 42.5 km/h, still a respectable cycling speed. Its possible a slight pedal length reduction could improve the effective gear inches and Sheldon Brown incudes pedal length in his “gain ratio” calculations (Brown 2008).

Conclusions

There seems to be no shortage of opportunity or desire to make working hubcycles and the technology seems ready to succeed in the form of commercial cycles which make a sustainable profit for their makers. Unicycles look promising as do 2-stage chain driven hubcycles.

About the Author

Stephen Nurse is an engineer from Melbourne, Australia. He has worked in the printing, pump, plastics, aluminium and electric motor industries and has been building and designing recumbent bicycles since 1987. He competed in the 2004 Faltliegerwettbewerb (folding recumbent competition) at Spezi in Germersheim, Germany. Stephen is currently updating his “Cycle Zoo” book - originally published in 2010. He has completed an industrial design research masters called Simple Leaning Trike and can be reached at 10 Abbott Grove Clifton Hill, Vic 3068, Melbourne, Australia. Email cesnur@iimetro.com.au. Website modularbikes.com.au.

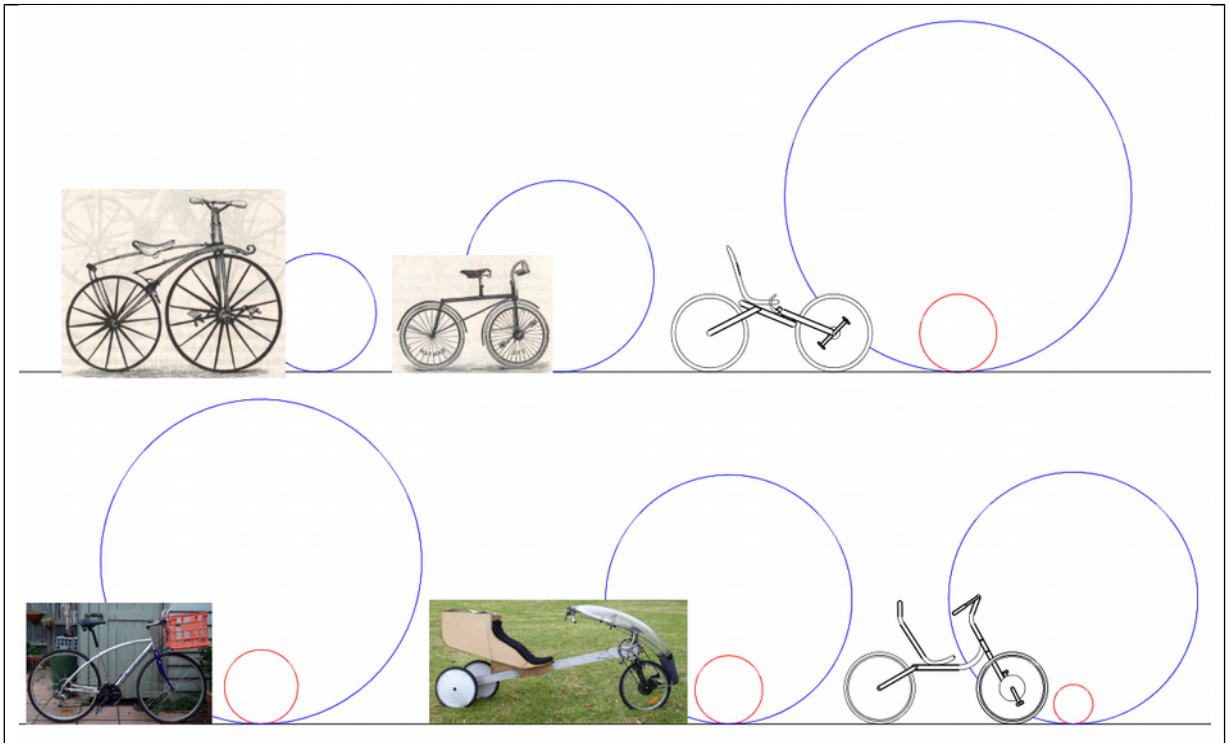

Figure 5: Maximum or only gear (blue), minimum gear (red) for Michaux Bike, Bantam bike, Planned Kretschmer bike, Derailleur geared bicycle, Leaning trike, and Kervelo Pinion bike.

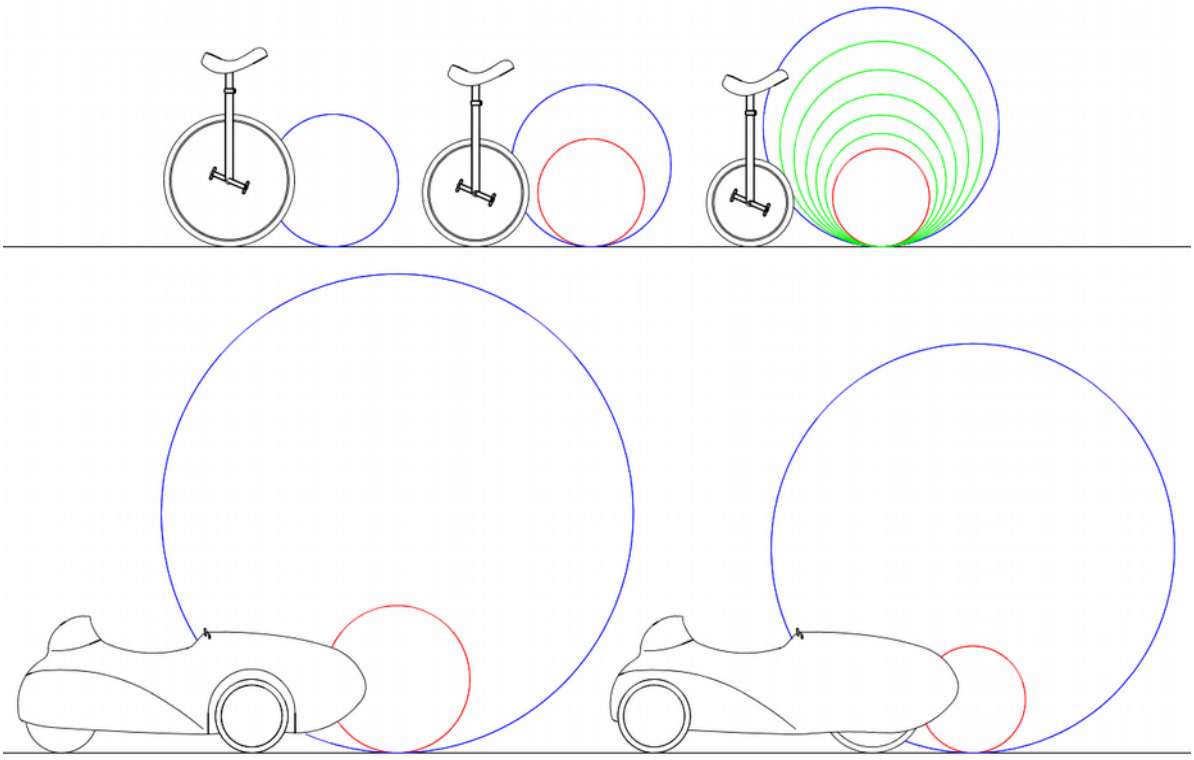

Figure 6: Unicycles showing all gears: 36” standard, 29” with Schlumpf gearbox, 24” hubcycle uni with gearing based on Kervelo Kernel 7 hub, Velomobiles: Sinner Mango with min (red) and max (blue) gear sizes as described by David Hembrow, Example hubcycle velo based on Sinner Mango, 29” drive wheel and Velotegra planetary gearbox.

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