# Method Of Enabling A Human Powered Vehicle With Power Assist To Be Used As An Exercise Machine

## Field of the Invention

This invention is an improvement to current human powered vehicles with power assist such as but not limited to electric pedal assist bicycles. More specifically, this invention is used to enable such vehicles to be used as an exercise machine such as those in a gym. This invention utilizes an electronic controller with sensors to compute, and cause to happen, a power level (or resistance) to compensate for external conditions such as climbing or descending hills, head and tail winds or other factors. This may allow the user to exercise at a desired power level and rate of exercise. Vehicles using this invention that have a means of additional resistance such as a friction brake, eddy current brake, generator or other means may provide a resistance to the user in those situations where the power required to propel the vehicle is less than the power desired by the user. For some users an additional resistance device may not be necessary as the natural resistance of the vehicle may be sufficient for the exercise they desire and situations such as going down a hill may be viewed as a rest period.

## The Problem

The pedal assist bicycle is currently the only human powered vehicle with power assist that I am aware of, however there may be other human powered vehicles with power assist that may benefit by being usable as an exercise machine. Such vehicles may include any vehicle with one or more wheels and which is powered by one or more humans and this invention may be applicable to them also. I will illustrate the problem my invention solves by using the pedal assist bicycle as the example as I am familiar with them and I have prototyped the invention on such a vehicle.

Pedal assist bicycles are bicycles that have an electric motor that may provide assist power when the rider is pedaling. The advantage over a regular bicycle is that the assist from the motor may overcome the extra effort needed for riding up hills or into a headwind. A disadvantage of a pedal-assist bicycle is that a rider using a bicycle for exercise may not feel that they are getting the amount of exercise they desire and they may feel that others are thinking they are “cheating” on an exercise program by riding an electric bicycle.

A problem with most anaerobic exercise machines is they are stationary and almost always indoors which is generally a less enjoyable experience than being on a bicycle outdoors. A problem when trying to use a non-assist bicycle as an exercise machine is that it may be difficult for the rider to maintain a desired exercise routine and the rider may have no indication of the force and power they are currently producing.

## The Solution

The initial implementation of the invention was on a pedal assist bicycle with a Bafang motor mounted in the bicycle bottom bracket and driving the rear wheel through the existing chain and derailleur. The control system for this implementation was a program written in C++ running on an ESP32 microprocessor along with a MPU-6050 6-DOF (Degrees Of Freedom) Inertial Measurement unit with a 3-axis MEMS accelerometer and 3-axis MEMS gyroscope. The accelerometer monitored the attitude of the bicycle and an output signal line to the power assist motor controller was used to control motor current. The existing motor controller system had a thumb throttle which sent a signal to the motor controller which set the power level of the motor. The microprocessor program utilized the thumb throttle signal line to set the motor current. The rider selected a power assist level that felt comfortable and established a pedaling cadence that was comfortable by selecting the appropriate gear for the bike speed. The microprocessor program monitored the G levels from the accelerometer and converted them to the current pitch angle of the bicycle. When the bicycle encountered a hill the pitch angle computed by the program increased from zero and the program computed a power level sufficient to overcome the additional resistance. The required increase in power was calculated from the pitch angle, the speed of the bicycle and the total bike weight (bike and rider) which had been entered earlier. The required power increase was converted to the thumb throttle signal level to set the required motor current. The relationship between thumb throttle signal level and motor current had been previously determined. Voltage to the motor was a constant so the current required was equal to the power desired divided by the voltage to the motor.

The initial implementation allowed the user to set a power level output they were comfortable with and they were able to maintain that level of output and speed in spite of encountering hills. The initial implementation displayed the rider power output which was calculated from the bike speed and a previously estimated wind drag coefficient.

The addition of sensors directly measuring the force exerted by the rider may improve the accuracy of the displayed user power output. These sensors may include but are not limited to force sensors at the pedals, strain sensors in the pedal crank arms or torque sensors in the bottom bracket. If the motor is not transmitting its power through the drive chain, a chain tension sensor may be used to determine rider output. If the motor also transmits its power through the drive train, a chain tension sensor will measure the sum of the user and motor power output and the rider power output may be determined by subtracting out the motor power. The power being supplied by the motor may be estimated from the product of the voltage and current into the motor. The motor power may also be estimated using the current into the motor and the RPM of the motor as parameters to determine motor power from motor performance curves or data. Motor power may also be estimated in any manner known in the art.

When using conventional exercise machines that may include but are not limited to treadmills, stationary bicycles or stair steppers, the user may set the desired rate of exercise for by setting the speed of the belt on a treadmill or, in the case of a stationary bicycle or stair stepper, by the user monitoring and maintaining the speed presented to the user through a meter or other means. A conventional exercise machine may allow the user to set a resistance level which may be indicated to the user and the actual power level may also be displayed.

Some exercise machines may allow a programmed exercise routine to be performed with a variable rate of exercise and resistance. In the case of a treadmill, both the rate of exercise (belt speed) and resistance (incline) may both be controlled by the system and may not be dependent on the user. In the case of a stationary bicycle or treadmill, the currently desired rate may be indicated to the user along with their current rate.

In the solution enabled by this invention, the user may set the rate of exercise with a combination of selected gear and desired speed and may allow the user to select an assist power level which produces the desired level of resistance to the user. The user may then be presented with information on the current vehicle speed, pedal cadence, motor power and/or estimate of the user power from either estimated wind drag or user power may be estimated from direct or indirect measurement of user force and rate of exercise. If a sensor measuring the incline of road is available, which may include but is not limited to accelerometers, gyros or tilt sensors, this solution may provide additional assist power to overcome the incline and maintain the current speed. If a sensor measuring headwind is available, the solution may enable additional power to overcome the wind resistance and maintain the current speed.

If sufficiently accurate estimates of user power are available then a system without accelerometers or gyros may maintain the desired power level in spite of hills or head wind by monitoring the user supplied power and supplying enough additional power to maintain the current speed. Including accelerometers and wind speed sensors would allow the system to more accurately maintain a desired exercise routine.

From the initial implementation it was also recognized that the system may perform better as an aerobic exercise machine if there was additional information, such as might be found on a conventional exercise machine such as a treadmill or stationary bike. This information may include, but is not limited to items such as user power output in various units such as watts or calories/min, user rate of power delivery (pedal cadence) and total energy expended by the user during the current exercise routine. Many higher end exercise machines allow the user to follow an exercise program where power delivery and rate are changed according to a predetermined schedule. Displaying the same information as existing exercise machines makes it easier for a user to adapt to an assisted vehicle with the invention integrated in it.

In this solution these same items may be displayed along with items such as the desired power expenditure, the total power propelling the vehicle, the power from the assist motor and the power being expended by the user. The power from the assist motor may be estimated from the product of the motor battery current and the voltage at the motor. This value may overestimate the output of the motor because of parasitic losses such as friction and electrical heat losses but if the motor performance characteristics are known, a motor speed (rpm) sensor and the motor battery current may allow a more accurate estimate.

There are multiple ways to estimate the force (lbf) and power (watts) the user is exerting to power the vehicle. If a force sensor measuring user force is available the estimate of force and power can be derived from the force and speed of user motion. If a user force sensor is not available, user power may be calculated by estimating the total power necessary to power the vehicle, including but not limited to road inclination, wind resistance and vehicle parasitic losses and subtracting out the motor power as described previously. The total power to propel the vehicle may be determined from the forward speed of the vehicle and a drag coefficient whose value determined by the system at a calibration time or through normal operation of the system.

**Description**

Figure 1 is a block diagram showing the components that may be included in a system implementing the method of enabling a human powered vehicle with power assist to be used as an exercise machine. The Exercise Microprocessor Controller 101 may be a separate unit or may be functionality provided by a controller providing other control functions. The Controller 101 may include non-volatile storage and may have interfaces to various sensors. Based on the sensor values and values that may have been previously stored in non-volatile memory, the Controller 101 sets a force level at the Motor Assembly 108 or the Retarder Assembly 106. The Controller 101 may also command the Gear Selector 109 to select the appropriate gear. The block diagram in Figure 1 groups the sensors into Vehicle Sensors 102, Biologic Sensors 104 and User Inputs 103. Vehicle Sensors 102 may include but is not limited to sensors for Wind Speed, Chain Tension, Pedal Force, Pedal

Speed, Vehicle Speed, Motor Current and Voltage, Acceleration in three axis, Gyroscope rotation rate in 3-axis and/or Tilt sensors. Biologic Sensors 104 may include but is not limited to sensors for Heart Monitoring, Pulse Rate, Blood Pressure, Respiration Rate, Blood Oxygen Level, Blood Sugar Level and Brain Waves. The Biologic Sensors 104 may be used by Controller 101 but not limited to optimize the exercise program, provide feedback to the user and/or warn the user of problems. User Inputs 103 may include but is not limited to sensors such as a Thumb Throttle, Buttons and Switches, Tactile sensors (for example the user squeezing a handlebar grip) and User Voice Input. In addition to controlling the force level at the Motor Assembly 108 or the Retarder Assembly 106,  the Controller 101 may provide a variety of User Outputs 105 which may include but limited to a Visual Display, Audible Feedback Devices and/or Tactile Feedback Devices (for example vibrating hand grips). The External Applications and Data Storage 110 may include but not limited to access to a Cell Phone or Tablet which may but is not limited to running applications and/or accessing the Internet and may have a connection to the Internet which may but is not limited to being used to run applications or access cloud storage. The Controller 101 may interface to the Battery to understand the Battery condition and the Retarder Assembly 106 which may provide a resisting force and may produce electrical energy that may be used for Battery charging. The Retarder Assembly 106 may also function as a vehicle braking device.

**Summary**

This invention allows a user to experience an exercise program similar to exercise machines, such as but not limited to, treadmills, stationary exercise bicycles, stair step machines and to experience this exercise program outdoors.

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