Title: BICYCLE POWER ASSIST

Abstract

In a bicycle having a power assist motor (10, 510, Fig. 5) activated manually by an on/off push button switch (530) activating a relay (520). A battery (500, Fig. 5) provides current to the motor. A battery (600, Fig. 6) can be recharged by connecting a battery charger to connectors (610). A fuse (700) provides protection against accidental short-circuiting of battery (600). A thermostat (710) senses the temperature of battery (600) when a predetermined temperature is exceeded.
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BICYCLE POWER ASSIST

Technical Field

This invention relates primarily to the addition of artificial power assistance to bicycles.

Background Art

After car traffic and inclement weather, hill climbing presents the greatest obstacle to increased use of bicycles. The present invention is directed to reducing the physical exertion of a bicycle rider when pedaling up hills and to increase the rider's speed and enjoyment.

Previous attempts to add power to bicycles have severely compromised the essence of cycling. The most commercially successful such powered bicycles are motorcycles. Motorcycling, while fulfilling to many of its enthusiasts is a very different experience than cycling. Motorcycling is exciting to those enthusiasts because of its unnaturally high power. However, motorcycling creates pollution (both air and sound) and eliminates exercise, whereas cycling is clean, quiet and beneficial to the cyclist's mental and physical health.

Previous attempts to overcome the noise and air pollution problems of motorcycles have centered on electrified bicycles. Many inventors have toiled for years producing overweight, over-expensive, underpowered electric motorcycles. These electric motorcycles have enjoyed only occasional and brief commercial success, (usually in months following an oil shortage). Such inventive attempts have battled against fundamental physics which indicate that any such inventions will continue to be disappointing (until some unexpected
materials discoveries occur) when compared with internal combustion-based motorcycles.

As is true with many of today's new technological "advances" the needs of the customer (and the needs of planet earth) have been overlooked when seeking ways to improve cycling with power assist. One of the primary benefits of cycling is that human effort is required for propulsion. Unfortunately, many people have grown up so immersed in a technological society that they don't understand (or appreciate on an intuitive level) that humans require much more activity than modern society demands. Our unnatural society has created millions of overstressed commuters who think that it is easier to sit in automobiles crawling along expressways than to use that time to give their bodies and their minds the aerobic activity they need.

While the present invention will not directly address this educational problem, it will make the cycling experience more practical and enjoyable. Thus, the present invention may serve as a catalyst for a much broader appreciation of the overall benefits of cycling.

**Disclosure of Invention**

A primary object of this invention is to encourage the use of bicycles for both recreation and transportation by reducing the normally excessive load on the cyclist during hill climbing. By eliminating this negative aspect, the cycling experience can become enjoyable even going up hills.

Many detailed benefits are provided by the present invention. A simple on/off push button controls the power assist while a clutch automatically handles both engagement and disengagement. The invention has produced a powerful (80 to 150 watts of power delivered to the bicycle tire), compact, lightweight (2.5 to 4 kg) system capable of boosting the hills of a 1 to 2 hour bicycle
ride. The system is compatible with most bicycles, is
easy to install yet includes a theft deterrent mount. The
system includes several safety features including a very
modest high speed limit (e.g. 12 mph) beyond which power
assist is automatically disabled, and a modest power level
which can be overridden by normal bicycle brakes.

Brief Description of Drawings

FIG. 1 and FIG. 2 are simplified side and rear
views, respectively, of a motor, transmission and clutch
assembly.

FIG. 3 is a schematic illustrating the
operation of the automatic clutch mechanism.
FIG. 4 shows the gravitational and balancing
forces acting on a drive wheel.

FIG. 5 is an electrical schematic showing a
remotely controllable battery.

Modes For Carrying Out the Invention

Referring to the drawings, motor 10 is
connected to small pulley 20 which transmits mechanical
power to large pulley/drive wheel 30 by means of belt 40.
Both motor 10 and large pulley 30 are mounted to bracket
50 which is rotatably mounted on axis 60 to clamp 70.
Clamp 70 firmly attaches the assembly to a bicycle frame
seat tube 80. Axis 60 is seen to serve the dual purposes
of attaching the clamp 70 and operating as a hinge pin for
the bracket 50 and thus is an example of a combined clamp
bolt and hinge pin. Large pulley/drive wheel 30 is
mounted on bracket 50 via bearings 90 and 100 and shaft
110. The shaft 110 does not rotate and is held in bracket
50 by retainer rings 120 and 130. Bearing 100 is held
onto shaft 110 by retainer rings 140 and 150, while
bearing 90 is held on by retainer rings 160 and 170.
Large pulley/drive wheel 30 is attached to bearing 90 by
set screw 180. This cantilevered shaft mounting system
enables quick and easy disassembly for repair or replacement with a differently sized drive wheel (portion 190).

The assembly 200 shown in FIG. 1 and FIG. 2 is compact and lightweight. Prototypes have been built which fit within the space defined by a bicycle's tire and frame and a rider's legs, while weighing less than one kg (2 pounds). A variety of motors can be used, but high speed (10,000 to 20,000 RPM) permanent magnet DC motors provide high power per unit mass, are reasonably efficient, low cost and available in large quantities. While the intent of this invention is that electric motors or similar clean power sources be used, it is apparent that other less ecologically desirable sources (e.g. internal combustion engines) may also use these improvements.

FIG. 3 contains a simplified version of assembly 200 and illustrates an operating principle which enables automatic engagement and disengagement of the drive system. A drivewheel is shown in the disengaged position 300 as dashed lines and in the engaged position 310 as solid lines. The drivewheel is connected via a bracket (position 320 disengaged, position 330 engaged) to pivot axis 340. The bracket is limited in its rotation between first stopper 350 and second stopper 360. When motor 30 is started from rotational rest a large torque begins to accelerate the rotor of motor 30. The reaction torque of forces the bracket 360 to rotate and the drive wheel 310 to move to push against tire 370. The direction of spinning of drive wheel 310 against tire 370 causes bracket 320 to rotate even further in the same direction. With sufficient torque from the motor 30 and no other geometric constraints, the bracket 320 would continue to rotate through a closest-drivewheel-approach position (pushing the drivewheel maximally into the tire 370) and on to an even greater angle (where the drive is pushed less and less into the tire) and eventually to a still
grater angle where the drivewheel would withdraw from touching the wheel. However, the first stopper 350 is located to assure that pressing contact is maintained so long as the drivewheel 310 is exerting torque against the tire 370.

It has been discovered experimentally that low vibration is produced by assembly 200 when the first stopper 350 is located to restrict motion of the bracket 330 to slightly beyond the closest-drivewheel-approach position. It is also possible to locate the first stopper 350 to restrict motion of the bracket 330 to less than the closest-drivewheel-approach position and thereby produce an automatically self adjusting torque mechanism. The higher the torque applied by the drivewheel 310, the greater the pressing force of contact between the drivewheel 310 and the tire 370. Since the amount of energy consumed in tire hysteresis loss per tire rotation depends on the amount of said pressing force, this automatic self adjusting torque mechanism can be used to produce a more highly efficient power transfer system. This system can be more efficient because when only low torque is demanded, only small pressing force (hence only small tire hysteresis loss) is used.

The automatic engagement can be activated simply by turning on motor 30. If the tire 370 is spinning at a rotational rate corresponding to certain road speeds (speed of the bicycle traveling down the road), then engagement will occur. If the road speed is too high engagement will not take place. The high speed limit for engagement is determined by geometry and corresponds to the motor rotational speed at which torque becomes so low that the drive wheel 310 cannot maintain is position against tire 370. Assuming the motor used is a permanent magnet DC type, this will occur at high RPM near the motors no-load speed. This feature of automatic non-engagement provides safety. Above a certain speed the
automatic engagement system prevents any power being transferred. In cycling applications, this means that power assist above a specific predetermined speed cannot occur. For example, several prototypes have been built which produce substantial power assist in the 5 to 10 mph range with diminishing power up to 12 mph at which speed non-engagement (or disengagement) occurs. Disengagement is another safety feature. Even if a cyclist slows sufficiently to engage the power assist, as soon as the speed exceeds the preset disengagement speed, the automatic system decouples the power assist.

FIG. 4 is a simplified version of assembly which shows how the weight of the assembly can be compensated for to produce a larger speed range in which the automatic clutch can operate. The mass of the assembly is represented by lumped-mass 400, which is suspended via bracket 410 which rotates about axis 420. Without compensation for assembly weight, the drivewheel 310 torque against the tire 370 must provide a lifting force sufficient to lift the assembly. Experiments have shown that the road speed must be below about 7 or 8 mph to ensure automatic engagement (when no weight compensation was used for the geometry of the example). FIG. 4 shows that a downforce "g" caused by the weight of the lumped-mass 400 can be opposed by a counterforce "s". The counterforce need not be exactly equal, nor need it be exactly opposite to the downforce. All that is needed is that the vertical component of the counterforce be approximately equal in magnitude (but oppositely directed) to the downforce. When weight compensation was used in the example just cited, automatic engagement functioned up to about 10 or 11 mph. Counterforce can be provided by a variety of springs (compression, tension, torsion, etc.) or by other forcing means (e.g. magnetic.

Referring back to FIG. 2 it has been discovered experimentally that by controlling the stiffness of the
bracket 50 one can control the low speed/low RPM characteristics of the assembly. This is useful for solving the high current/high torque problems inherent in some electrical motors. At low rotational speed some motors draw excessive amounts of power. Not only is this inefficient and wasteful of precious energy, but it is also potentially harmful to the motor. The motor windings can be overheated to the point of damage or secondary systems can fail rapidly. For example, motor bearings if overheated will lose their lubrication and fail. Also nearby items, plastic motor covers, bicycle parts etc. might be damaged by excessive temperatures.

One approach to preventing excessive temperatures is to monitor the current flowing through the motor electronically then with either analog or digital circuits control when (and for how long) the system should be shut down. In the presently preferred embodiment, the bracket 50 is sufficiently flexible so that when high torque/high current is produced, the bracket flexes causing slippage in the drive belt 40. The slipping generates an awful noise which signals the cyclist to turn off the motor. This approach is simple, inexpensive and rapidly trains the cyclists about which operating situations to avoid. For example, the cyclist should not start the motor when the bicycle is at a complete stop.

The auditory feedback of this approach (which could also be generated electronically) provides another safety feature. In the occasion of a panic stop, the brakes of bicycle can overcome the torque of a 200 watt motor. However, it is important that the motor be shut down to prevent any startling surges after the panic stop situation has been resolved. With the auditory feedback, the cyclist knows the motor is still on and can easily turn it off after using the brakes.

FIG. 5 shows a remotely controllable battery system which enables simple on/off push button control of
the power assist. Battery 500 provides current to motor
510 when relay 520 is activated by switch 530. Relay 520
is preferably a high current (greater than 10 Amperes)
type to enable significant power control capability to the
system. Relay 520 is a specific example of a power
management device. Other examples include other switching
devices (e.g. power transistors) and more sophisticated
variable controllers (e.g. switched-mode power supply
controllers). Switch 530 may be a simple manual switch
or a wireless system. The wireless system comprises a
manually operated switch which activates a wireless
transmitter, a wireless receiver, and a switch closure
activated by the wireless receiver. Possible wireless
transmissions include electromagnetic (radio, infrared,
optical, etc.) and sound (including ultrasound). The
transmissions can be encoded to prevent interference
between two or more wireless systems.

FIG. 6 shows a remotely controllable battery
which can be connected with one or more other such
batteries in a daisy-chain fashion. A characteristic of
the daisy-chaining connection is that each additional
battery which is added to the daisy-chain comprises enough
connectors for yet more batteries to be added. Battery
600 can be recharged by connecting a battery charger to
connector 610. Optional diode 620 protects battery 600
from being mistakenly "charged" with the incorrect
polarity. If the optional diode 620 is not chosen (i.e.
it is replaced by a simple conducting path), then the
connector 610 can serve as an optional power port to
deliver battery 600 energy to a wide variety of
accessories (including lights, radios, horns, cellular
phones, global positioning devices, and computers).
Daisy-chaining of batteries is enabled by the dual high
current connectors 630 and 640. Even more such connectors
can be incorporated, but two are enough to provide the
daisy-chaining capability.
The specific example shown in FIG. 6 also comprises a daisy-chain dual connection 650 and 660 for the switch line 670 which controls the high current relay 680. Diode 690 provides an example of an important isolation function. Without such a diode, the daisy chainable batteries would not be completely and automatically isolated during recharging. With diode 690, however, isolation is obtained. Isolation is important for some types of batteries (e.g. nickel-cadmium batteries) to avoid damaging overcharging.

The battery 600 is protected against accidental short-circuiting by fuse 700. Fuse 700 is a specific example of a current interrupting means. Other examples include circuit breakers and systems comprising electronic sensors which control high current relays. The battery 600 is protected during high current regenerative recharging (i.e. when the motor is used as a generator when, for example, the bicycle is coasting downhill) by a thermostat 710. The thermostat 710 senses the temperature of battery 600 and switches from a very low resistance state to a very high resistance state when a predetermined temperature is exceeded (which normally corresponds to excessive internal cell pressure). A common temperature for a Nickel-Cadmium battery thermostat is 45°C. The thermostat can be located within the cells of the battery or on its surface. When mounted on the battery's surface an advantage is gained for regenerative recharging in that a faster recovery time (time between when the thermostat causes the battery to be disconnected until the thermostat causes the battery to be reconnected) is produced. Optional diode 720 enables higher charging currents than would normally disrupt fuse 700. Optional fuse 730 establishes a safe maximum for recharge current while optional diode 740 protects fuse 700 from such recharge current.
As discussed earlier, the preferred coupling mechanism of this invention automatically disengages at a predetermined speed (12 mph in the example given). To enable regeneration with this coupling mechanism requires an independent means of forcing the drive wheel against the tire. This can be accomplished, for example by pulling on the point 210. The pulling for P can be provided by a cable or an actuator (e.g. a solenoid). The cable can be connected to an overcenter latch to positively lock the drivewheel against the tire.

Industrial Applicability

The invention has been described as mounted on the seat tube of a bicycle. This particularly attractive location is the preferred one because it offers compatibility with the widest variety of bicycle designs, yet minimally disturbs both the handling and the esthetics of the bicycle. This location has been made possible by the invention by combining a small, high RPM motor with a drive system which essentially folds over on itself. This folding results in a compact system which is short enough not to interfere with the normal pedaling motions of a cyclist.

It is clear that the invention can be mounted at other locations, for example behind the rear brakes or even on the forks (for use with the front tire). With such mounting it is even possible to eliminate the transmission and drive the tire directly from the motor shaft. While this direct shaft drive approach results in a lower cost, it also suffers from several disadvantages.

To match the high RPM (10,000 to 20,000) of a high power density motor to the low RPM (of the order of 100 at low road speed, e.g. 5 mph) of a bicycle wheel, a very small shaft-drivewheel must be used (about 6 mm). This results in inefficient power transfer as it has generally been found that rolling resistance is inversely
proportional to wheel diameter (in this case the shaft-
drivewheel's diameter). Also, it has been discovered
experimentally that when the minimum diameter (limited to
about 6 mm by practical bending considerations) shaft-
drivewheel was field tested, motor bearing failure
resulted. The bearing failure was experienced in motors
with ball bearings as well as with the more common sleeve
bearings. The failure resulted from the combined results
of excessive side loading (due to the direct transfer
game) and the fact that the shaft-drivewheel was
really not sufficiently small enough in diameter to allow
the motor to operate in its most efficient, higher RPM
range. As a result of running at lower than efficient
RPM, the motor generated excess heat, warmed itself
(including its bearings) up to high temperature, which
resulted in premature failure of the bearings.

It is possible to mount more than one motor
system on a bicycle. One reason for using more than one
motor is to produce a higher power assist. Another reason
for doing this is to simply and compactly produce a system
with a broader speed range. For example, a two motor
system could include one drivewheel with a small diameter
for low speed assist, and another drivewheel with a larger
diameter for a higher speed assist. Since the motor and
drive system is very compact and lightweight (under 1 kg),
this multiple motor approach may be more practical than
trying to incorporate multiple speeds into the
transmission. However, this can also be accomplished by,
for example, using a drivewheel which has two or more
segments with different diameters plus a mechanism which
shifts the region of contact between the drivewheel and
the tire between the segments.

While the present invention has been described
in terms of a common example, a bicycle, it should be
clear that it is applicable to many other systems. The
automatic coupling methods can be applied to any variety
of rotating members including machinery used in manufacturing processes. It should also be clear that the word bicycle is representative of a much broader class of human powered vehicles including those with other than two wheels.
What is claimed is:

1. A lightweight power assist system for a bicycle comprising;
   an energy storage means,
   a control means,
   a motive means, and
   a coupling means,
   said control means selectively governs an energetic connection between said energy storage means and said motive means,
   said coupling means provides mechanical connection between said motive means and a wheel of a bicycle,
   the mass of said system being less than 10 kg.

2. The lightweight power assist system for a bicycle of claim 1 wherein;
   said control means is governed by a simple electrical switch and said coupling means is automatic.

3. A compact power assist system for a bicycle comprising;
   a motive means,
   a control means, and
   a coupling means,
   said system being small enough to fit substantially between said bicycle's seat tube and rear tire and between the legs of a cyclist riding said bicycle.

4. The compact power assist system of claim 3 wherein;
   said coupling means is a folded-transmission.

5. A high rpm power assist system for a bicycle comprising;
   a high rpm motive means,
   a control means, and
   a coupling means,
said motive means normally operating at greater than 5,000 revolutions per minute.

6. A coupling mechanism for transmitting rotary power comprising:
   a bracket,
   a drive wheel mounted on said bracket,
   a driven wheel,
   said bracket mounted at a fixed location near said driven wheel, but free to rotate within a limited angle,
   a first stopper for limiting the rotation of said bracket in a first angular direction,
   a second stopper for limiting rotation of said bracket in a second angular direction.

7. The coupling mechanism of claim 6 for transmitting rotary power;
   wherein the said first stopper is positioned so that said drive wheel will be located near a closest-drivewheel-approach position.

8. A method of engaging for transmitting rotary power comprising:
   starting a motor,
   using the reaction torque from said starting to force contact between two or more rotating elements,
   then using the continuous torque from said motor to continue forced engagement between said rotating elements.

9. The method of engaging of claim 8 for transmitting rotary power further comprising;
   substantially balancing the static forces of the engagement mechanism thereby providing an enlarged range of rotary speeds over which successful engagement can be accomplished.

10. A method of disengaging from transmitting rotary power comprising;
    stopping a motor,
using the reaction torque from said stopping to enable disengagement between two or more rotating elements.

11. A method of forcing contact between rotating elements comprising,
rotating a driving rotary element in contact with a driven rotary element,
increasing torque of said rotating of the driving element automatically causing an increase in the force of contact between the elements.

12. The method of claim 11 of forcing contact between rotating elements comprising,
the method is used to automatically adjust the contact force over a range of load conditions,
thereby providing more highly efficient rotary power transmission.

13. The method of claim 12 of forcing contact between rotating elements comprising,
the method is used with a limit setting geometry which results in a substantially constant contact force over a range of load conditions,
thereby providing reduced vibration rotary power transmission.

14. A drive wheel comprising;
drive means,
pulley means,
bearing means,
said drive means and said pulley means being combined in a one piece unit.

15. A mounting system to cover a rotating element comprising,
a fixed shaft,
a cover attachment means,
said fixed shaft being coaxially located relative to said rotating element,
said cover attachment means being connected to said shaft.

16. A high power battery for use on a bicycle comprising;
   an electrical storage battery,
   said battery being capable of delivering at least 100 Watts of power.

17. The high power battery for use on a bicycle of claim 16 wherein;
   said battery is fit compatible with conventional bicycle water bottle cages.

18. The high power battery for use on a bicycle of claim 17 wherein;
   said battery capable of being recharged with more than 200 watts of power.

19. A high power battery mount for use on a bicycle comprising;
   a mount for an electrical storage battery,
   said mount being fit compatible with the holding nuts for conventional bicycle water bottle cages.

20. A remotely controllable battery comprising;
   an electrical storage battery,
   an electrically controllable power management device,
   a means for controlling said power management device.

21. A daisy-chainable battery system comprising,
   two or more remotely controllable batteries of claim 20,
   a wiring means for connecting said means for controlling between said batteries.

22. The daisy chainable battery system of claim 20 wherein;
said batteries are completely and automatically electrically isolated during recharging. (by wall chargers)

23. A cantilevered shaft mounting system comprising;
   a shaft,
   a support means,
   said support means being connected to said shaft from only one end.

24. The cantilevered shaft mounting system of claim 23 wherein,
   said system enables quick and easy removal of a drivewheel.

25. A combined clamp bolt and hinge pin comprising;
   a clamp bolt and
   a hinge pin,
   said clamp bolt and said hinge pin being one and the same.

26. A combined motor bracket and hinge plate comprising;
   a motor bracket, and
   a hinge plate,
   said motor bracket and said hinge plate being one and the same.

27. The combined motor bracket and hinge plate of claim 26 further comprising;
   a drive wheel shaft mount.

28. A lightweight drive wheel comprising;
   a fixed shaft,
   one or more bearings,
   a thin walled drivewheel,
   said drive wheel being located around said bearings, and said bearing being attached around said shaft.
29. An indirectly fastened drive wheel system comprising;
   a fixed shaft,
   a least two bearings,
   a driven wheel,
   a drivewheel,
   said drive wheel being fastened to at least one bearing,
   said drive wheel being not fastened to at least one other bearing,
   said other bearing being located substantially near the area of contact between said drive wheel and said driven wheel.

30. A high torque feedback system for a motor comprising;
   a sound producing means,
   said sound producing means being automatically activated whenever said motor produces high torque.

31. The high torque feedback system of claim 30 wherein;
   said sound producing means is provided by a substantially all mechanical means.

32. The high torque feedback system of claim 30 wherein;
   said mechanical means is provided by a complaint bracket.

33. A direct drive power assist system for a bicycle comprising;
   a rotary motive means,
   a control means, and
   a coupling means,
   an energy storage means,
   said coupling means being substantially a shaft extension of said rotary motive means.

34. A regenerative power assist system for a bicycle comprising;
an energy storage means,
a control means,
a motive means, and
a coupling means,
said control means selectively governs an
energetic connection between said energy storage and said
motive means,
said coupling means provides mechanical
connection between said motive means and a wheel of a
bicycle,
said system in combination with a bicycle being
capable of delivering energy to as well taking energy from
said energy storage means.

35. The regenerative power assist system for
a bicycle (see claim 34) wherein;
said coupling means comprises a lock-in means,
said lock-in means being capable of maintaining
said mechanical connection in spite of reverse torque
which is produced when energy is regeneratively stored.

36. The regenerative power assist system for
a bicycle (see claim 35) further comprising;
a thermostatic switch,
said thermostatic switch being used to prevent
excessive temperature in the energy storage means,
said thermostatic switch is located on the
outside of said energy storage means so it can cool
quickly allowing said energy to be used at the earliest
possible time after overheating.
### DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Relevant to claim No.</th>
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<tr>
<td>X</td>
<td>US, A, 3,991,843 (Davidson) 16 November 1976 (see complete disclosure)</td>
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<td>X</td>
<td>US, A, 3,773,131 (Jaulmes) 20 November 1973 (see complete disclosure)</td>
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<td>US, A, 4,044,851 (Shaw et al) 30 August 1977 (see complete disclosure)</td>
<td>1-5 &amp; 33</td>
</tr>
<tr>
<td>X</td>
<td>US, A, 4,122,907 (Davidson et al.) 31 October 1978 (see complete disclosure)</td>
<td>1-5 &amp; 33</td>
</tr>
</tbody>
</table>

* Further documents are listed in the continuation of Box C.  
  ** See patent family annex.  

- *: Special categories of cited documents:  
  - "A": document defining the general state of the art which is not considered to be of particular relevance  
  - "E": earlier document published on or after the international filing date  
  - "L": document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)  
  - "O": document referring to an oral disclosure, use, exhibition or other means  
  - "P": document published prior to the international filing date but later than the priority date claimed  
  - "T": later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  
  - "X": document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  
  - "Y": document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art  
  - "Z": document member of the same patent family

**Date of the actual completion of the international search:** 03 MAY 1994  
**Date of mailing of the international search report:** 27 MAY 1994  

**Authorized officer:** Mitchell J. Hill  
**Telephone No.:** (703) 308-1113  

**Facsimile No.:** (703) 305-3230  
**Box PCT Washington, D.C. 20231**
INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

   Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ✗ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos. 1-5 and 33.

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.
BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

Group I. Claims 1-5 and 33, drawn to a bicycle with a power assist, classified in Class 180, subclass 221.
Group II. Claims 6-7, drawn to coupling mechanism for transmitting rotary power, classified in Class 476, subclass 64.
Group III. Claims 8-9, drawn to a method of transmitting rotary power, classified in Class 74, subclass 7A.
Group IV. Claim 10, drawn to a method of disengaging from transmitting rotary power, classified in Class 192, subclass 0.07.
Group V. Claim 14, drawn to a drive wheel with a pulley, classified in Class 474, subclass to be determined.
Group VI. Claim 15, drawn to a mounting system to cover a rotating element, classified in Class 474, subclass 144.
Group VII. Claims 16-18 and 20-22, drawn to a battery, classified in Class 136, subclass to be determined.
Group VIII. Claim 19, drawn to a battery mount, classified in Class 180, subclass 68.5.
Group IX. Claims 23-24 and 27, drawn to a cantilevered shaft mounting system, classified in Class 180, subclass 337+.
Group X. Claim 25, drawn to a clamp bolt and hinge pin, classified in Class 16, subclass to be determined.
Group XI. Claim 26, drawn to a combined motor bracket and hinge plate, classified in Class 248, subclass to be determined.
Group XII. Claim 28, drawn to a drive wheel, classified in Class 305, subclass 56.
Group XIII. Claim 29, drawn to a bearing means, classified in Class 384, subclass to be determined.
Group XIV. Claims 30-32, drawn to a sound producing means, classified in Class 116, subclass to be determined.
Group XV. Claims 34-36, drawn to a regenerative power assist, classified in Class 180, subclass 165.