In Hub Gearbox Front Wheel Drive Cycles

Stephen Nurse

10 Abbott Grove, Clifton Hill, Vic 3068

Email for correspondence: cesnur@iimetro.com.au

Abstract

In 1999, Bike Culture Quarterly magazine and Thomas Kretschmer introduced the concept of a chainless bicycle featuring a wide range, front wheel drive gearbox hub. Twenty years later, the European company Kervelo are making production versions of these chainless gearbox cycles (Fig.1). This paper discusses how Kervelos were developed by meeting needs and through dedicated individuals and companies. It considers effective uses for human power based on front wheel drive chainless gearbox technology.

Figure 1: Thomas Kretschmer in 1999, Kervelo Cycle 2018 (Kretschmer, Kervelo)

1. Introduction

Change is taking place in human- and low-powered transport, especially cargo- and e-bikes. More bike styles are becoming accepted for more uses as we realize exercise and low carbon economies are essential (Cox 2015). Change in the way we do things is sociotechnical change. It depends on emerging socio-technical frames and the ingenuity and emotional commitment of individuals who consider readily available, established products inadequate (Bijker 1995, p. 4, Nurse 2016). This paper discusses a cycle style currently gaining acceptance and looks forward to newer designs.

2. Background

Direct front wheel drive cycles date back to Pierre Michaux's wooden boneshaker of 1865 (Bijker 1995, p. 27), and variations with speed-increasing gearboxes have existed since the 1891 Crypto Bantam. The Bantam was a form of safety cycle (Sharp 2003, p. 158), invented to make the liberating technology of the high wheel penny farthing less challenging and accessible to more people (Fig.2). Along with other early safety cycles, the Bantam design was swept aside by the rise to dominance of the rear drive safety cycle first popularized by the “Rover” of 1884 (Bijker 1995, p. 70). Although invented over 130 years ago, the Rover is still recognizable as today’s dominant bicycle type.

Figure 2: Michaux 1865, Bantam 1891 front wheel drive cycles, Rover 1894 bicycle, (Bijker, Garnet)

This paper does not provide more history of front wheel drive and gearbox cycles because of excellent coverage in Bijker and online in Garnet (2018). Instead, this story samples recent developments beginning with the Rohloff Speedhub, through Thomas Kretschmer’s designs and other concept bikes leading to today's commercial front drive gearbox hub cycles.

3. Rohloff Hubs and Rohloff Hub Cycles

The Rohloff Speedhub was developed in 1998 by Rohloff AG, a German company. For the first time, it provided cyclists requiring a wide range of gearing (see Appendix 1) with a fully-sealed alternative to derailleur gearing. Despite costing USD 1500 in 2009 (Berto 2012, p. 350), it was readily accepted for trekking bikes, recumbent trikes and mountain biking. Compared to bikes with twin derailleur gearing, a Rohloff-equipped bike is less prone to handling damage and chain wear, and because it is operated by a single control, gears are selected more easily. Because the Rohloff hub wheel does not need multiple sprockets, it can be used with maintenance-free belt drives and its spokes can be spaced widely and symmetrically on the hub, increasing spoke triangulation and wheel strength (Wilson 2004, p. 329).

Figure 3: Rohloff Hub Touring Bicycle, Rohloff Hub in icy conditions (Wikimedia Commons)

Although the hub's positives were recognized, for some mountain bikers, the Rohloff had issues. It puts weight in the centre of the rear wheel contributing significantly to unsprung mass, causing problems with fully suspended bikes.

Aaron Franklin from New Zealand is a motivated mountain bike builder who appreciated the Rohloff hub and sought to improve its performance in high end mountain bikes. These bikes have an established racing scene, and there are many people paying thousands of dollars for mountain bikes with light carbon fibre frames and advanced gearing systems, and agreeing on their value. One reviewer calmly states that more expensive electronic shifting would be a sensible addition to a gearbox equipped bike already costing NZD 10,080 (Chamberlin 2017, Zerodebikes 2018). This agreed value by a group is a sociotechnical frame.

A table of desirable features for various bike styles is shown below. This table draws on bike reviews and buyers guides.

Table 1: Criteria for various cycle types

	High End Mountain Bike (full suspension)	Transport Bike (dry / mild conditions)	Transport Bike (wet, muddy, icy conditions)	Transport Bike (Folding)	Transport Ebike (extended / assisted riding)
Economical Price	Not Important	Important	Desirable	Desirable	Desirable
Low Unsprung Mass (low wheel mass)	Critical	Not Important	Not Important	Not Important	Not Important
Low weight	Important	Desirable	Not Important	Important	Desirable
Gear Range > 400%	Critical	Important	Desirable	Desirable	Not Important
Simple Sequential Gearing	Critical	Not Important	Important	Important	Important
Sealed Gears / Transmission	Desirable	Not Important	Important	Not Important	Desirable
Phone & GPS Charging	Detrimental	Desirable	Desirable	Desirable	Important
Strong Wheels	Critical	Desirable	Desirable	Desirable	Important
Onboard Load Capacity	Detrimental	Important	Important	Desirable	Important
Not prone to damage or creating stains when transporting	Important	Desirable	Desirable	Critical	Desirable
Reference	Chamberlin 2017	Castle 2018	Castle 2018	Steen 2018	Steen 2018a

Franklin’s Lahar mountain bikes contained a Rohloff hub and placed it in a new central position in the frame. This sort of shuffling or breaking, blending and bending is constantly occurring in innovation (Jencks & Silver 2013, p. 43, Eagleman 2017, p. 54). Lahars were recognized for their wheel strength, robustness and low unsprung mass (Schebel 2010), but they had an adaptation of an existing technology, rather than a technology designed for the job.

Figure 4: Aaron Frankin with Cam Cole & Lahar Mountain Bike, Rohloff Hub in Lahar (Schebel)

My knowledge of the Lahar comes through the Australian Human Powered Vehicle community. Schoolteacher Bernard Weir wanted a bike with a wide-range gearing for towing, yet compact enough to carry easily and fit under a desk and on public transport. After researching, Bernard and trike manufacturer Michael Rogan combined to install a Rohloff hub with Lahar mounting brackets in a Velociraptor / Onza mini bike, a combination meeting Bernard’s needs (Weir 2002) and an example of mountain biking, non-transport cycling technology influencing and becoming transport cycling technology.

Figure 5: Bernard Weir’s mini transport bike with frame mounted Rohloff Hub (Weir)

The desirability of the Lahar showed that mountain bike technology could be improved fundamentally, that is by development of a purpose designed, frame mounted, wide ratio gearbox. Pinion Gearboxes fill this niche.

4. Pinion gearbox and Pinion gearbox cycles

Pinion cycle gearboxes use a two-stage spur gear technology and were developed in Germany between 2006 and 2010 by former Porsche transmission engineers and mountain bike enthusiasts Christoph Lermen and Michael Schmitz (Lerman 2017). Some Pinion models have a range of 636% exceeding that of the Rohloff hub (530%) as discussed in Cyclingabout (cyclingabout 2012).

Figure 6: Pinion gearbox with belt drive, Bosch electric assist with Rohloff hub (www.idworx-bikes.de)

Pinions require special frames, but these types of frames are becoming accepted through the socio-technical frame of ebikes. Electric assist units from Bosch and Shimano have Pinion-like mounting arrangements, so it is possible suppliers making some types of ebikes could consider adapting frames to suit Pinion gearboxes a small step. Several bike reviews (cyclingabout 2018 , dirtmag 2017) point out that Pinion gearboxes resemble electric motors.

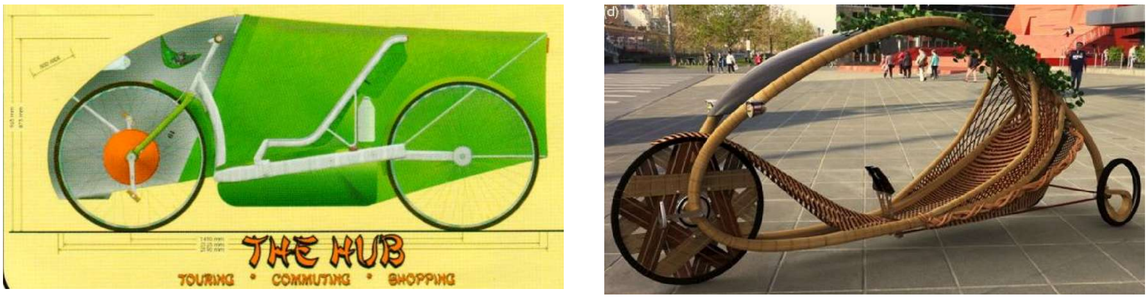
On their website, Pinion lists tens of cycle manufacturers supplying Pinion equipped cycles across recumbent, ebike, town bike, trekking, and mountain bike categories. The Pinion is providing a key step in commercialization of front wheel drive hub cycles.

5. Recent in hub front wheel drive gearboxes & cycles

In the late 1990’s Thomas Kretschmer promoted his concepts for wide-range, in-hub gearboxes for front wheel drive recumbents and other cycles. The gearboxes promised to be “immune to sand, water and mud” without the need for or mechanical losses of chains or belt drives. Kretschmer’s articles (1999, 1999a) show a prototype recumbent (Fig. 1), with its in-hub gearbox, along with other cycles which could use the gearbox (Fig. 7). Since then, designers have speculated on related cycles, John Stegmann promoting a faired bike and Alexander Vittouris bamboo velomobiles (Stegmann 2002, Vittouris 2011).

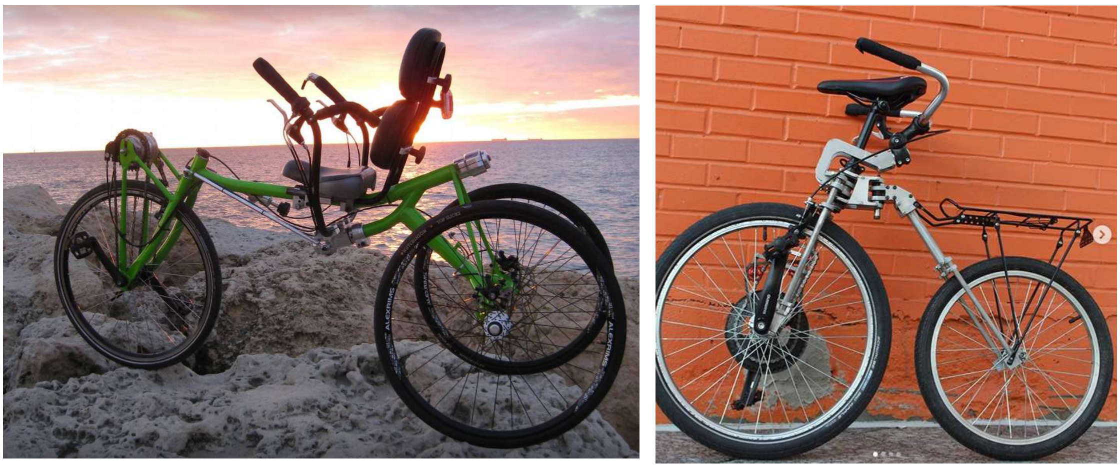
Figure 7: Kretschmer “Funbike”, MC2 Evobike assembly options (Kretschmer 1999a, MC2 Website)

Figure 8: In-hub front wheel drive concepts by Stegmann and Vittouris (Stegmann, Vittouris)



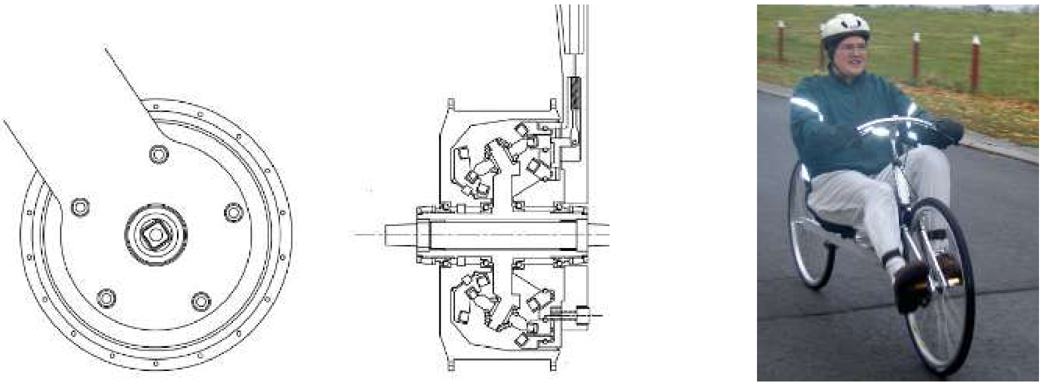
Several products using front wheel drive have attempted to launch through crowdfunding. The Trivek trike from Perth, Australia is still under development and uses a hub gear in a 2 chain drive system. Bell cycles from New York, USA successfully crowdfunded a do-it-yourself kit for a single speed bike with a high riding position.

Figure 9: Trivek and Bellcycles front wheel drive cycles (Trivek Facebook, Bellcycles Instagram)



Others including Jeremy Garnet and Marc Le Borgne and have taken up the challenge of producing effective cycles without a chain by developing mechanical gearboxes, and MC2 are producing modular (Fig. 7) versions of the cycles including electric assist models. Garnet wrote about the geometry of front wheel drive gearbox cycles, adapted a crank-mounted Schlumpf drive to increase speed on prototypes, then developed a bevel planetary gearbox with versions for bicycle rear hubs and front wheel drive recumbents (Garnet, 2018).

Figure 9: Velotegra gear hub and prototype bike by Jeremy Garnet (Garnet)



In 2017 Kervelo founder Marc Le Borgne used a new configuration of the Pinion spur gearbox to make and sell a range of front wheel drive recumbent cycles, bringing to life the modular “one direct drive hub, many bicycles” proposal by Kretschmer (2000) through ebike, bicycle, load trike, and leaning trike designs. This adaptation mounted the Pinion gearbox on the bike’s front fork and the front wheel on the Pinion output sprocket.

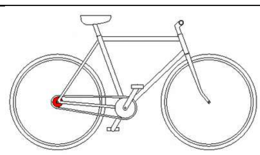
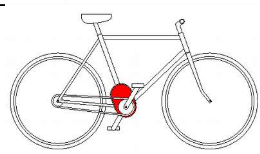
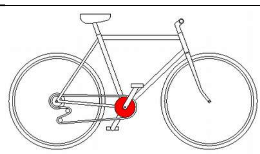
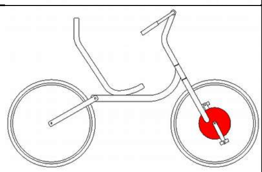
Figure 10: Kervelo adaptation of Pinion Gearbox and E-assist trike . (Kervelo.com)

In 2018 Kervelo introduced in-house-built planetary gearboxes with up to 12 gears and a 545% ratio for mounting in front hubs of recumbents and frames of bicycles. Kervelo plan to introduce integrated electric assist for their frame-mounted bicycle gearboxes. Their developments have taken place in parallel, designing fit-for-purpose gearboxes, and simultaneously selling and testing reactions to front wheel drive cycles.

Figure 11: Bicycle with Kervelo gearbox, Kervelo Gearbox (Kervelo.com)

Twenty years after Kretschmer promoted cycles using planetary front hub gearboxes, cycles using them are coming into production through MC2, Marc Le Borgne and Kervelo. This has been through adaptation of existing technology, and the following table summarizes some of the developments. Both Le Borgne and Garnet plan multiple configurations of their gearbox. Although they delight in recumbent cycles, they realize there may be bigger markets for their gearboxes in more mainstream bicycle applications. Walker and Cross (1976, p77) call this design of parts an escape route from the rigidity of single function objects. Wilson (2004, p. 326-332) provides a good summary of the technologies discussed here, and cyclingabout's (2017) analyzes of the efficiencies of Rohloff and Pinion gearboxes.

Table 2: Development Summary

Gearbox Location	Sketch	With Chain ?	Rohloff Planetary Gearbox	Schlumpf Planetary Gearbox	Velotegra Bevel Gearbox	Pinion Spur Gearbox	Kervelo Planetary Gearbox
Rear Hub		Y	Selling to multiple OEMS		Prototype Hub		
Bottom Bracket, Frame		Y	Selling by Lahar, Adaptation by Weir			Selling to multiple OEMS	Prototype
Bottom Bracket, Cranks		Y		Selling to multiple OEMS			
Front Hub with pedals		N		Adaptatio n by Velotegra	Prototype Hub	Selling by Kervelo	Selling by Kervelo

6. Layout Basics

In-hub gearbox front wheel drive is a simple technology but cycles that use it miss out on options available in most bicycles. Firstly, the bottom bracket height is the same as the front wheel radius without the additional height difference a frame can make. Secondly, the pedals run through the front wheel axis determining one part of the weight distribution on the wheels. Finally, gear ratios are set by the diameter of the front wheel and the gearbox without the additional difference chain and sprockets can make.

The *wheel size = bottom bracket height* constraint places limits on use of in-hub front wheel drive gearboxes. All cycles using the technology need to provide heel / pedal ground clearance, and bikes / leaning trikes need to provide this clearance when leaning during cornering (see also Appendix 2).

700C Wheel

This large wheel size could be best used for high speed cycles. The bottom bracket height means the rider can be laid back and aerodynamic, and still have shoe clearance to the ground. However it is still worth considering what pedal length and cleat position might be used to improve heel clearance (Appendix 2). On a 5:1 range ratio multispeed gearbox with a direct drive low gear, the development is 2.2 to 11m. These high developments are suitable for high speeds. On hills the front wheel may slip due to low weight on the front wheel. The laid back riding position does not help this issue as it keeps weight away from the front wheel (Appendix 3).

20” Wheel

This wheel size could be best used for load carrying. To avoid clipping heels on the ground during cornering, the riders leg position may need 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 and the developments achieved with a 5:1 range ratio multispeed gearbox with a direct drive low gear are 1.6 to 8m. These developments are more compatible with lower speeds.

7. Efficiency

Planetary gearboxes for cycles are most efficient when transmitting torque at 1:1, that is when the gears are locked and are not changing ratios or producing losses. In gearing systems using both hub gears and chain drive, that 1:1 position can be made to coincide with the most commonly used gear. For example on a Sturmey-Archer 3 speed AW type hub, 2nd gear is locked, does not create internal friction, and can be used for every-day riding on the flat. However in-hub front wheel drive gearboxes have no chain to vary ratios, so the 1:1 ratio will most likely coincide with a very low, rarely used gear. Although there is never chain innefficency, the most efficient gear ratio may be rarely used. Perhaps the best asset of a good in-hub front wheel drive gearbox is its immunity from mud.

8. Conclusion

Wide-ranging, multigear in-hub front wheel drive gearboxes were first proposed 20 years ago and are now reaching production. The gearboxes have variations which can make them part of more conventional cycles, and as front wheel drive cycles have pre-existing proposals for all-weather, aerodynamic and timber cycles in load trike, bike, leaning trike and ebike configurations. The newest gearboxes have every chance of success, however care needs to be taken in design to avoid issues such as heal strike.

Appendix 1: Gear Ratios

Cycles can be more effective when installed with selectable gear ratios. Low gear ratios overcome high resistive forces, ie pedalling uphill, or riding heavily laden or into headwinds. High gear ratios allow high speeds in favorable conditions on the flat, downhill or in tailwinds. Gear systems can be defined by the *development* (distance travelled per pedal revolution in metres) or *inches* (diameter of directly driven wheel producing the same distance travelled per pedal revolution) of their highest and lowest gears, or the development of the lowest gear and the *range ratio* between highest and lowest. Peter Eland (2009, 11) says that some riders get by with a single speed, 200% range is usual for flat urban utility cycling, 300%+ for hills or sporty flat urban cycling, 500%+ for really hilly and demanding terrain, and 700%+ for touring tandems and recumbent trikes. His inch-ranges for a touring bike (21 to 104”) and a commuting bike (40 – 90”) both average out to 62”. Complete equations quantifying forces on cycles and how they can affect speed and gearing are provided in Van De Walle (2004).

Table 3: Gear ratios and pedalling speeds for derailleur geared cycle and Kervelo Lowracer (sourced from Kervelo.com).

Wheel		Pedalling speed		Gearing					Speed	
radius, m	m/rev	rpm	rps	Chainring teeth	Sprocket teeth	Ratio	Development (m)	Inch	m/s	km/h
0.65	2.04	60	1.00	48	48	1.00	2.042	25.6	2.0	7.4
0.65	2.04	80	1.33	48	48	1.00	2.042	25.6	2.7	9.8
0.65	2.04	60	1.00	48	24	2.00	4.084	51.2	4.1	14.7
0.65	2.04	80	1.33	48	24	2.00	4.084	51.2	5.4	19.6
0.65	2.04	60	1.00	48	16	3.00	6.126	76.8	6.1	22.1
0.65	2.04	80	1.33	48	16	3.00	6.126	76.8	8.2	29.4
0.65	2.04	60	1.00	48	12	4.00	8.168	102.4	8.2	29.4
0.65	2.04	80	1.33	48	12	4.00	8.168	102.4	10.9	39.2
0.7	2.20	60	1.00	N/A Kervelo lowracer low gear		0.658	1.447	18.1	1.4	5.2
0.7	2.20	60	1.00	N/A Kervelo lowracer 1:1		1.00	2.199	27.6	2.2	7.9
0.7	2.20	90	1.50	N/A Kervelo lowracer high gear		3.57	7.854	98.4	11.8	42.4

Appendix 2: Heel clearance

Heel clearance on front wheel drive in-hub gearbox bikes and trikes depends on the front wheel size, the pedal radius, and the distance the feet reach below the pedals. The seat angle from the pedals and other factors influence the angle of the feet when they are closest to the ground. A large 700C wheel has a 350mm radius and with 170mm pedals there is only 180mm left to be taken up by underhanging shoes and ground clearance. However as shown below on lowracers, the feet can be a long way from vertical when the heels are closest to the ground.

Figure 12: Lowracer cycles showing the angle of the feet to the ground (Wikimedia Commons)

Appendix 3: Wheel Slip

Front wheel drive bikes may have problems climbing hills due to wheel slip. For example, wheel slip means my chain driven front wheel drive cycle can’t climb long hills with more than 10 degrees slope, see pictures below.

Figure 13: Author’s front wheel drive trike and the bike path slope angle where wheel slip starts.

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