CLAIMS

1. A sensor system (10) for monitoring a powertrain (20) having a drive shaft (1), the sensor system (10) comprising

- an optical fibre (2) comprising a strain sensitive element (3) configured to change its optical properties as a function of strain (S2) on the sensor;
- a connection structure (4) configured to connect the optical fibre (2) to the drive shaft (1) wherein a strain (S1) on the drive shaft (1) is passed by the connection structure (4) to cause a strain (S2) on the strain sensitive element (3);
- a light source (5) connected to the optical fibre (2) and configured to emit an input light signal (Li) to the optical fibre (2) for optical interaction with the strain sensitive element (3); and
- a light detector (6) configured to receive an output light signal (Lo) from the optical fibre (2) resulting from the optical interaction of the input light signal (Li) with the strain sensitive element (3) for measuring the strain (S2) on the strain sensitive element (3);

wherein the connection structure (4) is configured to hold at least a part of the optical fibre (2) with the strain sensitive element (3) at a radial distance remote from the drive shaft (1) for amplifying the strain (S2) on the strain sensitive element (3) with respect to the strain (S1) on the drive shaft (1).

2. The sensor system (10) according to claim 1, wherein the drive shaft has a shaft radius (R1) and the strain sensitive element (3) is held by the connection structure (4) at a distant radius (R2) from a centre of the drive shaft (1), wherein the distant radius (R2) is at least a factor 1.1 times the shaft radius (R1).

3. The sensor system (10) according to any of the preceding claims, wherein the connection structure (4) comprises a clamping ring (4a,4b) configured to clamp around an outer surface of the drive shaft (1).

4. The sensor system (10) according to any of the preceding claims, wherein the connection structure (4) comprises at least two rigid rings (4a,4b) configured to hold a length of the optical fibre with the strain sensitive element (3) there between.

5. The sensor system (10) according to any of the preceding claims, wherein the connection structure (4) comprises first and second parts (4a,4b) for connecting to the drive shaft (1) and a third part (4c) between the first and second part (4a,4b), wherein a rigidity of the third part (4c) is lower than respective rigidities of the first and second parts (4a,4b).

6. The sensor system (10) according to any of the preceding claims, comprising at least three strain sensitive elements (3a,3b,3c) arranged along at least three respective lengths (2a,2b,2c) of one or more optical fibres (2a,2b,2c), wherein the connection structure (4) is configured to hold the respective lengths (2a,2b,2c) along parallel paths with respect to each other, wherein the parallel paths extend at least in a direction along a length of the drive shaft (1).

7. The sensor system (10) according to any of the preceding claims, wherein the system comprises a fibre optic rotary joint (7) with an off-axis fibre optic slip ring.

8. The sensor system (10) according to any of the preceding claims, wherein the light source (5) and/or light detector (6) are comprised in the connection structure (4) rotating with the drive shaft (1).

9. The sensor system (10) according to any of the preceding claims, wherein at least a part of the optical fibre (2) comprising the strain sensitive element (3) is pre-stressed in absence of strain on the drive shaft (1).

10. The sensor system (10) according to any of the preceding claims, comprising a memory for recording the measured strain on the strain sensitive elements as a function of time; and a processor configured to calculate vibrational components in the drive shaft (1) based on the measured strain as a function of time.

11. The sensor system (10) according to any of the preceding claims, comprising an interferometer configured to receive two or more output light signals from the optical fibre (2) resulting from the optical interaction of the input light signal with two or more partially reflective elements (3e,3f) for interferometrically combining two or more output light signals from the elements (3e,3f) for measuring the strain by the interferometric combining.

12. A sensor system (10) for monitoring a powertrain (20) having a drive shaft (1), the sensor system (10) comprising

- one or more optical fibres comprising at least three strain sensitive elements (3a,3b,3c) arranged along at least three respective lengths (2a,2b,2c) of the one or more optical fibres wherein each strain sensitive element is configured to change at least one of its optical properties as a function of strain (S2) on the respective length of the optical fibre comprising the strain sensitive element; wherein the respective lengths (2a,2b,2c) of the one or more optical fibres are connected to the drive shaft (1) wherein the connection is configured to pass a strain (S1) on the drive shaft (1) to cause as a respective strain (S2a,S2b,S2c) on the strain sensitive elements (3a,3b,3c);
- one or more light sources (5) connected to the one or more optical fibres and configured to emit input light signals (Li) to the one or more optical fibres for optical interaction with the strain sensitive elements (3a,3b,3c); and
- one or more light detectors (6) configured to receive output light signals (Lo) from the one or more optical fibres (2a,2b,2c) resulting from the optical interaction of the input light signals (Li) with the strain sensitive elements (3a,3b,3c) for measuring the respective strain (S2a,S2b,S2c) on the strain sensitive elements (3a,3b,3c);
- wherein the respective lengths (2a,2b,2c) of the one or more optical fibres follow parallel paths with respect to each other wherein the

parallel paths extend at least in a direction along a length of the drive shaft (1).

13. The sensor system (10) according to claim 12, wherein the respective lengths (2a,2b,2c) of the one or more optical fibres comprising the strain sensitive elements (3a,3b,3c) follow parallel helical paths extending around the drive shaft (1).

14. The sensor system (10) according to claim 12 or 13, comprising a first length (2a) of the one or more optical fibres comprising a first strain sensitive element (3a), and a second length (2d) of the one or more optical fibres comprising second strain sensitive element (3d), wherein the first and second lengths (2a,2d) follow opposite helical paths around the drive shaft (1).

15. The sensor system (10) according to any of claims 12 – 14, wherein an optical temperature sensor (3T) is comprised in a length (2d) of the one or more optical fibres that is tightly wound around the drive shaft (1) and/or connection structure (4)..

16. The sensor system (10) according to any of claims 12 – 15, wherein the respective lengths (2a,2b,2c) of the one or more optical fibres are equidistantly distributed along a circumference around the drive shaft (1).

17. The sensor system (10) according to any of claims 12 – 16, wherein the respective lengths (2a,2b,2c) of the one or more optical fibres are connected to the drive shaft (1) by a connection structure (4) configured to hold the respective lengths (2a,2b,2c) at a radial distance remote from the drive shaft (1) for amplifying the strain (S2) on the respective lengths (2a,2b,2c) of the one or more optical fibres comprising the strain sensitive elements (3a,3b,3c) with respect to the strain (S1) on the drive shaft (1).

18. A method for monitoring a powertrain (20) having a drive shaft (1), the method comprising

– providing the sensor system (10) according to any of the preceding claims, wherein one or more optical fibres (2) of the sensor system (10) are connected to the drive shaft (1);

– emitting an input light signal (Li) to one or more optical fibres (2) for optical interaction with one or more strain sensitive elements (3);

– measuring an output light signal (Lo) from the optical fibre (2) resulting from the optical interaction of the input light signal (Li) with the one or more strain sensitive elements (3) for measuring the respective strain (S2) on the one or more strain sensitive elements (3); and

– based on the measured respective strain (S2), calculating one or more of a torque on the drive shaft (1), bending of strain (S1) on the drive shaft (1), or thrust strain (S1) on the drive shaft (1).

19. The method according to claim 18, comprising

– adjusting operation of an engine (21) driving the powertrain (20) based on the calculated torque, bending, and/or thrust.

20. The method according to claim 18 or 19, wherein at least three strain sensitive elements (3a,3b,3c) are arranged along at least three respective lengths (2a,2b,2c) of the one or more optical fibres (2a,2b,2c), wherein the respective lengths (2a,2b,2c) of the one or more optical fibres follow parallel paths with respect to each other wherein the parallel paths extend at least in a direction along a length of the drive shaft (1), wherein the method comprises distinguishing between a torque induced deformation (α) of the drive shaft (1) and a bending deformation (ß) of the drive shaft (1) by comparing respective signs of wavelength shifts in the optical properties of the at least three strain sensitive elements (3a,3b,3c).

21. The sensor system according to any of the preceding claims 1 to 17, wherein each strain sensitive element (3; 3a,3b,3c) is formed by a Fiber Bragg Gratings (FBG).

22. The sensor system according to any of the preceding claims 1 to 17 and 21, wherein the powertrain is a powertrain of a boat or ship

23. The method according to any of the preceding claims 18 to 20, wherein each strain sensitive element (3; 3a,3b,3c) is formed by a Fiber Bragg Gratings (FBG).

24. The method according to any of the preceding claims 18 to 20 and 21, wherein the powertrain is a powertrain of a boat or ship.