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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 "The building of my HPV" should be sent to *HPV News*). Contributions should also 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. Many contributions are sent out for review by specialists. Alas! We are poor and 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.

RIDING A BOAT LIKE A BICYCLE

David Witt

SUMMARY

This article describes some work at Oxford, England, on a series of pedal-powered boats which, having narrow single hulls for the sake of low resistance, are statically unstable in roll. But with a large rudder set forward, they can be kept upright in the same way as a bicycle, by the rider sensing any incipient roll and turning the rudder, via handlebars, to correct it.

INTRODUCTION

This work, on statically unstable human-powered boats, originated in 1984, when the writer was trying to think of interesting topics for student projects in Oxford University's Department of Engineering Science. Oxford is well-known for human-powered boats of the oared type, and it seemed a good idea to see if we could demonstrate some alternatives on the river (figure 1), and show that the acquired skill of keeping a bicycle upright need not be confined to the land. So far these, and other human-powered boats, have provided project topics for 34 final-year students.

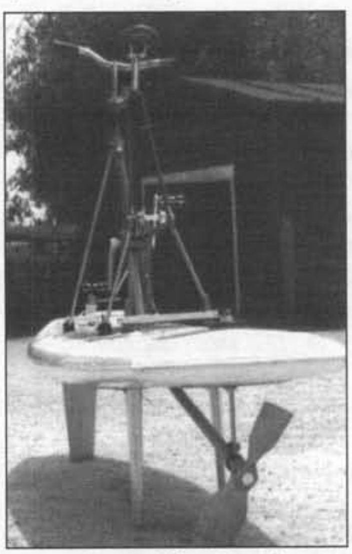

Figure 2. Propedalica from the stern

THE FIRST TWO BOATS

After an initial, and somewhat inconclusive, theoretical investigation into whether a semi-submarine would be ridable, we decided to go for something simpler. The first vessel to be built (figure 2) was just a bicycle frame on top of a reject sail-board hull, with a bevel gearbox to drive a propeller at the stern, and a spade-type rudder towards the bow. With a beam of 0.68 m, she was not far short of actually being stable in roll, but became much easier to ride when the rudder was enlarged, and two fins were added about 70% of the way back from the bow to stop the stern sliding sideways. She was named "Propedalica". This had nothing to do with pedals, but was coined from the Greek (pedalion = rudder) to imply "having her rudder in front", which seemed her most distinguishing feature.

Figure 1 The three boats on the River Thames. Skippy is in the foreground, Propedalica in the lead, and Daring furthest from the camera.

Propedalica was heavy, and not particularly fast, but demonstrated the principle that static stability was not essential (nor is it for e.g., a sail-board or sculling boat). So a second vessel was designed, ultimately to be christened "Daring" (figure 3). The hull is of fibreglass on polystyrene foam, 4 m on the waterline, and its shape was based on that of a typical destroyer. The reasoning behind this was that if one plots "speed-for-size" against "power-for-size" on logarithmic scales for a variety of full-sized ships, one gets a long line with oil tankers etc at the left-hand end, and planing craft on the right, and lightweight human-powered boats come in amongst the destroyers and frigates (figure 4).

One might expect human-powered boats to come rather below the line of full-scale ships on such a plot, on the ground that their lower Reynolds Number means that they suffer more from frictional resistance, so should have a lower speed for equivalent power. But against this, their propellers are potentially more efficient, since propeller diameter can be a much larger fraction of hull length. Atmospheric pressure too is on the side of small boats, since it is equivalent to an extra 10 m of water depth, and a powerful deterrent to cavitation, permitting much narrower blades and higher lift coefficients.

Destroyers and frigates tend to have fine, deep bows, and rather flat-bottomed after-hulls rising to a transom.[1] However the choice of such a hull shape turned out to be not entirely wise, since although such a hull does have low drag at these Froude Numbers, *Daring* has an embarrassingly large turning circle. This question will be returned to.

With a beam of only 0.4 m, and the mass centre typically 0.64 m above the metacentre (for a stable vessel the mass centre has to be below the metacentre), there was some doubt as to whether *Daring* would be ridable, so a simulation was devised to investigate it. It was assumed that the rider would sense roll-angle, or more likely angular rate, through the "semi-circular canals" in the ear cavities,[2] and move the handlebars to correct any incipient roll. It was discovered that a simulation which does not actually roll the subject, but presents information on a screen, has to present roll-rate as well as angle to be at

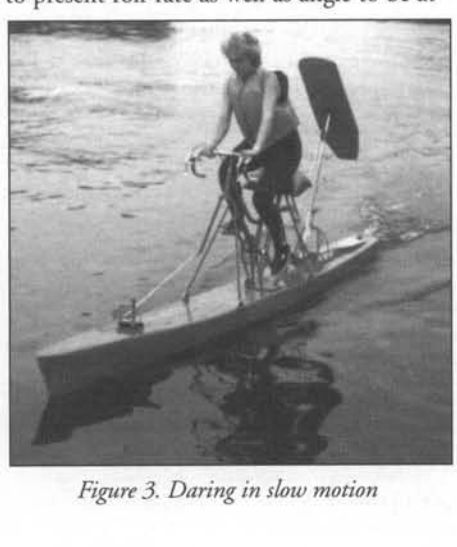

Figure 3. Daring in slow motion

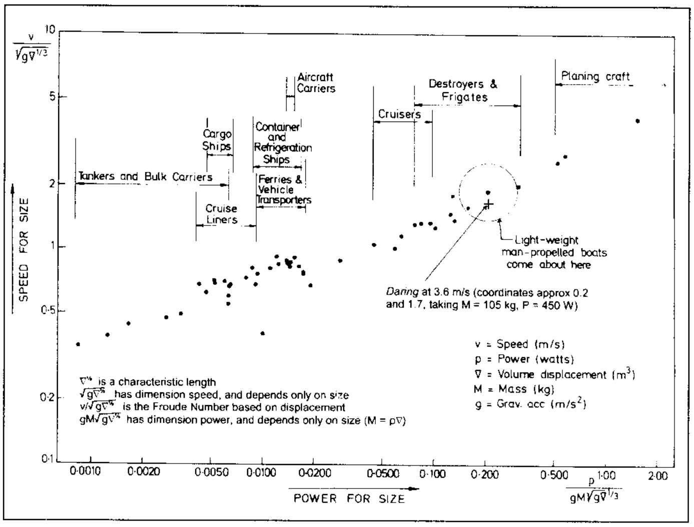

Figure 4. Power-for-size and speed-for-size

all realistic. The brain's processing of visual signals is rather slow.

In the event *Daring* seemed easier to ride than her simulation, at least on the straight, which was a considerable relief to the writer. The mathematical model has since been greatly refined, but it is difficult to devise experimental confirmation of it, except in the qualitative sense of predicting e.g., the need for stabilising fins aft, or that boat B will be easier to ride than boat A. The model is in the form of a transfer function from rudder angle to roll angle, with four real-axis poles, one of them unstable, and two real-axis zeros. The model implies for instance that the rider's "gain", from roll angle to rudder angle, must exceed a given figure for stability, eg 2.45° of rudder per degree of roll, for *Daring* at 3 m/s (6.7 mile/hr). For comparison, the theoretical figure for a typical bicycle might be about half that at the same speed,* but far less at typical cycling speeds. The steering mechanism can include a modest "step-up ratio" from the handlebars to the rudder, but it is important that it be free of backlash.

VIBRATION PROBLEMS

Daring was given a V-belt drive initially, for cheapness, but it proved very inefficient, so was replaced by a purpose-built bevel gearbox. This allowed some increase in speed, but revealed the next problem, severe vibration of the propeller-shaft at well under full power. The reason is believed to be as follows. When a two-bladed propeller turns on a downward-sloping shaft, the descending blade produces more thrust than the rising one. When the propeller is vertical, each blade produces the same thrust. So the propeller imparts to the shaft a bending moment which oscillates between zero and maximum at twice shaft speed. The shaft had been designed for a whirling speed of about 16 rev/s, in the belief that its top speed would be about 10 rev/s. But when the shaft ran at 8 rev/s the twice-speed bending moment was at 16 Hz, and the shaft went into resonance and banged violently against the sides of its tunnel, blocking any further acceleration. The solution was to "teeter" the propeller, ie allow it to pivot about an axis perpendicular both to the shaft and to the blade axis, as is done on two-bladed helicopters and some windmills. This cured the problem, and full power could then be applied. Top speed on a sprint is of order 3.5–4.0 m/s (8–9 mi/hr), depending on who is pedalling. 2.2 m/s (5 mi/hr) is a comfortable cruising speed.

MANOEUVRABILITY

Having the rudder forward has two rather contradictory effects on manoeuvrability. If the turning radius is fairly large, a forward rudder gives much better control over the path that the vessel takes (provided there is some fin area aft to give directional stability). This is because application of the rudder immediately moves the bow in the required direction, and the rest of the boat follows. If a stern rudder, on the other hand, is turned so as to put the vessel to, say, starboard, the first effect is that the stern sideslips to port. Only after a significant yaw has developed does the hull as a whole start to move in the required direction.[4] Thus if an obstacle suddenly appears directly ahead, it can sometimes be impossible for a stern-steered vessel to avoid it. Whichever way the rudder is put, the hull will hit the obstruction on one side or the other. A bow-steered vessel stands a better chance.

But a bow rudder is much less effective at producing a tight turning circle. When a stern-ruddered hull of typical form is steered along a circular path, the bow will point approximately along the path taken, while the stern will sideslip outwards. The cross-flow of water, gradually increasing from bow to stern, generates a lateral force fairly uniformly distributed along the length of the hull, and this supplies the centripetal force required. With a well-balanced hull design, there may be little force on the rudder in a steady turn - it is all on the hull. But if the rudder is forward, the point of zero sideslip is not near the bow, but much further back, probably aft of amidships. The bow sideslips inwards, and if it is a narrow deep bow (as on *Daring*), it requires a substantial force to make it do this. The rudder has to supply this force as well as most of the centripetal force required to make any mass follow a curved path, and the sum of these forces is likely to be large. So any attempt at a tight turn puts the rudder into a "stalled" condition, where the lateral force on it no longer increases with angle. If the vessel is statically stable, this merely limits the turning circle. But with boats of the type being described, it means that small corrections on the rudder are no longer effective at keeping them upright. Matters are made worse by the fact that the cross-flow under the hull varies with depth (greatest at the keel), so the rudder stalls first at its tip, where most of the righting moment is generated. A slight roll inwards drives the stalled condition up the rudder, and a capsize results. (If it is recognised early enough, one can sometimes escape by rapid acceleration!)

This effect limits *Daring*'s turning circle (with a practised rider) to about 24 m diameter. When roll is stabilised by an outrigger float, so that the rudder can operate fully stalled, tighter turns become possible.

A MORE MANOEUVRABLE HULL DESIGN

Some model tests were done to clarify this problem, and seemed to suggest a hull that was shallower at the bow, and this led to "Skippy" (figure 5). *Skippy*, like *Daring*, is 4 m on the waterline and has a transom stern, but a larger maximum beam (0.5 m against 0.4 m), and a keel that rises gradually to the surface at the bow. The centre of buoyancy is therefore a little further aft. She

* Applying simple feedback-control theory to the 2nd-order mathematical model of a bicycle developed in ref. 3 leads to the following expression for minimum roll-to-handlebar-angle gain: (Gravitational acceleration)×(wheelbase)/(speed)^2 A well-designed autopilot would probably have a gain of around double the minimum, and some phase-advance, too.

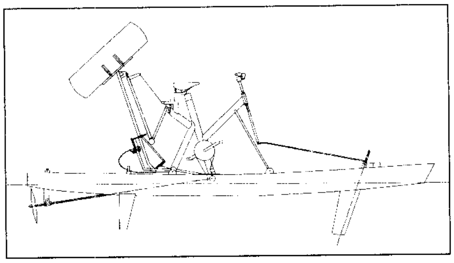

Figure 5. Skippy

is a much more manoeuvrable vessel, with a turning circle about half that of *Daring*, and is noticeably easier to ride (the theoretical minimum roll-to-rudder gain is about three-quarters of *Daring*'s at the same speed). Maximum speed is lower, since at full power the bow rides well out of the water, reducing the waterline length, but the effect is insignificant at cruising speeds.

Skippy in fact cruises quite well, and has done one-day trips of 39, 51 and 27 km (24, 32 and 17 miles) on local rivers, the Thames and Avon. These rivers have locks, so there is an enforced rest from pedalling every few miles. Speed between locks has usually been about 2.2 m/s (just under 5 mi/hr). The only capsize on these trips was a few miles into the first one, when re-mounting at an awkward spot after landing to look at a nearby village. As compared with other human-powered vessels on which one might cruise a river, one is facing forwards, with the head high up to get a good view, power comes from the legs rather than the arms, and the cruising speed is such that a satisfying distance can be covered without excessive fatigue. And, short of a capsize, the feet and seat remain dry.

One of the hazards on such a voyage can be the motor cruiser whose helmsman decides to overtake this strange vessel at full power. The resulting wash coming up behind at 45° to the hull can be a significant challenge. A good policy is to do a 135° turn and go through the waves perpendicularly, and then turn back again.

OUTRIGGER FLOATS

As can be seen in the illustrations, *Daring* and *Skippy* have retractable outrigger floats, which normally sit high up behind the rider, but can be released, using controls on the handlebars operating through Bowden cables, to fall down on one side or the other and lock in that position. The boat is then statically stable, and the rider can stop, go backwards, do a 3-point turn, leave the boat moored and unattended, etc. It is, for example, very helpful for going through locks, and also permits exploration of possibly shallow water or narrow dead-ends. On *Daring*, the float can be raised again only from the bank, but *Skippy*'s is a "second-generation" version which can be raised while under way by pulling on a cord behind the saddle. Another improvement in the second version was to make the float as an inflatable cylinder, instead of the narrow fibreglass one built for *Daring*. It now has much more buoyancy and is less liable to impact damage. Its higher drag is of no significance, since it is meant for use only at low speed. However, new riders have to be warned that it is not built to withstand the drag force that will arise from pedalling hard with it immersed. It is possible to travel with the float lowered, but still mainly or entirely out of the water.

In fact the two "cycle frames", together with the floats, are interchangeable between the two hulls. *Daring*'s is just a modified bicycle frame, but *Skippy*'s was designed for the purpose, and built from large-diameter, thin-wall, aluminium-alloy tubing.

PROPELLERS

Early propellers were fairly crude in design, first carved in wood, and then cast in aluminium using a wooden one as pattern (figure 2). We then did a more thorough design, and made it on a numerically-controlled milling machine. Its diameter is 360 mm. It seemed very successful, so we built a dynamometer to measure thrust and torque in the shaft while afloat, store them electronically, and play them back for analysis. Figure 6 has typical traces of thrust and torque so measured, showing the large variation arising from the pedalling process. The results imply a propulsion efficiency of about 72.3%. Theoretical analysis of the design, allowing for teetering and cyclic torque variation, suggests an efficiency of 75%. The discrepancy is not large. It is believed that torque variation lowers the efficiency by about 2–3%.

The traces of figure 6 were taken on a windy day, so the measured thrust is probably not representative of the total (air + water) resistance of the vessel in calm conditions. Calculations, supported by some towing tests done very early in the project with primitive instrumentation, suggest a resistance nearer to 50 N at this speed (2.74 m/s) and about 100 N at 4 m/s.

One advantage of the deep rudder and fins, although they do have significant resistance, maybe 15% or more of the total, is that in shallow water they will hit the bottom first, thereby protecting the propeller. The reason for two fins rather than one, incidentally, is that the complete vessel can be stood up stably on level ground, a great convenience. But their chord and thickness could perhaps be reduced.

POSSIBLE VARIATIONS

A question frequently asked is "Why not adopt the recumbent position?" It would certainly reduce air resistance, but that is only a small part of total resistance, except in a strong headwind. Lowering the rider would not make *Daring* or *Skippy* statically stable unless the beam were increased too, but it would reduce the roll-axis moment of inertia, thus making their control more sensitive to the reaction-time of the rider. And for cruising, one of the attractive things about the upright position is the excellent view one gets.

The waterline length could be extended considerably beyond 4 m, which would further reduce the resistance, but such a vessel, being more reluctant to turn, would probably be harder to ride. It might nevertheless be worth trying.

An alternative to the outrigger float would be to keep the hull narrow at the waterline, for the sake of low resistance, but

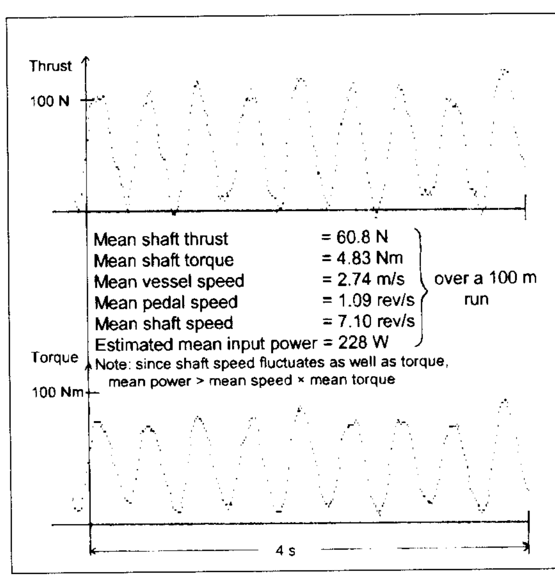

Figure 6. Thrust and torque in Daring's propeller shaft at 2.74 m/s

to broaden it higher up, so that it could be statically stable at, say, 20° roll angle. It could then be virtually uncapsizable. Some variable-geometry arrangement might be used to make such a hull stable in the vertical position when moored. One could then build a two-person cruiser in which the crew could sleep on the overhangs with the hull level, and an awning above for weather protection. It could then be restored it to its narrow-on-the-waterline, but uncapsizable, form, to cruise at a speed similar to that of most mechanically-powered river or canal cruisers.

ACKNOWLEDGMENTS

The project work of 25 people, too numerous to name, contributed, in many cases substantially, to the work reported here (others worked on later ideas). Many of the Department of Engineering Science's technical staff contributed too, not only in making many of the components, but also giving much valuable advice.

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Photos and drawings supplied by the author.

Editorial post-script: Since seeing David Witt's HPBs in Köln I learned through the hpv mail list of a similar boat that has been made commercially for the last two years in Québec: the Surfbike (e-mail: surf@surfbike.ca). I requested information and sent it on to David Witt, who wasn't aware of the development. He said that the hull is similar in size to his boats, though lighter. The rudder is a little further astern than on David's machines, and no outboard emergency float is used. Otherwise there is a great deal of similarity. I will send a copy of this issue to Andri Gauthier, president of Surfbike, who has promised to comment on David Witt's article and on the projected future of Surfbike. From the material sent it seems to be the most successful of the current generation of pedalled boats. —*Dave Wilson*

A COMPOSITE-PROPELLER-BLADE MANUFACTURING PROCESS FOR HUMAN-POWERED WATER VEHICLES

by Leo R. Benetti-Longhini and Bradley D. Klena

INTRODUCTION

A rapid and inexpensive method for producing small quantities of propeller blades for human-powered (HP) watercraft is presented. It is one of several methods typically used by HP enthusiasts and competitors to produce fiber-reinforced blades. The technique requires that a three-axis CNC milling machine, CAD/CAM software, and composites tooling and materials are readily available. Although the blades of the Torpedo III , a human-powered submersible, are used as an illustrative example (figure 1), the method can be readily adapted to other HP applications or vessels with similar power.

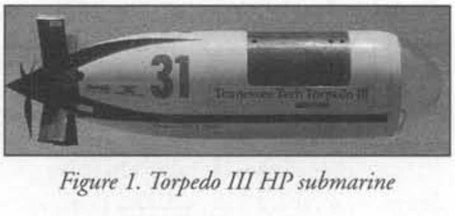

Figure 1. Torpedo III HP submarine

PROPELLER SYSTEM

The propeller hub used on Torpedo III allows for preset "on-shore" propeller-pitch adjustment. The resulting blade differs somewhat from a typical fixed-pitch propeller blade and a brief description is in order. The hub system (figure 2) is comprised of a fiber-reinforced epoxy cone, an aluminum squash-plate, and individual blades (two or three, depending on the plate/cone combination used).

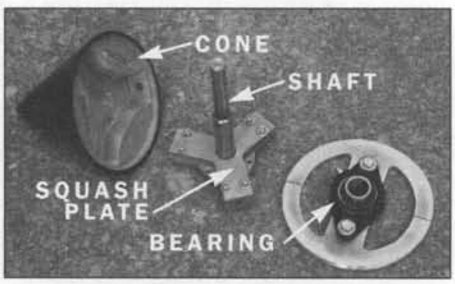

Figure 2. Three-blade hub system

The squash-plate, which resides within the cone, has a stub shaft for connection to the drive shaft within the submarine. The stub shaft is supported by a bearing in the tail of the vessel. The individual blades have 3/8-inch-diameter (9.5-mm) high-strength stainless-steel rods extending from within the blades at the hub end, allowing the blades to be clamped between the two halves of the squash plate and thus allowing for angular adjustment of the blades.

GEOMETRY

Before initiating the CAD/CAM procedure the overall blade geometry must be defined. The geometry is usually defined by the profile, the chord length, and angular orientation at a number of discrete locations along the length of the blade. See Poole (1991) and Larrabee (1984) for propeller-blade design information.

SURFACE MODEL

A computerized surface model is created from the geometry listing using the CAD/CAM software package. In this case Mastercam is used, but since most reputable software packages have surface-generation capabilities, the steps will be similar.

The first step is to draw the section profile by entering the section coordinates. The points are then connected with a spline (figure 3). The section is usually defined to have a unit chord length value so that it can be scaled easily. It is also advisable to "thicken" the trailing edge of the profile to avoid a finished blade with an overly delicate edge (note the squared-off edge).

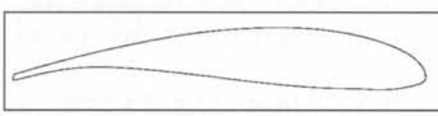

Figure 3. Representative profile

The 2-D profile is then copied along the third axis (figure 4) the same number of times as the number of discrete stations given in the geometry listing. [Ed: Authors agree that this is a simplified method of blade design. Most blade-design methods produce a different profile at each radius, for which system their method is fully applicable].

Each individual profile is then proportionately scaled to obtain the desired chord length (figure 5), and then rotated to the specified angle (figure 6). If the profile chord lengths have a unit value, as mentioned above, then the desired chord value is simply entered as the overall scale factor.

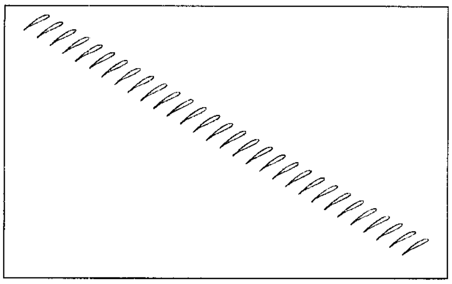

Figure 4. Profiles at blade sections

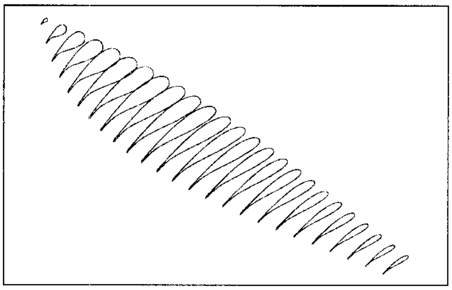

Figure 5. Profiles with scaled chords

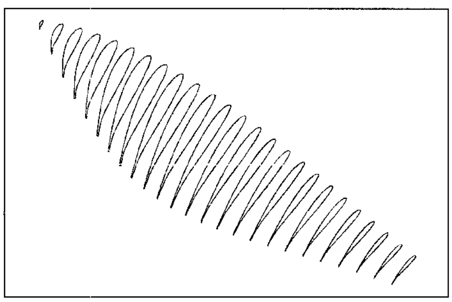

Figure 6. Rotated profiles

The point about which the profiles are to be scaled and rotated must be specified. The thickest location of the profile (typically about 30% from the leading edge) is usually chosen. The (0,0) axis can be positioned at this location to facilitate the scaling and rotation.

The profiles are next fitted with a surface via a lofting procedure (figure 7). Additionally, a conical surface representing the tail-cone is drawn by sweeping a line about the drive shaft axis.

The conical surface is used to "cut" the propeller surface to create a new propeller

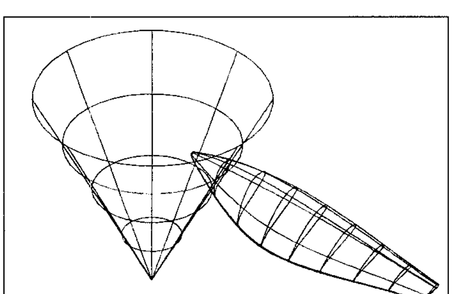

Figure 7. Lofted blade and conic

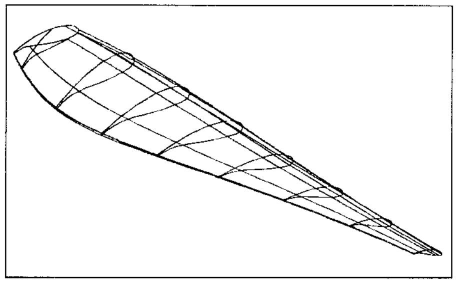

Figure 8. Completed surface model

surface (figure 8) that matches the real-world tail-cone. This final surface is rotated about the propeller axis so as to occupy a volume with minimal height. The rotation reduces the block size of the material used in the machining process.

TOOL-PATH GENERATION

The completed surface model is now prepared for the cutter-path generation. The first step is to separate the blade model into two separate surfaces. A "parting-line" command fits curves corresponding to the planform outline of the blade. The upper and lower surfaces (figures 9 and 10) are then created by splitting the blade at these parting lines. The parting lines do not necessarily match with the leading and trailing edges of the individual section profile.

The lower surface is then "flipped" or rotated 180 degrees about the zero-axis of the blade. Its exterior surface thus faces "upwards" so that it can be machined.

The tool and path parameters are defined. A spherical-tipped cutter is ideal for the compound surface. For this particular blade, a 0.25 inch (6.35 mm) tip diameter is

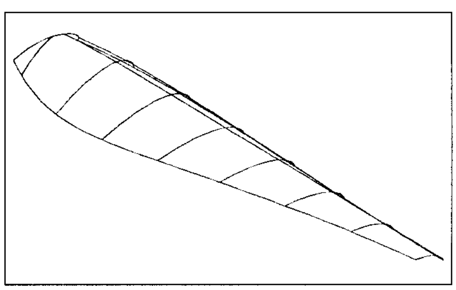

Figure 9. Upper surface of blade

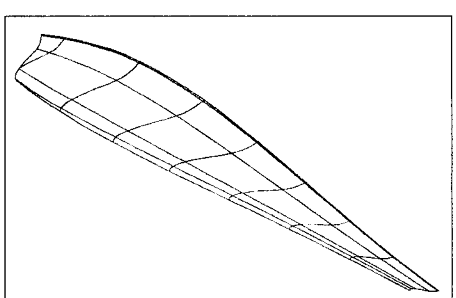

Figure 10. Lower surface of the blade

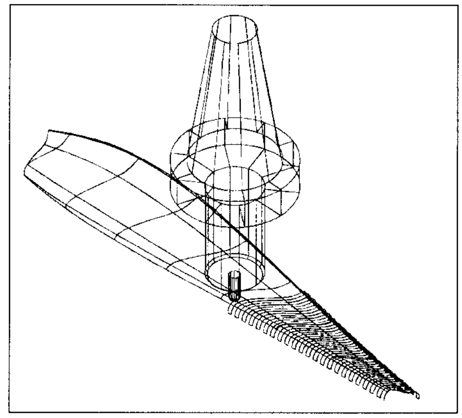

Figure 11. Lower-surface tool path

used. Cutter compensation for the tip radius can be performed by the software or, in many cases, by the CNC machine. In this case, the software compensation is chosen. Other parameter choices included the type of path, starting location, and the direction. A zig-zag path, starting at the blade tip, with chordwise travel, is suggested (figure 11).

THREE-AXIS MACHINING

Pattern materials range from high-density foam to metal. A cost-effective rectangular block of oak is used in this case; however, a denser, more-consistent wood, such as mahogany, is preferable. Note that the "height" of the block is dictated by the orientation of the surface model in figure 8.

Regardless of the material used, the block must be accurately squared on all faces with a fly-cutter or similar tool. This allows the block to be flipped over and accurately re-clamped to the table. The key to successful repositioning of the block is to locate the (0,0) axis of the blade at the internal centerline of the block. An edge-finder tool allows this to be accomplished.

The pattern is typically milled with a rough pass and then with a finish pass to reduce the "scallop" height (figure 12).

When the machining is complete, the pattern is painted with a low-viscosity epoxy to penetrate and seal the oak. Once fully cured, the peripheral oak material is trimmed away and discarded. Lastly, the ridges or scallops left by the ball-tip cutter are removed by careful hand sanding. This requires a great deal of patience and a trained eye. A primer of contrasting color is useful in judging if the ridges have been sanded away completely.

FIBERGLASS MOLD

A molding box (figure 13) is used to facilitate the "lay-up" of the two-piece fiber-

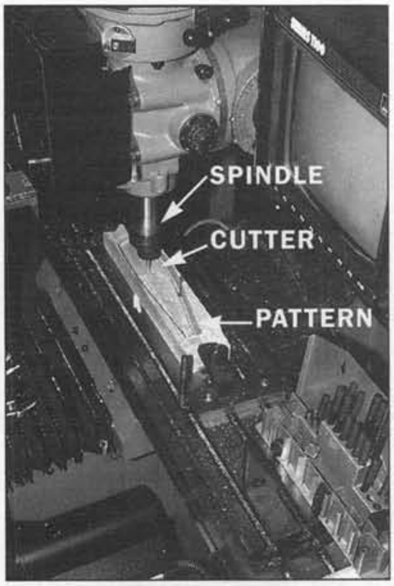

Figure 12. Milling the oak pattern

glass molds. The box has a center board containing an open trough for modeling clay and a semi-cylindrical groove for the blade rod. Four removable walls are clamped to the board perimeter with carpenter's clamps. The wall nearest the blade tip can be positioned anywhere along the center board to give different box lengths. This special wall is half the height of the three remaining walls. All "inside" facing wall surfaces are laminated with Formica since polymer resins do not readily bond to it.

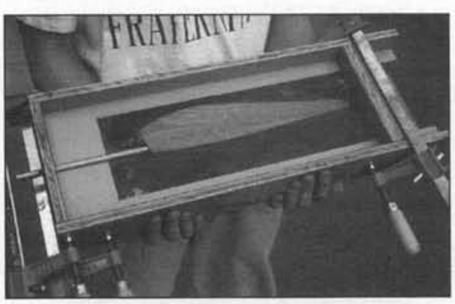

Figure 13. Pattern in molding box

The blade pattern must be positioned in the box with modeling clay. Oil-based clay is recommended since the water-based clays tend to shrink and crack. The objective is to re-create manually a clay parting line identical to the one created with the CAD/CAM package. The clay surface must be sculpted from the blade edges to the Formica edges of the center board, and must completely fill the trough. The surface away from the parting line is not critical and can be irregular. The last steps before fiber-glassing are to position a rod of appropriate size in the groove and to coat all surfaces with mold-release wax.

The first half of the mold is now laid up. To promote a "weave-free" and scuff-resistant mold surface an initial coating of West System epoxy thickened with colloidal silica and graphite powder is used. Once this coating has gelled, eight layers of a medium-weight glass cloth are applied, giving a mold wall thickness of 1/8 to 3/16 inch (3–5 mm). The excess fiberglass is trimmed at the top of the removable walls while still "green". Once fully cured the molding box and modeling clay are removed, leaving in place the blade pattern or the rod from the first side of the mold. The mold surface is cleaned with thinner to remove the modeling-clay residue, the four boundary walls (actually a "full-height" fifth wall is needed to replace the special end wall) are re-clamped to the "half-mold", and the surfaces are waxed. The second half of the mold is now laid-up. It is also trimmed while green. Once cured, a row of holes is drilled down each side of the mold so that the two halves can be clamped together. Only then is the mold opened and the pattern removed. Some touch-up work is usually required to complete the mold.

BLADE MOLDING

This is where the hard work produces dividends and identical blades can be produced at the rate of one per day or better. The two mold halves must be waxed and polished several times in preparation for the lay-up. Epoxy is used with carbon-fiber fabric and tow (roving) as the reinforcement. Appropriately cut pieces of fabric (paper templates are desirable) are placed in each mold half and thoroughly "wetted-out" to remove bubbles. This is followed by the application of lengths of tow oriented along the blade axis.

Each half mold is filled with wetted tow and, after the stainless-steel rod is positioned, clamped together with screws. It is usually apparent when there is enough material in each half mold, but it is inevitable that some bubbles will be trapped inside the blade when the two halves are joined; however, the bubbles are at the low-stress core of the blade. Samples can be tested by sectioning, if desired.

When the epoxy lay-up is fully cured, the screws are removed and the blade is removed by twisting the mold (figure 14). The thin film of "flash" is trimmed and the blade wet-sanded. The thickened trailing edge can now also be thinned by sanding. The blade is ready for installation after buffing and polishing.

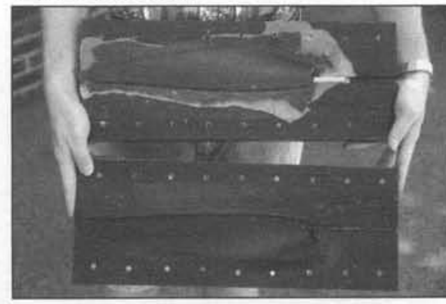

Figure 14. Molded blade with flash

SUMMARY

A multi-step procedure, using a combination of modern and traditional methods (figure 15), for making propeller blades for human-powered water vehicles, has been presented.

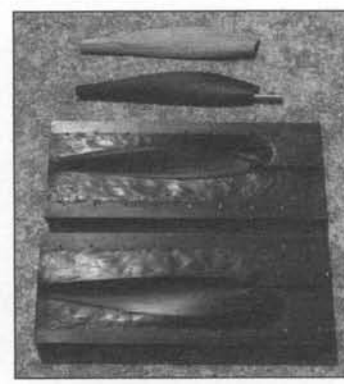

Figure 15. Pattern, blade and mold

There are other viable methods available to the HP enthusiast, ranging from hand carving to direct machining of blades on three-axis machines. However, considering that CNC machines are ever more accessible, that CAD/CAM software is competitively priced, and that most do-it-yourself people are familiar with the use of fiberglass, the method has definite practical advantages. It will give high-quality results (figure 16) for the HP enthusiast or college team with more time than money .

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Poole, P.K. (1991), A Propeller Design Process for Human-Powered Marine Vehicles. *Human Power*, 9(1), 6–16.

Larrabee, E. (1984), Five Years Experience with Minimum Induced Loss Propellers - Part 1: Theory; Part 2: Applications. SAE Reprints 840026 and 840027.

Mastercam. CNC Software, Inc., 344 Merrow Road, Tolland, CT 06084. Phone: (860) 875-5006 Web: http://www.mastercam.com

Figure 16. The business end of the sub

West System Epoxy. Gougeon Brothers, Inc. P.O. Box 908, Bay City, Michigan, 48707-0908. (517) 684-7286 Web: http://www.cris.com/~gougeon

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See the following web site for more HP-submarine information and an online version of this article: http://www.tntech.edu/life/orgs/sub/index.html.

Some details of the propeller are that it was based on a Wortmann FX-63 profile at all stations and was designed for a speed of 6.25 kts (3.2 m/s) at 180 rpm in the three-blade configuration. With a well-trained cyclist and this propeller, the Torpedo III obtained an official top speed of 6.15 kts (3.16 m/s). Untrained individuals usually exceed 5 kts.

TWENTY-FOUR HOURS IN KÖLN

David Gordon Wilson

By good luck and a little special pleading I was able to stop off in Frankfurt on August 1 1997 on my way to a further destination. Using the efficient German train, subway, and bus systems and the on-foot guidance of helpful local residents I arrived at the magnificent site of the IHPSC world championships on the outskirts of Köln (Cologne) in time not only for an evening meeting of national HPV organizations led by Carole Leone but for the end of the land competitions and the start of the water events. I was able to meet people whom previously I had known only via e-mail, including Carole (chair of the IHPVA reorganization committee) and the impressively effective problem-solving Christian Meyer (IHPVA board member), who, with Ludger Bütfering and Andreas Pooch and many other volunteers, was running the championships. I was also able to take a quick look at some of the HP technology, which is the topic of this note.

Writing in this way is likely to be invidious ("likely to give offense"). One is bound to mention something that appeals while omitting notice of worthier developments. I arrived after many of the land vehicles had been packed up by their owners and had left the site, and before some of the watercraft had arrived and been deployed. I was able to photograph only a few of the vehicles. These are, therefore, random observations made from a North-American perspective.

LAND VEHICLES

It is often said that Europe favors short-wheelbase (SWB) recumbents, while the long-wheelbase are preferred in North America. That is probably the case, but it isn't an overwhelming choice in either area. One of the several Avatar-influenced LWBs seen around the IHPSC site is shown in figure 1 (a Peer Gynt?).

Figure 1.

The LWBs were the older bikes, however. The newer SWBs tended to have front and rear suspension, for instance the "at-rest" model in figure 2. This was also fairly typical in that it had a front mudguard or fender, and a nice tailbox that made a rear mudguard unnecessary. Note also the "bumper guard" over the chain wheel to protect pedestrians and other riders. I couldn't find a maker's name nor the owner of this machine: if a reader recognizes it, would s/he please write? It was possibly a home-built because I could see little possibility for adjustment for rider size.

Figure 2.

An attractive configuration for me is what I believe is an Ostrad (figures 3 & 4). It is a compact LWB (CLWB), with dual suspension, under-seat steering (USS), and two equal-size wheels (of one of the 451 or 20" sizes - some people have baptized this

Figure 3.

Figure 4

configuration as a "20-20"). The single small chain wheel drives a derailleur on a countershaft that drives the final derailleur, giving potentially a huge range of gears. The upper front chain passes through a plastic tube, another popular feature on European machines. The seat width is very large.

Figure 5

There were several back-to-back or "Janus" tandems. One "20-20" dual-suspension USS model is shown in figure 5 demonstrating considerable agility in the slalom race, one in which a "normal(?)" LWB recumbent tandem would be at a considerable disadvantage. Another type shown "at rest" in figure 6 is another 20-20, with-

Figure 6

out suspension, with disk brakes, above-seat steering (ASS), and with a compendious baggage compartment between the seats. (This may also have been an Ostrad. The Ostrad principals promised me that they would write something for *Human Power* through our hard-working European editor, Theo Shmidt, figure 7).

Figure 7

WATERCRAFT

There were several well made paddle-wheel boats (e.g. the two-person "sociable" Argo, figure 8 and the opposed tandem "Blues-boot", figure 9) that created a great deal of both spray and fun.

Figure 8

Figure 9

A configuration that I hadn't seen before but used on several boats was to have two pedallers transversely seated between two hulls facing in opposite directions, each driving a screw propeller in one of the hulls (figure 10).

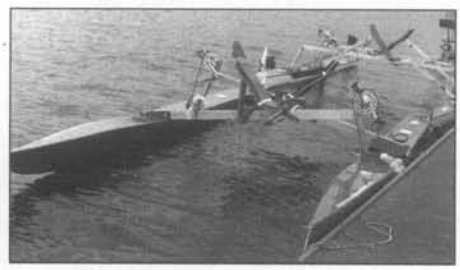


Figure 10

This is a potentially fast arrangement, and one requiring good coordination in turns. They appeared to be built to allow considerable flexibility between the hulls, enabling them to pass through occasional motor-boat wakes, for instance, but not for rough-water operation.

A dramatic photo of the two-person "Janus" hydrofoil "Af Chapman" from Chalmers University leaping out of the

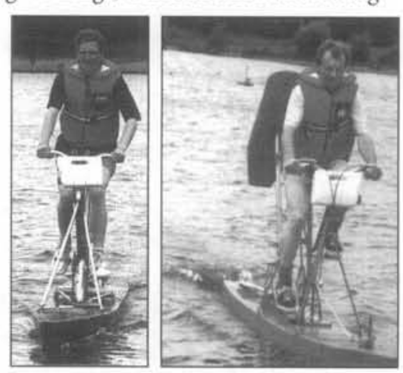
Figure 11

water has often been reproduced. It was so remarkable that I assumed that it was just the result of a momentary prodigious effort by the crew. Not so! It was entered in, of all events, the slalom, and had amazing agility in addition to speed when riding on the foils. Figure 11 shows it being set up. (I could not stay for the later speed events).

Two examples of another configuration of watercraft that I not seen before (although they have been used for several years) was brought by Oxford University's David Witt (figure 12) and some of his students and family. It is a single-hull screw-propelled front-rudder craft, operated in the same way as a bicycle. "Skippy" is shown in figure 13. The large pillow-like pneumatic float is used just for starting and occasionally for stopping (David Witt could ride up to the dock and dismount without the need for the float), and is almost invisible behind him in operation (figure 14). In a shot of David riding "Daring", the float looks like a wing

Figure 12

Figure 13



Figures 14 and 15

(figure 15). The ease of operation impressed me. (See David Witt's article on page 3.)

Please allow me to close this design review with some small shots of IHPVA leaders who went over from the US to Köln: Carole Leone, IHPVA president (figure 16); Jean Seay, executive VP (figure 17); Nancy Sanford, VP watercraft (figure 18);

Andrew Letton, board member and VP land (figure 19); and Matteo Martignoni, VP ATV, (figure 20). (Please forgive me for not showing more land and water vehicles and more of the people who organized this magnificent IHPSC). —Dave Wilson

Figure 16

Figure 17

Figure 18

Figure 19

Figure 20

LOW-COST AERODYNAMIC TESTING

Dominic Bencivenga

INTRODUCTION

Being an auto-racing fan I spend a lot of time reading about the technology of racing. When I attend races I spend much more time in the garage area watching the mechanics tear down the cars than I do watching the drivers on the track. I'm enthralled by the delicate ballet of mechanics as they deftly, silently remove an engine or make aerodynamic adjustments during a harried pit stop. As a high-school technology teacher I wondered how I could bring some of this technology to my classroom. As we all know, auto racing is a very expensive proposition. Competing at even the lowest levels (karting) would be well beyond our meager budget. In 1989 I read an article in *AutoWeek* magazine about a high-school technology club from Saginaw, Michigan that designed, built, and raced something called a human-powered vehicle. They competed in the International Human Powered Vehicle Association Speed Championships held that year at the Michigan International Speedway. I thought that this would be a terrific way to introduce students to the technology of racing at a reasonable cost. After contacting Mr. Bruce Isotalo, who started the technology club featured in the *AutoWeek* article, I had a good idea of what it would take to design and build an HPV.

THE CHALLENGE

What separates an HPV from a racing bicycle is its aerodynamic shell or fairing. Without a fairing even the strongest riders are incapable of sustaining speeds much over 14 m/s (31 mph). The science of aerodynamics plays a very important part in all forms of racing and separates the winners from the others. This is nothing new to long-time *Human Power* readers, but to my students and me it represented an interesting challenge. The first order of business was to research aerodynamic theories and formulate a design that would be adaptable to a bicycle fairing. Another consideration would be how we were going to test our designs before committing ourselves to full-scale production. I was well aware that wind tunnels were the most expedient way to test aerodynamic efficiency and that finding (or building) one to use for our class project was not going to be easy. I had seen the Wright brothers' wind tunnel at Greenfield Village in Dearborn, Michigan and realized that a wind tunnel didn't have to be a million-dollar production to be useful for simple comparison testing. After exhausting the limited aerodynamic offerings at our local public library and back issues of Human Power my research led me to a creative problem-solving activity that I found in an Odyssey of the Mind publication (*Problems to Develop Creativity* by Samuel C. Micklus). This activity, entitled "The Wind Tunnel," provided an easy way for us to test many different aero designs quickly and inexpensively.

THE PROCESS

The activity involves designing an aerodynamic fairing that could be mounted on a simple free-rolling test chassis. This consists of a block of wood about 100 mm by 230 mm with four wheels. On it is fastened a so-called "resistance plane" (about 150-mm high; see figure 1) that defines the maximum cross-sectional area of the fairing so that it is constant from one model to another. The fairing can be constructed from any suitable material: papier mâché, cardboard, Coroplast, etc. Being an admirer of the home-built-airplane designs of Burt Rutan (the designer of the Long-EZ, Defiant and the Voyager) I discovered that rigid extruded Styrofoam building insulation is a near-perfect material for building fairing prototypes. The foam is relatively inexpensive, easy to cut with a hot-wire saw (figure 2) and very easy to fair with coarse sandpaper. While the Rutan-designed aircraft are covered with layers of fiberglass in an epoxy matrix, our fairings are tested in the form that it is made in the material chosen. In this way the shape can be quickly produced for testing in the "wind tunnel".

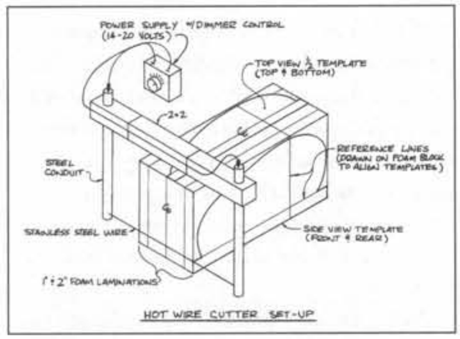


Figure 2. Hot wire-cutter set-up

Our wind tunnel is not strictly a tunnel, but a standard domestic "box" fan modified with a cardboard nozzle (figure 3). The fairing is placed on the chassis (with the resistance plane inside the body) and placed in the nozzle-outlet air stream of the box fan. Determining the most efficient design is done by simply comparing the rolling distance of each body in the air flow of the

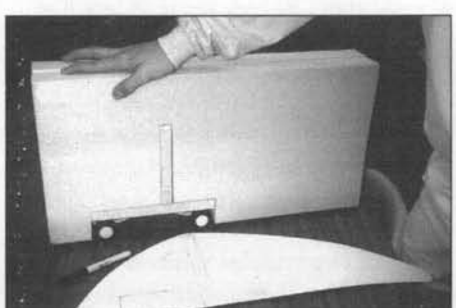


Figure 1. The Styrofoam blocks are cut to fit over the chassis with the "resistance plane".

Figure 3. Aaron and John test their creation in the "wind tunnel", a box fan fitted with a cardboard nozzle.

"tunnel". The most aerodynamic shape is the one that rolls the shortest distance. This works in the same way as a coast-down test except that it can be performed in a classroom or other relatively limited space. Hard data such as coefficient of drag and lift could be calculated, but for our purposes a comparison of the different designs is all we really need.

What we have found is that reducing the frontal area of a fairing is the single most important detail that determines the success of an aerodynamic design. This is closely followed by the shape of the body which, theoretically, should be as close in shape to a teardrop as possible. Our class test chassis is a generic design used for test purposes and does not bear any resemblance to a real HPV chassis. The only criterion for the chassis is that the wheels be as free-rolling as possible. The chassis is made from 18-mm (3/4") poplar and utilizes 43-mm (1-3/4") diameter rubber tires of the type commonly used on radio-controlled model aircraft. If you were testing an actual HPV design you would have to scale the resistance plane accurately to match the shape of the rider in his actual riding position.

CAD SOFTWARE

This activity is used in my CADD 1 classes as an application of what my students have learned about using *Cadkey 7* software. It is also a good way of introducing them to the design process. The activity begins with a discussion of general aerodynamic terminology followed by a slide show of many types of aerodynamic vehicles. This gives the students a basic idea of what role aerodynamics plays in everyday life. The students are paired in teams and encouraged to do some brainstorming before getting down to work on the CADD system.

All students are supplied with detailed drawings of the test chassis and are required to reproduce it on *Cadkey* before designing their body shape. *Cadkey 7* is an excellent drawing package that combines all the usual 2-D CADD features with full 3-D wireframe capabilities as well. For this activity a very handy feature is *Cadkey*'s ability to draw free-form spline curves. After laying out a basic envelope that conforms to the design parameters I set down, the students can very quickly integrate their slippery aerodynamic shapes with the chassis drawing. Advanced CADD students can take the design process one step further: *Cadkey 7* includes a 3-D surface-generation program called "Fastlite" that allows them to create a wire-frame image of their design. While this creates an impressive-looking drawing it really isn't a necessary step in the construction process of the 3-D foam scale models. Where "Fastlite" could come in handy is to produce section profiles along the centerline that would aid the builder in contouring the full-scale fairing. "Fastlite" can calculate the intersections of the vertical planes along the centerline and the 3-D surface of the fairing. This is very good for a US$129 (educational price) CADD program. The finished drawings include top, front and side views as well as basic dimensions.

Figure 4. After the posterboard templates are cut out, the chassis cut-out is traced onto the Styrofoam blocks.

When the drawings are complete they are plotted full scale on tracing vellum using a Roland GRX-300AG pen plotter. From these, white prints are made to facilitate the production of cutting templates. The white prints of the side and top views are fastened to sheets of poster board with 3M #77 spray adhesive. The designs are then cut out with scissors and utility knives. These templates are used as guides for the hot-wire saw (figure 4).

Hot-wire saws are very simple devices that consist of two lengths of 13-mm (1/2") electrical conduit attached to a piece of wood about 50-mm square. A length of 0.8-mm (0.032") stainless-steel wire is tightly stretched between the ends of the conduits. When a 10-14-volt DC current is passed through the wire it gets hot enough to melt Styrofoam. Extruded Styrofoam insulation can be purchased at most home-improvement stores or lumber yards. The higher-density extruded variety is easier to work with than the expanded-bead type (used for cheap picnic coolers) that is much less dense and more porous. Extruded Styrofoam is made in 1" and 2" (25.4 mm and 50.8 mm) thicknesses and sold in 4' by 8' (1.22 m by 2.44 m) panels. We cut the panels down to size on a table saw in the wood shop area. Before the pieces are glued together with the 3M #77 spray adhesive the cavity for the chassis is laid out and cut on a band saw (figure 5). Performing this operation before gluing the blocks together requires much less work than having to carve the cavity out of a solid block of foam. At this point the foam pieces are sprayed with adhesive (figure 6) and laid up. The spray adhesive is a contact-type glue so the foam is ready for cutting as soon as the blocks are made. After laying out some ref-

Figure 5. John cuts out the chassis opening in a 50-mm thick Styrofoam piece.

Figure 6. Applying adhesive to the Styrofoam

Figure 7. Cutting the foam block on two planes (plan and elevation)

erence lines to insure proper alignment, the side-view templates are fastened to the foam with a light tack coat of spray adhesive. There is a template on each side of the foam block. The hot wire will follow the body curvature without burning through the template (figure 7). The blocks are now ready for the hot-wire saw.

The temperature of the cutting wire should be adjusted and tested on a scrap piece of foam before the finish cut is made. The Rutan method suggests a cutting rate of 5mm/s (1" every 4–6 seconds). If the wire is too hot it will melt too much of the foam around the wire. When the wire temperature is set, cutting should begin on one end of the block. Students work together on this critical step. One will hold the saw and guide it over the template while his partner watches the back side to make sure the wire stays on the template. Because the Styrofoam is so forgiving even seemingly huge mistakes can be fixed later without too much extra work. When the side profile cut is complete, the templates are gently removed and placed in a safe place. Templates can be modified later for cutting new design variations.

A light tack coat of adhesive is sprayed on the cut surface so that the scrap piece can be temporarily reattached to the foam block. This will keep the foam block level and stationary for cutting the top profile. Next, the top-view template is cut along the longitudinal center line so that one piece can be glued to the top of the foam block and the other can be glued to the bottom. The foam block is laid on its side so that the hot wire can be guided along the side the templates are on. When this cut is complete the same procedure can be used for temporarily reattaching the scrap piece. The templates are removed and glued to the other side of the centerline to cut the other side. When cutting is complete all the scrap pieces are

Figure 8. The final countouring

removed. What remains is a square-cornered approximation of the body that needs to be contoured to its final shape. Large amounts of foam can be removed with a rasp or very coarse sandpaper (figure 8). Final contouring is done with 80–100 grit sandpaper. Carving Styrofoam is easy to do and will take only a few minutes to produce a test body ready for the wind tunnel. If there are surface imperfections such as holes or low spots, these can be filled with a lightweight, non-shrink spackling compound or masking tape.

Figure 9. Freshmen Aaron and John proudly display their winner, which soundly defeated all comers. This did not amuse the upperclassmen in the group!

After test fitting the body to the chassis it is weighed on a digital balance to get an accurate weight. For consistent comparisons it's important for the bodies to be of equal weight due to the increase in rolling resistance of the rubber tires as weight increases. If weight needs to be added, this is accomplished by using small beam weights (the kind used on analog balances) or anything handy (nails, coins, sinkers, etc.). To make this activity more interesting than just a analytical exercise, the student teams compete against each other to see which can produce the most efficient fairing shape (figure 9). The first-place team receives 200 points with the remainder being scaled down by their percentages of the winner's distance. Because some of the teams' designs perform considerably worse than those of their colleagues the grades are limited to no less than a "C" average to avoid discouraging them. Learning the process is much more important than the actual measurement of academic performance.

CONCLUSION

Simple aerodynamic testing methods such as the one I have outlined make it possible for any school or individual to participate in the development of more-efficient aerodynamic shapes that can be applied to many different applications. Those who are fortunate to have the ability and the budget may want to develop a more elaborate wind tunnel that would include more accurate measurements and performance analysis. If you are fortunate to live in the vicinity of a college or university you may inquire as to the availability of a wind-tunnel facility for observation of their test methods. Our local branch of the Pennsylvania State University has recently installed a scale-model wind tunnel for student research. I am optimistically planning to approach the university to develop a collaborative effort that would allow my students to test their creations in the PSU wind tunnel while being exposed to the university's engineering program and facilities.

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CORRECTIONS TO "STEERING TRAILING-ARM-ANGLE DETERMINATION" (VOL. 12 NO. 4, SPRING 1997)

Dietrich Fellenz (dfellenz@pacbell.net) of San Jose CA wrote that he had noticed a number of unfortunate errors in the above paper. In figures 5 & 6 referring to the steering geometry, the forward direction should be up, and right/left should be reversed. Equation 5 makes an error in the mass-to-weight conversion, which results in an error factor of about 96. Equation 6 has a dimensional error. These propagate into equations 7 and 8. Dietrich Fellenz sent along MathCad worksheets showing the effects. He added: "I would also like to comment on aspects of the text that can make comprehension more difficult. The word "optimum" is used in places where "correct" would be appropriate. When talking about an optimum, one must always think of "something being an optimum with respect to an objective". In the present case the objective of our optimization would be to minimize the scrub angle for the most probable range of turning radii. The parameters of the optimization would be the dimensions of the steering linkage.

"The word "maximize" was used to point out that the value of a parameter was increased. The maximum is supposed to be the top value a parameter can have. Also, there was a reference to a "dynamic" turn, where in fact a turn of short radius was meant. There is really no discussion of the dynamics in the paper. Most of it is about kinematics, i.e. the motion of the linkages or of the overall vehicle. In dynamics we would be looking at the forces associated with such motions.

"There seems to be a perception regarding the usage of the SI system of measurements that angles must be expressed in radians. Functions like "atan" give outputs in radians. But that does not mean that the angle must not be shown in degrees, which confers much easier visualization".

(Editorial note. I edited Dietrich Fellenz's letter to shorten it. I sent the full letter to Tim Gorman, the paper's author, with my apologies for not catching the errors in the first place. I had sent the paper to an expert in the field, who liked it. However, he did not have time to check the equations. I risked publishing on that basis, thus embarrassing *Human Power* and Tim Gorman, who replied as follows. Thanks to both people! —*Dave Wilson*.)

"I've reviewed the issues about which Mr. Fellenz wrote to you regarding my paper in the vol. 12, #4 issue of *Human Power*. I must say that he was correct in most of the errors that he found, and I hope that the following will rectify this.

As a result of using these revised formulas,

Substitute for equation 5:

$$P_L = 9.81\ M\,\mu_k\,V_L$$

Substitute for equation 6:

$$M = \frac{M_T(W_b+J)}{2W_b}$$

Substitute for equation 7:

$$P_L = \frac{9.81\ M_T\mu_k V(W_b+J)\sin\left(\dfrac{\operatorname{Atan}\left(\dfrac{W_b}{R-W_w-T}\right)-\operatorname{Atan}\left(\dfrac{W_b}{R+W_w+T}\right)}{2}\right)}{2W_b}$$

TABLE 1 (REVISED)

Turn radius (m)	Velocity (m/s) 1	2	4	6	8	10	12	14	16
2	72.5								
4	21.1	42.3							
6	9.70	19.4	38.8	(All values in watts)					
8	5.51	11.0	22.1	33.1					
10	3.55	7.10	14.2	21.3	28.4				
12	2.47	4.94	9.89	14.8	19.8	24.7			
14	1.82	3.64	7.27	10.9	14.5	18.2	21.8		
16	1.39	2.79	5.58	8.37	11.2	13.9	16.7	19.5	
18	1.11	2.21	4.41	6.61	8.82	11.0	13.2	15.4	17.6
20	0.89	1.79	3.57	5.36	7.15	8.94	10.7	12.5	14.3

table 1 should look like the above (Table 1).

As a comparison of this table with table 1 in the paper shows, I grossly undershot the correct, and significant, energy losses due to non-accommodated steered wheels. Many thanks to Mr. Fellenz!

For equation 8, the third term under radical sign should be $\mathbf{W_w}$ (without exponent). This does not affect any of the results in the paper. It was merely a typographical error on my part.

I have not been able to find an error with equation 11, but in the process of searching for one, I derived a simpler formula which can substitute for equation 11 and yields the same results:

Where Mr. Fellenz may have perceived error in equation 11 may have been as a result of the use of incorrect units. The data for **C** in table 2 and **P** in table 3 are in centimeters, and would have to be converted

$$\theta_L = \operatorname{Atan}\left(\frac{H}{W_w-P}\right)+\operatorname{Acos}\left(\frac{H^2-C^2+D^2+(W_w-P)^2}{2D\sqrt{H^2+(W_w-P)^2}}\right)$$

over to meters (divide by 100) before running them through equation 11. I was getting erroneous results as well until I remembered to do this. If this was the cause of Mr. Fellenz's results, I blame myself for not putting my tables in consistent units.

Tim Gorman
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St. Peter, MN 56082
(507) 931-6886
e-mail tim.gorman@cwcinc.com
(See also Lowell Zabel's letter, p. 17. —ed.)

LOW, HIGH, FOLDABLE AND GORGEOUS: THE WAVE

by Marga A.B. Ruitenbeek

The Wave three-position recumbent is a beauty. Just one nicely curved round tube with an elegant thin seat. The Wave is also practical. It has an upper position for use in town (figure 1), a low position for racing (figure 2). In the train the Wave can be folded up (figure 3). The bicycle is the final project of Erik Suijker at the Academy for Industrial Design in Eindhoven, NL.

By using a gas strut, the bicycle can be adjusted in height continuously, just like the desk chair at the office. In the upper position you can look around you in town. The lower position is good for speed: Suijker claims that a reduction of 45 percent in wind resistance is achieved between the upper and the lower positions.

The gas strut also works as rear shock, but is insufficient on its own.

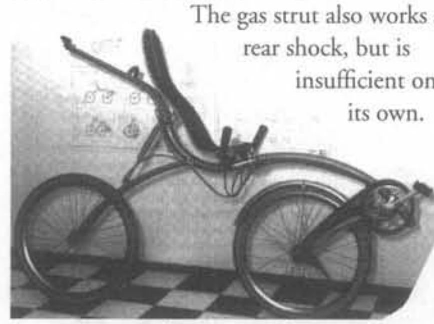

Figure 1. The Wave, in the upper position for use in town.

Everyone who has absently collapsed into a desk chair that was in the lowest position will remember the impact it gave. Suijker solved this for the Wave by using rubber. For the race position (figure 1), in which the strut is fully compressed, the suspension is

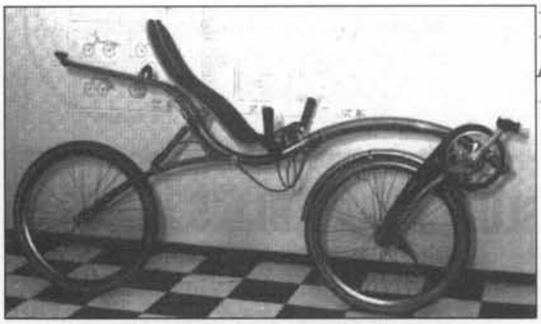

Figure 2. In the lower position— 45 % less wind resistance

controlled both at the front and the rear using blocks of rubber.

The frame of the Wave is made of stainless steel: "This was necessary for the stiffness of the bicycle," says Suijker. The wheels are ordinary 26 inch bicycle wheels. The Wave weighs in at 17.5 kg which the designer admits is "rather heavy".

The bicycle has hydraulic brakes, and a Sturmey Archer 7-speed gear system. The seat was also designed by Suijker himself: " It is made of laminated beech plywood and offers lumbar support," according to Suijker. Even in the upper position (figure 2) Suijker has, according to himself, not experienced any problems with balance when cycling with luggage on the rear carrier. In the pictures the bicycle is shown without a chain, for aesthetic reasons.

The Rotterdam designer is not planning to market his bicycle:" that bicycle has cost me 5.500 Guilders in materials alone. I have spent half a year drawing and designing prototypes. Building the Wave took three months. That would prove to be far too expensive." Suijker makes a living from his own company, that produces 3-D computer presentations.

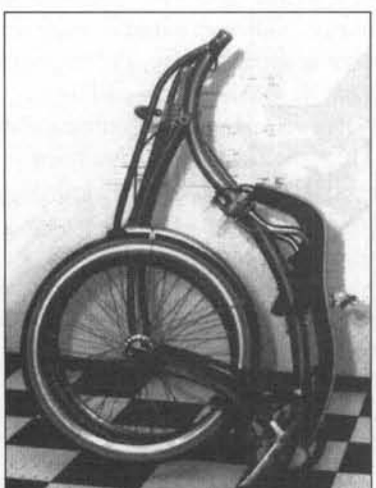

Figure 3. Folded, the Wave travels on the train.

From HPV nieuws, Nummer 1, 1996, p. 3. (De Nederlandse Vereniging Human Powered Vehicles; by permission) Translated by Wouter Suverkropp

REVIEWS

CD ROM: HUMAN-POWERED VEHICLES 1997

by Christian Meyer, Oliver Zechlin and Carsten Zerbst

Oliver Zechlin's CD is a wonderful resource for the HPV enthusiast, put together with great dedication. It is a very rich compilation of photos, with some line drawings and a few videos, of every HPV about which he/they could get people to send in information. The bulk is of bicycles and other land HPVs (including "railbikes"), but there are also aircraft and watercraft. It is an extraordinary collection. The photographs are generally of very high quality, usually occupying the left one-third (approximately) of the screen. One click on the photo enlarges it to full screen. Not all the illustrations are accompanied by descriptions—some are not even named—but one can usually decide which is which. Oliver Zechlin and his skilled collaborators have gone to great lengths to ensure that their work is accessible. "We have put all data in an HTML structure, so you can easily access pictures, text and video clips. If you do not have an HTML browser installed on your computer you can install one from the CD. For example we have included the Microsoft Internet Explorer for Windows and Macintosh. Your computer system should be able to display 65,000 colours at a 800X600 resolution. If you are not using a 4X-speed or faster CD-ROM drive you may copy parts of the CD to your hard-disk drive for faster access." My CD-ROM drive is much slower than this, but the response time seemed fast to me. The text is in German and English.

To find price and ordering information, e-mail Oliver at: hpv-cd@zechlin.com.

—*Dave Wilson*

SIX VIDEO GUIDES TO FAIRING CONSTRUCTION

Reviewed by Dave Wilson

How to build a Coroplast fairing for under $100
Presented by Ed Gin

Published by People Movers, 980 N. Main Street, N. Orange, CA 92867, phone 714-633-3663 (I paid $19.95 for the video, including shipping).

This is a cheerful, relaxed video made during what appears to be a full day's fairing-construction workshop in 1997 at People Movers' somewhat cramped showroom, attended by under a dozen keen amateur constructors. The instructor is Ed Gin, whose favorite instruction was accompanied by "You can do it, guys! This ain't rocket science!" He takes the group through the construction of a fairing for a short-wheelbase above-seat-steering (SWB ASS) recumbent (I believe a Rans V-Rex) using Coroplast foam board, PVC pipe and bends, and smaller components such as cable ties and worm-drive clamps. Ed Gin's instruction is clear and goes into detail whenever needed; the photography is amazingly good considering the cramped circumstances, the apparent absence of studio lighting, and the need for almost everything to be right on the first "take". There was almost no shop equipment: everything was done right there by hand or through the use of hand-held manual and power tools. The only special tool was an electric heat gun, as sold for paint-stripping. By the end of the workshop the fairing was finished and the bicycle was ridden away. No great imagination is necessary to apply the same techniques to LWB and USS recumbent bicycles. If a picture is worth a thousand words, a video is worth a whole lot of books. Seeing Ed Gin heat the foam board to the right degree before bending is something for which the video is invaluable. Everyone involved is to be congratulated.

FIVE VIDEOS FROM FIBRE GLAST DEVELOPMENTS CORPORATION

95 Mosier Parkway, Brookville, OH 45309, phone 800-821-3283

- **The basics of fiberglass**
- **A step-by-step guide to molding fiberglass**
- **Advanced moldmaking and plug construction**
- **Vacuum-bagging and sandwich-core construction**

• **The art of moldless composites**

(The five videos plus the set of backup booklets and shipping cost me $162.85).

I bought the whole collection of videos put out by Fibre Glast, together with all the backup booklets, after someone wrote in complimentary terms about one of the videos on the HPV e-mail network. They all lived up to the advanced billing. They are professionally produced, shorter and crisper than the Coroplast video reviewed above (and more expensive), and they introduce the viewer to more-professional methods of making high-quality fairings. All the videos are introduced by Marilyn Klein, owner and CEO of Fibre Glast, and demonstrated principally by Scott Campbell, marketing director, who shares the narration with his boss. I have been making fiberglass parts and fairings for many years, and I have never been very proud of the results. These videos showed me why. The degree of care required and attention to detail were well illustrated. The techniques were shown in close-up and fully explained. I particularly enjoyed the video on vacuum-bagging and sandwich-core construction, but I would imagine that everyone except an established expert would learn a great deal from any of the videos and especially from the set. After John Tetz's article in HP 12/4 on his faired HPV in which he mentioned using a moldless technique in making the fairing, there were several inquiries on how he did it. One of the videos gives the answer!

The presentation is friendly and low-key: the company's products were not promoted unduly. There was also an emphasis on safe practices, on wearing masks and gloves. On the other hand, one video was made as an exchange with a college making a super-mileage vehicle: Fibre Glast supplied Scott Campbell and materials and was allowed to videotape the whole procedure. I applauded the honesty with which Campbell showed how the techniques were improved during the project. What worried me was the way the students put on gloves which they used to scratch any itch that developed on any bare skin, and the way their arms became covered with epoxy. That was how I became severely allergic to epoxy (during a three-week all-out effort to develop some innovative pumps), with the result that now I often have to be hospitalized after getting a little hardener on my skin. Be warned! Other than this criticism, this is a highly educational and valuable set of videos, strongly recommended.

PROCEEDINGS OF THE SEVENTH INTERNATIONAL CYCLE-HISTORY CONFERENCE

Reviewed by Dave Wilson

The international cycle-history conferences were started in 1990 in Glasgow, when Nick Clayton, editor of *The Boneshaker*, the journal of what is now the Veteran-Cycle Club, invited people interested in cycle history to commemorate the supposed 150th anniversary of the first known pedalled bicycle, that of Kirkpatrick Macmillan in Dumfries, Scotland. (It was a suitable starting point, because little is known of Macmillan or his bicycle, or of its exact year of completion. Most historical "facts" about cycle history have turned out to be almost equally uncertain). Rob van der Plas has edited and handsomely published, through Bicycle Books (1282 7th Avenue, San Francisco CA 94122 USA) and Motorbooks International, the fourth (Boston) through the seventh (Buffalo) proceedings. They are excellent value at $30 and $45 (the price alternates) plus postage, hardbound. (This vlume is $45 plus shipping.) As this issue of *Human Power* goes to press the eighth conference should be meeting, again in Glasgow, Scotland, and we hope that Rob van der Plas will again bring the proceedings to us.

There are two views of the wisdom of studying the history of a topic before trying to develop something innovative. One is that knowledge about what others have done or attempted to do somehow limits one's creativity. The other view, attributed to various people, is that those who ignore history are condemned to repeat it. I endorse the latter view, having designed or helped in the development of several recumbent bicycles that turned out to have similarities with previous machines. At the time I had taken virtually no interest in cycle history. Another statement that is always true is that great inventors, scientists and others stand on the shoulders of giants. Some people acknowledge the prior giants; others pretend that they made a huge leap on their own. It irritates me when Edison is credited with inventing the electric light bulb, when in fact he took the carbon-filament bulb over from Joseph Swan of my home town of Birmingham, England. Some believe that the great Einstein owed a great deal of his relativity theory to his wife, whom he didn't acknowledge, in addition to the several men whom he did. I am regularly sent draft contributions for *Human Power* on topics or developments that have been well covered before. I return them, asking the authors to refer to the previous work and to point out the improvements that have been made. (The contributions are seldom resubmitted).

My purpose in this preamble is to encourage you to read, or at least to scan, this volume and its predecessors for yourself. I will, however, attempt a short summary of those papers that I believe will be of especial interest to *Human Power* readers.

Dicycling Down the Decades
by Roger Street

"Dicycle" was the name that came to be given to a two-wheeled vehicle in which the wheels are parallel and co-axial, (the illustration is from Sharp) usually with the rider(s) striding with a form of yoke around the chest or, for pedalled machines, sitting on a seat that may have the rider's center of gravity below or above the wheel axis. (The wheels were therefore usually over two metres diameter.) I have never taken dicycles seriously: I have never seen one, and they are not given much space in either of the two nineteenth-century books on which I rely most. Roger Street's eight-page paper shows that dicycles were, in fact, earnest attempts at providing improved, safer, locomotion, first appearing apparently in Britain after Karl von Drais introduced the first bicycle as a "running machine", and later in the U.S. and Britain with pedals after the French velocipede developments in the 1860s. Speeds of up to 9 m/s (20 mph) over a measured mile were claimed even for the early foot-propelled models, and long trips at reasonable speeds for the pedalled versions. These co-existed with "ordinaries" or high-wheelers, the dangers of head-first "croppers" from which were well known. One could not "come a cropper" with a dicycle, although I would imagine that if one wheel encountered something that suddenly slowed it during a high-speed descent the result could be exciting.

H. Cadot and his Relevance to Bicycle History
by David Herlihy

"True" historians are detectives, sifting through murky evidence to find out who did what and when. (Most people who try to popularize history are "recyclers", using others' work, all-too-often inaccurately.) David Herlihy is a Boston-area historian who has been engaged for several years in what I have found to be an exciting search for the origins of the French velocipede. He believes that Pierre Lallement was the inventor, and that others copied him and then claimed credit. (Herlihy has thus annoyed some guardians of the old order.) This paper about a velocipede builder from Lyon adds intriguing evidence to the puzzle. Herlihy ties the Olivier brothers, two behind-the-scenes well-to-do collaborators with Pierre Michaux, who is usually given credit for originating the velocipede, with Lallement and Cadot. It is almost cloak-and-dagger work, and good reading.

Who Invented the Penny Farthing?
by Nick Clayton

This is either a leg-pulling or a deliberately provocative title, because most cycle historians have a passionate objection to the use of the term "penny-farthing" to identify the ordinary or high bicycle. (It is reckoned to be a derisive term used by London urchins long after the heyday of the high-wheeler.) Nick Clayton starts by pointing out that some long-standing mysteries of cycling history have been resolved, and cites the acknowledgment that Von Drais was the maker of the first two-wheeled machine and that the supposed inventions of the Compte de Sivrac were pure myth, along with the person himself. Clayton said that he was told in 1980 that no one would ever know who started the development of the velocipede into the high-wheeler, and that he spent sixteen years trying to disprove this statement. He examined 24 histories, of which nine stated that a M. Magee of Paris was responsible, while eight credited James Starley of Coventry, UK. A fascinating account of his researches leads to the conclusion that an early misprint, coupled with many writers of history (perhaps of the "recycling" type) repeating the misprint without checking, gave Meyer as Magee. Studying reports of bicycle races in Birmingham and Wolverhampton, UK, Clayton found that all the winners in April 1870 were riding "boneshakers with wheels under one metre in diameter", while by October the winners were using machines with wheels around 25% larger. He then found that the leading racer of the day, James Moore of Paris, wrote in 1931 that "in the early summer of 1870, I was riding a 43" Meyer tension-wheel bicycle and used toe-pedals, whilst my opponents were yet pedalling from the instep on Phantom 36" wheels which enabled me to overlap my opponents". Someone many years ago sent me a copy of a page containing a sketch of a tension wheel by Sir George Carley, who was trying to build aircraft in the early nineteenth century, so that Eugene Meyer probably did not invent the tension wheel itself. But it now seems very likely that he developed the metal wheel (Cayley's seemed to be wood and rope) and thereby led bicycles from heavy, slow "boneshakers" to light, fast exciting steeds.

Derailleur Pulley Resistance
by Ron Shepherd

Ron Shepherd is a professor of engineering at Melbourne University, Australia. He gives a short but interesting history of the derailleur gear, mentions briefly his students' work on the analysis of gear losses, and reports that the power losses in derailleur pulleys is generally considerably less than one percent of the power put into the pedals. (He states also that the efficiency of chain transmission is normally over 99%, a higher figure than I have seen quoted. I have written to ask if he would contribute something on the subject to *Human Power*).

Rear-Derailleur Development Since D-Day
by Frank Berto

Frank Berto is the foremost expert on derailleur gears, having produced many lucid accounts and tests of different models and systems for *Bicycling*, *Bike Tech* and other journals. This account of developments in the last half-century or so is full of insight and useful comments.

Were There Bicycles in Milan in 1811?
by Les Bowerman

Three years ago my wife bought me a handsome little book entitled *Bicycles*, translated from Italian, full of beautiful illustrations and a fair amount of nonsense about the supposed history of bicycles. But one of the lovely illustrations was of an ordinance that banned the use of "so-called velocipedes (bicycles) in the streets of downtown Milan." There were, we all thought, no bicycles anywhere until Von Drais' running machines of 1817. Yet the illustration appeared to be genuine. I wrote to the authors and publishers and sent copies to various museums and friends in Italy to find, without success, whether or not it was genuine, and then sent it to Derek Roberts in Britain. He and his brother founded the (Southern) Veteran-Cycle Club many years ago, and he is generally recognized to be the leading cycling historian in the world. Les Bowerman gives us a progress report, which is essentially that the ordinance could well be genuine, but, if so, it probably refers to vehicles other than bicycles.

Other Papers

These (above) are the papers principally concerned with cycling technology. There are also several papers on bicycle racing, on Colonel Albert Pope and the development of mass production, on early bicycle accessories, including the trumpet and bugle, and an extensive history by Ross Petty of women and cycling. The whole volume gives great pleasure to the human-power enthusiast. If there is space in future issues of *Human Power* I may review the earlier volumes.

—*Dave Wilson*

LETTERS

ACKERMAN, GORMAN AND THREE-WHEELED HPVS

I have just read the article on Ackerman steering for three-wheeled HPVs with interest. The paper is well written and organized, but I do feel that some comments are in order. Mr. Gorman uses a steering configuration that includes two tie rods and a rack and pinion to connect the trailing arms. I have never seen this system used on tricycles although it is common in automobiles. A much simpler and lighter system uses a single tie rod with a second small tie rod connecting the handle-bar tube to one of the trailing arms. The use of a single tie rod also simplifies the equations used to compute the trailing-arm angle.

I have written a computer program to make the calculations and plot the error in wheel turning angle for various turning radii. My results correspond to those of Mr. Gorman's when the value **T** in his equations is made zero. It is interesting to note that the difference in wheel angles, inside-outside, is correct only at zero turning angle and at the angle at which the trailing arm angle is calculated. Maximum error at other turning angles normally will be in the order of .03 degrees, but can be as much as 0.1 degrees. A scrubbing angle of 0.1 degrees seems to me to be negligible.

If anyone is interested, I will be happy to e-mail the program to him.

Lowell W. Zabel <LWZ@nut-n-but.net>
Ret (many years ago) Prof Chem Eng U ME

As an aside, there is a simple way to check wheel scrubbing on an existing vehicle. Place a piece of paper under the outside wheel while the wheels are turned. Roll the bike forward a few feet. If the paper rotates, the difference between the inside wheel angle and the outside wheel angle is not correct.

(Lowell Zabel and his wife continue to tricycle in their eighties —ed.)

ANOTHER BIZARRE IDEA

This last Saturday I had the task of taking my son to a "fun park" after delivering my daughter to a party. My ten-year-old son and I spent five hours at the fun park.

The major fun was in the go-karts. These were (it appeared) 3 to 5-hp go-karts with full 360-degree bumpers and a small track with bumpers as well. You wore a four-point harness and the carts were limited to some speed under 10 mph. Environmental note: they were using the new Honda four-cycle OHV engines, maybe in anticipation of small-engine smog rules about to hit in California.

Other than getting a sunburn and some wicked bruises from the about-one-g turns (I found out that if you took the turns just right, you could do the whole course full throttle) I had a weird idea.

What if you set up a HPV trike race in the same sort of track? Even at 10 mph, the track had so many sharp turns, and the effect of 10 cars trying to pass on lanes that were basically 2.9 cars wide is quite thrilling. The course had five turns, one 180-degrees that was basically two lanes wide, some other tight corners, and a "sweeper", also small hills and dips.

There's a lot of strategy and the sensation of speed is amazing. The neat thing is that the entire race is viewable. And since driving skill plays a huge role in the outcome it would be an interesting event. I also think that HPVs would be even more fun than the gas carts—faster than these 10-mph-speed-limited ones—at least.

Is this a good idea? Maybe there's a track in [Las] Vegas?

William Volk
<bill_volk@qmail.lightspan.com>

THE *TOUR* REVIEW

Dave Wilson wrote:

"The data are very interesting and important. They show pretty convincingly that "normal" unfaired LWBs with riders have higher air drag that do the same riders on road bikes".

On this point I disagree. There was no road bike tested (the MTB in the test was definitely no normal road bike but a racing bike with wider tires!). There was no appropriate comparison in the test!

The rider on the racing machine couldn't stand the position for more than one km, if I remember the value correctly. There are very few riders who can stand this extreme seating position in the test for a longer time. Therefore they lumped together totally different machines!

In addition, the testers noted that the front fairing of the Peer Gynt could increase the aerodynamic drag when it was not properly fastened. (They didn't need an expensive wind-tunnel test to tell them that!)

Also the rear fairing of the low-racer was not well shaped. The photos published in *Tour* showed that the front edge of the rear fairing protrudes away from the body into the airstream, very poor for aerodynamic drag. The low-racer should have given better results in the test.

If someone wants to write a comment of a test, or to set up a new test series, ensure that like machines are compared, including similar fenders, lighting equipment, luggage and so forth. Measuring aerodynamic drag is hard enough: we should get everything right.

Joachim Fuchs
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fttp://www-ifia.fzk.de/personal/fuchs

CONGRATULATIONS!

(Normally I don't publish complimentary letters. We do receive a few. However, Paul MacCready's letter was so good for the morale of the many people involved in putting out Human Power that I could not bring myself to exclude it. Paul MacCready is the chairman of the board of AeroVironment and the IHPVA international president. —Dave Wilson)

I just received the spring 1997 *Human Power*. It is so good I wanted to write to congratulate you and everyone else involved. Especially delightful was the set of substantive summaries of the articles in the table of contents. If the momentum can be continued, this will become a very significant journal.

Paul B. MacCready
222 East Huntington Drive
Monrovia, CA 91016

SLOW ON HILLS?

Here is a theory regarding your comments in *Human Power* about some Tour de France riders being slow on hills: The best hill climbers tend to be small wiry guys because they have the best power-to-weight ratio. But the bigger guys have more total power, so they do better in the flats. Their greater weight is not a disadvantage in the flats, and the little guys are not little enough to get a wind-resistance advantage over them.

I am afraid I can't shed any light on recumbent hill-climbing issues. Some of the physiology studies you have published suggest maybe the recumbent position isn't the best for power generation. Has Edmund Burke ever weighed in on this? In various places he has published studies that get right down to the activity of various muscle groups, but I haven't seen anywhere he does this with recumbents. The people who make and sell various recumbent exercise bikes make some claims in ads sometimes, but I have never seen their research published either.

I recently re-read the section in John Forester's *Effective Cycling* about recumbents. He uses lame analysis. Among other things, he completely dismisses the comfort question by saying that sling seats are available for conventional bikes. In the first place I know of only one; in the second place it, or any sling seat, can't work very well because of the need for your legs to extend downward. I am sorry to see that section in what is apparently a recent edition of "EC".

John Riley <j.riley16@genie.com>

A MINI-HISTORY OF HPVS
Arnfried Schmitz

It was Laurent Chapuis (some HPV people will know him!) who asked me: "What was the reason for all [the excitement about

HPVs]? Give as short an answer as possible!" That is difficult, because some reasons come from a long while ago.

1910: The Prussian government forbids motor-paced bicycle races. Speeds of around 100 kmph generate some terrifying accidents. The race organizers slow down the bicycles by separating them somewhat from the drag shields. There are lots of rules and definitions. So pure speed becomes second to show.

1913: There is much laughter about the "Torpedo Bike". How can an added aerodynamic fairing around a bike, adding also considerable weight, raise the speed? But it does! Others try emulating the experiment, but the UCI race organizers stop this for regular racing. World War I does also.

1934: A so-called horizontal bike, legal, but much faster than a classic machine through its low and ergonomic construction, is banned from regular racing and from qualifying for world records. One of the reasons: "Technical bases should be equal for every sportsman", which means "technical progress is dubious in sport cycling". The inventor and constructor C. Mochet dies. He should have taken the power abuse to court ...

1984: The champion F. Moser achieves a world record, but on an illegal bike. Afterwards the regulations are adapted to allow it. This means "Don't touch an established hierarchy!"

In the period between these last two events of note, 1974, the Californians Lambie and Kyle founded the IHPVA, freeing bicycle development by open racing. The speed increase is fantastic, but the publicity impact is small. Today the association has clubs in most industrialized countries, but is growing slowly. A young generation is coming. May everyone remember Peter Ernst's words: "Ask not what the club can do for me, but what I can do for the club?"

The UCI, the world's racing body for traditional bicycles, does have a free category, at present totally unoccupied. Will you encourage this to be taken over one day?

Arnfried Schmitz
Lioux Gordes, Quartier Gallas, F-84220 France.

(We were allowed to publish Arnfried Schmitz's fascinating and valuable article "Why your bicycle hasn't changed for 106 years" in our issue vol. 11 no. 3. —ed.)

NOTES

SUSTAINABLE-TRANSPORTATION CONFERENCE

by David R. Conn

In mid-1995, a document was posted on the Internet to the HPV discussion group. It was an announcement of an international transportation conference to be held in Vancouver, Canada in March 1996. The conference was to be presented by the Organization for Economic Cooperation and Development, and hosted by the Canadian and British Columbia governments. I live in Vancouver, and decided to attend the conference to promote human-powered vehicles.

I wrote to the conference organizers in Ottawa and offered to organize a display and make a presentation on behalf of the IHPVA. They replied that they wouldn't have displays, and it was too late to schedule a presentation, but invited me to attend and to submit a paper for possible publication in conference procedings. I didn't submit as I couldn't make the deadline given.

The OECD is an independent body representing 25 industrial countries. The conference was called "Towards Sustainable Transportation". The preamble in the conference program questioned whether transportation could be sustainable, pointing out, "Improvements in fuel efficiency and pollution control during the past two decades have been more than offset by increases in the ownership, use and power of motor vehicles of various kinds." It added that there are 600 million motor vehicles in the world, and their use is growing well beyond the rate of population growth.

There were presentations scheduled over three days, most of them dealing with land vehicles. 78 papers were summarized in the conference program, to be published later. The best known speaker was Amory Lovins, the author and consultant. On the last day, all participants convened to discuss and adopt a statement of sustainable transportation principles which began bluntly, "Our current transportation system is not on a sustainable path." It placed most of the blame on our use of the private automobile. Bicycles and the use of human power seemed to be a very small part of a big picture: how to move huge numbers of people and vast amounts of freight about the globe without continuing to damage our ecosystem.

There was a paper by Vancouver's new nonprofit Alternative Transportation Center. The Center aims to decrease automotive dependence, with an emphasis on cycling. There was a paper by the activist group Vélo Québec, about efforts to integrate the bicycle into the transportation mix in the Montreal area. There was a paper by Hugh McClintock, a lecturer at Nottingham University, about planning for urban cyclists in Britain and continental Europe. Out of 78 papers accepted, only those three dealt primarily with the bicycle.

I expected to see professors and government policy-makers as presenters and audience members, but was pleased to also see engineers, executives, activists and planning students. Bicycle activists made the point in open discussion that bicycles are vehicles too, and could have a substantial part to play in transportation becoming sustainable. Because of their remarks, changes were made in the final conference statement of sustainable transportation principles.

I certainly learned something from attending the conference. A few thoughts that stay with me are as follows.

Total mobility can't be our ultimate goal. It is possible to have too much mobility, and that destroys communities. The layout of our cities and towns is a major part of the problem; it makes car ownership almost essential (for those who can afford them).

A lot of fine minds among the presenters are working to save our ecosystem from the automobile, but they aren't considering muscle-powered vehicles seriously.

My own influence was limited to leafleting for the IHPVA and promoting human-powered vehicles to other delegates at lunch. Had I known the hotel floor plan, I could have parked my Tour Easy recumbent in view of the delegates to create a subversive display. I hope that other IHPVA members will attend transportation conferences to help get our point of view across to government and industry decision-makers. Many of them have never heard of human-powered vehicles, and have no idea of their capabilities or potential. If members would like to order conference procedings, contact:

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Towards Sustainable Development
Canadian National Organizing Committee
Place Vincent Massey
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TECHNICAL NOTE

How thin may the braking rim of my wheel get?

by Chris Juden

Dick King asks how thin a rim may wear (due to braking) before failing and Jim Papadopoulos asks if such failures are disastrous.

I wrote an article entitled "Exploding Rims", for the February 1993 issue of our CTC magazine (*Cycletouring & Campaigning*), in which I fully described this problem. Leading up to that article I had been receiving an increasing number of reports of blown-out rim flanges, some accompanied with sections of rim, and have since received many more.

The design of cycle rims changed significantly in the 1980s. Steel rims and straight-sided alloy went out, hook-edged rims became ubiquitous. By the early '90s a lot of these rims had become worn enough to be blown away by tyre pressure, but their users were not aware of that (even when changing a tyre) because the thickened edge conceals the state of wear of the thinner section of rim wall immediately below it. And while a few rims failed soft, gradually bending outwards and warning of impending failure by causing brake snatch, others went with a bang.

When this happens a length of the rim edge peels off, usually but not always from the joint (welded rims also fail), and the inner tube pops through the resulting gap. Although a lot of failures occur while inflating the tyre, some quite serious road accidents have also resulted. Some riders have crashed due to loss of control upon sudden deflation of the tyre and one was also stabbed in the back of the leg by the flailing strip of rim edge!

I cannot single out any particular makes: most of those commonly used by our members are represented in my collection of bits of exploded rim. All have hooked edges (road and off-road types are now similar in this respect). It seems that in the past alloy rims just got thinner and thinner until they wore through into the pinning hollow, or the edges progressively bent over and became sharp, or they simply lacked the strength to stay true. But I am aware of one manufacturer (Alesa) who has recognised the danger of such failures and produces a rim (with the Alesa Safety Line feature) which is designed to wear through into the pinning hollow before the flange becomes thin enough to fail.

The thickness of rim wall at explosive failure obviously varies with material strength and inflation pressure. The thickest I've seen is about 0.7 mm, the thinnest 0.5 mm. But this measurement isn't easy to make prior to failure, due to the hooked edge, and one cannot expect average riders to check their rims in this way.

So long as you know how wide and thick the rim was to start with you could check overall width; and to give a margin of safety I recommend discarding a rim after 1 mm of total wear. But even this is perhaps a little technical for the average bicyclist.

I suggest a simple proof test every few hundred km after 3000 km (the shortest distance I've known any road rider wear a rim out—off-road use can be much more abrasive). Inflate the tyre to a pressure one bar (15 psi) or so higher than you'll ever ride at, wait for a minute, during which interval you may usefully spin the wheel and inspect the tyre for distortion or other signs of weakness, then let it down again to normal pressure. I shouldn't need to explain to this readership that proof testing is a respectable engineering procedure. If nothing went bang or looked out of shape, then the wheel should be as safe to ride as it was beforehand. But it's advisable to wear overalls, gloves and goggles when testing—which should be scheduled for when your favourite builder has the right kind of replacement rims in stock and not the day before a tour!

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(Chris Juden and Mark Marsh were kind enough to allow me to use their contributions in the "HBS: hardcore bicycling science" mail list, organised and moderated by Jim Papadopoulos. —ed.)

Another comment on how thin may the braking rim get?

by Mark Marsh

Jim Papadopoulos wrote "Has anyone out there actually experienced the failure — is it disastrous (sidewall blows off, wheel jams) or benign (sidewall spreads a little, grazes the brake pad)?

Both failure modes you suggest can happen: the rims often go when being pumped up. However, both my experiences have been of the catastrophic type. The first wasn't so bad: the rear rim blew a section out while descending off road and as a consequence the rear tyre blew out. It may have locked the rear wheel but since I was braking quite heavily at the time I didn't notice. The most dangerous part of it was the 400-mm length of sharp rim wall that was flapping around my legs until it fatigued off (the rim not my leg!).

The second occasion was much worse: the front rim blew out whilst descending a 30-degree dirt track at about 7 m/s (15 mph). It locked the front wheel instantly and I was thrown straight over the handlebars. I managed to tuck and roll, but it was quite a hard landing nonetheless.

I now run ceramic rims on the mountain bike. The ceramic coating makes the wheel last a lot longer: it is just starting to wear through after two summers and winters of riding (most Sundays) in quite poor conditions. As a rough guide we (both my usual riding companions use ceramics) think they triple the wear life of the rim. Since they cost roughly three times the price of an uncoated rim this saves the cost of a couple of rebuilds (and the inconvenience). Currently they have done twice the mileage I would expect from an uncoated rim and they still have 85% coated surface and the 'normal' rim to wear through before they will need replacement.

If you tend to wear out a rim before breaking it then I would recommend the ceramic coatings; obviously if you tend to wreck rims through impact they offer little advantage. We seem to get about 3000 km (1800 miles) in dry conditions, and 2000 km (1200 miles) in wet.

Interestingly I am still using the original XT brake pads fitted when I put the rims on: they are now nearly worn out. Normally I would expect to get through a set of LX pads every 6–8 weeks in the winter. I am told that this is probably a function of the change from LX to XT pads rather than the change to ceramic rims but I believe that the ceramic coating also extends the life of the pads due to the lack of the grey abrasive sludge that the rim wall normally turns into.

Mark Marsh <marshm@vicorp.co.uk>

ZACH KAPLAN ON FAIRINGS

This was written by Zach Kaplan in the hpv@ihpva.org list, and is reprinted with his permission - Ed.

Unlike many of the fully faired two-wheeler riders, most of my riding experience with them has been on public roads, not closed track. In fact I have been on closed tracks with them only a total of a few hours at HPV events.

In general I really like riding fully faired two-wheelers on the road. I find the fairing makes me much more visible and I get a lot more respect and courtesy from motorists with a fully faired recumbent than on an unfaired recumbent—which in turn gets more respect than a conventional upright bike. Not only does the fairing greatly increase my visibility but it also makes the HPV look like a heavier vehicle than it really is. Motorists often ask me if it is electric or what type of motor it has. Most find it hard to believe it is just a pedal bike. This is a good image to put forth: if they think it is a heavy motorized vehicle they are going to be less likely to hit it for fear of doing major damage to their car.

The increased aerodynamic efficiency of the full fairing allows me to keep up with the speed of traffic on 40–50 km/h roads. This allows me to take a full lane which is safer than being off to the side going slower than the traffic flow. The effect of passing cars also gives me more of a draft with the full fairing than on an unfaired recumbent. A minivan two car lengths up ahead will easily allow me to bring my cruising speed up to 55 km/h if it accelerates gradually enough. I often get these semi-free rides for considerable distances while still being able to keep a safe following distance. I love getting passed by huge trucks. I watch as my speedometer goes up several km/h after the truck passes. Surprisingly the big trucks rarely create handling problems. They tend to push me away slightly as they approach but never by much. Oncoming big trucks at high speed on a two-lane road are more of a cause for concern. The shock wave from them hits like an explosion. The bike moves laterally a bit for a second or so but once you get used to that it is no big deal. If I am going extremely fast I will slow down if I see an oncoming truck on a two-lane road. Once in a time trial I didn't bother slowing down and it was no big deal: the oncoming air from the truck felt as if it were hard braking, but after a second or two everything was back to normal.

Here in the San Francisco Bay Area it is often windy but not usually extremely windy. I have to remove the fabric mid-fairing only a few times per year around here. However there are some gusty downhills such as the one going down into Sausalito from the Golden Gate bridge. On a calm day or at night I let it fly at close to 80 km/h on this hill. On a windy day I just "burn out" the brakes and hold it down to 30 km/h or so. This isn't a very long hill.

For dealing with very gusty conditions in high-traffic areas I have developed a technique I call "going with the flow." I do this when there is a lot of traffic on the road and I don't want them to pass me closely in case I need that section of the road due to a gust. I simply keep a loose grip on the handlebars and let the wind do what it wants to with the HPV. I'll let it move laterally about 1 metre in either direction if it's really gusty. I am in complete control while this is going on and can always use the brakes or lean into the gust if I want to hold a straighter line. It really freaks out the motorists behind me though. They get 'way behind me which is where I want them, and don't attempt to pass unsafely.

I have never heard of faired bikes being outlawed in certain areas. Can you cite any examples? I can tell you that if every cyclist riding today were riding a fully faired bike using today's technology they most certainly would be banned in short order. Right now the faired bikes are fairly easy to ride in no-wind conditions but take a lot of skill to ride in windy conditions, particularly at higher speeds. I think I once told an upright rider that he was using more muscle power but I was using more brain power to ride. I of course don't want things to stay this way. I don't want faired HPVs to remain something elitist, requiring special skills. I would like to see many more faired HPVs out there on the road. But we are going to need to design more easily controllable vehicles before this can happen. This is where my thoughts turn to three-wheelers, semi-automatic control-surface-compensation systems, and lower riding positions. Keep in mind I am no expert on what will or won't work. I have never had the pleasure of riding a fully faired three-wheeler or ultra-low faired two-wheeler on a windy day. Those designs might not be enough of an improvement or they might be. I don't know yet. Anyone want to loan me one so I can tell you?

Hugh Murphy, the organizer of the Death Valley double century, phoned me up when he received my registration and told me I wouldn't be allowed to ride with the full fairing. I ended up telling him a bunch of technical terms and telling him how the HPV I was using was suitable for these conditions and how I would be very careful. He ended up giving me special permission to ride fully faired so long as I absolutely would not ride beside any other cyclists except when passing and give them as much space as possible while passing. I ended up doing the ride with the full fairing and it did turn out to be quite windy. About two thirds of the way into the ride I determined conditions where too unsafe to keep the fabric on so I took it off and folded it up completing the rest of the ride with just the nose and tail installed. Even then it was hard to keep anything close to a straight line. Everyone was getting blown around on that ride. I heard that a tandem got blown off the road.

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CALL FOR PAPERS FOR DENMARK 1998 EUROPEAN CHAMPIONSHIPS

A human-powered vehicles symposium will be held in conjunction with the HPV European championships in Roskilde, Denmark, 5–9 August 1998. The symposium, organized by Carl Georg Rasmussen, will take place at the Roskilde Tekniske Skole on Wednesday, 5 August 1998.

Contacts: Dr. Andreas Fuchs, Ingenieurschule Bern HTL, Morgartenstrasse 2c, CH-3014 Bern, Switzerland. Phone: +41-31-333 0625; <fuchs@isbe.ch>.
Dr. Joachim Fuchs, Morgenstrasse 45, D-76137 Karlsruhe, Germany. Phone: +49-721-826539; <fuchsjo@aol.com>; home page: http://www-ifia.fzk.de/personal/fuchs
Other links: http://www.ihpva.org/;
Dansk Cyklist Forbund:
http://webhotel.uni-c.dk/dcf/

Deadlines: for abstracts, 1 March 1998; for camera-ready papers, 1 June 1998.

BICYCLES AND THE TAX-MAN
by Richard Veffer

In a press release dated August 18 1995, Secretary of State Vermeend, of Finance, [NL] announced that commuting by bicycle will finally become attractive in terms of taxation. As per the first of September 1995, a number of measures are in force in connection with this announcement.

The following measures have been taken:

1. The Secretary of State wants to encourage employers to give a bicycle to their employees for commuting. If the value of the bicycle (as determined by the recommended retail price of the bicycle) is below Dfl 1500 (including tax), income tax will only be levied once for the amount of Dfl 150. It is allowed to give one bicycle per three years only.
2. If the bicycle is used for commuting only, and as such remains property of the employer, no income tax is levied. Again, the ruling that the recommended retail price of the bicycle has to be Dfl 1500 or less (including tax) applies.
3. Probably with the mostly unfaired upright bicycles in mind, on which the rider is exposed to the elements, the Secretary of State has decided to allow the employer to pay for the cost of public transport through a railway 5-return ticket or universal ticket, without being taxed. However this decision is only valid for the bicycle made available by the employer, not for the employees who have been given a bicycle. Take note, if your employer gives you money so you can buy your own tickets this rule is unlikely to apply.
4. Furthermore, items directly related to the bicycle, such as foul weather clothing, locks, maintenance, etc., can be reimbursed by the employer up to an agreed limit, after consultation with the tax office.
5. If you are not given a bicycle by your employer, or have one made available to you, and you use your own for business trips, your employer is allowed to pay you up to 12 cents per kilometer untaxed. If your employer does not give you this allowance, you are allowed to deduct 12 cents per kilometer from the taxed costs (however this only applies if the employee pays for both bicycle and bicycle related costs).

Finally , there are two more rulings which should make it attractive for the employer to give bicycles away or make them available:

- The full cost of bicycles with a cost price of Dfl 1000 or less can be deducted from company profits in one go, and so they do not have to be depreciated during the economic life cycle
- Bicycles with a cost price of more than Dfl 1000 can be depreciated in three years, even if the economic lifespan is longer.

At the tax office a central information source will be set up: the Bicycle-information point. Here, both employers and employees can get all the answers to questions related to the taxation of bicycles.

With this arrangement Vermeend shows that is he is not deaf to the cries from the (organised) bicycle industry. For the recumbent cyclist, the rulings are not applicable in their standard form. The recommended retail price of recumbents is well above the Dfl 1500 mentioned before.

This complication has two possible solutions: on the one hand, the employee who is given a bicycle worth (say) Dfl 3250, could decide to pay Dfl 1750 himself. In this case, he is only given Dfl 1500 worth of (part of a) bicycle. In this situation it is to be expected that the rulings described above are applicable.

Another solution could be reached if the employee gets in touch with her or his own tax inspector (note: only the employees tax inspector is duly authorised to make any agreements, not the [income] tax inspector of the employer!). He or she can present the situation to the tax inspector and make agreements as to what amount should be earmarked as income. In 1994, before this arrangement existed, I myself was able to reach an agreement with the tax inspector, that said that for a recumbent worth Dfl 2350, Dfl 150 one-off would be regarded as taxable income.

According to the newly created ruling this amount will possibly be slightly higher in the future, but a similar tax agreement will still be cheaper for the employee than sharing the costs of the bicycle with the employer.

Should you have questions or comments about these rulings, you can reach me via the editors of *HPV Nieuws*.

Translated by Wouter Suverkropp

(1 US dollar was about 1.68 Dfl [when this was translated], wbs)

EDITORIALS
The outing of impotence

Bicycling displayed two acts of courage in 1997. One was an article in the July issue generally favorable to recumbents. The second was a follow-up in the August issue in which a senior editor confessed not only that he had been rendered impotent by riding on hard bicycle saddles (there was an accompanying article about the topic) but had switched to a recumbent bike, a type for which he normally had some disdain, and after only six weeks had considerably recovered. To most of us in the HPV community the pain and nerve damage in the neck, wrists and crotch that come from long-duration riding in the traditional bicycling position are well known (incidentally the medical emphasis in the *Bicycling* interview was on blood-vessel damage), but it was still remarkable that the principal main-line bicycle magazine would be so broad-minded and honest. It was obvious that this was an explosive issue that tabloid journalists, maybe others too, in all media would want to exploit. On September 18, 1997 the ABC program 20-20 interviewed Lisa Gosselin, *Bicycling*'s editor, who had obviously been subjected by the bicycle manufacturers that advertise so widely in her magazine to the kind of pressure that the tobacco companies used to put on editors who dared to publish an article that suggested that smoking was anything but gloriously healthful. She chose her words very carefully. "Yes, he is still bicycling," she said in response to a question from Dr. Timothy Johnson, ABC's in-house medical specialist. "He adjusted his riding style." (That at least is a tacit acknowledgment that recumbents are now main-line bicycles).

The tiny recumbent-bicycle industry has been helped generally by these events. We hope that the manufacturers of traditional bicycles and components will react in a manner as different from that of the tobacco companies as possible. For years there have been saddles available that have promised to avoid putting pressure on delicate areas for males and females. There have been handlebars that allow frequent changing of the wrist position and that reduce pressure on the ulnar nerve. The avoidance of damage to the neck seems to me the most intractable. At the end of the first twenty-four hours in a typical Race Across America, over half the lean, superbly fit athletes who start have quit, most, I believe, because of neck pain. Even in what seemed like a comfortably upright mountain-bike position on wide saddles my wife and I, in a recent low-pressure 1200-km tour of New Zealand's Southern Alps, had severe pain in all three areas of concern, but the neck pain lasted longest after the trip was over. Some people have made periscopes so that they can ride with their heads comfortably down. That seems an extreme response. HPV enthusiasts want to co-exist with a healthy and healthful traditional-bicycle industry, and we wish it a speedy and effective response.

—*Dave Wilson*

GUEST EDITORIAL

Record rules and altitude

Paul Buttemer

The recent debate about IHPVA record rules in general, is one that we have much to gain from resolving. I believe that the context of the debate should be expanded, and that there is far more at stake than simply "who's best".

Firstly I'd like identify myself, so that readers will have an idea of my perspective. My involvement with the IHPVA has been mostly as a participant in IHPVA sanctioned events. I have been very fortunate to be able to ride, since 1990, in the Varna vehicles built by George Georgiev. I have competed in the annual IHPVA Championships in 1990 (Portland), 1991 (Milwaukee), 1992 (Yreka), 1994 (Eureka), and 1996 (Las Vegas), and in the 1993 Colorado Speed Challenge. George and I hold one record, namely the one-mile flying-start TT. George's vehicles have, along with good results in other events, placed first and second in the 200-m sprints at the 1994 and 1996 Championships. My personal interest, though, goes deeper than that of an "engine", as I am fascinated with the very young science, and the art, of aerodynamics.

There is no question that altitude affects performance, and at this time we can't accurately quantify how much it does, as there are too many variables to consider. So, it is quite reasonable that one competitor, who doesn't have access to high-altitude venues, should want to qualify the performance of another competitor, who does have this access. The simple solution, one which we are currently pursuing, is to make one or more categories based on altitude.

Furthermore, many factors, altitude being only one, affect performance on a given course. Let me cite an example: at the 1994 Championships, the sprint course was right at sea level. In the cold, humid, but still, early morning air, my top speed was about 77 kmph. Later in the warmer, less humid air, I was able to attain about 85 kmph in a gusty cross wind. At this venue, the environmental change resulted in a substantial difference in performance. Back home, there is a stretch of road, also at sea level, that we (Team Varna), occasionally practice sprints on. The pavement is very good, but the slope is such that one point in the course pokes up just barely above the 2/3 percent line, making it illegal for any record activity. It is necessary to use this road very early in the morning to avoid traffic, so generally we're out on it at 5:00 A.M. or so. I can attain speeds of about 100 kph on this course in still wind conditions. So, when we compare this course with the one in Eureka, which is at the same altitude, we see a dramatic difference of almost 25 kmph! My point is, that the situation we face in qualifying performances is far more complicated than just resolving the altitude question.

We could go ahead and impose altitude rules, but this is not going to prevent one competitor from having a large advantage of another, by virtue of other factors to do with the air and with the course surface. When we are dealing with streamlined vehicles (as opposed to a normal unfaired bicycle), factors other than altitude become more significant. We simply cannot, at this point in time, compare performances on two different courses, even if they are at exactly the same altitude. If we really want to "make things fair", we need to impose a myriad of rules and restrictions, some of which haven't even been considered yet. This will take much time, will probably give rise to some ill feelings, will make fewer venues available, and will cause fewer and fewer competitions to take place. We need more competitions, not fewer, to take place under any reasonable conditions. The only way to find out "who's best" (if this is what you are interested in), is to have competitors go head to head on a number of varied courses. Beyond this, our competitions are the proving grounds for our theories on aerodynamics, power transmission efficiency, and the dynamics of the human engine. They can be the source of immensely valuable scientific data, if we choose to record these data. The accumulation of these data will eventually allow us to determine accurately how such things as altitude, barometric pressure, temperature, humidity, slope and the course surface affect performance. I have seen (notably in *Human Power*) all kinds of theories about the effects of these factors, so it is obvious that they are of general interest. What better place is there to apply, and possibly verify, these theories than data accumulated, without bias, in real-world circumstances?

At the recent championships in Las Vegas the course for the 200 m sprints was held on an airport runway, with a gradient somewhere between one and two percent (exact figure unknown at the time). My subjective estimate is that this gradient added about 20–22 kmph over what our speeds would be if the course was level. (I did this by travelling down and up the course at various levels of effort, and found that the difference in speed, between down and up, was always 40–44 kph at the same effort level. This was a very crude experiment, at best, but it was interesting for me to know about how much the slope was adding to our speeds.) The speeds were unrealistically fast, but, I suspect that every competitor thoroughly enjoyed the thrill of being on this course. It would be a shame to reduce the possibility of using such a course, which seemed to be at the outer limit of armchair reason.

In conclusion, I would like to propose that we move our focus away from trying to determine fair rules for world records. It cannot be done. Instead we should put our efforts into having more competitions, and to the creation of a database that will contain results of every performance and details of the factors surrounding each performance. We could still at any time, if we want, design an arbitrary set of criteria as a filter for the database and pull out an "official" world record.

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