

Claims

1. Tremor stabilisation apparatus comprising a housing that is attachable to a part of a user's body, and a rotatable flywheel assembly mounted to the housing, the rotatable flywheel assembly comprising:
 - 5 a rotatable flywheel;
a prime mover arranged to rotate the flywheel about a flywheel rotation axis; and
a gimbal to which the flywheel is attached, the gimbal being pivotally mounted to the housing at a hinge formed between the gimbal and the housing and defining a precession axis such that the flywheel can precess with respect to the housing about
10 the precession axis, the precession axis being fixed relative to the housing;
wherein the tremor stabilisation apparatus further comprises a biasing member arranged to oppose precession of the rotatable flywheel assembly and urge the rotatable flywheel assembly to an equilibrium position.
2. The tremor stabilisation apparatus of claim 1, wherein the housing and the gimbal
15 are arranged to provide a maximum angle of precession about the precession axis from the equilibrium position of about 60 degrees or less, preferably about 30 degrees or less, more preferably about 10 degrees, most preferably about 5 degrees.
3. The tremor stabilisation apparatus of claim 2, wherein the housing comprises a stop
20 arranged to contact the gimbal when the gimbal is rotated to the maximum angle of precession.
4. The tremor stabilisation apparatus of claim 3, wherein the stop comprises a seat arranged to support the biasing member.
5. The tremor stabilisation apparatus of any preceding claim, wherein the biasing
25 member is arranged between the gimbal and the housing, and wherein the tremor stabilisation apparatus further comprises an elastomeric damper disposed between the biasing member and the housing.

6. The tremor stabilisation apparatus of any preceding claim, wherein the biasing member is configured to increase a biasing force provided by the biasing member as the angle of precession increases.
7. The tremor stabilisation apparatus of any preceding claim, wherein the biasing member comprises a spring.
8. The tremor stabilisation apparatus of any of claims 1 to 6, wherein the biasing member is arranged between the gimbal and the housing, and wherein the biasing member comprises a magnetic assembly comprising:
- a first magnet attached to the gimbal, and
 - a second magnet attached to the housing such that the first and second magnets repel each other.
9. The tremor stabilisation apparatus of any preceding claim, wherein a side of the housing comprises a mount for attachment of the tremor stabilisation apparatus to the part of the user's body, the side of the housing defining a plane that is approximately parallel to a surface of the part of the user's body, and wherein in the equilibrium position an angle between the flywheel rotational axis and a normal line from the plane of the side of the housing is between about +45 degrees and about -45 degrees, preferably about 0 degrees.
10. The tremor stabilisation apparatus of any preceding claim, wherein the biasing member comprises an adjustable force biasing member comprising an actuator for adjusting the biasing force provided by the adjustable force biasing member, and wherein the tremor stabilisation apparatus further comprises a controller arranged to control the actuator to adjust the biasing force.
11. Tremor stabilisation apparatus comprising a housing that is attachable to a part of a user's body, and a rotatable flywheel assembly mounted to the housing, the rotatable flywheel assembly comprising:
- a rotatable flywheel;
 - a prime mover arranged to rotate the flywheel about a flywheel rotation axis; and

a gimbal to which the flywheel is attached, the gimbal being pivotally mounted to the housing at a hinge formed between the gimbal and the housing and defining a precession axis such that the flywheel can precess with respect to the housing about the precession axis;

- 5 wherein the tremor stabilisation apparatus further comprises an adjustable force biasing member arranged to oppose precession of the rotatable flywheel assembly and urge the rotatable flywheel assembly to an equilibrium position;

wherein the adjustable force biasing member comprises an actuator for adjusting the biasing force provided by the adjustable force biasing member; and

- 10 wherein the tremor stabilisation apparatus further comprises a controller arranged to control the actuator to adjust the biasing force.

12. The tremor stabilisation apparatus of claim 10 or claim 11, further comprising a sensor arranged to detect a characteristic of a movement of the part of the user's body to which the tremor stabilisation apparatus is attached in use, and wherein the controller is
15 configured to receive a signal from the sensor and control the biasing force of the adjustable force biasing member based on the detected characteristic.

13. The tremor stabilisation apparatus of claim 12, wherein the characteristic of a movement of the part of the user's body comprises a tremor characteristic of the part of the user's body, for example a tremor amplitude, a tremor frequency, and/or a tremor
20 acceleration.

14. The tremor stabilisation apparatus of any of claims 10 to 13, further comprising a sensor arranged to detect rotation of the flywheel about the precession axis, and wherein the controller is configured to receive a signal from the sensor and control the biasing force of the adjustable force biasing member based on the detected rotation of the flywheel
25 about the precession axis.

15. The tremor stabilisation apparatus of any preceding claim, further comprising:
a prime mover controller configured to control the prime mover and the rotational speed of the flywheel about the flywheel rotation axis, and

a sensor arranged to detect one or both of:

a characteristic of a movement of the part of the user's body to which the tremor stabilisation apparatus is attached in use; and/or,

rotation of the flywheel about the precession axis;

5 wherein the prime mover controller is configured to receive a signal from the sensor or sensors and control the rotational speed of the flywheel based on one or both of: the detected characteristic of a movement of the part of the user's body; and rotation of the flywheel about the precession axis.

16. Tremor stabilisation apparatus comprising a housing that is attachable to a part of a
10 user's body, and a rotatable flywheel assembly mounted to the housing, the rotatable flywheel assembly comprising:

a rotatable flywheel;

a prime mover arranged to rotate the flywheel about a flywheel rotation axis;

15 a gimbal to which the flywheel is attached, the gimbal being pivotally mounted to the housing at a hinge formed between the gimbal and the housing and defining a precession axis such that the flywheel can precess with respect to the housing about the precession axis;

a controller configured to control the prime mover and the rotational speed of the flywheel about the flywheel rotation axis; and

20 a sensor arranged to detect one or both of:

a characteristic of a movement of the part of the user's body to which the tremor stabilisation apparatus is attached in use; and/or

rotation of the flywheel about the precession axis;

25 wherein the controller is configured to receive a signal from the sensor and control the rotational speed of the flywheel based on the detected characteristic of a

movement of the part of the user's body; and rotation of the flywheel about the precession axis.

17. The tremor stabilisation apparatus of claim 15 or claim 16, wherein the characteristic of a movement of the part of the user's body comprises a tremor characteristic of the part
5 of the user's body, for example a tremor amplitude, a tremor frequency, and/or a tremor acceleration.

18. The tremor stabilisation apparatus of any of claims 15 to 17, wherein the prime mover controller is configured to control an acceleration and/or deceleration of the flywheel based on the detected characteristic.

19. The tremor stabilisation apparatus of any preceding claim, wherein the gimbal comprises a mounting portion for attachment of the flywheel, and a hinge portion extending radially of the mounting portion to cooperate with a hinge seat of the housing to form the hinge defining the precession axis.

20. The tremor stabilisation apparatus of claim 19, wherein the gimbal comprises a first
15 hinge portion extending in a first radial direction with respect to the flywheel, a second hinge portion extending in a second radial direction with respect to the flywheel, and wherein the gimbal further comprises an arm extending from the mounting portion in a radial direction with respect to the flywheel between the first hinge portion and the second hinge portion, the arm being arranged to engage the biasing member.

21. The tremor stabilisation apparatus of claim 20, wherein the gimbal comprises a first arm extending from the mounting portion in a radial direction with respect to the flywheel between the first hinge portion and the second hinge portion, the first arm being arranged to engage a first biasing member, and wherein the gimbal further comprises a second arm extending from the mounting portion in a radial direction with respect to the flywheel on an
25 opposite side of the first and second hinge portions, the second arm being arranged to engage a second biasing member.

22. The tremor stabilisation apparatus of claim 19, wherein the hinge portion of the gimbal extends in a first radial direction with respect to the flywheel, and wherein the

gimbal further comprises an arm extending from the mounting portion in an approximately opposite direction to the hinge portion, the arm being arranged to engage the biasing member.

23. The tremor stabilisation apparatus of any of claims 1 to 18, wherein one of the
5 gimbal and the housing comprises a ball, and the other of the gimbal and the housing comprises a socket adapted to receive the ball, and wherein the ball is configured to rotate within the socket to define the precession axis.

24. The tremor stabilisation apparatus of claim 23, wherein the socket comprises a guide
10 arranged to limit rotation of the ball within the socket to a single plane such that the precession axis is fixed relative to the housing.

25. The tremor stabilisation apparatus of any preceding claim, wherein the flywheel
comprises a central disc portion and a circumferential skirt extending in an axial direction of the flywheel rotation axis, the circumferential skirt defining a recessed cavity.

26. The tremor stabilisation apparatus of claim 25, wherein the circumferential skirt
15 comprises at least 50% of the total mass of the flywheel, preferably at least 75% of the total mass of the flywheel.

27. The tremor stabilisation apparatus of claim 25 or claim 26, wherein the gimbal is at least partly nested in the recessed cavity of the flywheel.

28. The tremor stabilisation apparatus of any of claims 25 to 27, wherein the prime
20 mover is mounted to the gimbal, and wherein the prime mover is at least partly nested in the recessed cavity of the flywheel.

29. The tremor stabilisation apparatus of any preceding claim, wherein the prime mover comprises an electric motor having one or more of:

25 an aspect ratio of a height dimension in an axial direction of the flywheel rotation axis to a width dimension perpendicular to the height dimension of about 1 or less; and/or
a brushless electric motor; and/or

a brushless DC motor; and/or

a DC motor comprising a diametrically-polarised permanent magnet rotor;
and/or

a DC motor comprising slotless and/or coreless windings and/or

5 an axial flux configuration.

30. The tremor stabilisation apparatus of any preceding claim, wherein the prime mover comprises a motor, and wherein the motor includes a motor housing and a motor mount wherein the motor housing is mounted within the motor mount; wherein the motor housing is generally axially cylindrical about an output shaft of the motor and includes a plurality of
10 co-planar tabs extending radially therefrom and substantially uniformly spaced; wherein each tab is located within a corresponding slot formed in a correspondingly cylindrical inner surface of the motor mount; wherein each slot has a dimension greater than that of the corresponding tab in a circumferential direction; and wherein a biasing member is provided between a corresponding face of each tab and an adjacent wall of the cylindrical surface of
15 the motor mount.

31. The tremor stabilisation apparatus of any preceding claim, wherein the prime mover comprises an electric motor, preferably a DC motor, and the tremor stabilisation apparatus comprises a controller configured to control the electric motor; wherein the controller is configured to brake the electric motor in pulses to reduce braking torque generated by the
20 flywheel during braking.

32. A method of controlling a tremor stabilisation apparatus for attachment to a part of a user's body, the tremor stabilisation apparatus comprising: a rotatable flywheel assembly having a rotatable flywheel, the rotatable flywheel assembly being hingedly mounted to a housing such that the rotatable flywheel assembly can precess; and an adjustable force
25 biasing member arranged to oppose precession of the flywheel and urge the flywheel to an equilibrium position;

wherein the method comprises:

detecting a characteristic of a movement of the part of the user's body to which the tremor stabilisation apparatus is attached; and

controlling the biasing force of the adjustable force biasing member based on the detected characteristic.

- 5 33. A method of controlling a tremor stabilisation apparatus for attachment to a part of a user's body, the tremor stabilisation apparatus comprising: a rotatable flywheel assembly having a rotatable flywheel, the rotatable flywheel assembly being hingedly mounted to a housing such that the rotatable flywheel assembly can precess; and an adjustable force biasing member arranged to oppose precession of the flywheel and urge the flywheel to an
10 equilibrium position;

wherein the method comprises:

detecting precession of the rotatable flywheel assembly; and

controlling the biasing force of the adjustable force biasing member based on the detected precession of the rotatable flywheel assembly.

- 15 34. A method of controlling a tremor stabilisation apparatus for attachment to a part of a user's body, the tremor stabilisation apparatus comprising: a rotatable flywheel and a prime mover arranged to rotate the rotatable flywheel;

wherein the method comprises:

- 20 detecting a characteristic of a movement of the part of the user's body to which the tremor stabilisation apparatus is attached; and

controlling the prime mover to rotate the rotatable flywheel based on the detected characteristic.

35. The method of claim 32 or claim 34, wherein detecting a characteristic of a movement of the part of the user's body comprises detecting a tremor characteristic, for
25 example a tremor amplitude, a tremor frequency, and/or a tremor acceleration.