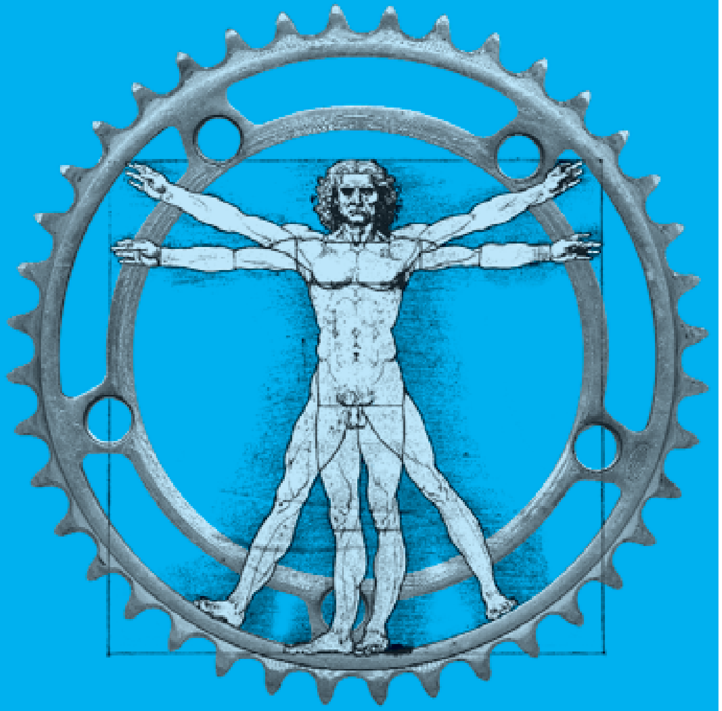

HUMAN POWER

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NUMBER 49, WINTER 1999–2000

Articles

Technical notes

Letters

Editorials

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Editor
David Gordon Wilson
21 Winthrop Street
Winchester, MA 01890-2851 USA
dgwilson@mediaone.net

Associate editors
Toshio Kataoka, Japan
1-7-2-818 Hiranomiya-Machi
Hirano-ku, Osaka-shi, Japan 547-0046
HQI04553@niftyserve.ne.jp

Theodor Schmidt, Europe
Ortbühlweg 44
CH-3612 Steffisburg, Switzerland
tschmidt@mus.ch

Philip Thiel, Watercraft
4720 - 7th Avenue, NE
Seattle, WA 98105 USA

Production
JS Design & JW Stephens

IHPVA
Paul MacCready, Honorary president
Chris Broome, USA, Chair
Ben Wichers Schreur, The Netherlands,
Vice-chair,
Jean Seay, Secretary/treasurer

Publisher
IHPVA
PO Box 1307
San Luis Obispo, CA 93406-1307 USA
Phone: +805-545-9003; hp@ihpva.org

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IN THIS ISSUE

Velocar variations

Arnfried Schmitz has written an account of his experiments with recumbent designs that makes an exciting bridge with the most illustrious people of recumbent history: the Mochets. The range of his designs and his observations on the performance of each will earn your respect.

Generators for bicycle lighting

Frank Krygowski and Don Slanina review these humble devices and show aspects of their performance that your editor, at least, found surprising. For instance, when a generator is driven well beyond its full-output speed, it does not necessarily "waste power." They suggest improvements as a result of their extensive tests.

Direct-drive (chainless) recumbent bicycles

Thomas Kretschmer has become the prophet preaching in the wilderness on the virtues of having a multispeed hub gear integrated with the cranks in the front wheel of recumbent bicycles. His message, given in his comprehensive website, has begun to attract wide attention, and he worked with us to produce an article based on it.

Cycle rickshaws as a sustainable transport system for developing countries

Anil Rajvanshi and his team have developed three improved forms of rickshaw for India and other countries. His economic arguments for the benefits that they could bring are persuasive and striking and, one hopes, will carry weight with governments and entrepreneurs alike.

Is the .deciMach Prize attainable?

Mike Eliasohn uses his formidable newspaper-reporter's skills to interview leaders in the record-breaking field to put together this survey of prospects for the latest speed prize being won soon.

Body shapes and the influence of the wind

Matt Weaver wrote a masterful response to the proposal that the magnitude of the wind did not matter if a HPV were travelling on a circular or closed-loop course. He shows that a fairing can "sail" in even an adverse wind, so that there is a considerable net gain from wind when a faired vehicle competes on a track or velodrome.

Letters

Ian Sims discusses the Rohloff 14-speed hub; Raoul Reiser comments on Danny Too's data; Peter Ross writes on relations with the UCI, the body governing racing of conventional bicycles; Smiley Shields advances some views on the hill-climbing characteristics of recumbent bicycles; and Ray Wijewardene sends greetings, comments and compliments from Sri Lanka.

Editorials

A guest editorial from Theo Schmidt, former IHPVA chair and principal organizer of the world championships in Interlaken, Switzerland in 1999, laments the lack of public interest in our sport. Your editor's topic is related to this: the huge awards and required expenditures on safety-related aspects of automobiles, contrasted with the almost complete lack of interest in apparently more-serious characteristics of bicycles.

—Dave Wilson

CONTRIBUTIONS TO HUMAN POWER

The editor and associate editors (you may choose with whom to correspond) welcome contributions to *Human Power*. They should be of long-term technical interest (notices and reports of meetings, results of races and record attempts and articles in the style of "Building my HPV" should be sent to *HPV News*). Contributions should be understandable by any English-speaker in any part of the world: units should be in S.I. (with local units optional), and the use of local expressions such as "two-by-fours" should be either avoided or explained. Ask the editor for the contributor's guide (available in paper, e-mail and pdf formats). Many contributions are sent out for review by specialists. Alas! We cannot pay for contributions. They are, however, extremely valuable for the growth of the human-power movement. Contributions include papers, articles, reviews and letters. We welcome all types of contributions, from IHPVA members and nonmembers.

VELOCAR VARIATIONS

by Arnfried Schmitz

INTRODUCTION

Velocars were the unusual bikes that set world records in the 1930s. They were banned from regular racing because they were faster than traditional racing bikes. Apart from the 1984 "Moserbike", the 1992 Olympic Boardman bike, and the Graeme Obree machines, no revolutionary bicycle has achieved that distinction.

Charles Mochet, inventor and builder of the Velocar, made only one record-setting bicycle because his only goal was that it be short enough to be within the UCI regulations of the time: the maximum length was set at 2 m. He achieved this by reversing the front fork. I wanted to make a replica, and Charles' son Georges drew a set of blueprints for me. The advantages of the design are evident from the old press photos (figure 1). The rider, who for the 1933 records was Francis Faure, is seated as if in a deck-chair. His head is in a normal position, giving him a good view. His arms are along his body and fall naturally on the handlebars, just above his hips. Therefore his legs have no restrictions to movement and are supported from his back, which in turn is cradled on a long seat and back-rest. He can push higher gears and has lower drag because of the low frontal area [and the fact that his legs are in the front "shadow" of his body —ed.]. The two 20" wheels have lower weight and lower aerodynamic drag than do normal-size wheels. My hobby: building new types of bicycles. Building "future-bikes" often happens without formal designing and calculations. I start with, sometimes, a small concept. Ideas come as tubes are brazed together and the wheels fitted. Giving the chain a free run is often a puzzle. Georges laughs "Your bike-building is an adventure!" I like to experience the development in full realism of my ideas. In eighteen years I have built a lot of bikes, with none turning out exactly as I had expected. I like the building work: it's exciting!

Figure 1. The race Velocar, equipped for the track. All photos, courtesy author.

THE VELOCAR REPLICA

When I build a bike for Georges I try to change something on his blueprints. This always gives trouble, because he is an excellent designer. But for the Velocar replica I followed his drawings strictly. Only the wheels were shrunk to a modern 14" front and 16" rear. This bicycle was for personal test purposes. The steering universal joint came from a Fiat 127 steering column. Lots of water was used during the necessary welding so as not to overheat the bearings (figures 2 and 3). (It was the only component for which Mochet applied for and was given a patent at that time.)

Figure 2. The first Velocar replica. Figure 3. (Inset). The original Velocar (patented) steering joint

A STRETCHED VELOCAR

My son and I wanted to try out the bicycle, but our legs were at least 100-mm too long for comfortable pedalling. So serious testing was not possible, but I had a nice machine to look at. In 1989

Figure 4. Stretched Velocar being demonstrated by Arnfried Schmitz at the Tour de Sol, 1989.

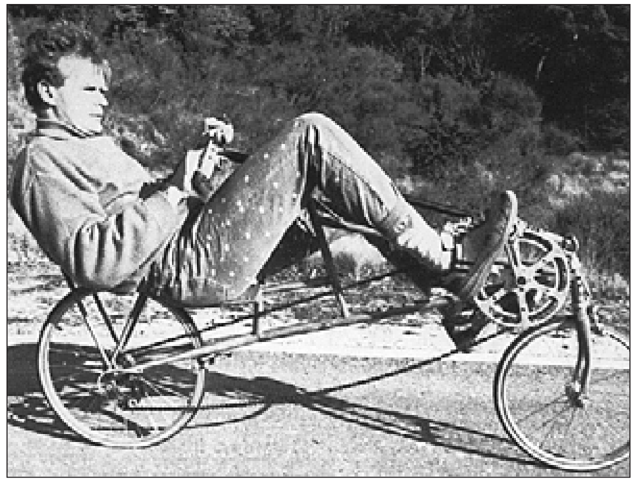


Figure 6. Laurent Chapuis on the direct-drive Velocar replica No. 4

my son wanted to race in Switzerland. We thought that a faired machine would be heavy uphill and would need lots of braking downhill. A Velocar could be the ideal bicycle. On an upright bike one pulls out the seat-post. Here I built a completely new machine with a wheelbase increased by 100 mm (figure 4). This length was added in the middle to preserve good balance. However, the steering was wobbly, coming from all the weight being on the rear wheel. Would the rear tire (a 20" "boy's-racer" tubular) be strong enough? In fact it gave some trouble during the race, because the heat from braking softened the tire glue. Back home I tested the bicycle on the velodrome. With a fixed gear I applied steady pressure on the pedals and may have produced better front-wheel tracking. The universal joint worked perfectly, and the wheels were well aligned. Nevertheless, I couldn't steer to keep on the lines, and I didn't get to feel accustomed to the bike. The bike by itself felt well-balanced, and it could be hung up by one hook at the steering-tube support.

Figure 5. Rear: Velocar no. 3; Front: Velocar no. 4

VELOCAR NO. 3

The third replica (the rear bicycle in figure 5) shows the bottom bracket ahead of the fork to give room for long legs. A 64-tooth chain-wheel and a 9-T Moulton cluster permits a direct chain to be used, i.e., without a step-up intermediate countershaft. The handling was improved. However, the bottom bracket could be further forward.

VELOCAR NO. 4

The last replica (the front bicycle on figure 5 and in figure 6) incorporated Super Vitus tubing, high-end components, an ultra-narrow bottom bracket just in front of the fork, and weighed an excellent 9.5 kg for the road version. Would you like to try it out?

DIRECT STEERER NO. 1

For subsequent bikes I didn't want to use indirect steering: on recumbents the low center of gravity and the small wheels make steering already difficult. I wanted to be able to feel the front-wheel reactions to learn what was really happening there. The resulting bicycle (figure 7) was ridden for two years. Only the Velocar seat remained from the previous design. The head angle was about 55 degrees to make direct steering possible. This was a short-wheelbase (1.1 m.) model, with the bottom bracket far in front of the fork. The 24" rear wheel was a compromise for compact design and high gearing. A wide range was obtained through a three-speed Sturmey-Archer hub in a countershaft between the primary and secondary chains. A wide range was needed between cruising on slight downhills at 60 km/h and climbing at 7–8 km/h, just a little faster than walking. The 16" front wheel had a Sturmey-Archer hub brake to isolate the small tire from the braking heat .

The cow-horn handlebars were not pretty—but they worked, and they allowed free movement of the legs. The arms were close to the body for good aerodynamics. I felt safe on it, and travelled comfortably downhill at 80 km/h (when the road was smooth!) How would I improve it? I would like wider handlebars set 100 mm further back, and a steeper head angle for easier handling.

MONOCOQUE

The next of my machines was a monocoque (figures 8 and 9) made from sheet metal. The head angle was steeper but all the weight seemed to be on the front wheel. The big 28" rear wheel was too far behind the bike. It seemed to pursue it rather than being part of the bike. Worst of all, the taut upper run of the chain passed inside the frame and rattled horribly. This bike was an oddity! Forget it!

MOULTON CONVERSION

A pleasant interlude occurred with my transformation of a Moulton (figure 10). It was very easy to cut the seat tube and to braze it on to the steering tube and then to weld a bottom bracket to the top of the saddlepin. The seat was made from nailed and glued plywood,

Figure 7. Touring frame

adjustable by sliding it on the horizontal tube. The seat-back angle was halfway between upright and laid back (supine), far from ideal. The handlebars gave trouble: the classic head angle put them 200 mm in front of where I wanted them. I solved this problem by using a long stem extension and pretzel-shaped bars. It is a good bike to ride, absolutely stable even at the high angle of the velodrome turns. Suspension should be specified in future bikes!

RECUMBENT TRACK BIKE

For my next bicycle I indulged in months of contemplation, thinking to myself that the track bike has to be the purest bicycle. It is made only for speed, uncompromised by any requirement for brakes, gears, drink bottles, luggage and the like. It is near perfection! I decided to make a track recumbent and to compare the two types. The bike of figure 7 was stripped down and some tubes could also be dispensed with (along with the intermediate drive!) The seat was curved and upholstered with 8-mm foam, but it wasn't as good as the three boards of the Velocar. The bike is shown in figure 11, rear. Now it was quite exciting to change from the recumbent to the crouch position. It was like coming home after many long years. I did only a little track racing 45 years ago, but I felt secure. The large wheels gave a respectable gyroscopic stability, and I could easily follow the track lines, sprint, and draft close to the wheel of a track partner. Nirvana in a track recumbent! The recumbent track bike just described was more comfortable than a traditional track bike and gave the impression of greater speed. Yet I dared not approach the other bicyclists too closely: the steering always felt tricky. Georges Mochet watched me and proposed a different fork, according to rules based only on his experience! The wheels were 20" rear, 18" front, tubulars, and the chainwheel had 53 teeth and the sprocket 13. The resulting bicycle (figure 11, front and figure 12) is like the first track recumbent but with a straight fork. And that was it! It became as easy to steer as an English roadster. This will be the new Velocar! Yet, to become really faster than the track community, I have to think about an efficient fairing!

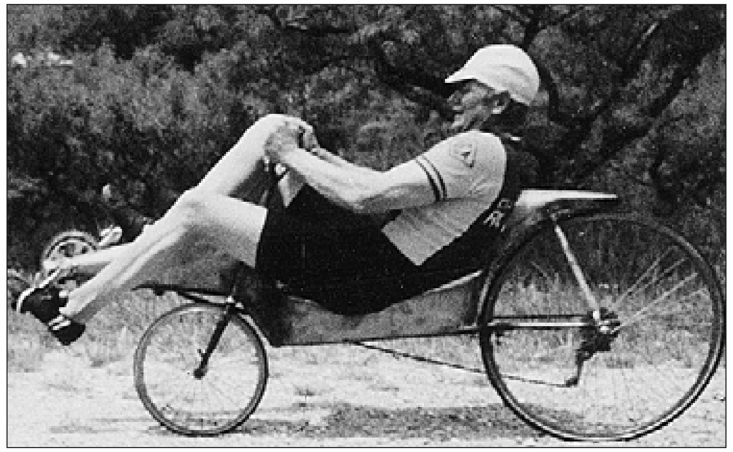


Figure 9. Monocoque on the road

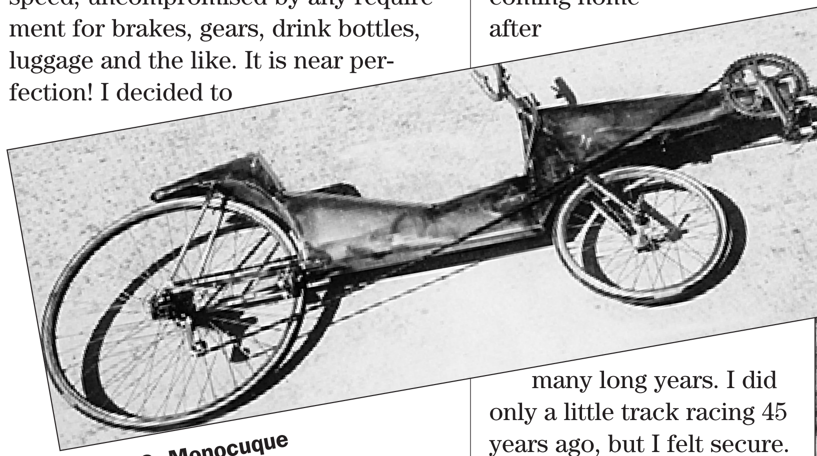


Figure 8. Monocuque

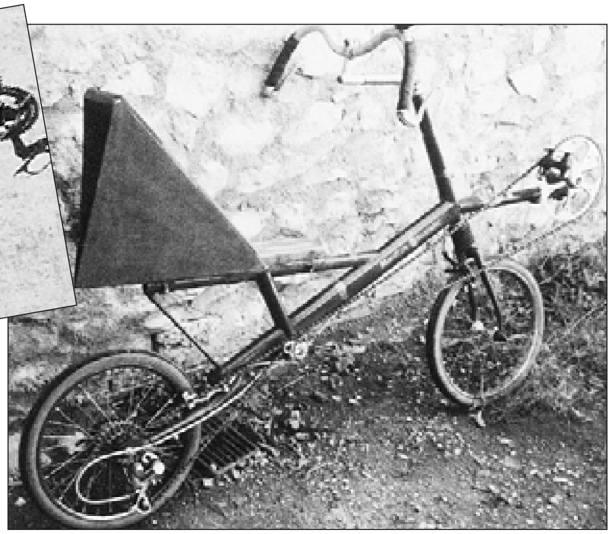


Figure 10. Moulton transformation

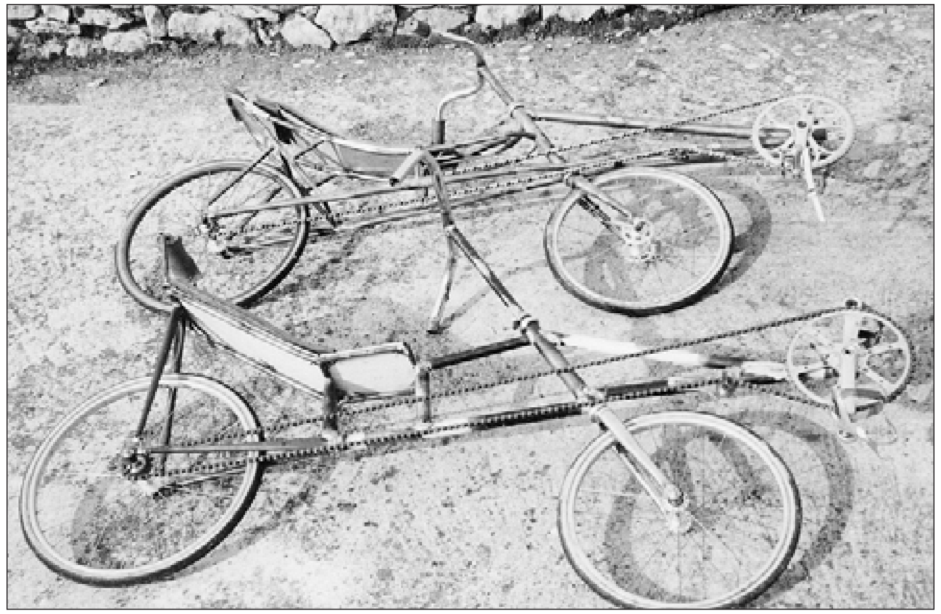
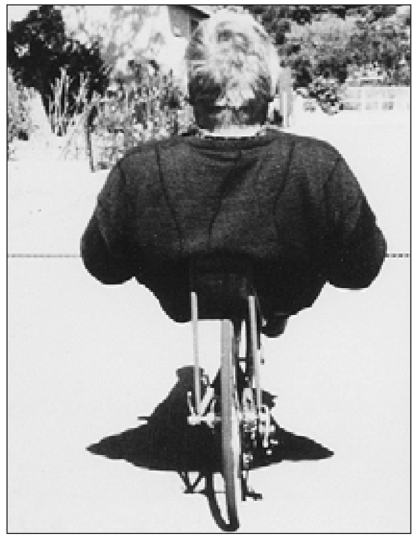


Figure 11. Rear: recumbent track bike; Front: straight-fork track bike

Figure 12. Another view of the straight-fork recumbent track bike

Arnfried Schmitz is known by some of the older HPV generation as "the goatherd from Provence." When he was a young West German he travelled and worked as a shipbuilding student and mechanic in most European countries. This travelling was taken up as a Frenchman for the HPV idea in the 1980s with little success. He had time to think about all this and contacted some of the European "gurus". His partly autobiographical HPV story (1912-1993) will, he hopes, be published in the spring, 2000.

—Arnfried Schmitz
Quartier Gallas
F 84220 Lioux Gordes, France



And so we leave....

LETTERS

ROHLOFF 14-SPEED HUBS

(This letter was posted on the hpv internet mailing list, and is reproduced here with permission from Ian Sims. —Dave Wilson)

I can confirm these hubs are very well presented, in a good box, with a booklet in A5 format, containing 31 pages!

We got the cross-country, aftermarket ones, with a polished-alloy finish. The attention to detail is impressive, with proper oil seals on both sides, a filling and draining hole for the oil, and full "grub"-type sealing on the gear-change cables.

There are several features which I believe are unique with this geared hub.

It is quick-release. Not only does it use a quick-release skewer, but the cables *and* the torque-reaction arm are quick release—just push a button and the long drilled alloy arm releases.

Efficiency: all other hubs I've seen have *plain* bearings for the pinion gears. These gears revolve at higher than wheel speed, with a fairly heavy loading, and thus cause a loss in efficiency. With the Rohloff, the pinions revolve on needle bearings, which should give a considerable reduction in friction. In my opinion this supports the claims of having an efficiency similar to derailleur gears.

Ratios: one of the problems with derailleur gears is you *cannot* get an even arrangement of gearing steps—and you often end up with a lot of useless overlapped gears: e.g., a 21-speed MTB system often has only 11 gears that do not overlap. This hub claims even 13.6% steps between each of the 14 gears. The ratios are, according to the handbook: 0.279, 0.316, 0.36, 0.409, 0.464, 0.528, 0.6, 0.682, 0.774, 0.881, 1, 1.135, 1.292, 1.467.

The twist grip control does have 14 gears marked on it. It has a triangular shape for a good grip, and all the indexing takes place in the hub, so there should be no need for frequent cable adjustment.

The hub comes with a 16-T cog, but

please turn to page 26

GENERATORS FOR BICYCLE LIGHTING

Frank Krygowski and Don Slanina

A review of fundamental principles of operation of bicycle generators, illustrated by results of tests of two representative generators, with comments on possible improvements in the technology.

BASIC PRINCIPLES

The use of generators or dynamos for bicycle lighting is somewhat out of fashion in the United States; however, in other countries they are quite popular for several reasons. With a generator there is no need to tend an expensive rechargeable battery carefully, or to incur the expense of disposable batteries. The light is always ready, like the headlights on an automobile. There is no time limit imposed by the limited capacity of a battery.

But generators have shortcomings. For example, limited power is available for lighting. While large rechargeable batteries may deliver 10 to 30 watts to headlights, typical generators are rated at just three watts output. Also, generators draw their power from the rider. While this has a certain appeal on environmental grounds it means that the ride is more difficult. Those who pay for $20 titanium bolts are unlikely to accept the modest performance penalty of a generator.

This article will address the operating principles of typical generators, and briefly discuss possibilities for overcoming their shortcomings. Data resulting from tests of two typical generators will be used to illustrate these principles and possibilities.

Electrical principles

A bicycle generator is a simple device, yet its operation is surprisingly sophisticated—much like the bicycle itself.

To begin, there is a semantic difficulty. Although technically the term "generator" means any mechanical device which produces electric current, many people use the term "alternator" when alternating current is produced, and mistakenly assume that bicycle generators produce direct current. Bicycle generators actually produce alternating current, and this causes considerable misunderstanding of these devices, which is compounded by the relative complexity of AC electrical theory. (British cyclists often refer to these units as "dynamos", which is merely a synonym for generator.)

The alternating current output is desirable for two reasons: first, it is simpler to produce, and second, it allows a simple and elegant method of voltage regulation—although this voltage regulation relies on principles that may be unfamiliar.

Generator source voltage is produced in accord with Faraday's Law, which states that when a moving magnetic field passes over a conductor, a voltage is produced which is proportional to the velocity of the motion. Bicycle generators use the wheel to rotate magnets in the presence of wire coils. As the bicycle's speed increases, then, so does the source voltage.

But incandescent lamps are quite sensitive to voltage. Voltage proportional to bicycle speed would cause insufficient light at low speeds and would blow bulbs at high speeds. Fortunately, a simple means of regulation is at hand. When the magnetic pole passing the coil changes from north to south, current reverses direction, so alternating current is produced. The frequency of this alternating current is proportional to the rotational speed of the generator, and therefore to road speed. This produces an effect which counters the rising voltage.

The alternating current causes the generator's coils of wire to impede the same electricity they generate. The coils have resistance (that is, the tendency to impede the flow of all electricity) but they also possess inductance. Inductance opposes *changes* in current, thus opposing the flow of alternating-current electricity. This opposition is termed *inductive reactance.*

Inductive reactance, calculated by $X_L = 2\pi f_L$, is proportional to frequency (f), and thus to bicycle speed. Thus, the same increase in speed which produces more source voltage produces more inductive reactance. With proper design, these effects can be balanced to attain reasonably constant current and voltage over a wide range of speeds. It is this effect which provides voltage regulation for most bicycle generators. It is important to realize that this regulation is not equivalent to "wasting" power: it causes no loss in efficiency.

The generator and lighting circuit can therefore be modeled as a variable-frequency sinusoidal AC voltage source, with both source voltage and frequency proportional to road speed. In series with this source voltage are the inductance of the generator's internal coils and the coils' resistance. While this simple model ignores such details as hysteresis in the magnetic circuit and eddy-current losses, it can serve as a basis for understanding the generator system's behavior.

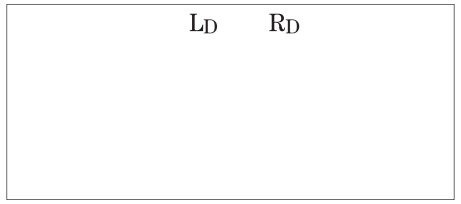


Figure 1. Circuit model of a bicycle generator.

Using this circuit as a model, voltage at the load can be calculated. Inductive reactance X_L (which is the impedance to alternating electrical current caused by inductance) is given by:

$$X_L = 2\pi f L_D$$

where f is the frequency of the alternating current and L_D is the internal inductance of the generator. The total impedance due to the external load R_L, the generator's internal resistance R_D, and X_L is given by:

$$Z_{TOT} = \sqrt{(R_D + R_L)^2 + X_L^2}$$

Defining the constant of proportionality between source voltage and frequency K_V (measured in Volts/Hz), and the constant of proportionality K_f between frequency and road speed (in Hz/kph or similar units), Ohm's law can be used to calculate the circuit current, then the voltage over the load. The resulting expression is:

where S is road speed, in appropriate units. Examination of this equation indicates that V_L increases rather quickly at low speeds, but the increase is much less at higher speeds due to the effect of the inductance.

Unfortunately, the voltage regulation achieved in this manner is not always sufficient. In particular, halogen bulbs (which have higher efficiencies, in terms of lumens per watt) require closer regulation than standard incandescent bulbs. One simple means of providing improved regulation is the fitting of back-to-back Zener diodes in parallel with the load, as shown in figure 2. Zeners conduct in their reverse direction only above V_Z, their designed breakdown voltage. In conjunction with a series resistor (or the resistance of the coils themselves) these provide cheap and effective improvement in voltage regulation.

Figure 2. Control using back-to-back Zener diodes

Note that Zeners respond to instantaneous voltage, and tend to clip the peak of the voltage waveform. Incandescent lights respond to RMS voltage (the effective value of the sinusoidal waveform), which means a 6-volt bulb will *not* use 6-volt Zeners for protection. Inductive effects complicate the calculation of optimum Zener voltage, and these calculations are beyond the scope of this article; but Zener voltages of roughly 8 volts are typically optimum for a 6-volt bicycle generator system.

A well-designed generator, then, will produce a sufficient voltage at even low speeds to light an incandescent bulb. Ideally, at high speeds, the voltage will remain essentially constant, thus protecting bulb life. If necessary, Zener diodes can be fitted to improve voltage regulation and bulb life.

Mechanical design

There are several common designs of generators. The most common is known as the "sidewall" or "bottle" generator, since its drive roller contacts the sidewall of the tire, and the unit is shaped like a bottle with a thin neck. These mount to a chainstay or fork blade alongside the tire. Another design is known as the "bottom bracket" or "roller" generator. These rotate in the same plane as the tire, are driven by the tread area of the tire, and mount below the bottom bracket, in front of the rear tire. A third design, least common, is built into a special wheel hub which replaces a standard hub.

Each variety has advantages and disadvantages. Bottle generators are simple and inexpensive, and typically mount high on the bicycle, away from the road's mud and water. They are less prone than roller generators to slip in wet conditions, since sidewalls carry less water than the tread area. However, wear of thin tire sidewalls is sometimes a problem. Proper alignment (to minimize friction losses) may be more difficult. Noise level is generally higher.

Roller generators may have less friction loss at the area of contact, since the direction of rotation is parallel with the driving wheel. They have a reputation for slipping due to rain, snow or mud. Their low central mounting makes them resistant to accidental damage, but makes them less convenient to reach for turning on and off.

Hub generators, which replace the standard front wheel hub, are reported to have highest efficiencies, are immune to slip and drive friction, and are best protected from the elements. Gearless hub units suffer no more mechanical friction than standard hubs, and there is little weight penalty compared to a standard hub and separate generator. However, a hub generator's first cost far exceeds those of other designs, and there is additional expense of building a new wheel around the hub. (One hybrid design features a removable generator which mounts essentially concentric with an existing front hub, and is driven by the existing wheel's spokes.)

TESTING

To better understand the performance of generators, tests were performed to measure the power input and power output as a function of speed for two representative designs. Resistive loads of 6, 12, 18 and 24 ohms were used to investigate the effect of resistance on power output and efficiency. (Note that standard load resistance for these units is 12 ohms. At the nominal output of 6 volts, this gives 3 watts power output. Typically, 2.4 watts goes to a 15-ohm headlamp, with the remainder going to a 60-ohm taillamp in parallel.) Power output was determined by multiplying the voltage and current as measured using true-RMS ammeters and voltmeters. (Since the loads were resistive, current and voltage were in phase.)

Power input was a more difficult measurement. To accomplish this, the generators were mounted in trunnion frames which allowed the body of the generator to pivot on ball bearings concentric with the generator axis of rotation. The assemblies were mounted on a standard bicycle frame mounted on a workstand, allowing the generators to be driven in the usual manner, but care was taken that the axes of rotation were horizontal. The cranks were turned by hand, with speed measured by a standard electronic cyclometer. (Speeds were originally recorded in miles per hour, but have been converted to meters per second for this article.)

The trunnion frames carried a lever arm which contacted a digital scale. Once the static force on the scale was subtracted, the downward force measured by the scale multiplied by the arm's effective length indicated the reaction torque necessary to keep the generator body stationary. This was taken to be equal to the input torque applied to the generator. This torque, when multiplied by the generator rpm, allowed calculation of input power.

Unfortunately, this technique for measuring input power does not measure one type of loss in the system, namely the power required to overcome hysteresis losses in the tire's contact with the generator's roller. Thus, this article does not address whether such hysteresis loss is a significant source of drag on the moving bicycle, nor include such losses in calculations of generator efficiency. Juden's article[2] describes the use of computer data acquisition to determine generator drag from the deceleration of a flywheel—a technique that would correctly measure all drag sources, but at considerably greater expense. While a direct comparison is not possible, the efficiency results shown here are comparable to those of Juden's article.

RESULTS

Measured current output, voltage output, calculated power output and calculated efficiencies are summarized in the figures 3 through 6 for two generators: a Union bottle generator and a Soubitez roller generator (see figures 3 and 4).

Generators operate by entirely different rules than batteries. A battery is essentially a constant-voltage device whose current output is inversely proportional to resistive load. But for generators, increases in resistance caused only minor changes in current flow. Thus, generators are more nearly *constant-current devices*.

Ideally, output voltage would rise to nominal voltage at a low walking speed and never vary at higher speeds. In practice, the mechanism of regulating voltage using inherent inductance is less perfect.

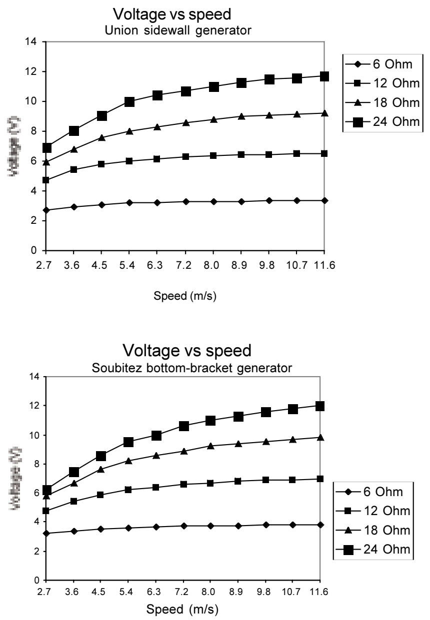


Figure 4. Voltage vs. speed for two generators

With the standard 12-ohm load, voltage regulation was quite good with these generators. Adding resistance has a counterintuitive effect. With higher resistance, output voltage increases. (With an open circuit, essentially infinite resistance, voltage can exceed 30 volts; see figure 5.)

The effect of the load's electrical resistance on generator output power is striking, (figure 5). Because the current (I) is approximately constant, and because power can be calulated by $P = I^2 \times R$, an increase in load resistance R produces an *increase* in both voltage and power output—at least, once high enough speeds are reached. This counterintuitive effect indicates that fitting of *a higher resistance bulb will allow a larger power output* from a generator, provided the bulb is a good match in terms of voltage and current.

Efficiencies varied between the two models, with the roller generator being the more efficient (figure 6). For the standard 12-ohm load, measured efficiency at 5.4 m/s (12 mph, 19 kph) was 29% for the bottle generator, versus 42% for the roller model. Efficiency tended to decrease with speed. Again, these efficiency calculations do not include hysteresis losses at the contact point with the tire.

POSSIBILITIES

Unfortunately, generators using present technology are unlikely ever to match the light output of a high-end battery light. A battery light producing 10 watts is, by current standards, only moderately bright (although the authors judge it more than sufficient for practical road riding). But to produce 10

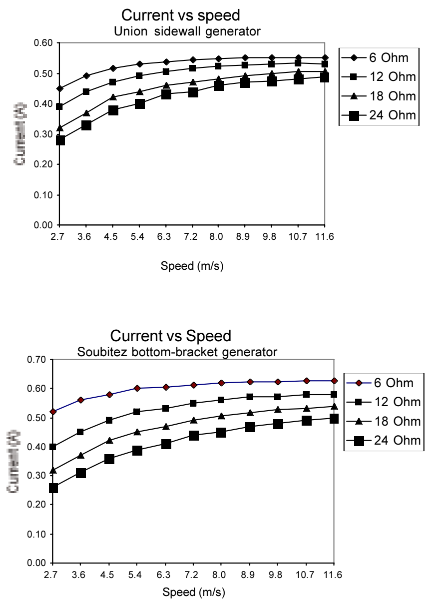


Figure 3. Current vs. speed for two generators.

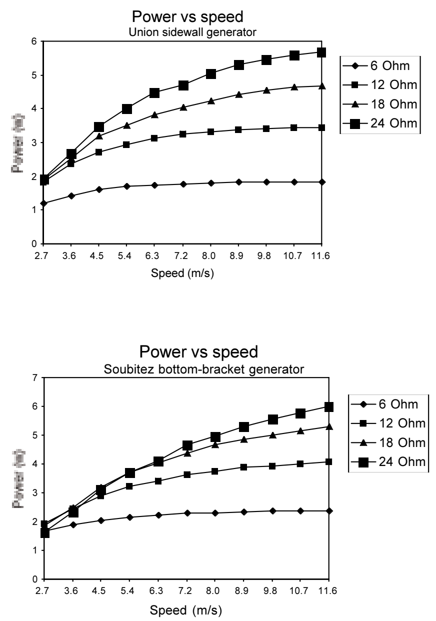


Figure 5. Power output vs. speed for two generators

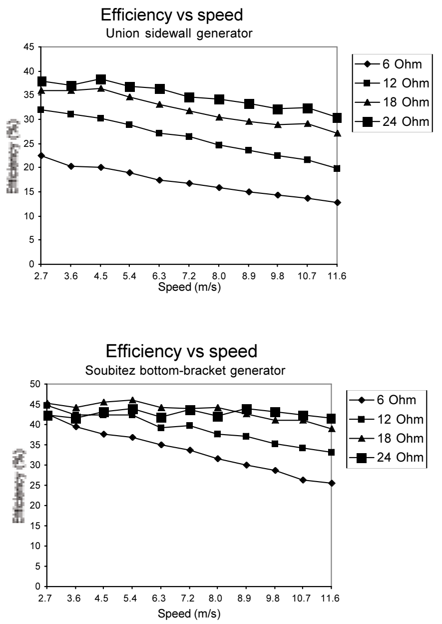


Figure 6. Efficiencies vs. speed for two generators

watts output from even a 50%-efficient generator, an input of 20 watts is required from the rider. Given that only 50 watts input is required to pedal a bicycle at 5.4 m/s (12 mph,19 kph),[4] it is unlikely that many riders would be willing to pay this cost in power.

Nonetheless, a reduction in the effort needed to drive the generator can be achieved by choice of a generator with higher efficiency. Efficiency figures for commercial generators are rather difficult to find, but Juden's article[2] gives efficiencies for 15 presently available models.

Imperfect efficiencies are *not* a result of the built-in voltage regulation caused by the inductance. This mechanism does not regulate output by "wasting" power. If that were the case, efficiency would fall off with speed much faster than was measured above, and generator bodies would become hot through the waste heat generated. Efficiency losses occur instead because of effects such as friction losses at the tire contact point; internal mechanical friction; eddy-current losses in the internal metal of the generator; windage losses inside the generator; and to a small degree, by resistive losses in the windings. Techniques which reduce any of those losses hold promise. Gearless hub generators, such as the "Schmidt's Original"[3] greatly reduce or eliminate several of these losses, and give efficiencies as high as 60%.

Since the ultimate objective is light, rather than mere electrical power, lamps must be chosen with high efficiencies. With present technology, this means choosing halogen bulbs over standard incandescent bulbs (and protecting them from over voltage, which they tolerate poorly). Also, careful attention should be given to headlamp optics. The lower power output of generator lights *vs.* heavy battery lights mandates that the generator's light be directed exactly where needed.

Increasing power output—for more light at a given speed—can be achieved with presently available generators by running higher-resistance bulbs. For proper performance, the bulb's current rating must match the generator's current output. (Bulb ratings normally mention voltage and current rather than resistance and power, but these are easily determined by Ohm's law, $R = E/I$, and by $P = E\times I$.) Unfortunately, while standardization makes many 15-ohm bulbs available (6 volt, 0.4 amp, 2.4 watt) it is difficult to find higher-resistance halogen bulbs with the same current rating.

Since current output of a generator is nearly constant, the simplest method of increasing the resistance of the load is to place more bulbs in series. Two standard bicycle-generator headlight bulbs, when placed in series, can be driven by one generator at essentially full brightness. This arrangement allows nearly twice the power to be put into front lighting. Unfortunately, there are two shortcomings. The fundamental one is that the increased power comes from the rider's effort. The second shortcoming is that at low speeds, the generator's output voltage is insufficient to light both bulbs.

A solution which has been used is a circuit shown in figure 7. The bulbs are placed in series, with a switch shunting the second bulb. With the switch closed, only one bulb is in the circuit, so light output is identical to a standard setup. When sufficient speed is reached (so the generator is capable of sufficient voltage) the switch is opened, placing the second bulb in the circuit. Each bulb can be individually protected by Zener diodes. The principle could be extended to multiple bulbs and automatic electronic switching, with manual override.

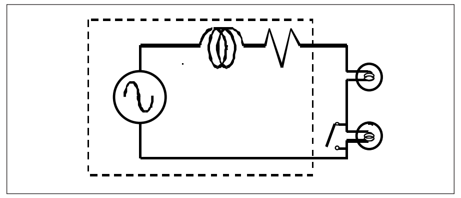


Figure 7. Control through use of two bulbs in series

The authors also ran tests of generators with series capacitors to improve the power factor of the system, chosen for maximum power transfer at 5.4 m/s (12 mph). While power output was increased, efficiency slightly decreased—a finding which is consistent with increased internal resistive losses. Because this technique did not seem promising, the results are not presented in detail here.

Systems have been built which use bridge rectifying circuits to rectify the alternating-current output of a generator and use it to charge an appropriate battery. While there are likely penalties in efficiency and complexity, such a system has the advantage of providing light while the bicycle is stationary.

It may be that the recently developed metal-halide bicycle headlights will ultimately be powered by bicycle generators. Metal-halide lamps are roughly four times as efficient (in lumens per watt) as halogen lamps, and theoretically provide the possibility of either greatly increased light or greatly reduced drag. Unfortunately, these lamps are at present very expensive: the only model currently on the market costs several hundred dollars.

Finally, it is worth remembering that even with their present technology, generators are perfectly acceptable to millions of cyclists around the world. At moderate cost, they provide a light adequate for seeing, for being seen, and for meeting the legal requirements of any political jurisdiction. No nighttime cyclist should ever be without a headlight, and generators remain practical means of powering bicycle headlights.

The authors wish to thank Wilfried Schmidt and Jim Papadopoulos for their assistance with this article

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see next page

DIRECT-DRIVE (CHAINLESS) RECUMBENT BICYCLES

by Thomas Kretschmer

This was taken and freely edited, with permission, from Thomas Kretschmer's web site http://www.ginko.de/user/thomaskretschmer/website.htm (enthusiastically brought to my attention by John Stegmann) by Dave Wilson.

It would be delightful if there were a bicycle that had no cogs and chain-rings to wear out; that wouldn't dirty your pants even without a chain guard; that didn't require you to unthread the chain just to repair a tire; that didn't have a chain making noise due to elongation and dirt; and that had an always-clean and service-free drive.

All these features would be given if the crank spindle were inside the hub! We call this the direct-drive solution.

HISTORY

The first rotary pedalled bicycles (in the 1860s) had the crank spindle integrated into the front hub. The gearing was very low: to overcome this problem the front wheel was increased in size to the maximum degree possible (limited by leg length) giving the "ordinary" or "high-wheeler". Bicycling became correspondingly precarious because: (1) the saddle was extremely high, and (2) the cyclist had to sit nearly vertically above the contact point of the front wheel and the ground.

Hard braking frequently caused the rider to be thrown forward, usually trapped by the handlebars, and, therefore, hitting the ground all-too-often with his head.

Inventors tried to produce safer bicycles in different ways. One approach was to develop transmissions such as planetary gears, allowing the use of a smaller front wheel. One could still be thrown over the handlebars, but the fall was from a lower height. The second principal approach was that of the 'safety bicycle' with its diamond-frame geometry and a chain drive between a separate crank spindle and the rear hub.

Reduced saddle height and a seating position much further to the rear in comparison to the ordinary were the advantages which caused the triumphant success of this bike concept, while the relatively primitive stage of technical development of planetary gears prevented the further evolution of the other.

Table 1. Comparison between geometry of each bike

attribute	traditional bike	direct drive bike
Height of saddle	depends on hgt. of rider	approx. 65 cm
Wheel base	95–110 cm	120 cm
Steering angle	65–75 degrees	45 degrees
Rake	4–7 cm	2–3 cm

Most recumbent bicycles from the 1890s onwards were influenced by safety bicycles in that they used chains and rear-wheel drive. Front-wheel drive is used today on only very few bicycles, such as the Flevo-bike and the Staiger airbike.

The first multiple-speed hubs had already been patented at the end of the 19th century. In spite of the more complex construction they achieved popularity some decades earlier than chain derailleurs. Not until the last decade of the twentieth century have multiple-speed hubs make up lost ground on chain gearing: Sachs came out with the 'Elan' 12-speed hub in 1997; the German company Rohloff followed with a 14-speed hub; and in 1999 the company Biria proposed to develop and market a hub with a continuously-variable transmission.

THE DIRECT-DRIVE BIKE

The advanced stage of development of hub transmissions and the development of new bicycle configurations make it possible to return to the historically primary path of bicycle construction: the chainless bicycle drive with the crank spindle in the hub. The result is: a bike without a chain; with a low and rearward center of gravity; and with a multiple-speed hub having a wide transmission range and fine gear increments.

Such a bicycle changes accepted concepts: the steering angle, the wheel base and the rake are in contradiction to everyday experience. In table 1 and figure 1 you can see a comparison between the modern direct-drive bicycle on which I have been working (and for which I have filed patents) and conventional diamond-frame bicycles.

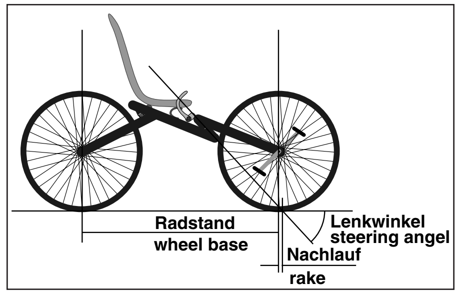

Figure 1. Comparison of geometry of both bikes.

WHY HAVE ALL THE ACCEPTED PROPORTIONS OF BICYCLES BEEN THROWN OVERBOARD?

The flat steering angle is optimized not for steering but for pedalling. While the rear wheel of a normal bike is used for traction and the front for steering, the rear wheel of a direct-drive bike has hardly anything to do but roll. The front wheel takes over both steering and driving. Nevertheless you can ride it no-hands! As the direction of force while pedalling a direct-drive bicycle is nearly parallel to the steering axis, pedalling

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continued from page

AUTHORS

Frank Krygowski is the coordinator of Mechanical Engineering Technology; Don Slanina is the coordinator of Electrical Engineering Technology at Youngstown State University in Youngstown, Ohio. Both have MS degrees in Engineering from YSU, both are registered professional engineers, and both are lifelong cyclists.*

—Frank Krygowksi
School of Technology
Youngstown State University
Youngstown, Ohio 44555 USA
frkrygow@cc.ysu.edu

**Author for correspondence*

Table 2. Advantages of the direct-drive bike compared to other bicycles*

Other	Advantages (of direct-drive)
N	less wind resistance due to less area
L,S,F,N	less frictional loss without chain
N	fairings can easily be mounted
N	seating posture more relaxed; less strain on the spine
N	wrists, abdominal and pectoral muscles more relaxed
L, S	can be ridden no-hands
F, S	short learning period
S	crankset does not swerve while cornering
L,S,N	easy integration of rear suspension with no chain
N	feet can be placed on the ground without leaving saddle when stopped
S,F	with the low crank set, feet can be more easily put on the ground when stopping
N	tipping sideways can easily be caught by extending a leg
N,S	impossible to topple over the handlebars
L,F,S	both front and rear wheels can be 26", 27" or 28", lowering rolling resistance
L,S	fewer different-size parts (rim, tube, tire, spokes) with same-size wheels
L	a short wheel base of 1.2m gives compactness and light, responsive operation
L	short wheel base allows easy transportation in bicycle compartment on trains
L,S,F,N	folding rear wheel, bike is more readily transported and stored
L,S,F,N	no greasy stains caused by chains during transport and handling
L,S,F	good channeling of force, no torsion, light frame
L,S,F,N	less wear, maintenance and lower weight (chain, cogs, rings)
L,S,F,N	aesthetic motivations can dominate design as there are fewer technical components to be considered.

***Key**

F = recumbent bike with front-wheel drive (FWD), using a chain;
L = long-wheelbase (LWB) recumbent (with crank spindle behind the front-wheel axle);
N = normal upright bike (rear-wheel drive; rider sitting on saddle with high center of gravity);
S = short-wheelbase (SWB) recumbent (with axle of the front wheel between the crank spindle and the rear wheel

will have virtually no influence on steering—only forces perpendicular to the axis and at once offset laterally can affect steering. To make the steering motion similar to that of normal bikes, we have included a spring between the frame and the fork that compensates for the small steering angle.

The short rake compensates for the longer wheel base and small steering angle, so that inertial forces in steering are similar to those on a normal bike.

ADVANTAGES

Table 2 shows the advantages of the direct-drive bicycle over some popular alternatives (see abbreviations key at the bottom of the table).

SHIFT ELEVEN GEARS USING THREE PLANETARY TRANSMISSIONS!

Three planetary transmissions are coupled for the direct-drive bike. They differ by the size of the planetary gears, the sun gears and the annulus gears. The sizes of these cogs are correlated in such a way that the planetary cogs of the three stages sit on one and the same shaft, i.e., there are four such shafts, each of which skewer one planetary cog of each stage.

In order to increase the number of possible gears, these cogs are rigidly attached to the shaft, meaning that all of the planetary gears are always revolving with identical angular velocities. Shifting gears involves the selection of one of the three sun gears to be engaged to the front wheel, while the other two sun gears revolve freely. In the same fashion, only one of the three annulus gears is held rigid, while the other two are allowed to revolve freely.

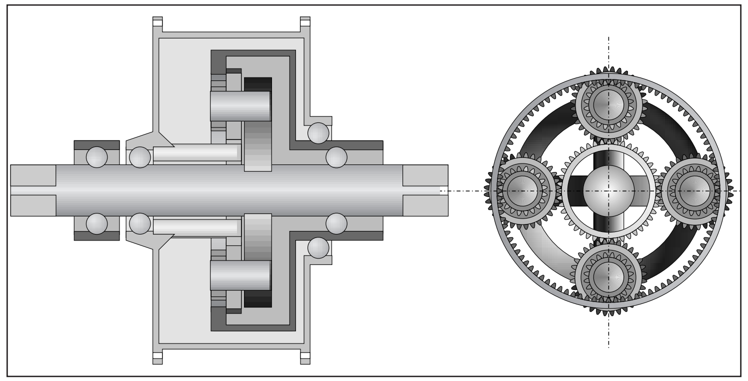

Figure 2. Cross section of transmission hub.

The planetary gear carrier is driven by the cranks. The annulus wheel engages the small planetary cogs, which revolve at higher speed. Since these revolve at the same angular speed as the larger planetary gears with the greater circumference, the tangential velocity of the larger cogs is higher and they therefore drive the sun gear faster than could the smaller cogs. Thus we have a higher transmission ratio at our disposal. The other gears which are disengaged have been left out for clarity.

CONNECTED PLANETARY GEARS IN THE DIRECT-DRIVE HUB

Even the simple construction shown allows $1+3^2 = 10$ gears as a result of the combinatorial possibilities between annulus and sun gears as illustrated in table 3.

Table 3: Combinations of sun gears and annulus gears

gear	rigid annulus gear	engaged sun gear
1	small	large
2	small	middle
3	small	small
4	middle	large
5	middle	middle
6	middle	small
7	large	large
8	large	middle
9	large	small
10*	none	none

* in 10th gear, the front wheel is directly engaged with the planetary-gear carrier and therefore revolves at the same rate as the cranks, i.e., in a 1:1 ratio.

In calculating the transmission it will be noticed that the high speeds are finely incremented up to the sudden jump from a 2:1 to the 1:1 ratio. Of course this is not acceptable for an all-purpose bicycle. Lower transmission subdivisions are required for riding in headwind or climbing. For this the principle described above is reversed: instead of an annulus gear being held fast and a sun gear engaging the front wheel, shifting into a low gear connects an annulus to the hub while freezing a sun gear. Theoretically this results in nine further gears.

Table 4: Supplementary speeds by driving annulus gears and freezing a sun cog

gear	engaged annular gear	rigid sun gear
11	small	large
12	small	middle
13	small	small
14	middle	large
15	middle	middle
16	middle	small
17	large	large
18	large	middle
19	Large	small

Unfortunately the resulting increments are too small for practical purposes, and it is necessary to leave out some of the gears while shifting in order to approximate the ideal characteristic curve having equal percentage increments. Eleven gears remain. This suffices for any walk of life, and is definitely superior to a 21-speed chain-drive transmission because ratio overlapping is eliminated and the increments are uniform.

MANIFESTATION OF THE HUB

For the user, shifting should be as easy as possible. The shifting process in the hub itself is rather complex: sometimes annulus gears are shifted, sometimes sun gears, sometimes a sun gear is engaged, sometimes an annulus. In order to realize all of these procedures with a single cable, a cam disk programmed to “know” the order of the gears is integrated in the hub, eliminating overlapping and ignoring superfluous speeds. In this manner 11 of the 19 gears are used and the otherwise necessary back-and-forth operation of different levers is transformed into a uniform motion of a single cable.

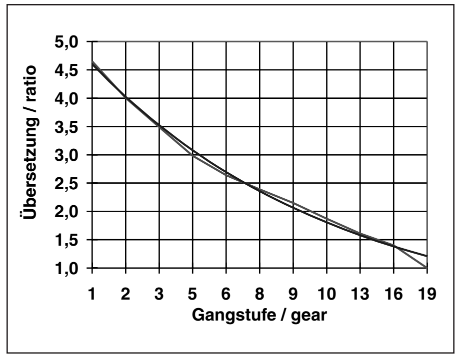

Figure 3. Transmission flow, an example of an optimized direct-drive hub

TRANSMISSION FLOW, AN EXAMPLE OF AN OPTIMIZED DIRECT-DRIVE HUB

The diagram shows how fine the increments can be. The steps correspond almost exactly to the ideal characteristic curve. The ideal curve is the case of uniform percentage increments between neighboring gears.

CONCEPT OF THE COMPLETE HUB

The hub is attached to the front fork via flanges. The crank spindle is coupled to the planetary-gear carrier. In every gear, the planetary-gear carrier is propelled by the crank spindle. The planetary-gear carrier holds the planetary-gear shafts on bearings; of the four planetary-gear shafts, only one is shown. The rear part of the planetary-gear carrier supporting the opposite end of the planetary-gear shafts is attached to the front part in the spaces between the shafts. The three cogs of each set of planetary gears are rigidly held onto their shaft. They mesh on the inside with the three sun gears and on the outside with the three annulus gears. Two of each of these rotate freely while one of each is engaged. The engaged sun and annulus gear each mesh with a selector switch that selects the corresponding gear for engagement. Shifting is performed by sliding the selector switches into position via pins. These pins are stationary relative to the axle around which the switches rotate.

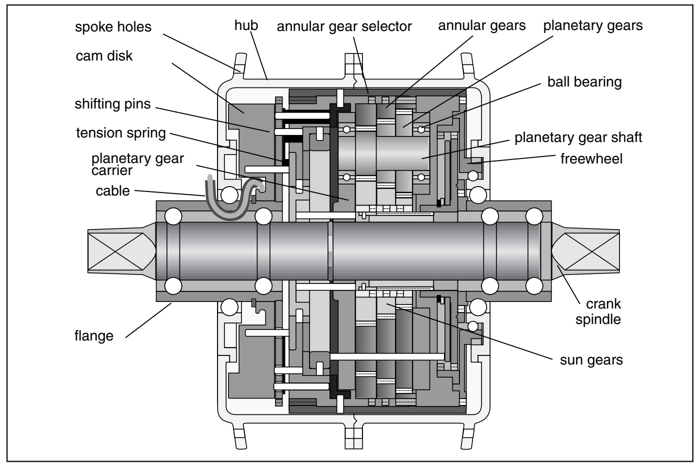

Figure 4. Manifestation of the hub.

Furthermore, the ‘sun-gear rigid/rotate’ toggle switch determines whether the selected sun gear is coupled to the revolving wheel and the selected annulus to the rigid flange or vice versa. The 1-to-1 transmission is obtained when both sun and annulus gears are connected with the front wheel. All gears are selectable by way of horizontally shifting pins. A cam disc rotating around the crank spindle controls the shifting pins.

By turning the cam disk into position by a cable, the shifting pins slide into pits of varying depth in the cam disk. The arrangement of these cams determine the order of gear engagement, particularly ignoring superfluous speeds, as the control cable is pulled. We refer to the sun and annulus gear-selector switches and toggle switches as ‘shifting elements’. There are three shifting pins arranged around the circumference of each of these shifting elements. They are placed at slightly different diameters in order to accommodate free use of the cam disk’s rotational area.

The width of the hub is 80 mm; pitch diameter of the spoke holes, 107 mm.

A comparison of relative tooth stresses

It can be shown by comparative calculations that the direct-drive hub can be sturdier than a conventional hub transmission systems using the same gear width.

The following illustration shows the forces on a tooth.

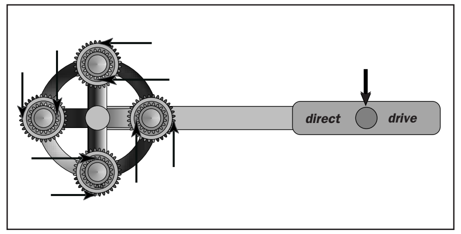

Figure 5. Forces on a tooth

Table 5 compares the forces in a direct-drive hub to those in a conventional three-speed hub. The finding: the

Table 5. Computation of forces for the direct-drive hub.

Computation of forces for the *direct drive hub*

Assumed force on pedal	2000	N	corresp. 200 kg
Crank length	170	mm	standard
Diameter planet gear carrier	**57.4**	**mm**	optimized
Number of planets	4		optimized
Force on planet shaft	2 962	N	
Diameter small planet gear	14.7	mm	optimized
Diameter large planet gear	24.5	mm	optimized
If only one tooth per planet gear interlocks at once, the load each tooth carries is:			The worst case is the combination of smallest planet with largest sun gear or vice versa, all other combinations result in lower forces per tooth.
large planet gear:	1 111	N	
small planet gear	1 851	N	

Comparison to conventional hub

Assumed force on pedal	2 000	N	as above
Length of crank	170	mm	
Ratio chainring/cog	2.47	-	corresponds to a cog of 17, chainring with 42 teeth
Diameter of annular gear	38	mm	measurement of a 3-speed hub by renownd mfg.
Number of planets	3	-	standard for multispeed hubs
If only one tooth per planet gear interlocks at once, the load each tooth carries is	2 414	N	Worst case: annular gear-driven

Calculation

F_P: force on each planet gear shaft
L : length of pedals
F_T: force on pedal
D_P: diameter of planet gear carrier up to center of planet gear shaft
n: number of planet gear shafts

F_K: force on small planet gear
F_D: force on large planet gear
D_K: diameter of small planet gear
D_G: diameter of large planet gear

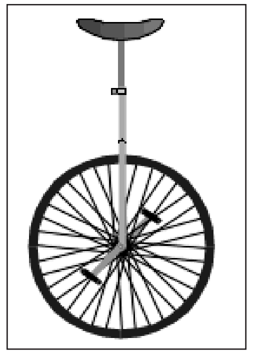

Figure 11. Unicycle with transmission surely won't need all those gears, but after a slight modification of the hub, the unicyclist enjoys higher speed.

load on a tooth of the direct-drive hub is 23% lower!

ONE DIRECT-DRIVE HUB: MANY BICYCLES.

A whole new spectrum of bicycles emerges with the coming of the direct-drive hub. Use of the hub is thus not limited to chainless recumbents. The following pictures show possible variations with further specific advantages.

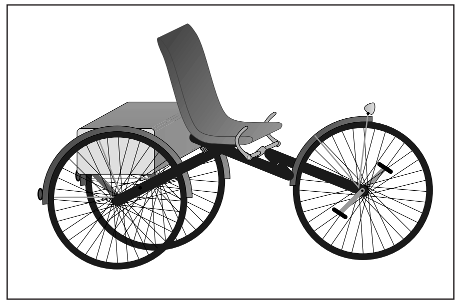

Figure 6. Recumbent tricycle: with direct drive this trike neither requires a differential nor is it driven on just one side.

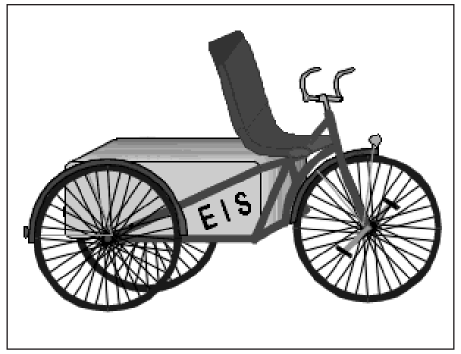

Figure 7. Cargo Bike: Don't be working on a chain gang!

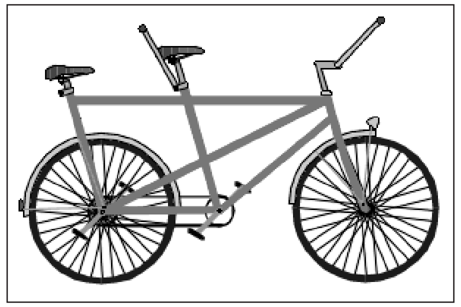

Figure 8. Tandem: Not much longer than a 'normal' bike

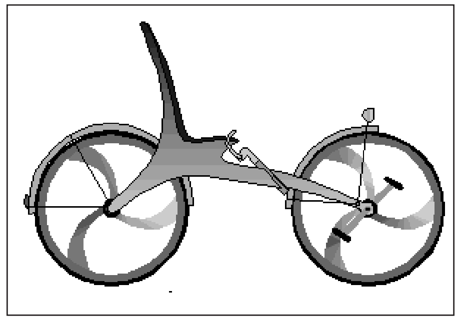

Figure 9. Recumbent, carbon: This form won't be "laid in chains"!

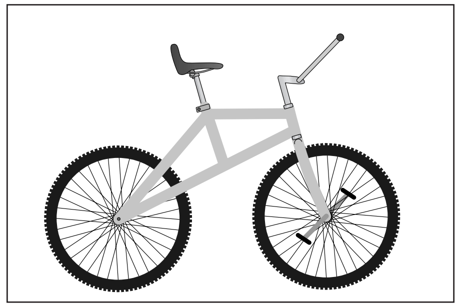

Figure 10. Funbike—with a drive immune to sand, water and mud

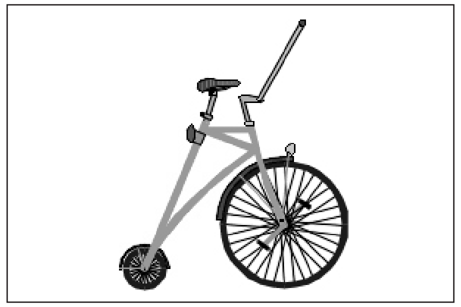

Figure 12. Smilebike: The bike for special occasions.

PRESENT STATUS

The multispeed direct-drive hub is not yet a reality, but a prototype should be finished in 2000. The test bike used until now has only one gear, with a ratio of 1:2.5 and without a freewheel. When the prototype is finished, the author hopes to find a manufacturer who would be interested in producing a hub for general sale. There are no restrictions on production and sale of the hub anywhere the world except Germany: the patents are German.

Thomas Kretschmer is an engineer working in a small German company. Until now, bicycle construction was only a hobby for him.

—Thomas Kretschmer
Nithackstraße 4
D-10585 Berlin, Germany
E-mail: ThomasKretschmer@ginko.de
Telephone: +49 30 348 27 59

CYCLE RICKSHAWS AS A SUSTAINABLE TRANSPORT SYSTEM FOR DEVELOPING COUNTRIES

by Anil K. Rajvanshi

ABSTRACT

Most cities in developing countries are highly polluted. The main reasons are the air and noise pollution caused by transport vehicles, especially petrol-powered two- and three-wheelers called autorickshaws. We have developed three types of improved rickshaws: (a) a pedalled rickshaw (IPCR); (b) a motor-assisted pedal rickshaw (MAPR); and (c) a completely battery-driven rickshaw called ELECSHA™. The details of these rickshaws are presented in this paper. It is shown that these rickshaws can provide an environmentally friendly, energy-efficient and cost-effective transport system and can replace the existing autorickshaws. An economic analysis of these rickshaws is presented and policy issues are identified. Besides reducing pollution, these rickshaws could provide large-scale employment in urban and rural areas of India.

INTRODUCTION

To illustrate the pollution problem mentioned above, in India there are close to 18 million petrol-engine-powered two-wheelers and about 1.5 million petrol- and diesel-powered three-wheelers. The population of these vehicles is growing at a rate of about 15% per annum. Besides being a major hazard to people's health, these machines consume petroleum products for which the country has to pay dearly in foreign-exchange outflow.

An electric cycle rickshaw can provide a nonpolluting and silent transport system for urban and rural areas of India. It is in addition a very energy-efficient and cost-effective vehicle. Work done at our institute has shown that improved cycle rickshaws powered by electric motors and batteries have a potential to provide an attractive alternative to petrol- and diesel-powered three wheelers. They can also provide large-scale employment and extra income to the rickshaw puller.

Figure 1. NARI improved pedal-cycle rickshaw (IPCR)

EXISTING CYCLE RICKSHAWS

There are approximate estimates that close to one million cycle rickshaws ply the Indian roads carrying about three to four billion passenger km/year. In some cities they are the major means of transport. They provide year-round employment to about 700,000 rickshaw pullers (plus work for migrant and seasonal workers), are very maneuverable, and are completely nonpolluting—hence they provide an environmentally friendly means of transport. It is very unfortunate that deliberate policies in most of the urban towns of developing countries have been made by the concerned authorities to phase out these rickshaws. These nonpolluting vehicles are being replaced by polluting (both air and noise pollution) petrol- and diesel-powered three-wheelers. Our data show that three-wheeler diesel "tempos" in Lucknow city (capital of Uttar Pradesh) produce a noise of close to 70–80 decibels at a distance of 1–2 m, besides emitting huge amounts of particulates into the air .

Nevertheless the existing standard rickshaw is poorly designed so that it takes a heavy toll on the health of a rickshaw puller. The existing cycle rickshaw has hardly changed since it was introduced in India in the 1930s and '40s. The gearing gives a very poor impedance match. Hence the rickshaw puller has to work very hard while climbing even a slight slope. A common sight is of a rickshaw puller dismounting so that he can, on foot, pull the rickshaw and passengers. The braking system is also poor in that only front brakes are fitted. Thus when going downhill at high speeds sudden braking produces a catapult effect. Similarly the seating arrangement is very uncomfortable and the aerodynamic drag of the system is very high. It is therefore humanly degrading to pull the existing inefficient cycle rickshaw. Yet because of poverty, laborers become rickshaw pullers and suffer adverse consequences to their health.

Rickshaw manufacturing presently is a footpath industry with no quality control and there are as many rickshaw designs as cities in which they ply. These rickshaws are so poorly made that often they have to be replaced completely every two years. Thus there is a need to improve the existing rickshaw and bring quality control into its manufacture.

NEWLY-DEVELOPED MODELS

Our institute has therefore designed and developed three types of rickshaws: (1) an improved pedal-cycle rickshaw; (2) a motor-assisted pedal-cycle rickshaw; and (3) a completely battery-driven rickshaw called ELECSHA™. The details of the work accomplished follow.

Improved pedal-cycle rickshaw (IPCR)

The new design of pedal rickshaw has a five-speed gear, a reduction in the length of the long chain drives used in existing rickshaws, back-wheel braking, better suspension and a lower aerodynamic drag than the existing rickshaws, as shown in figure 1, the improved NARI rickshaw. Tests done at our institute have also shown that it enables a rickshaw puller to take two passengers on a 6–10% slope quite easily and without getting down from his seat. This rickshaw is made of mild-steel angles, is light in weight and is sturdy. The weight of the rickshaw is 90 kg; its life estimated to be 7–10 years.

Our data from urban towns of India have shown also that many rickshaw pullers are migrant laborers from villages whose sole possessions are their rickshaws. Hence at night they often sleep on the cramped seat of the rickshaw for fear of its being stolen. Our new design allows the seats to be arranged in such a way that a long bed results which allows a rickshaw puller to sleep properly without the fear of his rickshaw being stolen at night.

The cost of this rickshaw is estimated to be Rs 7000 in mass production and compares very well with Rs 4000–5000 which is the cost of existing regular rickshaws.

[In October 1999, $1.00 = Rupees (Rs) 43.44; 1 Euro = Rs 46.84. —Ed.]

Motor-assisted pedal rickshaw (MAPR)

Our data (from discussions with rickshaw pullers) also revealed that with a small battery-driven motor [permanent-magnet DC (PMDC) type] attached to the improved rickshaw (with a five-speed gear) it may be possible for the rickshaw puller to go uphill with ease. Similarly he can also carry loads at speeds of 10–15 km/h. Consequently calculations showed that a 0.375 kW PMDC motor with a 24-V, 40-A-h lead-acid battery could easily take two passengers on a 10% slope at a speed of 10 km/h without the rickshaw puller getting down from his seat. This would be a major improvement for him. A simple strategy has been employed in this rickshaw. A manual contact switch allows the rickshaw puller to switch the motor on or off depending upon his convenience and load. Thus the gearing is arranged such that pedal and motor work in tandem to ease the load on the rickshaw puller. A current-overload switch cuts off the circuit when motor draws more than 20 amps. However the rickshaw puller has to pedal continuously: thus it is a motor-assisted pedal rickshaw (MAPR). The weight of this rickshaw (including batteries) is 129 kg (figure 2).


Figure 2. Motor-assisted pedal rickshaw (MAPR)

The cost of this rickshaw is envisaged to be Rs 17,000 in mass production. The price includes rickshaw, PMDC motor and battery. Patents have been applied for for both the IPCR and the MAPR.

ELECSHA

In major cities of India there are petrol- and diesel-powered three-wheelers called autorickshaws. They are some of the most polluting vehicles on Indian roads. They use two-stroke engines, inherently more polluting than the regular four-stroke engines. In addition, data we have collected show that in the traffic conditions prevalent in most inner-city areas these autorickshaws run at only 15–20 km/h. They therefore produce even more pollution because they are designed to run efficiently at 40–45 km/h. The pollution is further compounded because they are continually starting and stopping. Our data also show that on an average these autorickshaws travel about 50–60 km per day. Based upon these data it was felt that an electric rickshaw designed to run 60–80 km/charge and with speeds of 25–30 km/h would be an excellent substitute for these autorickshaws. In a fair-weather country like India, a silent and nonpolluting electric rickshaw with the above attributes could be a boon.

Consequently an electric cycle rickshaw has been designed and built. It has been patented and registered as ELECSHA™ (figure 3). At the time of writing it has logged more than 3500 km in test runs. It runs on a 36-V 100-A-h lead-acid battery that powers a 1.3-kW PMDC motor. An electronic card “soft starts” ELECSHA and provides dynamic braking. It is estimated to cost about Rs 70,000 in mass production, which would compare very favorably with the cost of petrol- and diesel-powered three-wheelers which are priced in some cities between Rs 75,000–1,00,000. Table 1 shows the specifications of the ELECSHA. Efforts are being made to reduce its weight and to make it easy to drive. This could also help it to become a low-cost personal vehicle for middle-class families.

ECONOMIC ISSUES

We plan to introduce these rickshaws in Lucknow and Pune, cities having the maximum number of cycle rickshaws and autorickshaws respectively. The comparison of electric rickshaws and autorickshaws can take place only when ELECSHA is used in actual conditions. However, a simple economic analysis based upon existing data has been accomplished, as follows.

IPCR

Discussions with rickshaw pullers in various cities reveal that they propel their rickshaws to a maximum of 25–30 km/day. During the hot season (which is the majority of the year) their range is reduced to 15–20 km/day. On an average they charge Rs 3–5/km. Hence they can make between Rs 75–125/day. After giving Rs 15/day as rickshaw hiring charges they can earn about Rs 60–110/day. Data on our rickshaw have shown that with gears the rickshaw puller can easily go 30–40 km/day. The addition of a five-speed gear could therefore increase his earnings substantially.

MAPR

In this case our data have shown that a rickshaw puller can easily pedal 50 km/day and in some tests he has increased this distance to 70 km/day in two shifts. Thus with the cost of MAPR at Rs 17,000 he can earn at least Rs 150/day (by charging Rs 3/km). If the rickshaw owner charges Rs 40/day as hiring charges (the puller will get at least Rs 110/day as net income) then the owner will be able to repay the rickshaw loan in five years. He will also at the same time earn a profit of about Rs 4,600/year for ten years on each rickshaw. This includes battery replacement cost every third year and 18% interest on the loan.

ELECSHA

The ELECSHA owner can make a net profit of Rs 25,400 every year for ten years. This requires that the fare will be Rs 3.50/km and that the rickshaw will travel 70 km/day. Other assumptions are:

- Driver will be paid Rs 75/day;
- ELECSHA will run for 300 days/year;
- Battery replacement cost is Rs 15,000 and it will be replaced every other year;
- Interest is 15% per annum and loan has to be paid back in five years; and
- The electricity cost is Rs 5/kWh.

Presently the petrol autorickshaws charge Rs 4.50/km and hence, even with the reduced fare for ELECSHA, the owner can make a good profit. This is because of the low running cost of ELECSHA. Thus it seems that for both rickshaw puller and owner it is economically viable to ply these rickshaws.

OTHER ISSUES

The battery and its charging

One of the major issues facing the large-scale introduction of electric vehicles is the issue of batteries. With the present level of technology development the batteries used virtually have to be lead-acid. Deep-discharge lead-acid batteries are presently imported into India and are very heavy. The issue of battery charging can be tackled in two ways.

1. An onboard charger that can be plugged into any electrical outlet can be fitted. This concept has been used in most of the electric vehicles. This concept can be attractive for private owners of ELECSHA. However the disadvantage of this method is that it increases the cost of ELECSHA since the charger will be a part of it.

2. A network of battery-charging stations could be developed. In this concept it is envisaged that the battery-charging station would take out the discharged batteries from ELECSHA and put in a set of charged ones.

The advantages of this concept are that one does not need to worry about charging and the battery could be of lower capacity and hence lighter weight, which in turn will improve the performance of the vehicle. Also, regular automotive batteries could be used which can be discharged to only 50% depth. At the same time no extra cost of a charger is incurred. This concept will be very useful for rickshaws being used as taxis. Nevertheless, the issues of old vs. new batteries and the economic viability of charging stations will have to be sorted out.


Figure 3. Electric cycle rickshaw (ELECSHA™)

The electricity to power these batteries could come from any renewable power plants like biomass, solar thermal, solar photovoltaic, wind, etc. In these cases these rickshaws could truly be called a renewable-energy transport system. To convert all existing one-million rickshaws in India into electric rickshaws would require only one 600-MW power plant to run them. [If battery-charging is carried out off-peak, including during the night, no additional generating plant would be required. —Ed.] It is also instructive to look at the energy efficiency of electric rickshaw vis-à-vis petrol-engine-powered autorickshaws. From power-plant to traction-energy point of view ELECSHA consumes 110 Wh/passenger-km as compared to 175 Wh/passenger-km consumed by petrol autorickshaws. In this calculation we used the following assumptions.

ELECSHA

- The efficiency of electric power plants including transmission and distribution losses = 0.255;
- Charging/discharging efficiency of batteries = 0.64; and
- The Elecsha takes two passengers and travels 80 km per charge.

Petrol autorickshaw

- Average mileage = 25 km/l of petrol
- Calorific value of petrol 8.74 kWh/l

Thus if the ELECSHA uses batteries charged from fossil-fuel power stations, it would use 60% less petroleum energy than a petrol autorickshaw. Besides being environmentally-friendly ELECSHA is also very energy-efficient. We also feel that small systems like rickshaws are most suited for electric-vehicle development. This is because the present level of battery technology precludes large power outputs from lightweight batteries. Hence, the electric rickshaw can be easily designed with existing motor and battery technology.

Policy issues

There is need for a policy decision by governments of developing countries to permit only improved cycle rickshaws and electric rickshaws in congested areas of inner cities. This

TABLE 1. Specifications of the NARI ELECSHA™

Payload	180 kg
Gross vehicle weight	230 kg
Range	60–80 km (for 60%–80% depth of discharge)
Top speed	30 km/h
Battery type	Exide Automotive Battery
Battery weight	96 kg for 3 batteries
Battery capacity	100 Ah
Battery specific power	7.95 W/kg
Battery energy density	39.7 Wh/kg
Battery pack voltage	36 V (Nominal)
Cycle life and self discharge	150–200-cycle for battery at 60% discharge depth
Charger	36-V 10-A standard Indian make, running from wall plug
Charge time	10–12 h
Motor	1.2-kW PMDC, Indian make
Transmission	belt pulley/sprocket with 6:1 ratio
Controller	Indian make, high-frequency, micro-processor-based MOSFET controller
Frame/body type	Rolled-steel-angle construction
Frame/body material	Mild steel
Length/width/height	2390/1050/1330 mm
Ground clearance/turning radius	200 mm/2.3 m
Maximum gradeability	6–10%
Tires	Regular two-wheeler tyres
Wheel	Regular two-wheeler wheels
Brakes	Hub braking (both front and back wheels)

will help reduce pollution, provide a clean sustainable transport system and provide employment. Already courts have banned three-wheeled diesel “tempos” from certain parts of Lucknow. Electric and improved rickshaws could provide an attractive alternative to help the “clean air” movement. There is also a need for the government to enact legislation such that banks could provide lower-interest loans to the rickshaw owners. Since this is a renewable energy system, it should get all the benefits presently available to such systems in other areas. Besides creating a non-polluting transport system in India, electric rickshaws would also provide dignity to rickshaw pullers. Presently rickshaw pullers are treated as belonging to the lowest rung of society. Many rickshaw pullers told us that a motorized rickshaw would give them dignity. It is felt that the police and the people in general treat the drivers of motorized transport with slightly more respect. Besides giving dignity, electric rickshaws could also provide extra income to the rickshaw puller since he can ply his rickshaw to greater distances in one day.

CONCLUSIONS

In developing countries most of the cities are very congested with narrow roads that for historical and political reasons cannot be broadened. For such roads non-polluting vehicles like those described could provide a very attractive transport system. With enlightened government policies allowing only such vehicles in these areas, the cities of developing countries could become pollution-free and livable.

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By the time this issue of Human Power is mailed, this paper will have been published in the proceedings of “International Symposium on Automotive Electronics and Alternative Energy Vehicles” to be held in I.I.T. Kanpur from 19-21 November 1999. Anil K. Rajvanshi is a mechanical engineer. He earned his B.Tech. and M.Tech. from I.I.T.Kanpur in India and his Ph.D. from University of Florida, Gainesville, USA. He is the director of Nimbkar Agricultural Research Institute (NARI), a non-profit organization. NARI does R&D in renewable energy and agriculture.

—Anil K. Rajvanshi, Director
Nimbkar Agricultural Research
Institute (NARI)
P.O. Box 44, Tambmal,
Phaltan-415523, Maharashtra, INDIA
anilrajvanshi@vsnl.com
Phone: +91-2166-22396/20945
Fax: +91-2166-21328

Is the .deciMach Prize attainable?

by Michael Eliasohn

In 1986, Fred Markham pedaled the Easy Racer Gold Rush to 65.5 mph (105.4 kph) to win the DuPont Prize of more than $18,000 for the first human-powered vehicle to exceed 65 mph. In 1992, Chris Huber pedaled the Cheetah 68.7 mph (110.6 kph) to break Markham’s mark. There was no monetary prize, but being on the cover of *Popular Science* may have been compensation.

The new barrier for straight-line speed is 75 mph (120.7 kph). It’s the barrier established by the .deciMach Prize for Human Powered Speed, the prize being $21,000 plus interest to the first rider/team to exceed that speed, which is approximately one-tenth of the speed of sound. There’s no deadline for winning the prize. (Contributors to the prize are Garrie L. Hill, 10 shares; the HPVA, five shares, and one share each from the Indiana chapter of the HPVA, Easy Racers, Inc., and Rob Hitchcock.)

The speed has to be attained over a distance of 200 meters on a course “flat to within 2/3 of 1 percent,” to quote from the rules. Making the task more difficult are some of the requirements: Attempts (scheduled annually) must be made at a course specified by the prize committee and the altitude cannot be more than 700 meters (2,297 feet) above sea level.

.deciMach Prize organizer Garrie Hill, a long-time HPV builder/racer and HPV race organizer from Granville, Ohio, points out one change has been made from the original rules, which specified “all vehicles must demonstrate the ability to self-start and stop without assistance.” So-called unlimited vehicles, which need outside assistance for starting and stopping, are now permitted. However, if the winning .deciMach prize vehicle has self-starting/stopping abilities, there is a premium (amount to be determined) that will be added to the $21,000 prize. Hill said the maximum 700 meters altitude was selected because that’s the average elevation above sea level worldwide. He said “people bitched” about the high altitude allowable for earlier speed-record attempts. Both Markham and Huber made their record runs at altitudes of at least 7,700 feet (2,347 meters) to take advantage of the thinner air at that altitude.

see next page

Does Garrie Hill think it’s possible for an HPV to go 75 mph? “A lot of people feel it’s possible, but not probably with anything that exists today,” he said during the North American HPV Speed Championships in Sparta, Wisconsin, in August 1999. Hill said before establishing the prize, he talked to some aerodynamicists and physiologists who thought 75 mph is attainable.

“I think what will happen is someone will build something from scratch, maybe with a breakthrough in air-flow control,” he said in talking about what it will take to win the .deciMach prize. The only two vehicles in Sparta with a history of high speed were the Varnas raced by Sam Whittingham and Paul Buttemer. The front-wheel-drive mostly carbon-fiber Varnas were built by George Georgiev of Gabriola Island, British Columbia. He has built four so far, each slightly different.

At the International Human Powered Speed Championships in 1996 near Las Vegas, California, on a course with too steep a slope to be legal, Whittingham pedaled through the 200 meters to a speed of 73.3 mph (118.0 kph), with Buttemer second at 71.0 mph (114.3 kph). The fastest legal speed done by Whittingham was 63.8 mph (102.6 kph) to win the Colorado Speed Challenge in 1993. But that was done at high altitude. In July 1998, he set the IHPVA 200-meter low-altitude record (below 700 meters) at 62.2 mph (100.1 kph).

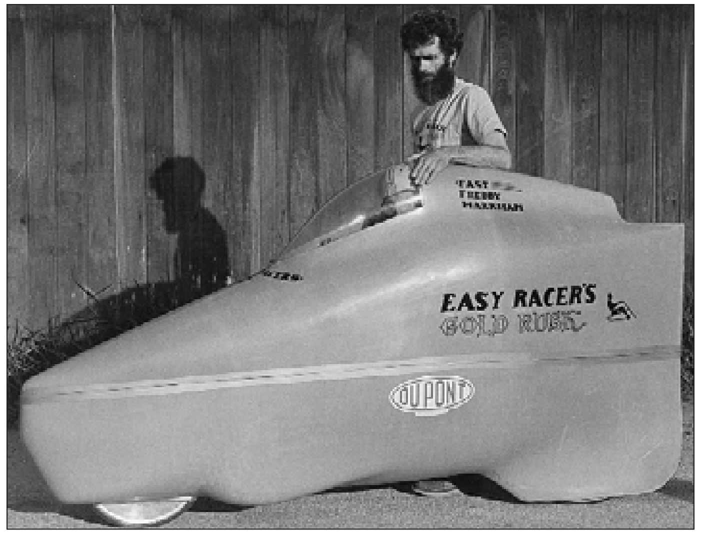

Figure 1. Gardner Martin and “Fast Freddy” Markham with the Gold Rush that won the DuPont Prize. —Courtesy G. Martin

Buttemer’s response to the question of whether 75 mph is atttainable was that he feels it’s possible, but only with a top athlete riding the best vehicles available today, on an ideal course (10-kilometer run-up and 2/3 percent downgrade) with ideal weather conditions (hot, dry and low barometric pressure). Huber had a run-up of about 2.5 miles to set the present record, according to Whittingham. Markham needed 1.8 miles to get up to 65 mph.

Buttemer said the idea of the super-long run-up (6.2 miles) is to get up to cruising speed without working at full power, then to sprint up to the maximum speed. The Varna riders said that a big oval track would do; the long run-up doesn’t have to be in a straight line.

Gardner Martin, builder of the first HPV to go 65 mph, also stressed the importance of having the proper course and conditions. For starters, find a course as close to the 700-meter maximum elevation as possible. Next find the maximum downward slope of 2/3rds of one percent. He suggested one of the big oval test tracks used by the auto companies in Arizona might do and somewhere along its length would be 200 meters with the allowable downward slope. Next, have the runs on a suitably hot day, since air gets thinner when it’s hotter. “As any aviator knows, it’s harder to take off on a hot day,” Martin said. For instance, a temperature of 95 degrees F may mean a 2,000-foot elevation (about 700 m) would be the equivalent of racing at 4,000–5,000 feet. But, he cautioned, it can’t be “so hot it cooks the rider.”

As for the long run-up that Whittingham and Buttemer feel is necessary, Martin said as much as three miles may be necessary, but stressed some riders might need more, some less. “Different athletes like to work differently.” Buttemer said the run-up issue doesn’t depend on just the rider: it also depends on the position that the rider is in. The Gold Rush position (seat higher than the bottom bracket) is much better for acceleration than the Varna position (seat lower than the bottom bracket), meaning that someone riding Gold Rush would require less of a run-up than the same person riding a Varna.

Martin said he feels the key to going 75 mph may be in the .deciMach rule that says, “Vehicles may be of either single- or multiple-rider design.” He suggested that it may be possible for an HPV to go that fast without a design breakthrough simply by using more than one rider.

Martin used the 1993 Colorado Speed Challenge to make his point. Whittingham had the top speed of the meet, 63.8 mph (102.7 kph; over 200 meters), with Markham in the Gold Rush second at 63.5 mph. But those riders teamed to propel the Double Gold Rush to 65.0 mph (104.6 kph). “It’s quite obvious the Double Gold Rush is faster than the single Gold Rush,” Martin said. It’s not fast enough to go 75 mph, however, even under the right conditions. “I don’t have a vehicle currently that can do 75 mph,” Martin said.

However, at the fourth International HPV Symposium in August 1992, he suggested a design for such a vehicle. The front rider, flat on his back, powers the front wheel. The rear rider, powering the rear wheel, is in a prone position and does the steering. The rear rider's upper body and head is over the front rider's upper body and head. Height of the proposed record breaker is only 32 inches; the length is 13 feet. Tantalizingly, the maker of Tour Easy recumbent bicycles said he has seen an HPV capable of going 75 mph, but wouldn't say anything more. Martin suggested that the first vehicle to go that speed may do so at high altitude, which would set an IHPVA record, but wouldn't win the .deciMach prize.

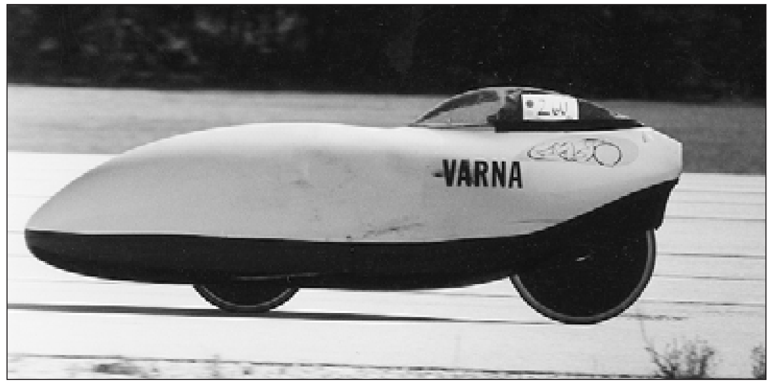

Figure 2. Paul Buttemer racing Varna at Sparta in July 1999.

Hill suggested using a female rider or riders, pointing out that a premium is to be awarded if the grand prize winner is female. "It is my opinion that there are some awfully powerful female racers out there who could pack into an extremely compact cross-section fairing," he wrote to this author. "Perhaps a tandem all-female unlimited vehicle is in our future to win the maximum prize!," Another way to boost "horsepower," of course, is to use a top racing cyclist for record attempts.

Buttemer feels using a top cyclist would give a "tremendous" advantage, but pointed out the skills needed to ride a streamlined HPV require more than just strength. "When you're riding these things, you need lightning reflexes to keep the rubber side down," that is, to keep the machine upright, he said. Thus skill and experience in riding the quirky streamliners are as important as rider power. Other than the issue of the power of the rider (or riders) is the question of the design of the vehicle itself. Neither Whittingham, Buttemer or Martin believe there is any type of transmission, for instance linear drive, that will work better than conventional chain and sprockets for the purpose of going fast. Though Martin did say there's "no better system now available." [However, see Dave Larrington's editorial in *Human Power* no. 48, p. 25. —Ed.]

One reason for interest in linear or lever drive is that it requires less frontal area than do conventional rotary cranks —presuming that the cranks are mounted lower than the mass of the rider. However, the Varnas overcame that problem by having the cranks mounted much higher than the seat. (Is that pedaling position less efficient than having the seat higher or level to the bottom bracket? See Buttemer's article in the summer/fall 1998 issue of *Human Power*.)

The ultimate compliment regarding Georgiev's design comes from Martin. "I think the Varna is the best case study of a small package," Martin said. The Gold Rush designer said sometimes it's best to compromise the perfect airfoil shape in order to get smaller frontal area. But is there some shape—or something else —that can boost the speed of an HPV? "There may be a breakthrough at some point," Buttemer said, for instance, achievement of laminar flow. If that can be achieved across the body of an HPV, "it will go *much* faster than anything we've seen so far," he said.

"Laminar flow" refers to the behavior of the air in the thin layer (a millimeter or so thick) right against the fairing surface. Aerodynamicists refer to this as the "boundary layer." At the front or leading edge of a body like a fairing, the boundary layer is always "laminar", meaning that the air is sliding smoothly over the surface and giving little air friction. Somewhere along any surface, at a distance that depends principally on the surface shape and roughness and the relative air speed, the boundary layer will grow thick enough to switch suddenly to a form known as "turbulent", in which the smoothly flowing layers of air break up into high-friction vortices. The longer this transition to turbulent flow in the boundary layers can be delayed, the lower is the overall air friction. Aircraft designers have been working on the "laminar-flow wing" for a long time. Bruce Holmes of NASA Langley spoke to an IHPVA workshop (reported in *Human Power* vol. 5 no. 1, winter 1985) as follows: "Shape your fairing to produce as great a proportion of natural laminar flow as possible by putting the maximum-area cross-section well aft, and, if you want to capture some speed records, use suction through slots or porous bands to force laminar flow on much of the rest of the surface. The power required for suction will, unless done extremely crudely, be a small proportion of the power saved in overcoming drag, if the speed is of the order of 29 m/s, 65 mph…." Holmes' graph showed how great the saving from sucking the fairing boundary layer to produce laminar flow would be. It makes it seem as if the .deciMach prize should be easy to win.

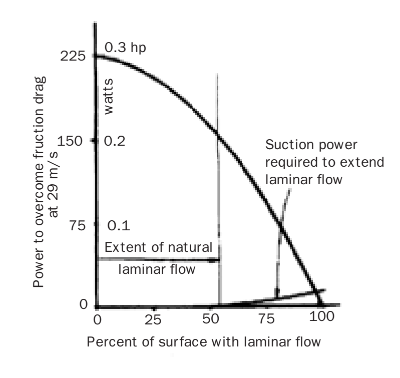

Fig. 3. Power to overcome aero drag vs. extent of laminar flow for a typical HPV at 29 m/s. (After Holmes)

Michael Eliasohn, a long-time supporter of HPV activities in Michigan, is a newspaper reporter and a frequent contributor to Human Power.

—Michael Eliasohn
<meliasohn@heraldpalladium.com>
203 Ward Avenue
Saint Joseph, MI 49085-2215 USA

TECHNICAL NOTES

BODY SHAPES AND INFLUENCE OF THE WIND

by Matt Weaver

(Peter Ross was reasonably concerned with the influence of wind on HPV performance, and inquired my opinion on several points. The following is a slightly revised version of the e-mail response I sent Peter. Peter presented my response to Human Power for publication. Matt Weaver.)

"Stubby wings"

Fully streamlined bicycle bodies, especially those with fairly long or tall trailing edges and low ground clearance, act much like half of a stubby wing turned on edge (the other "imaginary" half extends into the ground). As the ground clearance increases, the body's sensitivity to the wind decreases. But even with good ground clearance, if there is still an appreciable trailing edge the body will produce definite lift in a side wind. Typically it is not too efficient, but by virtue of high vehicle speeds and low body drag, the forward thrust is seldom negligible.

Estimated sailing characteristics

These lift characteristics can be well approximated for certain body shapes, and others can ultimately be plugged into a computer if coordinates are available (assuming the overall body flow is "well attached"—which can be checked by the computer, and which is valid for the top streamlined bikes, but not for many automobiles). I am familiar with both methods and have tools and know the math, though I've looked at side-wind effects primarily to compute the lift and "moment" forces on the body for stability and steering-geometry considerations (regarding the "moment"—most bodies like to torque away from the side wind, as if the lifting force is acting on an imaginary point beyond the front of the nose).

Some lift and drag relations

Some bodies are designed with low-drag "natural laminar flow" airfoil sections. These airfoils have low drag at zero flow incidence (i.e. no side wind). As the side wind increases beyond a certain point, the pressure distribution over the section changes such that the boundary layer on the downwind side of the airfoil becomes largely turbulent instead of extensively laminar. At that stage the drag of say a 50-60% natural-laminar-flow airfoil section will roughly double. The lower-drag part of the characteristic is sometimes referred to as the "low-drag bucket" on lift/drag plots of various airfoils. You can shape an airfoil to have a "wider" low-drag bucket (that is, it would cover a wider range of side winds) but the bucket becomes less deep (i.e., the low-drag portion is increased).

"Turbulent" as used here refers to the state of the thin blanket of "boundary-layer" (BL) air near the body surface. It is not the same thing as "separation"—which is what happens at the rear of blunt bodies such as most automobiles. A "laminar" BL has much lower shear or "skin friction" rubbing against the surface of a body than a comparable turbulent BL. A BL starts in a laminar state, and may irreversibly "trip" (a bit like a wave breaking on the beach) into a "turbulent" BL. The skin friction increases locally as much as ten-fold as the BL transitions from laminar to turbulent, and drag of identical-looking sections can vary as much as three-fold, depending on the overall state of the BL.

Lift of symmetric sections is independent of drag

Interestingly, regardless of whether the boundary layer is laminar or not, or what the airfoil section profile is (large nose-pointy tail, or pointy nose-shorter tail), the lift coefficient of a symmetric airfoil section is largely a function of the incidence of the flow alone.

Lift, drag and forward thrust

As the side wind increases with low-drag "natural laminar flow" sections, the lift keeps rising, but the forward thrust will reduce temporarily when the body drag jumps up, but typically any wind produces a net forward thrust for the body at all times regardless of whether or not the body drag has gone up (i.e. the body drag has increased, but the forward or "thrust" component of the lift has increased more than the drag and thus gives a net propulsion).

Not considering changes in drag coefficient, the potential forward "thrust" from the wind goes roughly with the square of the side-wind speed.

Estimates of sailing characteristics of the "White Hawk"

I'll spare the summary of math details here because they go on for a page or so, and just give you numbers for a single case. The "White Hawk" as well as the "Tomahawk" look like fairly good vehicles for side winds with their low ground clearance and fully developed height and trailing edges. Other fast streamlined bicycles exhibit similar estimates: slightly greater sensitivity for the Gold Rush and Cheetah, and slightly less for the Varna Mephisto and Cutting Edge.

Estimates for a 5-mph (2.24 m/s) side wind at 50-mph (22.35 m/s) vehicle speed are as follows based on a model from images of the "White Hawk":

- 2.56 pounds (11.4 N) forward component of lift (thrust)
- 1.84 lb (8.18 N) induced drag (in the form of a vortex cone coming off the upper trailing edge)
- net forward thrust of 0.72 lb (3.2 N)
- corresponding wind power slightly under 0.10 horsepower (75 W)
- vehicle lean angle of about 7 degrees (fairly modest)
- At 50 mph (22.35 m/s) and 0.50-HP rider power output, velocity increment would be about 3 mph (1.3 m/s).

Course geometry and side winds

A linear "out and back" closed course is sensitive to wind direction; a circular course is not. Closed courses of varying eccentricity naturally fit somewhere in between. Giving respective weights, with 1.0 = perfect perpendicular side wind, the following holds:

- linear with perfect perpendicular side wide = 1.0
- linear with head/tailwind = <0.0 (You don't get back downwind all that you put in upwind.)
- circular = 0.45–0.50 (The math is interesting—I did it for the whole loop; this is the range where it ends up. There is a slight penalty for the "headwind/tailwind" region of the loop, else it would be basically 0.50.)

The principle is a little like that of a "Darrieus" or "egg-beater" wind turbine.

So, for a circular course, you get a little less than half of what you'd get perfectly aligned with the side wind at all times, which is pretty good considering the ideal linear course is not a likely scenario.

Considering the previous case listed above with an average 5-mph (2.24-m/s) wind (regardless of direction) and a circular course, wind power would amount to about 0.045 horsepower (34 W), or about 1.5-mph (0.67-m/s) increase in vehicle speed near 50 mph (22.35 m/s).

Wind and hour records

I hadn't considered the matter closely until you asked, nor did I even know there was an issue with Lar's record!

"5 to 10 mph winds reasonably significant"

I would consider the above estimations reasonable—of about 1.5-mph speed increase in a closed-loop hour run near 50 mph with a 5-mph side wind. For winds much higher than 10 mph, the vehicle might start to have a hard time, but I would consider increases in average speed as much as 3 mph or a little more very likely before handling begins to deteriorate.

"High winds"

Higher winds—such as the 15–25-mph (6.7–11.2-m/s) range as experienced in Yreka—are adverse for most streamlined bicycles. Furthermore, the lifting characteristics may be nearly maxed out or stall separating—or in other words—lift is no longer increasing much, but drag is. The bicycle gets buffeted around and likely ends up running slower.

"Displacement of HPV records"

Considering the history of the hour record for the last ten years, the average increment between records has been less than 1.5 mph (0.67 m/s), and thus a modest wind in the 5-to-10-mph range could result in a displacement of an otherwise true "human powered vehicle" record. I think such displacements generally stifle efforts to set records, and ultimately slow the improvement of both the vehicles and the records. Such displacements are bound to happen, and have, and the effects are evident too.

Considering that, I'd say the wind is relevant if you are seeking to know what is the most efficient "human-powered vehicle" rather than say the most effective "local-natural-power vehicle" (e.g., local muscle, wind, gravity, solar). The question then is it worth the trouble to measure the wind, or how might you measure it?

Measuring the wind

An "instant-wind-speed" anemometer is next to useless (unless it feeds into a data-logger). What you want to know is how much total wind (flow distance) has occurred within the hour period and ideally sub-periods within it. The average wind (total distance/ time) is a good approximation. A more exact calculation would be to have additionally the total distance every 2 to 5 minutes or so or even arbitrary weighted sub-periods, and do a "velocity-squared" average. Interestingly, the power assist of the wind for a streamlined bike goes with the velocity squared—the reason in part being that the vehicle velocity is largely independent of the wind speed, unlike say a windmill. For a windmill, the "velocity-cubed" power average is the most accurate (as is commonly done in assessing windmill sites using wind speed distribution (Weibull curve, etc.) characteristics of the site.

Large tracks

Interestingly, for a large site—such as two-mile (three-km) or larger track, the instantaneous wind speed at one end of the track tends to correlate poorly with the opposite end, but the average wind speeds are remarkably consistent (assuming one end is not grossly "shadowed" by some structure). This makes average-wind-speed measurements for a long event like the hour far more meaningful than wind-speed measurements for say, a top-speed sprint.

Sprints

The top-speed sprint covers a large distance (often two miles or more of acceleration) and the wind speed for the brief instant the vehicle passes through the time trap has little to do with the wind speed over the entirety of the course. In other words, the wind speed at the end of the course may or may not correlate well with the wind the vehicle experiences over the acceleration distance, but at least it gives a probable idea, especially if multiple runs and readings are performed. It would make more sense in the case of a sprint to measure the wind speed for the entire duration of the run-up and sprint and optionally take a velocity-squared average. This can be done by simply reading the time and feet of wind when the bicycle starts rolling and when it finishes and then divide total distance/total time. Good runs are then actually less likely to get ruled out because of a little gust and vice-versa (i.e. if it is generally calm, everyone will have good runs, rather than some getting ruled-out).

Probability of getting "legal" winds

A quick analysis of available weather-station data for a number of locations suggests that the probability is high to get "legal" (sub 1.66 m/s) winds as previous hour records required—in the early morning hours. Typically a window of three hours or so after sunrise exists. After that, winds are likely to persist until midway through the following night. Later in the day, such low winds are far less certain and each site must be considered individually.

So, if you want to set an hour record with low winds, plan on running in the early morning.

Key "power assist" areas

For streamlined bikes, there are three major areas of "power assist" that are most likely to occur.

- Gravity
- Wind
- Pressure gradient

Gravity is significant—it is one of the primary keys to fast runs recorded in the past—typically more so than altitude. A hardly discernible and "legal" downhill assists dramatically at higher speeds. (For instance, gravity adds a steady additional 0.25 HP (187 watts) at 65 mph on a (legal) 2/3% slope for a rider-plus-vehicle weight of 215 lb., 98 kg.)

Wind as discussed—looks as if it gives modest yet significant assist by default to leading streamlined bicycles before it grows too large and hinders handling.

Pressure gradient, the unrecognized aerodynamic advantage, becomes probable if a "pursuit" automobile is following behind a streamlined bicycle. The effect is far more dramatic than most HPV enthusiasts would suspect. An automobile can approach a streamlined bicycle from behind and gently accelerate, and long after the cyclist stops pedaling the streamlined bicycle will continue to "ride" the pressure-gradient "wave" extending significantly several car lengths in front of the automobile. The streamlined bicycle essentially accelerates on its own. (For instance, a truck approaching a streamlined bike from behind may never be able quite to catch up no matter how fast it can go!) This effect holds true up to Mach numbers well over 0.5, and eventually diminishes to zero approaching the speed of sound.

There are some neat research references dating back to the 1930s well documenting this effect. Dolphins know it well, often racing for hours directly in front of ships. It also applies to a crouched racing cyclist on a standard bicycle, but it is far less dramatic than with a fully streamlined bicycle.. I have carefully tested this after witnessing some unusual performances in several time trials in the Tour de France. Even with a compact car the effect is very repeatable and correlates well with some "unexplainable" margins.

At least one of the exceptional performances in a trans-continental race may have utilized the pressure-gradient advantage. Without going into specific incidents, the general application has been to follow the cyclist closely with a large support vehicle, and to go so far as to substantially increase the frontal area (and extent of the pressure field) of the vehicle by mounting a large "billboard" banner extending several feet above the top front edge of the vehicle.

I should add one interesting quotation that may relate to this question, and that appeared in the *San Francisco Chronicle* (Monday, 8 Feb. 1993): "I felt like I was dying," "At [*x*] miles per hour I'd gone anaerobic, but I forced myself to keep turning the cranks and our speed kept rising. It felt like the [*n*] was accelerating on its own, a real testimony to aerodynamics."

The "felt like I was dying" anaerobic state is strongly associated with a decay in power output, which is associated with a fundamental reduction in speed with few exceptions, not "accelerating on its own." A rather interesting quote!

The "HPV"

Anyway, I like to call an "HPV" an HPV if it really is what its title claims: a "human-powered vehicle." Then you can look at the very fundamental contest that combines solely the power of a human's muscles and a human's mind to pure movement, speed and efficiency going from A to B—the very stuff so central to our existence and so pervasive in our daily lives. Such a contest reveals vehicle efficiencies far exceeding all other vehicles I know of—for a given speed times occupancy, nothing does as much with as little.

To clarify, in my opinion the DuPont prize for top speed was brilliantly won fair and square by Freddy Markham in Gardner Martin's Gold Rush at 65.48 mph (29.27 m/s), but the fastest official "human-powered-vehicle" record now stands at 62.51 mph (27.94 m/s) set in 1999 by Sam Whittingham in Georgi Georgiev's Varna Mephisto in dead-flat, near-zero-wind conditions.

To increase this "HPV" record to, say, 70 mph (31 m/s) will require a nearly 40% increase in rider output or vehicle efficiency.

There is lots of energy all around us in the form of wind, and surely we should better utilize it. But I consider racing a "hybrid" sail-HPV, from which phenomenal performance is possible, a different contest.

Milwaukee hour

Just a note on the Milwaukee hour you mentioned—I crashed for the first time at about 48 mph (21 m/s) earlier that day, and I was a bit uneasy to race at all. I decided I'd run if I rode on the outside of the track, and we measured and estimated I traveled over 3 miles (5 km) extra over the course of the run. Not to mention I started about 1/2 lap late as my windshield came loose just before the start of the race! I honestly didn't notice the wind. My hydration system failed, my head was overheating with the ventilation messed up due to the last-minute windshield fix, and so I was more or less persisting to the finish!

To my surprise, I actually passed the Gold Rush on the last lap. I believe he was ahead of me at the 60-minute mark, but the rules required us to complete our last lap. Gardner ran down the track and signaled to Freddy to ride through the last lap. If you have video of the race, you might see this all happen. The officials said I was a lap behind Fred, and it took Freddy to tell them that I was in fact on the same lap as he before they'd admit their error. I was happy with Freddy being the winner since he led most of the race, so no matter what the rules said there. Interestingly they somehow managed to get our marks recorded to the nearest 0.001 mile for the record! (I wonder what measurement they used?!)

The next day was faster—I wish they had recorded the lap times. Other than the caution lap, I averaged just shy of 48 mph (21 m/s), and would have been happy to keep going at that rate except there were more trees off to the side of the course than I cared for so I limited my speed except for the last lap in which I sped up and averaged just under 52 mph (23 m/s). I wanted to go fast enough to "wear down" Freddy so that he wouldn't take me at the finish with some mean sprint, but not so fast that I might crash and get hurt. Freddy and Paul Swift and Bobby Livingston were all real excited after that event—they all said they wanted to ride the Cutting Edge and see who could go the fastest! I'd love to see what they could do! The only problem was that the bike was too long for all but Paul Swift's legs!

Conclusions

1. Modest winds appear significant—reasonable and confident estimations for leading streamlined bicycles indicates speed increments of about 1.5 mph (0.67 m/w) with a 5-mph (2.2 m/s) randomly oriented side wind at steady hour-record speeds (50 mph, 22 m/s) on a closed circular course. Increments as much as 3 mph (1.3 m/s)are probable before significant notice of wind effects by the rider on most vehicles. Handling problems may eventually arise with winds greater than about 10 to 15 mph with detriment to performance.
2. A 1.5-mph increment in vehicle

speed is larger than the average increment in the world hour record over the last four or so records set in the last ten years.

3. Circular courses—yield about 45% of the power assist a perfect side wind would give.
4. The probability is high to obtain "legal" (sub 1.66 m/s or 3.71 mph) winds in the early morning hours for most courses, but the probability of having "legal" winds is not very high at other times of daylight.
5. Instantaneous wind measurements may correlate poorly at different points on the course, but averages are remarkably consistent over several miles or more in flat areas assuming no wind shadowing at the point of measurement.
6. Wind measurement is relatively simple and meaningful if done as "total distance" of wind per hour. More precise readings would involve a "velocity squared" average for land vehicles (not velocity cubed as for windmills).
7. Weather data of Frankfurt/Main suggest that there may have been wind in the 5–10 mph (2.2–4.5 m/s) range at the 8 PM European time 7 Aug. 1999 of the latest hour record attempt.
8. Check if the track has a weather station as most test tracks do, or other nearby station evidence of the conditions. If the track weather station confidently shows legal wind at the time of the race, then that measurement should be respected and considered official.
9. Previous records and other teams have been held to certain requirements that appear to have significant effect on performance. Until the rules are changed, it is a simple matter to uphold this well-known and simple-to-measure requirement if an official record is desired. Otherwise, to exempt generously the latest claim simultaneously rejects the previous official record holder's title and may also displace potential future HPV record achievements.
10. The position of any "chase" or support vehicle behind the streamlined bicycle should be clearly documented demonstrating following distances in excess of 100 feet at all times except maybe momentarily at the finish for marking purposes only.
11. Arbitrary wind should be allowed for long-duration records (two hours or more) from a practical standpoint, but should still be recorded and maybe velocity-squared power averaged for purposes of meaningful comparison of achievements (not unlike the documentation of altitude or course slope).

—Matt Weaver, Aptos, CA
<weaver@e2000.net>

LETTERS

COMMENTS ON ABSTRACTS OF TOO'S DATA

Dr. Too has made a significant contribution to recumbent design and it was helpful of him to allow the IHPVA to reprint several of his research abstracts along with the questions and answers from the IHPVA list server in *Human Power* (No. 46, pp. 14–20). The abstracts combined with his comments fill in some of the gaps left by my review article (Reiser and Peterson, 1998. "Lower-extremity power output in recumbent cycling: a literature review." *Human Power*, No. 45, pp. 6–13).

While review articles and abstracts help to consolidate information, they are an incomplete substitute for the work from which they are drawn. Many of the details of a study must be left out when reducing a multi-page document to a couple of sentences or even a couple of paragraphs. This can lead to confusion and misinterpretation by the reader. One such example of being too concise for clarity is the abstract for "Comparison of joint angle and power production during upright and recumbent cycle ergometry" (Too, 1996). After reading the abstract I was left with the impression that anaerobic power output was greater in the recumbent cycling position (15° seat-tube angle relative to horizontal) compared to the standard cycling position with a 75° seat-tube angle. This result was very surprising to me, so I tracked down the complete article. It seems that I misinterpreted Too's definition of the non-recumbent position, termed "standard upright-cycle ergometer position".

The complete article explained that while the seat-tube angle was the standard 75° for an exercise ergometer, the subject's upper body was kept perpendicular to the ground. Requiring the upper body to stay perpendicular to the ground is not "standard" when cycling at a 75° seat-tube angle. Subjects generally prefer to lean forward approximately 30° from vertical. This 30° difference in the standard torso position and the upright torso position could account for the reduced power produced in the upright position compared to the recumbent position, making recumbent cycling no more powerful that standard cycling. The tested upright cycling position required the subjects to cycle with the hips in an extended position, reducing the length and force capacity of the hip musculature compared to the recumbent position.

This upright cycling position was also tested in "Comparisons between upright and recumbent cycle ergometry with changes in crank-arm length" (Too, 1998).

Additionally, in Too (1996), subjects were not tested in a random order. The testing also included a three-month interval between the upright and recumbent test position. In addition, a slightly different definition of seat-to-pedal distance was used in each position. However, it does not seem that the order of testing, time between testing, and different seat-to-pedal distance affected the results dramatically. The results in "The effect of hip position/configuration on anaerobic power capacity in cycling" (Too, 1991) showed similar positions being tested and the same conclusions were drawn. However, the discrepancies in the data collection could cause erroneous results and, at the very least, change the magnitude of the differences which would change the levels of significance. This example illustrates how abstracts, and possibly review articles, may become too concise for clarity.

Clarification of some of the confusion (in particular Too, 1996) may benefit other interested parties, since the abstract in question has been misinterpreted elsewhere.

—Raoul F. Reiser II, M.A., C.S.C.S.
Dept. of Mechanical Engineering
Colorado State University

RELATIONS WITH THE UCI

(Following is a letter from Peter Ross to the IHPVA board in response to an inquiry on who had made approaches to the UCI. He and they have given me permission to reproduce it here.
—Dave Wilson.)

Yes, it was I who wrote to the UCI during the time that the Re-organization Committee was preparing proposals for the new IHPVA. The reaction was friendly, and the UCI accepted that they had categories (now dormant) that would allow cycles not meeting the current UCI racing rules to compete.

The way matters were left was that the new president of the IHPVA, when he/she was finally appointed, should arrange an informal meeting with the UCI administration.

I still think that this would be a good idea, so long as it was on a strictly exploratory basis. I also think that we should attempt to revive the dormant UCI rules, and get them to agree that we should administer them on their behalf. This would allow national cycle clubs to sanction HPV races as part of regular bike contests without falling foul of the UCI, and avoid the risk of UCI licence holders losing their licence if they took part in such an event.

One of the by-products of my brief contact with the UCI was the recognition that we, in the HPV movement, should draw up and agree on a definition of an unstreamlined HPV for record-breaking purposes. At the moment the IHPVA recognises only ultimate speed by any vehicle (without stored power), and of course the fastest bikes all have aerodynamic fairings. In my opinion the current European rules for non-faired racing HPVs have become ridiculous, with any competitor wanting to do well having to fit what is virtually the rear half of a full hard-shell fairing, which does not have to perform any load-carrying function whatsoever, and makes fixing a rear-wheel puncture a near impossibility.

My suggested definition would be:

"Machines of all kinds that function by the power of one human only, that require no apparatus or device intended to reduce air resistance and that do not exceed the dimensions of 2 metres in length and 750 mm in width. " It is no coincidence that this is virtually the identical wording of UCI Article 31 as it was in 1933 when Francis Faure broke the hour record in the Mochet Velocar.

We would now need to add that there should be no stored energy at the start of the attempt. For US readers 2 metres is 78.74 inches (6 ft 6.74 in) and 750 mm is 29.53 inches (2 ft 5.53 in).

—Peter Ross, UK

GREETINGS FROM ALASKA

I greatly enjoyed the last two issues of *Human Powe*r, especially the discussion of hill climbing. My experience on hills with recumbents vs. uprights has been the same as Mr. Buttemer's and many others. Recumbents are slower than uprights on hills and the steeper the hill the greater the differential. In an attempt to correct this I varied the seat height on my recumbent (a medium-wheel-base 1040 mm, 41", made from an old Moulton 4-speed) by as much as eight inches (200 mm) above to one inch below the bottom-bracket height. It didn't seem to make much difference. If anything, the lower seat is slightly better but it is a mute point because any one of my uprights loaded to the same weight — even my fat-tire mountain bikes— are much faster up the same hill. Over the years I have had all too much time to think about this problem while twiddling my recumbent up hills. I have come to the conclusion that much of the poor performance of recumbents is due to the following.

Because of their low center of gravity, recumbents are inherently more difficult to balance than uprights. At moderate to high speeds the difference is not much but the lower the speed the greater the differential, even on the flats. (Does this sound familiar?) However, not all of the difference in low-speed handling (balance) is due to the height of the center of gravity. A good share of the difference is due to the fact that while the upper bodies of upright riders are unrestricted relative to lateral movement, the seats of recumbents greatly restrict this type of movement. Therefore, at low speeds, recumbents must be steered, in the main, by handlebar steering as opposed to weight-shift steering. In my own experience of climbing hills it seems like there is a positive feedback loop in operation. As my speed decreases I find myself having to concentrate more and more on balancing and trying to ride a straight line. This affects technique which affects efficiency which decreases speed which makes it harder to balance so more effort goes into steering until a "speed equilibrium" is reached.

I am sure that I am not the only person who has advanced this hypothesis but I wonder if it has ever been tested. Perhaps a simple frame attached to an upright that would prevent lateral movement would give information. By the way, much of this hunch comes from playing in my other favorite HPV, my 3.8-m (12.5-ft) double-paddle canoe. This wonderful little boat is essentially an open kayak with increased freeboard. When I built it I included a form-fitting seat back that is quite comfortable. Under relatively pacific conditions I lean back a few degrees and enjoy it.

However, when things get rough and balance becomes more difficult I lean forward until I am bolt upright or inclined slightly forward—which frees me to lean laterally all the way from my glutes. I have played in beam waves with my paddle resting across my lap out of the water, i.e., without even the opportunity to "brace". With my back freed from the restriction imposed by the seat I can survive waves that would otherwise cause me to capsize. This may give us a clue about what is happening with recumbents at low speeds on hills. Perhaps a recumbent seat that rotated on an axis equivalent to the top of a seat for an upright rider could be used to test this?

By the way, about five years ago I built a bike out of the front end of a

Moulton 4-speed that had been run over in a garage, and the rear end of damaged road bike. I put a Zzipper front fairing on it (made for a Moulton). This bike was blazing fast and a decent hill-climber. Unfortunately, I missed on the size and it was a little small for me but it was a great bike!

—Smiley Shields, Ph.D.
<sshields@alaska.net>

GREETINGS FROM SRI LANKA

Many thanks for a specially fine (summer issue) of *Human Power*. Theo Schmidt's article on PropSim was extremely informative. Carl Etnier's article was specially sensitively written, and I am planning to order a copy of that intriguing book on *Chasing Rickshaws* and am sure it will provide me some pointers into how to help raise the dignity of human power in our part of the world versus the disdain with which it is now looked down upon by the rest of us in our automobiles and who are the *real* beggars! Petroleum may be justified as a resource when it bubbles out of your ground .... or even justified when you go to war for it in order to 'defend your way of life'.... But for us who have to scrape for it to come from the other side of the world it is an absolute shame … and below beggary! What price 'globalisation?'

The guest editorial by Dave Larrington was specially interesting, as Dave Wilson will remember the 'K-Drive' (or whatever it is now called) with which we were experimenting when he visited us in Sri Lanka during the early '80s incorporated into a recumbent we had built which included *both* front-wheel *and* rear-wheel shock-absorber-suspensions (using rubber-bands and rubber-balls) and which he rode. He especially commented on the comfort of the cane-woven contour seat to help 'breathe' off one's perspiration. We have pictures of this event.

I shall look forward to a future issue where Kingsbury explains how he minimises the added friction which inevitably creeps into these drive systems. I have long felt that this drive is specially well suited to the recumbent as it helps eliminates the 'lifting' of the legs (stretched out in front of you) and enables them to concentrate on the direct ('push') thrust of the 'drive-stroke'.

A particularly interesting point was raised by Dave Larrington to the effect that "… the human engine, like the I.C. engine, requires an exhaust stroke, and moreover that the duration of the exhaust stroke is of the order of six times that of the preceding power-stroke.'" Quite how the figure of 'six-times' is achieved, I do not quite understand. But certainly in the flight of birds the 'up-stroke' takes about 50% to 100% longer than the 'down' (or driving) stroke … and this depends upon how much of a hurry the bird is in!

I have video records of the flight of flamingos and pelicans taken from alongside (in a gyroplane) and have slowed the rate of 'flap' in order to time it better. The more leisurely the flight the longer the bird appears to take on the (virtually 'gliding') up-stroke. My corresponding videos of a pigeon could not slow the rate-of-flap down sufficiently for this to be timed.

However, most experts in animal energetics and locomotion (e.g., McNeill Alexander, Brodsky, Goldspink, etc.) confirm the need for the 'recovery period' for the animal muscle, and also the vital necessity for the 'harmonic' action for economising thereof. This is evident when observing a dog trotting or even the trotting action of the 'pingo' carrier (the flexible beam on the shoulder of a porter with a load suspended from either end.) I have used the latter during trials and confirm the need also for one's breathing to coincide with the oscillations of the loads.

—Ray Wijewardene
133 Dharmapala Mawatha
Colombo 7, Sri Lanka
Tel/fax :+94-1421881
E-mail: <raywije@eureka.lk>

(Ray Wijewardene is an expert in sustainable agriculture and an enthusiast for human power and for home-built light aircraft—he has built fourteen! He writes that at 75 he is slowing down in that area. He and I worked, in different areas, in Nigeria in the 1950s and 1960s. —Dave Wilson)

from page 6 (letter from Ian Sims)

15 and 17 are available. Smallest allowed chain ring is 38-T with the 16-T.

As for how many hubs have been produced, the photos in the manual show number 000305, and we have numbers 001504 and 001505.

Application for recumbents: in my view the gear range is not wide enough on its own, thus we will be using them with either a Mountain Drive or a double/triple chain-ring set. These hubs actually arrived with a chain tensioner, to provide chain take up for bikes with suspension. It's rather like a short-arm derailleur without the linkage.

Spoke holes: it seems that the hub comes with only 32 holes, instead of the more normal 36 holes for geared hubs. I guess this is because the end cover has eight fixing screws, and there is room for only two spoke holes between each two screw bosses. Thus you would need a casing with a 9-screw pattern to use a 36-spoke pattern.

The pitch-circle diameter is 100 mm, so care will be needed in both rim selection, hole drillings, and spoke patterns. I believe you would need to use a X1 pattern for a 20" rear wheel, and the manual actually recommends X1 for wheels less than 26". It does not recommend radial spoking.

The twist-grip shifter is far from ideal on vertical handlebars, as it is only about 1-1/2" (38-mm) long (we may investigate lengthening it in some way) we found the original long Sachs Power Grips worked quite well.

Overall I think this is an exciting hub, and we will probably drool over it for awhile before deciding what trike or bike to test it in.

—Ian Sims
Greenspeed Recumbent Bikes, Trikes
69 Mountain Gate Drive
Ferntree Gully, VIC 3156
Australia
Phone: +61 3 9758 5541
Fax: +61 3 9752 4115
E-mail: ian@greenspeed.com.au
URL: http://www.greenspeed.com.au

EDITORIALS

BOUNCING OFF THE MAINSTREAM

No, this has nothing to do with propellers or human-powered space craft this time. Having spent a lot of effort helping organise the recent World HPV Championships held in Interlaken, it was a bit of a shock to realise how little the human-powered movement has encroached in the "mainstream", i.e., in the awareness of the general public.

We had a good event (see reports in *HPV News*) with a good turnout—several thousand spectators overall, but there were far fewer of these than at the traditional wrestling match a week later and even the more spectacular feats weren't picked up by the national or international media (e.g., the flight of Peer Frank's airplane Vélair, a stunning display of most of the world's best water vehicles, the presentation of the most advanced power-assist bikes available, etc.). We have a severe communication problem in that HPVs combine sport, fun, technology development, and environmental issues, yet sponsors and media alike love simple issues with a clear (or no) message.

So what, you may say, what public interest has there ever been in HPVs? What has ever interested the media except scandals and dead bodies? Well, we did think maybe we could create a bit of a stir in tiny Switzerland, a country with a comparatively "green" awareness, a country with lots of cyclists and with governments at least paying lip service to clean air and energy-saving transport, a country which had invented the Tour de Sol and has stood mostly spellbound by the side of the road applauding a motley parade of fun and furious vehicles for about ten years.

What is the way forward? How can we generate some real public interest in our exciting sport and in using HPVs for transport? Maybe the approach we have tried so many times, combining sport, technical development, and a bid for sane transport, just doesn't work, is too complicated a message. But what, what must we do? Answers, please!

—Theo Schmidt
Immediate past chair, IHPVA
Human Power associate editor
for Europe

UNCOMFORTABLE SUITS

My interest in lawsuits increased after Georg Rasmussen, the designer-developer-manufacturer of the Leitra HPV, asked me to talk about the effect of US liability lawsuits on HPV design at the third European seminar on velomobile design (*Human Power* 46, new numbering.) I tried to reassure European HPV manufacturers that we in the US were over the peak of lawsuit mania. Then in the summer of 1999 the relatives of some victims of a car crash were awarded over US$4 billion against General Motors because they died after a drunk driver ran into the back of their stationary car at between 50 and 70 MPH (80–113 km/h; 22–31 m/s). (The amount was later reduced, and in any case is now on appeal.) What has this to do with HPVs? I believe the following reactions are relevant.

First I had conflicting emotions. The people died from fire, not from impact, and perhaps the engineers could have placed the fuel tank in a safer position as the plaintiffs claimed, and the family would have survived. On the other hand, as an engineer I felt some pride that we are now expected to be able to design a car in which people will survive having a drunkard at the wheel of another car hit us at such a speed.

And then came my reactions as a user of HPVs. This lawsuit was carried out largely on my taxes. The litigators in a US lawsuit pay very little of the prodigious public costs involved. The whole community of US automobile owners and users are also hugely subsidized on my taxes. It is difficult not to regard them as spoiled brats (even though I'm occasionally one of them.)

The next emotion was a tinge of jealousy. Because of lawsuits, government regulation and fierce competition, cars are now so safe for the users that they can be driven at high speeds into other vehicles and into obstacles such as bridge abutments with a good probability of the occupants surviving. Very little public or private money has been spent to increase the likelihood that the pedestrians, bicycle and HPV riders and miscellaneous wildlife will survive their mayhem. We riders have to face the unfortunate fact that the safer motor vehicles are made, the more risks are taken by the more foolhardy of drivers, who tend to get their jollies by driving at a perceived level of their personal danger. The danger to the rest of us therefore increases year by year.

My tinge of jealousy narrowed down to our own vehicles. While highly subsidized motor vehicles have become safer for the users and more dangerous for nonusers, unsubsidized bicycles and other HPVs have seemed to me to have become rather less safe over my lifetime in almost every way. I have used this bully pulpit previously to report that when the front tire of my brand-new recumbent deflated I was thrown off in front of a large and very close truck. The fault appeared to be an appallingly sloppy fit - and a total absence of standards - of the tire to the rim (watch out for a technical note later on this topic). Just before writing this I was brought to a sudden stop in traffic on the same bicycle when a rivet dropped out of the still-new derailleur shifter, snapping the mechanism into the rear wheel and locking it. This could have been fatal if I had been negotiating a difficult turn in traffic. Extremely casual workmanship and quality control must be blamed (with no blame to the bike's builder). If failures of such components had occurred in an automobile, there would probably be a required massive recall and expensive replacements of offending parts. We in the HPV community, however, suffer from "misplaced machismo" and put up with it. We need to find an optimum path to effect change that is between excessive lawsuits and excessive government regulation. We are at present in an unhappy no-man's land.

—Dave Wilson

International Human Powered Vehicle Association

IHPVA
PO Box 1307
San Luis Obispo, CA 93406 USA
http://www.ihpva.org