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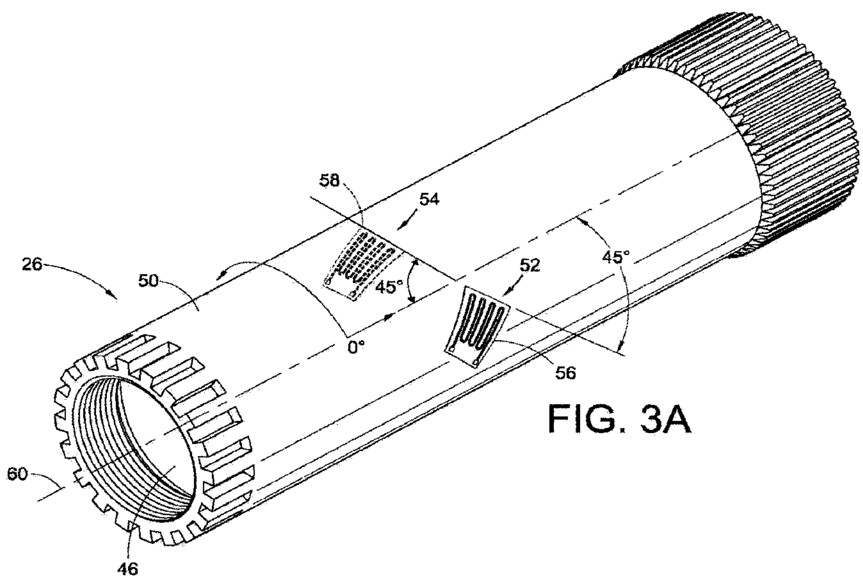

FIG. 3A

(57) Abstract: A torque sensor (26) for a human-powered object includes a spindle (50) connecting crank arms (16) of the object. In one embodiment, the object can be a bicycle. The torque sensor (26) further includes at least one strain gauge (52, 54) mounted to the spindle (50) in a shear pattern to measure shear strain perpendicular to a radius of the spindle (50). In some embodiments, the torque sensor (26) further includes a carrier fixed to a hollow interior of the spindle (50), where at least one strain gauge (52, 54) is mounted to the spindle via the carrier. Advantageously, the torque sensor (26) provides a low cost method to measure power.

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TORQUE SENSOR

[0001] This application claims priority to and the benefit of the filing date of U.S. Provisional Patent Application No. 61/508,793, filed July 18, 2011, which application is hereby incorporated by reference.

BACKGROUND

[0002] The present exemplary embodiments relate to torque sensing. The present exemplary embodiments find particular application in conjunction with power meters for human-propelled vehicles, such as bicycles, and will be described with particular reference thereto. However, it is to be appreciated that the present exemplary embodiments are also amenable to other like applications. For example, the present exemplary embodiments find application in suspension systems, power assisted bikes, chain derailleur shifting, other human powered objects, such as hand cranks and torque wrenches, and so on.

[0003] Current power meters employ a number of different approaches to measuring power. Some approaches measure power using deflection measurements in the crank spindle, otherwise known as the bottom bracket. U.S. Patent No. 6,356,847 to Gerlitzski uses two optoelectronic sensors located on the bottom bracket to measure deflection in the crank spindle. EP Patent Application No. 1978343 to Etsuyoshi et al. uses a magneto resistive material arrangement with several cylindrical sleeves on the bottom bracket to measure deflection. U.S. Patent Publication No. 2010/0006760 to Glueck et al. senses magnetization changes due to the bottom bracket deflecting. U.S. Patent Publication No. 2010/0093494 to Smith employs strain gauges on a specially designed crankset and spindle to measure deflection.

[0004] A number of other approaches to measuring power also exist. U.S. Patent Publication No. 2009/0120208 to Meyer and EP Patent No. 0386005 to Schoberer measure power in the crank spider of a bicycle using strain gauges. U.S. Patent No 6,356,848 to Cote et al. measures power by vibrational tension methods in the chain using an acoustic sensor. U.S. Patent No. 6,418,797 to Ambrosina et al. measures power in the rear hub using strain gauges. WO Patent Publication No. 2010/000369 to Redmond et al. measures power using strain gauges integrated into the cleat of a rider's shoe. Systems are also known which measure power using strain gauges located in the rear wheel, sensors to indirectly measure power based on Newton's third law, and strain gauges based on bending moment deflections in the pedal spindle during cycling.

[0005] While a number of different approaches to measuring power exist, they all have room for improvement. Approaches based on deflection measurements are challenging because bending strains and torsion strains occur simultaneously and the bending strains are equal to, if not greater than, the torsion strains. Decoupling these strains is complicated and often times costly. Pedal-based approaches are known to be expensive. Approaches directly measuring power require that the manufacturer do calibration, which is costly and time consuming. Thus, there is a need for a low cost power meter that can be calibrated by the operator and includes a low cost, accurate and direct power sensor.

[0006] The present exemplary embodiments provide an improved power meter and sensor which overcome the above-referenced problems and others.

BRIEF DESCRIPTION

[0007] In accordance with one aspect of the present application, a torque sensor is provided. The torque sensor includes a carrier which can be mounted to an associated spindle connected to at least one crank arm of an associated torqued object. The torque sensor further includes a strain gauge grid mounted to the carrier in a shear pattern to measure shear strain in a direction perpendicular to a radius of the associated spindle.

[0008] In accordance with another aspect of the present application, a power measuring unit is provided. The power measuring unit includes a torque sensor and a processor. The torque sensor includes a carrier which can be mounted to an associated spindle connecting crank arms of a human-powered object. The torque sensor further includes a strain gauge grid mounted to the carrier in a shear pattern to measure shear strain from torsional forces. The processor is programmed to receive strain data from the torque sensor and measure torque from the received strain data.

Further, the processor is programmed to provide power data calculated from the measured torque to a receiving device.

[0009] In accordance with another aspect of the present application, a torque sensor is provided. The torque sensor includes a shaft and a pair of strain gauge grids. The pair of strain gauges are mounted to the shaft in a shear pattern to measure shear strain in a direction perpendicular to a radius of the shaft and electrically connected in a Wheatstone Bridge arrangement to measure shear strain from torsional forces whilst negating shear strain from bending forces.

[0010] In accordance with another aspect of the present application, a bicycle is provided. The bicycle includes a pair of crank arms connected by a spindle. Further, the bicycle includes a torque sensor. The torque sensor includes a strain gauge oriented to measure strain at 45 degrees to an axis of the spindle and perpendicular to a radius of the axis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIGURE 1 is a perspective view of a bicycle;

[0012] FIGURE 2 is a perspective view of a bicycle less a power transfer system and a torque sensor;

[0013] FIGURE 3A is a perspective view of a torque sensor according to aspects of the present disclosure;

[0014] FIGURE 3B is a perspective view of the front and back of the torque sensor of FIGURE 3A;

[0015] FIGURE 4 is a schematic of a Wheatstone bridge;

[0016] FIGURE 5 is a perspective view of a torque sensor with a carrier according to aspects of the present disclosure;

[0017] FIGURE 6 is a graph illustrating the output of a torque sensor; and,

[0018] FIGURE 7 is a block diagram of a sensor detection unit according to aspects of the present disclosure.

DETAILED DESCRIPTION

[0019] With reference to FIGURES 1 and 2, a human-propelled, wheeled vehicle **10**, such as a bicycle and so on, includes a frame **12** and a human support **14**, such as a seat, mounted to the frame **12**. The support **14** supports an operator of the human-propelled vehicle **10** and positions the human operator within arm's reach or leg's reach of a pair of crank arms **16** rotably mounted to the frame **12**. The crank arms **16** rotate about a common axis **18**, typically perpendicular to the mid-sagittal plane of the operator, and transform reciprocating motion of the operator's arms or legs into rotary motion. In some embodiments, a pair of human interfaces **20** mounts to the crank arms **16** to aid the operator in rotating the crank arms **16**. Human interfaces **20** can include, for example, pedals, hand grips, and so on.

[0020] The crank arms **16** rotably mount to the frame **12** via a shell **22** (FIGURE 2), such as a bottom bracket shell, of the frame **12**. The shell **22** includes a hollow region **24** disposed between a first open end and a second open end. In some embodiments, the shell **22** is cylindrical in shape. A torque sensor **26** (FIGURES 3A and 3B) extends through the hollow region **24** of the shell **22** and operatively connects the crank arms **16**, one at each open end of the shell **22**, to one another. For example, the crank arms **16** can be mechanically connected to the torque sensor **26**. As discussed in detail hereafter, the torque sensor **26** measures torque about the common axis **18**.

[0021] A power transfer system **28** mounted to the frame **12** transfers the rotary motion of the crank arms **16** to a drive system **30** mounted to the frame **12**. The transfer may be performed electrically, mechanically, and so on. For example, the power transfer system **28** may include a generator that transforms the rotary motion to electrical power employed by the drive system **30**. As another example, the power transfer system **28** may include a belt and/or chain **32** transferring the rotary motion to the drive system **30**. In some embodiments, the crank arms **16** include a drive crank arm **34** and a non-drive crank arm (not shown). The drive crank arm **34** is the crank arm from which rotary motion is transferred. For example, where the rotary motion is mechanically transferred with the belt and/or chain **32**, the drive crank arm **34** is the crank arm with chainrings **36** connected thereto.

[0022] The drive system **30** receives power from the power transfer system **28** and propels the human-propelled vehicle **10** therewith. The drive system **30** can include, for example, a wheel, a propeller, a rotor, and so on. Further, in some embodiments, the drive system **30** may further include a sprocket or the like **38** for receiving the mechanical power from the power transfer system **28**. Additionally, in some embodiments, the drive system **30** may further include an electric motor for receiving electrical power from the power transfer system **28**.

[0023] The human propelled vehicle **10** can further include a sensor detection unit **40** and a receiving device **42**, optionally, having a display **44**. The sensor detection unit **40** calculates power based on data received, typically over a first, wired communication link, from the torque sensor **26**. Additionally, or alternatively, the sensor detection unit **40** stores the received data and/or calculated power data locally in a memory, and/or transmits the received data and/or calculated power data to the receiving device **42** over a second communication link. Typically, the second communication link is a wireless communication link. However, the second communication link can be a wired communication link, such as a universal serial bus (USB) communication link. In some embodiments, the second communication link is further employed to write and/or otherwise update firmware of the sensor detection unit **40**. The receiving device **42** receives the data over the second communications link, and one or more of stores the received data in a local memory and displays the received data on the display **44**. The display **44** is, for example, one of an LCD display, an LED display, a plasma display, a projection display, a touch screen display, and the like. The receiving device **42** is, for example, a mobile device, such as an iPhone®.

[0024] The sensor detection unit **40** and/or the receiving device **42** are typically removably mounted to the frame **12** so they can be moved from one human-propelled vehicle to another. For example, the sensor detection unit **40** can be removably mounted in a hollow space **46** (FIGURE 3A) of the torque sensor **26** or to the crank arms **16**. As another example, the receiving device **42** can be removably mounted to a steering device **48**, such as a wheel, handle bars, and so on, of the human-propelled vehicle **10**. In some embodiments, the receiving device **42** is integrated in to the sensor detection unit **40**.

[0025] With reference to FIGURES 3A and 3B, the torque sensor **26** includes a spindle **50** and at least one strain gauge **52, 54** mounted to the spindle **50**. The at least one strain gauge **52, 54** can be mounted to an interior surface of the spindle **50** or an external surface of the spindle **50**. Each strain gauge **52, 54** includes at least one grid **56, 58**. Hence, at a minimum, the torque sensor **26** includes at least one grid **56, 58**, where the at least one grid **56, 58** can be on a single strain gauge or on separate strain gauges for mounting. Further, each grid **56, 58** is arranged in a shear pattern on the spindle **50**. In other words, each grid **56, 58** is arranged at either about positive or negative 45 degrees from an axis **60** of the spindle **50**. About 45 degrees from the axis **60** of the spindle **50** typically means 37 to 53 degrees from the axis **60** of the spindle **50**. As used herein a grid is also known as a strain gauge grid.

[0026] Typically, the torque sensor **26** includes a single pair of grids, as illustrated in FIGURES 3A and 3B. However, other embodiments are contemplated. For example, the torque sensor **26** can include a single grid. As another example, the torque sensor **26** can include a plurality of pairs of grids, such as two pairs of grids. With reference to FIGURE 3B, each grid **56, 58** of the single pair is axially located on the spindle **50** radially positioned at about 180 degrees from the other grid (i.e., on opposite sides of the spindle **50**) and the grids **56, 58** have the same orientation with respect to the axis **60**. About 180 degrees from the other grid typically means 165 to 195 degrees from the other grid.

[0027] When the torque sensor **26** includes two pairs of grids, a first pair and a second pair, each of the pairs is positioned as done for the single pair, except that the first pair is positioned to measure positive strain and the second pair is positioned to measure negative strain for the same torsional load. Hence, for each of the first pair and the second pair, each grid of the pair is located on the spindle **50** axially positioned at about 180 degrees from the other grid (i.e., on opposite sides of the spindle **50**) and the grids have the same orientation with respect to the axis **60**. As noted above, about 180 degrees from the other grid typically means 165 to 195 degrees from the other grid. If the grids of the first pair are orientated at about positive 45 degrees from the axis **60** of the spindle **50**, the grids of the second pair are oriented at about negative 45 degrees from the axis **60** of the spindle **50**. If the grids of the first pair are orientated at about negative 45 degrees from the axis **60** of the spindle **50**, the grids of the second pair are oriented at about positive 45 degrees from the axis **60** of the spindle **50**.

[0028] The state of pure shear stress at the surface of a shaft (i.e., with no bending forces) is equivalent to equal tensile and compressive stresses on an element rotated through an angle of about 45 degrees. Therefore, a rectangular element with sides at about 45 degrees to the axis of the shaft will be submitted to tensile and compressive stresses. If a bar made of a material that is weaker in tension than in shear is twisted, failure will occur in tension along a helix inclined at about 45 degrees to the axis. This is easily observed by twisting a piece of chalk. Thus, a strain gage grid aligned at about 45 degrees to the axis of a shaft (i.e., in a shear pattern) will measure shear strain from the shear stress in a shaft subjected to torsion. Only one grid in a shear pattern is needed to measure torsional strain for a shaft in pure torsion.

[0029] If bending forces, with no torsion, are applied to a shaft having a grid at about 45 degrees to the axis, the grid may also measure axial strain from the axial stress from the bending force depending on location of the grid. This can be observed by placing two parallel circular marks around a cylindrical eraser and then applying a bending force to the eraser. The bending strain will be observed to vary from tensile to compressive by observing that the spacing between circular marks increases and decreases for the tensile and compressive strains respectively. One side of the eraser surface will be in tension, whereas the axially located side positioned radially opposite at about 180 degrees will be in compression. Close to about 90 degrees from maximum compression or tensile strain there will be no strain (i.e., the neutral axis).

[0030] In view of the foregoing, it should be appreciated that the grids **56, 58** measure shear strain (compressive or tensile stress) caused as the non-drive crank arm is rotated about the common axis **18**. The grids **56, 58** also measure bending strain due to bending forces, which causes both axial compressive and tensional strain on opposite sides of the spindle **50** and which is exhibited as shear strain at about 45 degrees to the axis **60**. As will be shown, when bending forces cannot be eliminated mechanically, two grids in a shear pattern properly located on a shaft and electrically connected in a Wheatstone bridge can measure just the torsional strain.

[0031] With reference to FIGURE 4, the grids **56, 58** of the single pair of grids are electrically connected in a Wheatstone bridge arrangement **62**. Due to the physical arrangement of the grids **56, 58** on the spindle **50**, strain measured in the grids **56, 58** due to bending forces result in subtractive voltages in the Wheatstone bridge arrangement **62**, while the torsional strain measured by the grids **56, 58** from torsional forces result in additive voltages. In contrast, if the torque sensor **26** only included a single grid, torsional strain and bending forces, if present, would both be measured.

[0032] Each grid **56, 58** is connected in series with a resistor **64, 66**, each resistor **64, 66** having a resistance equal to that of its corresponding grid **56, 58**. The two series combinations of a grid and a resistor are connected in parallel, such that the grids **56, 58** are indirectly electrically connected to one another through the resistors **64, 66**. An input voltage **E**, such as 3 Volts, is provided across the Wheatstone bridge arrangement **62**. The output voltage e_0 is the voltage extending between the mid-points of the two series combinations and is proportional to torque. Theoretically, output voltage e_0 is not effected by bending strain. However, in practice, tolerances in gauge positioning cause the observance of some bending strain (if present). Nonetheless, 95% or more of the bending strain is typically cancelled. In some embodiments, the input and output to the Wheatstone bridge arrangement **62** terminate at electrical plugs.

[0033] The Wheatstone bridge arrangement **62** can also be employed for two pairs of grids. In such an embodiment, the resistors are replaced with the second pair of strain grids, which are of equal resistance as the first pair. Further, the output voltage e_0 is double what it would be with a single pair of strain grids.

[0034] With reference to FIGURE 5, another embodiment of the torque sensor **26** includes a carrier **68** mounted to the spindle **50** within the hollow space **46** of the spindle **50**. In contrast with the embodiment of FIGURES 3A and 3B, the at least one grid **56, 58** is mounted to the carrier **68**, instead of the spindle **50**. The strain gauge grids **56, 58** are mounted to the carrier **68** in the same manner as done for the spindle **50**. Namely, the strain gauge grids **56, 58** are mounted in a shear pattern, where each strain gauge grid **56, 58** is about 45 degrees from an axis **70** of the carrier **68**. About 45 degrees from the axis **70** of the carrier **68** typically means 37 to 53 degrees from the axis **70** of the carrier **68**. Further, for a pair of grids, the grids are axial positioned at about 180 degrees from the other grid (i.e., on opposite sides of the carrier **68**) and the grids have the same orientation with respect to the axis **70**. About 180 degrees from the other grid typically means 165 to 195 degrees from the other grid. The electrical interconnection of the strain gauge grids **56, 58** remains the same as described above.

[0035] Any approach to fixing (i.e., mounting) the carrier **68** to the spindle **50**, direct or otherwise, is acceptable, so long as the carrier **68** does not radially slip at areas **72, 74** to which the carrier **68** mounts to the spindle **50** while under torsional load during rotation of the crank arms **16**. Direct approaches include one or more of pressing, swaging, threading, screwing, riveting, pinning, wedging, welding, epoxying, removably fastening, or the like. Removable fasteners include, for example, expanding bolts, set screws, or the like. Indirect approaches include mounting to another component of the human-propelled vehicle **10** that is torsionally coupled to the spindle **50**, such as a crank arm bolt that directly fastens to the spindle **50**, using one of the direct approaches noted above. As shown, the spindle **50** includes a smooth bore **76** within which the carrier **68** is inserted, and the carrier **68** is mounted to the spindle **50** at the areas **72, 74** by expansion. However, modifications to the spindle **50** and carrier **68** so as to facilitate mounting are contemplated. For example, one or both of the areas **72, 74** to which the carrier **68** mounts to the spindle **50** may be threaded for mounting the carrier **68** to the spindle **50**.

[0036] Strain gauges, especially of the resistant type, have known cyclic fatigue limits as a function of strain, whereby they require that the strain be limited. The torsional stiffness (angle of twist per unit of torque) of either the spindle **50** or the carrier **68** is proportional to the Ip (polar moment of inertia), G (shear modulus of elasticity), and L (length). Therefore, angle of twist per unit length is based on Ip x G. G is dependent on material properties, and Ip is dependent on geometry. With proper design of the spindle **50**, the strain can be kept below the fatigue limit. In a like manner, the strain on the carrier **68** can also be held below fatigue limits.

[0037] An advantage to using the carrier **68** is that the carrier **68** need not have to carry bending loads, since the carrier **68** can be designed to include a coupling **77** which supports and transmits torsional loads (strain from torsion) but not bending loads. The carrier **68** can be designed to flex due to bending loads similar to couplings that have zero backlash (i.e., a bellows, universal joint, flexible shaft or the like). The benefit is that misalignment of the strain grids **56, 58** on the carrier **68**, as well as of the mounting to the carrier **68** to the spindle **50**, is much less sensitive to mechanical tolerances, thereby achieving a more accurate measurement of torque in the spindle **50**. In addition, the spindle **50** may undergo high bending loads, while the carrier **68**, if located interior to the spindle **50**, will undergo very little bending load since then it will be located along the neutral axis of the spindle **50** where bending strain is near zero. Note that bending strain is always positive on one side of the spindle **50**, but negative on the other, and thus must be zero at the neutral axis.

[0038] While the spindle **50** has been shown and described as hollow thus far, it is to be appreciated that the spindle **50** can be solid or at least partially solid. For example, a portion of the spindle **50** upon which the at least one strain gauge **52, 54** is mounted can be solid, whereas the remaining portion of the spindle **50** can be hollow. The crank arms **16** can then be mounted to the hollow portions of the spindle **50**.

[0039] With reference to FIGURE 6, a graph illustrates the output of the torque sensor **26** after amplification. The ordinate corresponds to torque, and the abscissa corresponds to time. As can be seen, there is peak torque during revolution of the spindle **50**, and peak-to-peak corresponds to one revolution. Angular velocity can therefore be determined based on the observing torque as a function of time. Since power is the product of torque and angular velocity, power can also be determined.

[0040] With reference to FIGURE 7, an embodiment of the sensor detection unit (or power measuring unit) **40** includes an analog-to-digital converter **78** that receives the output from the torque sensor **26** and converts it into digital data. In some embodiments, the sensor detection unit **40** further includes an operational amplifier **80** for amplifying the output of the torque sensor **26** before it passes to the analog-to-digital converter **78**. The operational amplifier **80** can be integrally formed with the analog-to-digital converter **78** or be separate. A microcontroller **82** of the sensor detection unit **40**, optionally integrated with the analog-to-digital converter **78**, receives the digital data. In some embodiments, the microcontroller **82** further receives data from an angular velocity sensor **84**. As with the torque sensor **26**, this data may be passed through an analog-to-digital converter (not shown).

[0041] In some embodiments, the angular velocity sensor **84** determines angular velocity by detecting position as a function of time, such as a reed or Hall effect switch and magnet or some form of an encoder with a predetermined number of counts that may be used with a counter and timer. Alternatively, in some embodiments, the angular velocity sensor **84** determines angular velocity by reverse calculating velocity and position using acceleration data from an accelerometer. Alternatively, in some embodiments, a gyroscope (not shown), such as those that utilize the Coriolis principle, is used to detect angular velocity measurement. This provides redundancy and additional accuracy in the power meter measurement and calculation. Another advantage to using the gyroscope is the power measurement is improved, especially at lower cadence, when there is a larger variation in angular velocity in the pedal stroke.

[0042] The microcontroller **82**, using the digital data from the torque sensor **26** and, optionally, the angular velocity sensor **84**, calculates power from the non-drive crank arm. A processor of the microcontroller executes processor executable instructions on a memory that perform the calculations. As noted above, power is the product of torque and angular velocity. Therefore, where data is received from the angular velocity sensor **84**, power is simply the product of the current torque and the current angular velocity. Where an angular velocity sensor does not exists, angular velocity is determined by observing torque as a function of time, shown in FIGURE 6. For example, the number of cycles (peak-to-peak) per unit of time, such as seconds or minutes, is counted using a clock of the microcontroller **82**. Power is then the product of angular velocity, as determined by counting the number of cycles per unit of time, and current torque.

[0043] The torque sensor **26** measures only the torque applied to the non-drive crank arm. Therefore, the microcontroller **82** typically multiples the calculated power by two. Multiplying by two is sufficient for power calculations for the majority of operators since the power applied by the two human limbs to the two crank arms **16** is generally the same. For situations where this is insufficient, the sensor detection unit **40** permits the measurement of power from both crank arms by using another power meter or possibly another torque sensor with a modified spindle and spider arrangement. As to the former, the microcontroller **82** can receive total power measurements from the other power meter. Power at the non-drive crank arm can be calculated using the torque sensor **26** and power at the drive crank arm **34** can be calculated by subtracting the non-drive crank arm power from the total power received from the other power meter. Advantageously, for those operators who have power meters that only provide total power, better resolution of the power at each crank arm can be obtained through use in combination with the torque sensor **26**.

[0044] After calculating total power and, optionally power for each crank arm, the calculated power and, optionally the data used to calculate power, are transmitted to the receiving device **42** using a transceiver **86**. Suitably, the transceiver **86** is a wireless transceiver making use of an antenna **88**. However, the transceiver **86** can be connected to the receiving device **42** over a wired connection, such as a USB connection. In some embodiments, the transceiver **86** is also employed to receive firmware and/or firmware updates (i.e., processor executable instructions or updates to the processor executable instructions) for the microcontroller **82** of the sensor detection unit **40**.

[0045] Referring back to FIGURE 5, the sensor detection unit **40** is shown within the spindle **50**. This is to be contrasted with the positioning of the sensor detection unit **40** shown in FIGURE **1**. Further, as shown, the sensor detection unit **40** and the torque sensor **26** receive power from a battery **90**. Power is transferred from the battery **90** to the sensor detection unit **40** and the torque sensor **26** over a cable **92**, such as a ribbon cable. The cable **92** also carries data between the torque sensor **26** and the sensor detection unit **40**. In other embodiments, separate data and power cables can be employed.

[0046] One advantage of the torque sensor **26** disclosed herein is that strains from bending can be measured and negated from strains due to compression and tension caused by torque applied to the spindle. Further, power can be computed by reviewing torque as a function of time. The torque sensor **26** disclosed herein is simple and low cost. It has only a reduced number of components because the components are separated, there is easier trouble shooting and lessened repair costs. Further, a bike can be made “power meter ready”. Moreover, an off-the-shelf bicycle bottom bracket can be retrofitted.

[0047] The present disclosure has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. For example, it should be appreciated that other types of human propelled vehicles could also employ the torque sensor disclosed herein. So too could a variety of other objects, such as hand tools and other products. It is intended that the recent disclosure be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

CLAIMS:

1. A torque sensor comprising:

a carrier which can be mounted to an associated spindle connected to at least one crank arm of an associated torqued object; and,

a strain gauge grid mounted to the carrier in a shear pattern to measure shear strain in a direction perpendicular to a radius of the associated spindle.

2. The torque sensor according to claim 1, wherein the carrier is fixed to a hollow interior of the associated spindle.

3. The torque sensor according to claim 1, wherein the carrier mechanically flexes due to bending forces from the associated spindle whilst torsionally straining from torque forces transmitted from the associated spindle.

4. The torque sensor according to claim 1, further including:

a second strain gauge grid mounted to the carrier and sharing a common orientation with the strain gauge grid, the common orientation being about 45 degrees from an axis of the carrier, and wherein the strain gauge grid and the second strain gauge grid are radially opposite from each other.

5. The torque sensor according to claim 4, further including:

a second pair of strain gauge grids mounted to the carrier in a shear pattern to measure shear strain in a direction perpendicular to a radius of the associated spindle.

6. The torque sensor according to claim 4, wherein the strain gauge grid and the second strain gauge grid are electrically connected in a Wheatstone bridge arrangement to output a voltage proportional to shear strain caused by torsional forces.

7. A power measuring unit comprising:

a torque sensor comprising:

a carrier which can be mounted to an associated spindle connecting crank arms of a human-powered object; and,

a strain gauge grid mounted to the carrier in a shear pattern to measure shear strain from torsional forces; and,

a processor programmed to:

receive strain data from the torque sensor;

measure torque from the received strain data; and

provide power data calculated from the measured torque to a receiving device.

8. The power measuring unit according to claim 7, wherein the measured torque is multiplied by two for power data calculations.

9. The power measuring unit according to claim 7, wherein the power data is wirelessly provided to the receiving device.

10. The power measuring unit according to claim 7, wherein the processor is further programmed to:

receive angular velocity data from an angular velocity sensor, wherein the power data is calculated from the measured torque and the angular velocity data.

11. The power measuring unit according to claim 10, where the angular velocity sensor includes a gyroscope.

12. The power measuring unit according to claim 7, wherein the power measuring unit is disposed in a hollow interior of the associated spindle.

13. The power measuring unit according to claim 7, wherein the torque sensor further includes:

a second strain gauge grid mounted to the carrier and sharing a common orientation with the strain gauge grid, the common orientation being about 45 degrees from an axis of the carrier, and wherein the strain gauge grid and the second strain gauge grid are radially opposite from each other and electrically connected in a Wheatstone Bridge arrangement to measure the shear strain from torsional forces whilst negating shear strain from bending forces.

14. A torque sensor comprising:

a shaft; and,

a pair of strain gauge grids mounted to the shaft in a shear pattern to measure shear strain in a direction perpendicular to a radius of the shaft and electrically connected in a Wheatstone Bridge arrangement to measure shear strain from torsional forces whilst negating shear strain from bending forces.

15. The torque sensor according to claim 14, wherein a portion of the shaft is hollow.

16. The torque sensor according to claim 14, wherein the shaft is associated with one or more crank arms torqueing the shaft.

17. A bicycle comprising:

a pair of crank arms connected by a spindle; and,

a torque sensor comprising:

a strain gauge oriented to measure strain at 45 degrees to an axis of the spindle and perpendicular to a radius of the axis.

18. The bicycle according to claim 17, wherein the torque sensor further includes:

a second strain gauge grid sharing a common orientation with the strain gauge grid, the common orientation being about 45 degrees from the axis, and wherein the strain gauge grid and the second strain gauge grid are radially opposite from each other and electrically connected in a Wheatstone Bridge arrangement to measure shear strain from torsional forces whilst negating shear strain from bending forces.

19. The bicycle according to claim 17, wherein the torque sensor further includes:

a carrier coaxially aligned with, and mounted to, the spindle, wherein the strain gauge is mounted to the carrier.

20. The bicycle according to claim 17, wherein the carrier is mounted in a hollow interior of the spindle.

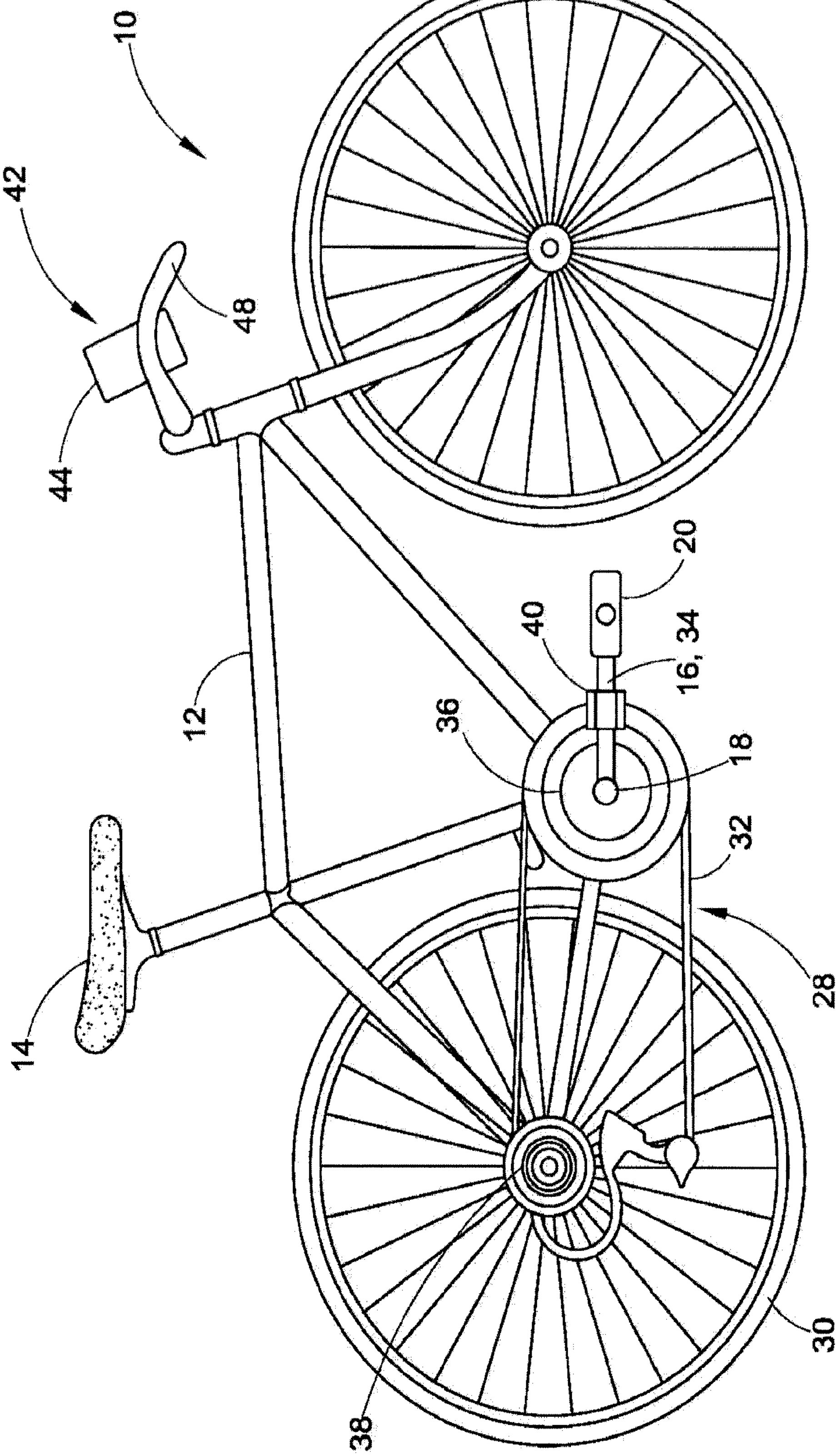


FIG. 1

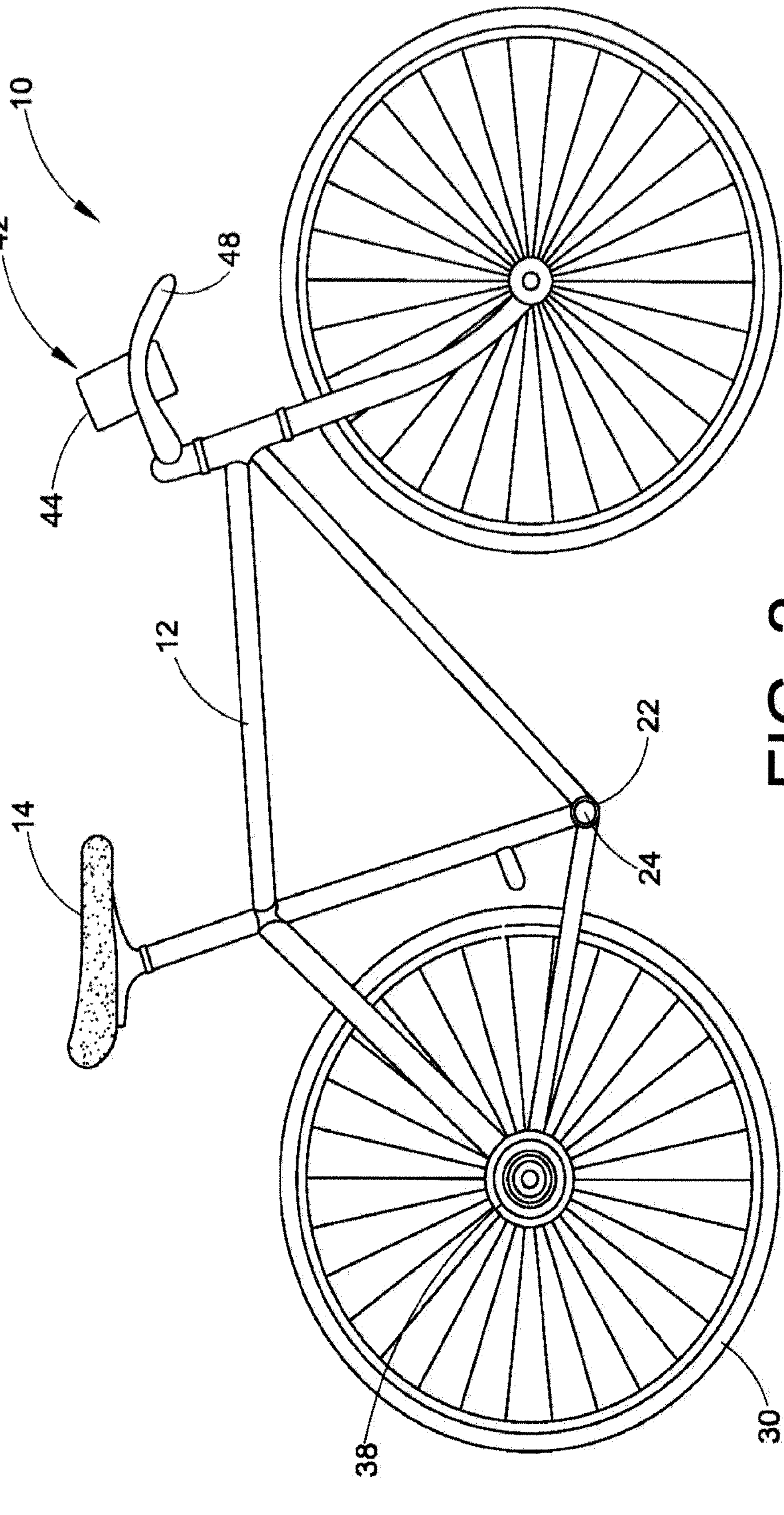
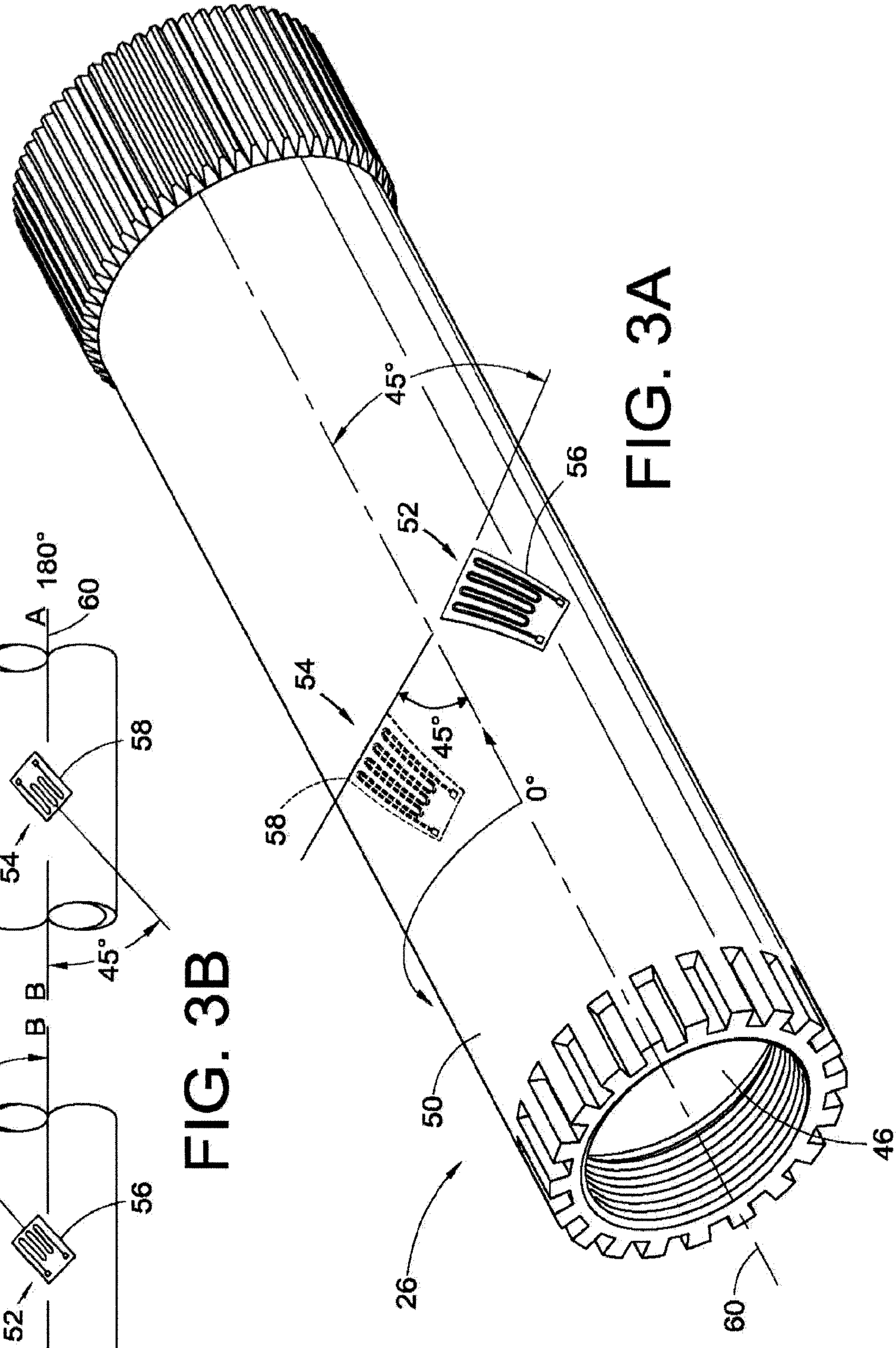


FIG. 2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54
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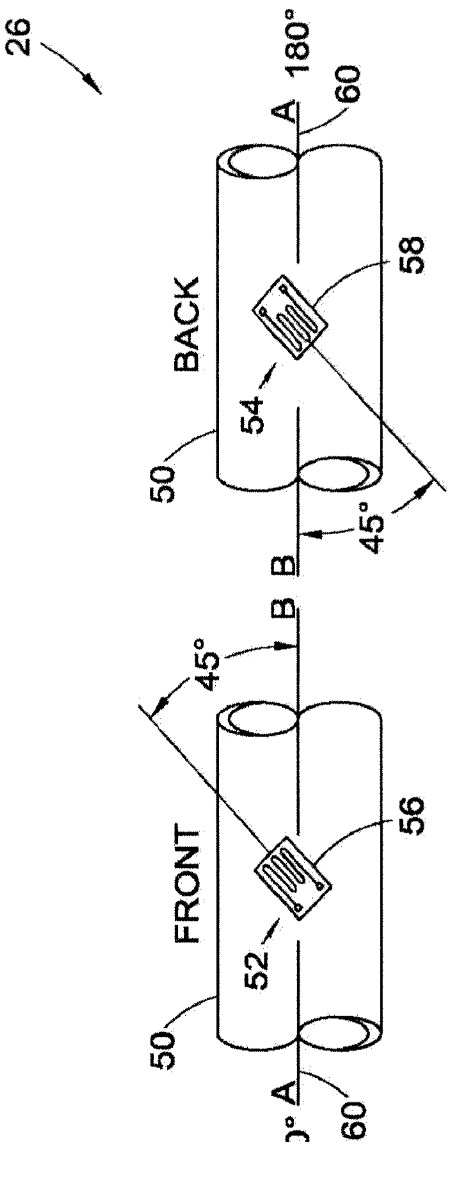
58
50
46
60

FIG. 3A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BACK
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B
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60
50
52
54
56
58
45°

FIG. 3B

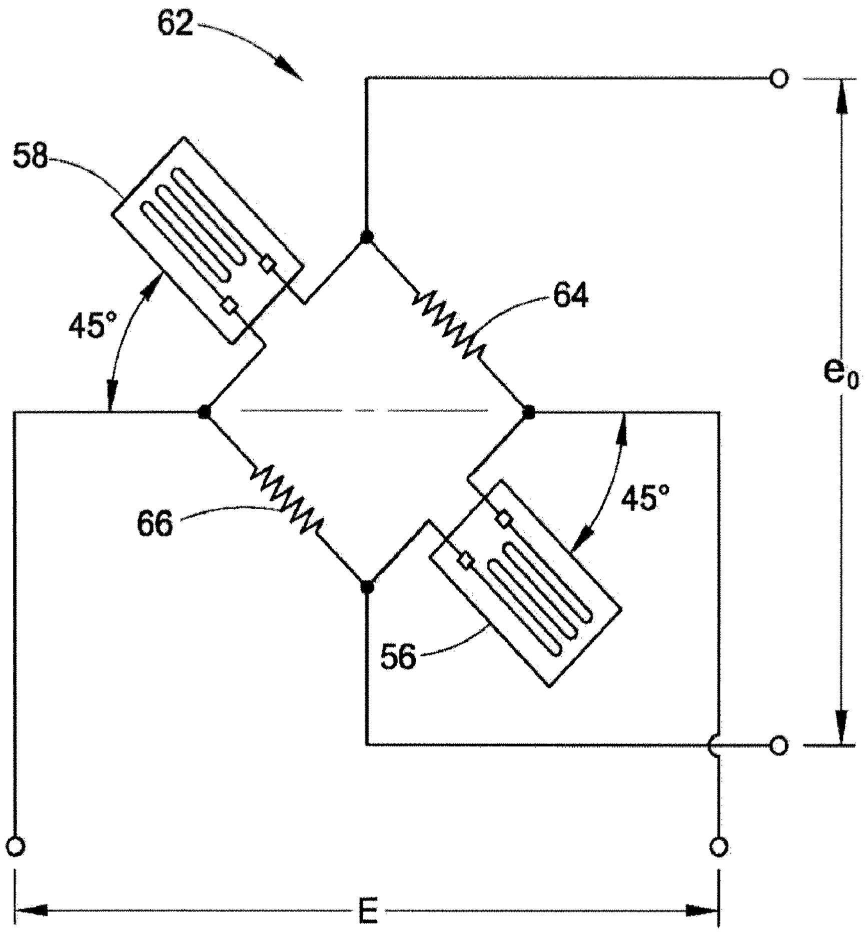


FIG. 4

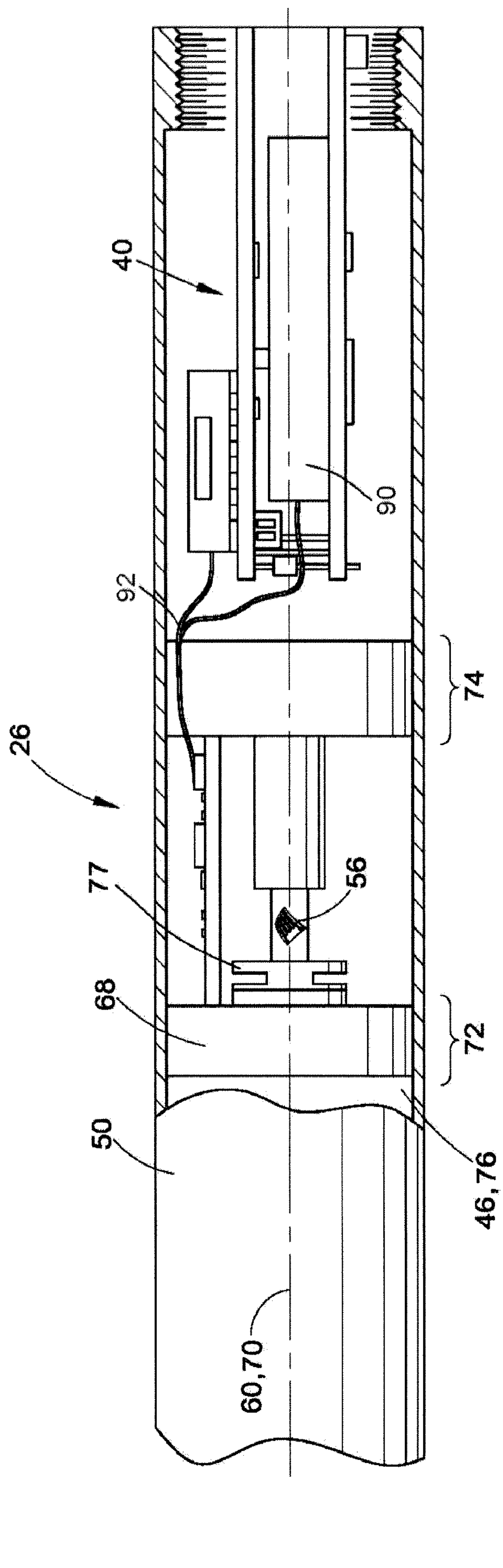


FIG. 5

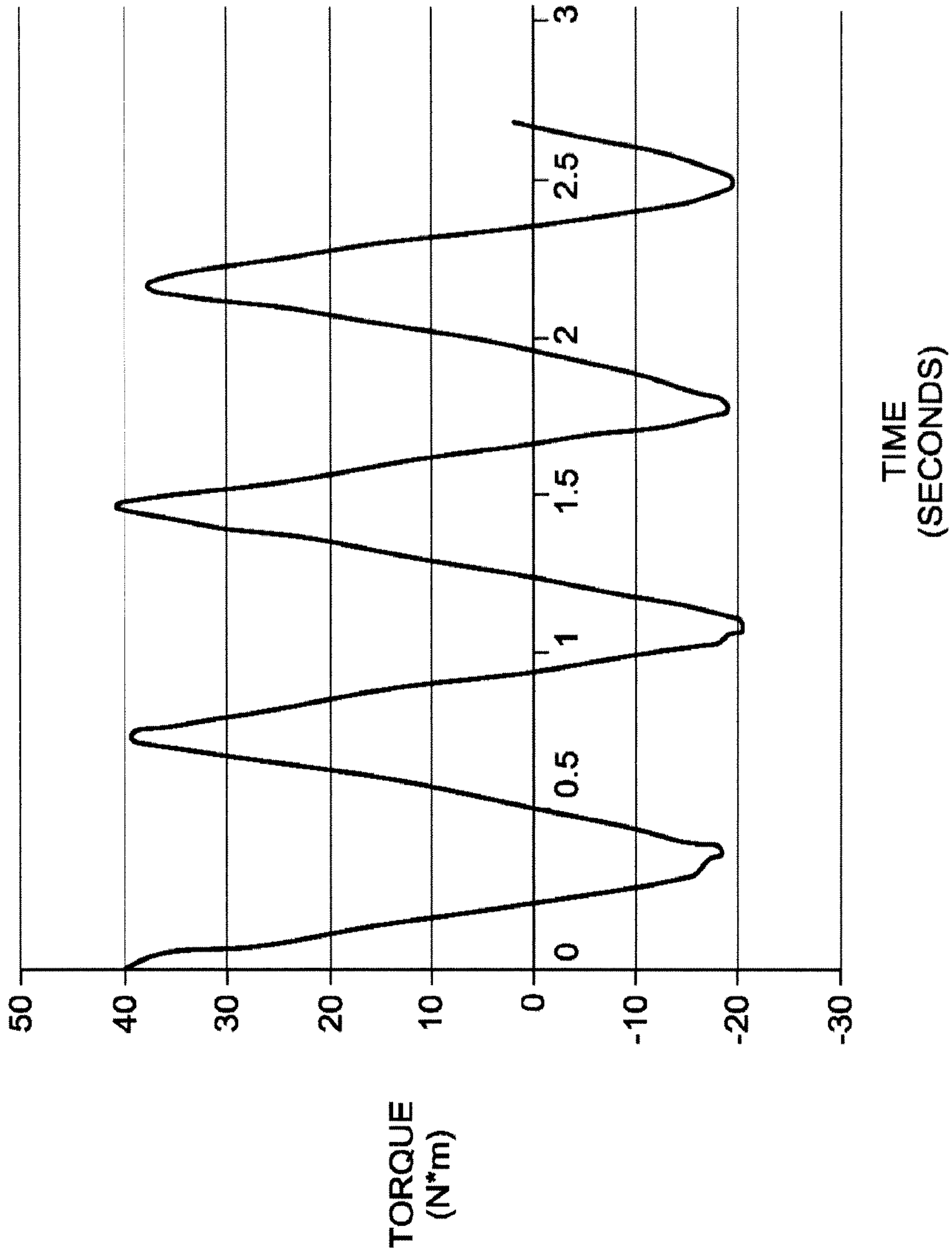
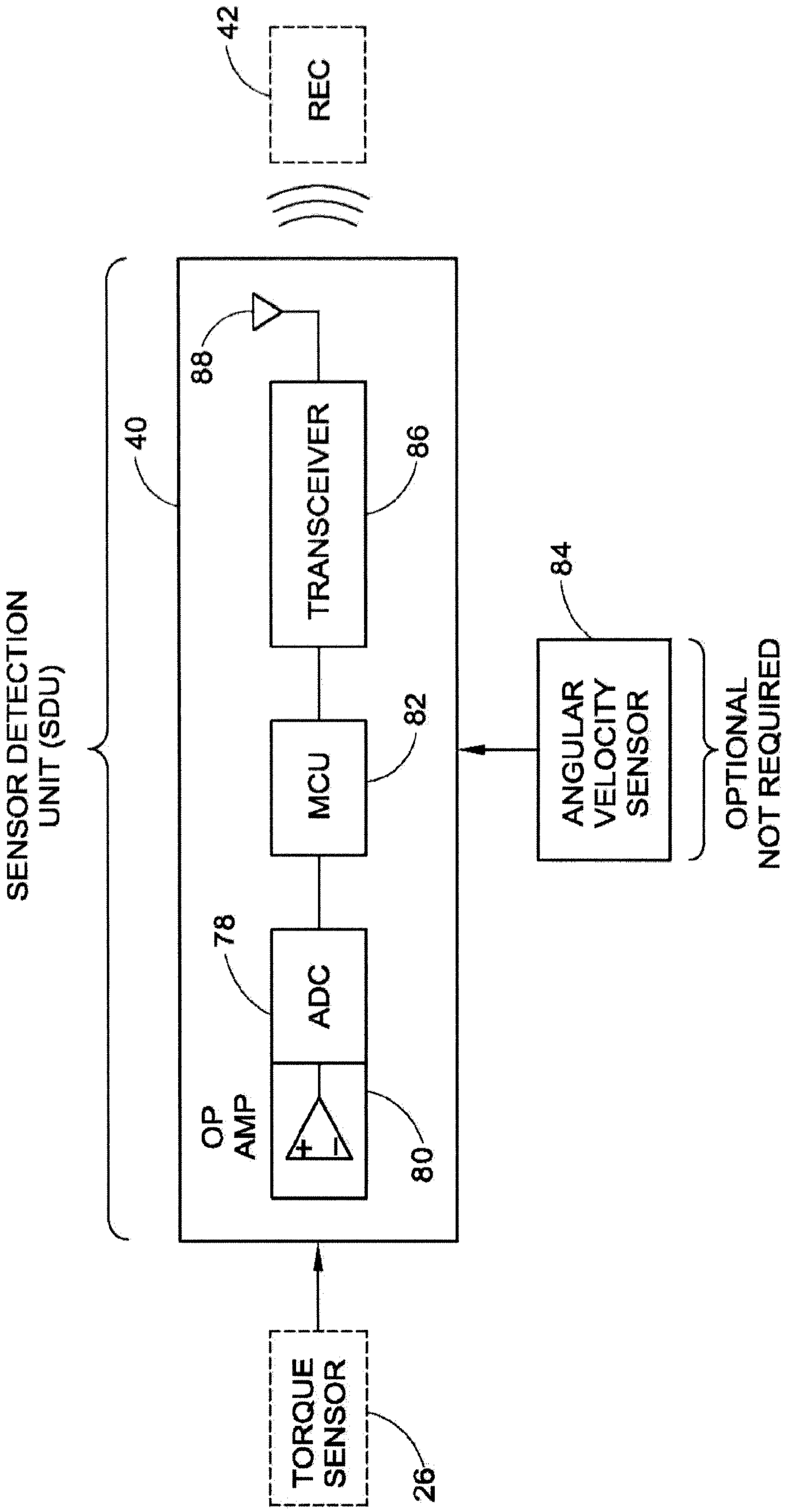


FIG. 6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88
TRANSCEIVER
86
84
ANGULAR
VELOCITY
SENSOR
OPTIONAL
NOT REQUIRED
SENSOR DETECTION
UNIT (SDU)
MCU
82
78
ADC
OP
AMP
+
-
80
TORQUE
SENSOR
26

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/047079

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01L3/10 A63B24/00 B62M3/08 B62M6/50
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010/088888 A2 (MOMES GMBH [DE]; BIERMANN MICHAEL [DE]; ASFOUR JEAN-MICHEL [DE]) 12 August 2010 (2010-08-12) figure 3 -----	1-20

☐ 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

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"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2012	02/11/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Vytlacilová, Lenka

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2012/047079

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2010088888 A2	12-08-2010	AU 2010210239 A1	15-09-2011
		DE 202009001463 U1	30-04-2009
		EP 2394151 A2	14-12-2011
		US 2012166105 A1	28-06-2012
		WO 2010088888 A2	12-08-2010