Recent progress in blending HPV efficiency with practicality by Gerald E. Pease

SUMMARY

At least one practical streamlined bicycle, the Lightning F-40, is now commercially available. The author has purchased one and found it to be far more efficient than other bicycles, or HPVs in general, that meet usual standards of practicality.

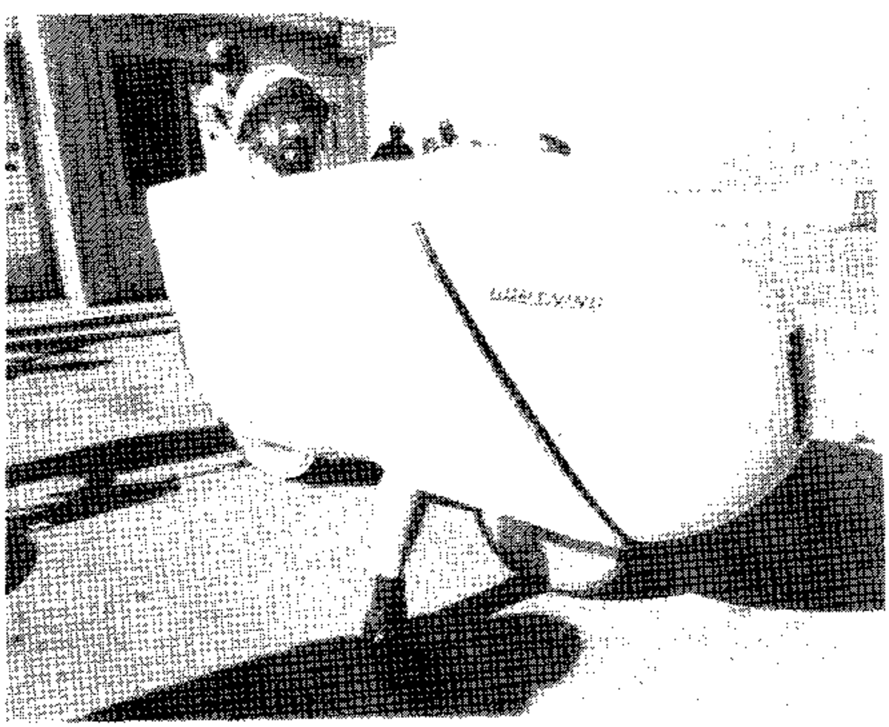
It is now common knowledge that IHPVA members have achieved remarkable success in the area of land speed records for human-powered vehicles. It is no secret that these accomplishments, in the tradition of UCI records, have been attained using vehicles totally unsuited for any other purpose. Indeed, a UCI sprint bike would be considered a model of practicality compared with the typical streamliner, which usually requires a pit crew to assist the rider in entering, starting, stopping, and exiting. The fastest vehicles have a reputation for being easily blown over by light cross winds. The lack of adequate ventilation means they are unfit to ride even moderate distances. Thus has efficiency come to be equated with uselessness in the real world, where cost effectiveness and convenience rule above all else.

The most popular bicycle combining practicality with some measure of efficiency is still the lightweight multi-gear diamond-frame Safety concept, available with a wide choice of tires, handlebars, and saddle designs. A current trend appears to be away from efficiency in order to achieve modest improvements in comfort, safety, and durability. This tradeoff is exemplified by the ubiquitous Mountain Bike and its City Bike cousin. The popularity of these machines seems to hinge on their jack-of-all-trades nature, particularly the ability to perform competently on rarely encountered bad road or even off-road conditions. This is somewhat analogous to the current popularity in metropolitan areas of four-wheel-drive trucks, which also are significantly compromised in street efficiency by their rarely used off-road capabilities. But in the case of motorized vehicles, high performance and efficiency are also popular. Where are the Porsches and Ferrari F-40s of the bicycle world?

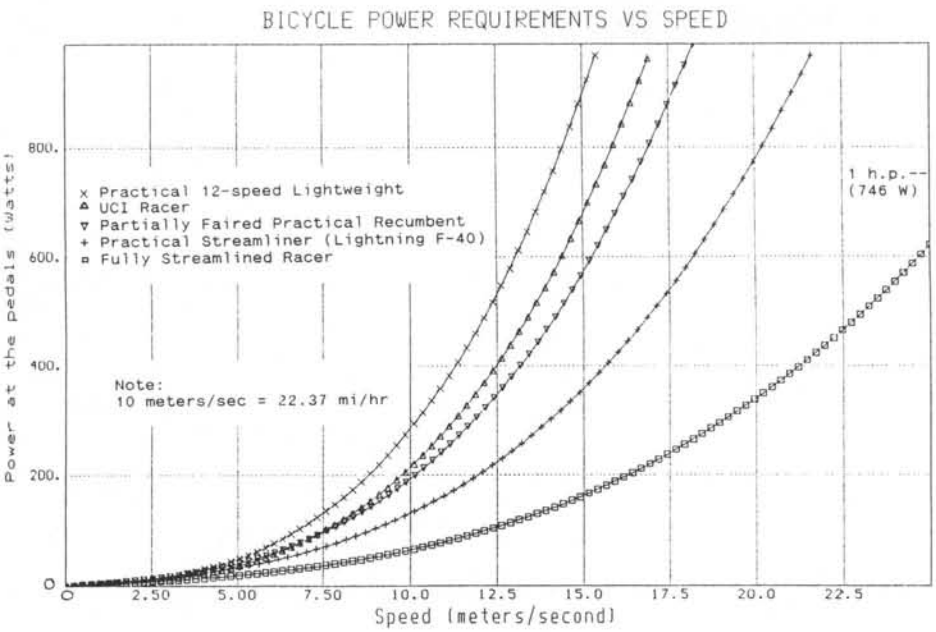
Enter the darling of the HPV enthusiast, the recumbent bicycle. In unfaired and partially faired forms, recumbents offer a big improvement in comfort and a worthwhile improvement in efficiency. They are not popular. Not a single recumbent design has ever been mass produced. We know that people say they don't buy them because they are confused by the lack of standardization and because the racers claim they are no good on hills. They are also usually more difficult to transport, and the ratio of price to perceived quality is not favorable. As marketed, there is no competition class for them (they are not competitive with fully faired racing recumbents), so the flat-road performance edge doesn't count for much. None of them is a match for the UCI road racer in an out-and-out hill-climbing contest which is, naturally enough, considered by traditionalists to be one of the most important tests of real-world performance.

With the sudden appearance of the Lightning F-40 on the scene and its startling victory in the 1988 Argus Tour, a new standard of efficiency for practical vehicles now exists. This commercially available 15-kilogram streamlined recumbent bicycle is easy to enter, start, stop, and exit without assistance. Ventilation is outstanding for a streamlined vehicle and is adjustable. Best of all, the bike is not blown around by normal crosswinds. In extreme conditions of temperature or wind (over 32 degrees Celsius or 9 meters/sec windspeed) the major part of the fairing, made of nylon Spandex, can be removed and stowed in less than a minute. A worthwhile bonus for touring in cold or wet weather is the protection offered by the fairing, which can be ordered in waterproof stretch Cortex. Other touring options that are available include extra-wide-range gearing, a front drum brake, mudguards, and aerodynamic pannier carriers integrated with the fairing.

The efficiency of the Lightning splits the huge gulf between the partially faired practical recumbent and the impractical full streamliner required to be competitive in short-distance HPV races. The F-40 requires only half the power at the pedals needed by a UCI racer on a flat surface at 18 meters/sec. In other words, we are



Gerry Pease is ready for some fast touring in his Lightning F-40. (Photo by Matt Decell)



looking at a new generation of bicycle for touring and long-distance road-racing. These tasks are performed inefficiently by standard bikes and not at all by most fully streamlined recumbents. A legitimate question is whether or not the improvement in efficiency justifies the cost (about double that of a good partially faired recumbent) and the additional inconvenience in transporting by automobile. It was affordable enough for my budget but I'm still working on the transportation problem. A good roof rack should do the job if the Spandex part of the fairing is removed from the bike prior to transporting. This is a relatively minor inconvenience.

The accompanying figure illustrates the efficiency spectrum of existing types of bicycles for which speed is an important design consideration. The Lightning F-40 curve more or less defines the present limit of efficiency for a practical vehicle. There may be some "practical" tricycle designs with comparable level-road power requirements, but I feel their additional width and lower profile causes them to be too dangerous in traffic, while the extra weight, complexity, and cost may not be justified by the stability advantage. At this point I also think it makes more sense to attempt incremental improvements to the workable streamlined recumbent bicycle design rather than to try to make the fully streamlined racer either more practical or faster. I would like to see a shock-absorbing front suspension added to decrease rolling resistance and to improve the ride quality and handling on rough surfaces. The ride quality is presently good, provided that the tires are inflated to touring pressures rather than racing pressures.

The well-known equation for power requirement, P, as a function of level-road speed, v, in windless conditions was used to generate the curves, expressed as

$P = av^3 + Bv$, where
$A = (Cd \times Af \times Da)/(2 \times Em)$, and
$B = (Cr \times Wt)/Em$.

Cd and Cr are the respective aerodynamic drag and rolling coefficients. Af is the frontal area. In each case 1.226 kilograms per cubic meter was assumed for air density, Da, at sea level. Total weight, Wt, was obtained by multiplying the total mass of bike and clothed rider in kilograms by the acceleration of gravity, 9.806 meters/sec^2 at sea level. Mechanical efficiency, Em, was assumed to be 0.95 except for the Lightning, which has a drive-side idler with precision bearings. For the Lightning, 0.94 was assumed for overall mechanical efficiency. The other constants peculiar to the type of bicycle and rider are tabulated on the following page. The estimates of drag coefficient and frontal area were based on coast-down tests and accelerometer measurements of effective frontal area performed by experimenters other than myself. Because of the population sample variation in most of the constants in the table, they should be considered "ball park" representative estimates, but numerous speed comparisons performed by me indicate that they are reasonably accurate for the class of practical vehicles (I don't have access to a fully streamlined record HPV).

For more information on the Lightning F-40, contact

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Tradition meets Innovation on the bike path. (Photo by Matt Decell)

Constants affecting bicycle power requirements

	Practical 12-speed Lightweight	UCI Racer	Partially Faired Recumbent	Practical Streamliner (F-40)	Full Race HPV
Drag Coefficient	0.95	0.89	0.6	0.3	0.12
Frontal Area (m^2)	0.40	0.33	0.39	0.44	0.45
Rolling Coefficient	0.004	0.003	0.0045	0.0045	0.0031
Total Mass (kg)	85	81	94	95	95
A (kg/m)	0.25	0.19	0.15	0.086	0.035
B (kg-m/sec^2)	3.5	2.5	4.4	4.5	3.0

$P_{Watts} = Av^3 + Bv$ for Vm/sec

To calculate v directly as a function of P, A, and B:

$$v = (X + Y)^{1/3} + (X - Y)^{1/3},$$

where $X = P/2A$

$Y = [X^2 + (B/3A)^3]^{1/2}$.

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Gerald Pease is a 51-year-old satellite-orbit determination analyst at the Aerospace Corporation in El Segundo, California, who is finally fulfilling his 25-year quest for a practical bicycle fast enough to allow him to stay in front of any pack of racers he is likely to encounter.—ed.

Human-powered vehicle steering and suspension design by Robert L. (Rob) Price

INTRODUCTION

The first part of this article discusses human-powered-vehicle steering. After briefly reviewing bicycle steering geometry, automotive steering is used to illustrate steering with two wheels. The second part discusses suspensions, using motorcycles and cars as models. The lean-steer mechanism and linkage I will use in my next HPV are shown as a summary.

STEERING

Many articles have appeared on the theory of bicycle steering. The intent here is to illustrate only some basic principles and compare them to steering geometries developed for automobiles.

Figure 1 shows head-tube angle, which is measured from horizontal; fork rake, measured from the center of pivot of the fork-tube bearings to the center of the axle; and trail, being the distance from the intersection of the fork-tube centerline and the ground at the point where the center of the tire patch meets the road. Common value ranges are shown in the figure.

There are several tracking stabilities inherent in well-designed bicycles. Trail is the first stability. The tire patch tends to follow the point where the steering axis intersects the road. This is known as 'caster' in the automotive world and can be easily observed on grocery-store carts. These have vertical steering axes on their castering wheels. Bicycles have angled steering or fork axes, which complicates matters.

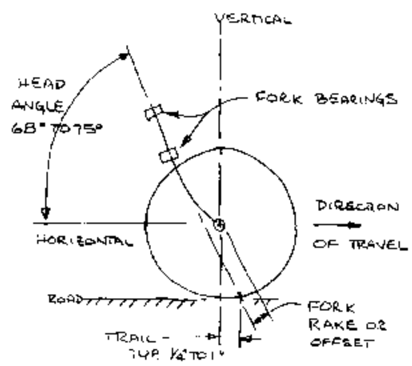

Figure 1. Bicycle fork geometry

Figure 2 illustrates the second stability, which is the 'well' the head tube sinks into when the bicycle is going straight ahead. When the handlebars are turned, the effective fork rake along the centerline of the bicycle is reduced and the head tube rises slightly. The steering tube wants to centralize in the well, making the bike track straight under the weight of bike and rider.

Bicycles have fork rake to reduce the amount of trail. This increases the sensitivity of the steering. When the fork has too much rake for the head-tube angle, trail approaches zero and the machine becomes unstable. When the fork has too little rake or is installed backward (as was popular a few decades ago) there is plenty of trail, but the 'well' becomes a 'hump.' The effective shortening of the fork rake when the wheel is turned occurs behind the fork-tube-bearing centerline, making the head tube fall slightly in a turn.

A bicycle leans in a turn, which increases the effective depth of the well.

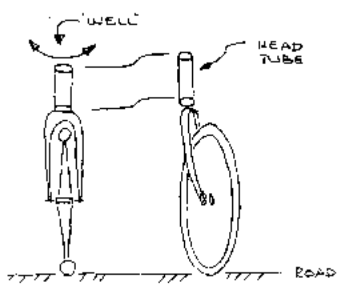

Figure 2. Bicycle steering stability