Claims

1. A sensor system (40) for monitoring in time a geometric property of a gasket (30), wherein the gasket sealingly interconnects and extends along a path between adjacent edges (24, 25) of two structural members (20, 21) of an at least partially subterraneous and/or immersed structure (10), wherein the sensor system comprises:

- a sensor (42), configured to measure indications of position for a plurality of gasket surface portions (48) at different measurement times (t_i) and relative to a reference (26, 27, 47) associated with at least one of the structural members, and
- a processor (44), communicatively coupled with the sensor to receive the measured indications of position, and configured to:

derive indications of displacement (ΔY) for each of the gasket surface portions based on the measured indications of position;

compare the indications of displacement for each of the gasket surface portions with at least one threshold value (Ty), and

generate a warning message for an operator if at least one of the indications of displacement transgresses the at least one threshold value.

2. The sensor system (40) according to claim 1, wherein the structural members (20, 21) are positioned so that the adjacent edges (24, 25) enclose a space (38) with a non-zero gap width (ΔXg) in a longitudinal direction (X), and wherein the sensor (42) is configured to be accommodated inside the space between the adjacent edges.

3. The sensor system (40) according to claim 2, wherein the gasket (30) forms a composite gasket that comprises:

- an inner gasket member (32) extending in an annular path along the adjacent edges (24, 25) of the structural members (20, 21), and facing an interior region (18) of the structure (10);
- an outer gasket member (34) extending in a further annular path along the adjacent edges and around the inner gasket member;

wherein the space forms an annular space (38) enclosed between the inner and outer gasket members and the adjacent edges of the structural members;

and wherein the sensor (42) is configured to be positioned inside the annular space and to measure a geometric property of the outer gasket member and/or the inner gasket member.

4. The sensor system (40) according to any one of claims 1-3, wherein the gasket surface portions (48) form parts of an inner gasket surface (36) that faces towards an interior region (18) of the structure (10);

wherein the sensor (42) is configured to measure indications of transverse position for the gasket surface portions, relative to first and/or second walls (22, 23) of the structural members (20, 21);

and wherein the processor (44) is configured to derive indications of transverse inwards displacement (ΔY) for each of the gasket surface portions based on the measured indications of transverse position.

~~5. The sensor system (40) according to any one of claims 2-4, wherein the gasket (30, 34) is mechanically and sealingly fixed to a first edge (24) of a first structural member (20), and abuts a second edge (25) of a second structural member (21) while allowing slight relative motion maintaining a sealing engagement with the second edge;~~

~~wherein the gasket surface portions (48) are located at non-zero distances (ΔXs) from the second edge and along the longitudinal direction (X), the distances (ΔXs) being smaller than half of the gap width (ΔXg).~~

~~6~~5. The sensor system (240) according to any one of claims 1-~~5~~4, wherein in the gasket surface portions (248a, 248b, 248c) are arranged in a sequence of distinct positions along the gasket (234);

wherein the sensor (242) includes a plurality of optical transceivers (243a, 243b, 243c) that are configured to be attached in a sequence along an edge (225) of at least one of the structural members (223) and facing respective ones of the gasket surface portions, wherein each of the optical transceivers is configured to emit optical radiation (250) towards a respective gasket surface portion, to receive further optical radiation (251) returned by the respective gasket surface portion, and to measure the indications of position based on a comparison between the emitted and received optical radiations;

and wherein the processor (244) is configured to derive the indications of displacement (ΔY) for each of the gasket surface portions based on the measured indications of position.

~~7~~6. The sensor system (240) according to claim ~~6~~5, wherein the optical transceivers (243a, 243b, 243c) are configured to emit the optical radiation as pulses (250) towards the respective gasket surface portions, and configured to receive the further optical radiation as return pulses (251) reflected by the respective gasket surface portions, wherein the indications of position are time differences (ToF) measured between emission of pulses and subsequent receipt of return pulses;

and wherein the processor (244) is configured to calculate travel distances from the measured time differences and a predetermined value for a propagation speed of the optical radiation, to derive the indications of displacement (ΔY) for each of the gasket surface portions;

or wherein the optical transceivers (243a, 243b, 243c) are configured to emit optical radiation in the form of continuous waves (250) with a specified frequency towards the respective gasket surface portions, and configured to receive optical radiation in the form of continuous waves (251) reflected by the respective gasket surface portions, and wherein the indications of position are phase differences between the transmitted and received waves,

and wherein the processor (244) is configured to calculate travel distances from the measured phase differences, to derive the indications of displacement (ΔY) for each of the gasket surface portions.

~~8~~7. The sensor system according to any one of claims 1-~~5~~4, wherein the gasket surface portions are arranged in a sequence of distinct positions along the gasket;

wherein the sensor includes a plurality of acoustic transducers that are configured to be attached in a sequence along an edge of at least one of the structural members and facing respective ones of the gasket surface portions, wherein each of the acoustic transducers is configured to emit an acoustic pulse towards a respective gasket surface portion, and to receive an acoustic return pulse reflected by the respective gasket surface portion, wherein the indications of position are time differences (ToF) measured between emission of the acoustic pulses and subsequent receipt of the acoustic return pulses;

and wherein the processor is configured to calculate travel distances from the measured time differences and a predetermined value for acoustic propagation speed, to derive the indications of displacement (ΔY) for each of the gasket surface portions.

~~9~~8. The sensor system (240) according to claim ~~7~~ 6 or ~~8~~7, wherein the optical transceivers (243) or acoustic transducers are configured to emit and receive signal pulses through air, wherein the space (238) between the adjacent edges (224, 225) of the structural members (220, 221) in which the sensor (242) is accommodated is filled with a liquid, such as water, and wherein the processor (244) is configured to convert readings from the optical transceivers or acoustic transducers by multiplying with a ratio of a propagation speed of light or sound in the liquid to a propagation speed of light or sound in air.

~~10~~9. The sensor system (440) according to any one of claims 1-~~5~~4, wherein the gasket surface portions are arranged in a sequence of distinct positions along the gasket;

wherein the sensor system comprises a plurality of electromagnetic, EM, markers (446) that are configured to be attached to respective gasket surface portions (448);

wherein the sensor (442) includes a plurality of EM transducers (443) that are configured to be attached along an edge (425) of at least one of the structural members, with each transducer facing a respective one of the EM markers, wherein the EM transducers are configured to continuously generate EM fields, and to detect perturbations of the EM fields caused by the EM markers, to acquire the indications of position.

~~11~~10. The sensor system (40) according to any one of claims 1-~~10~~9, further comprising:

- a temperature sensor (666) arranged at or near the sensor (642), and configured to continuously or intermittently measure indications of temperature of the sensor (642) during operation of the sensor system;

- a heater element (668) arranged at or near the sensor (642), and configured to provide heat to the sensor;
- a temperature controller (667), in signal communication with the temperature sensor and the heater element, and configured to process the indications of temperature received from the temperature sensor and to control the heater element in order to keep a temperature of the sensor (642) at a stable value above a maximum ambient temperature of the space (38) enclosed by the gasket (30) and adjacent edges (24, 25) of the structural members (20, 21).

~~12~~11. The sensor system (40) according to claim ~~11~~10, comprising a substrate (662) that defines a first surface on which the sensor (642) is arranged, the substrate including cut-outs (663) that extend from the first surface, entirely through the substrate, to a second surface of the substrate opposite to the first surface, wherein the cut-outs extend around and enclose a partly isolated portion (665) of the substrate where the sensor (642) is located, and wherein the cut-outs are mutually separated by bridge portions (664) that mechanically connect the partly isolated portion to a remainder of the substrate that surrounds the cut-outs and the partly isolated portion.

~~13~~12. The sensor system (40) according to claim ~~12~~11, wherein the number of bridge portions (664) equals three or four, and wherein the bridge portions are preferably arranged in a regular distribution around the partly isolated portion (665) in order to prevent mechanical displacement of the partly isolated portion relative to the remainder of the substrate.

~~14~~13. The sensor system (40) according to claim ~~12~~ 11 or ~~13~~12, wherein the temperature sensor (666) and the heater element (668) are both arranged near the sensor (642) and at the partly isolated portion (665) of the substrate (662), wherein the temperature sensor preferably is arranged on the first surface, and wherein the heater element preferably is arranged on the second surface.

~~15~~14. A method for monitoring in time a geometric property of a gasket (30), wherein the gasket sealingly interconnects and extends along a path between adjacent edges (24, 25) of two structural members (20, 21) of an at least partially subterraneous and/or immersed structure (10), wherein the method comprises:

providing a sensor system with a sensor (42) and a processor (44) according to any one of claims 1-~~14~~13;

measuring, with the sensor, indications of position for a plurality of gasket surface portions (48) at different measurement times (t_i) and relative to a reference (26, 27) associated with at least one of the structural members;

deriving, with the processor, indications of displacement (ΔY) for each of the gasket surface portions based on the indications of position measured by the sensor;

comparing, with the processor, the indications of displacement for each of the gasket surface portions to at least one threshold value (Ty), and

generating a warning message for an operator if at least one of the indications of displacement transgresses the at least one threshold value.

~~16~~15. The method according to claim ~~15~~14, wherein the structural members (20, 21) are positioned so that the adjacent edges (24, 25) enclose a space (38) with a non-zero gap width (ΔXg) in a longitudinal direction (X);

and wherein the method further comprises accommodating the sensor (42) inside the space between the adjacent edges, prior to measuring.

~~17~~16. The method according to claim ~~16~~15, wherein the gasket (30) forms a composite gasket that comprises:

- an inner gasket member (32) extending in an annular path along the adjacent edges (24, 25) of the structural members (20, 21), and facing an interior region (18) of the structure (10);
- an outer gasket member (34) extending in a further annular path along the adjacent edges and around the inner gasket member;

wherein the space forms an annular space (38) enclosed between the inner and outer gasket members and the adjacent edges of the structural members;

and wherein the method further comprises positioning the sensor (42) inside the annular space, and measuring a geometric property of the outer gasket member and/or the inner gasket member.

~~18~~17. The method according to any one of claims ~~15~~14-~~17~~16, wherein the gasket surface portions (48) form parts of an inner gasket surface (36) that faces towards an interior region (18) of the structure (10), and wherein the method comprises:

measuring, with the sensor (42), indications of transverse position for the gasket surface portions relative to first and/or second walls (22, 23) of the structural members (20, 21), and

deriving, with the processor (44), indications of transverse inwards displacement (ΔY) for each of the gasket surface portions based on the measured indications of transverse position.

~~19~~18. The method according to any one of claims ~~15~~14-~~18~~17, wherein the provided sensor system is in accordance with claim 6 or 7, wherein the method further comprises:

attaching the optical transceivers in a sequence along an edge (225) of at least one of the structural members (223) and facing respective ones of the gasket surface portions;

emitting, with the optical transceivers, pulses of continuous waves (250) of optical radiation towards a respective gasket surface portion;

receiving, with the optical transceivers, return pulses or continuous waves (251) of optical radiation reflected by the respective gasket surface portions;

measuring time differences or phase differences between emission of pulses or waves and subsequent receipt of corresponding return pulses or waves, to obtain the indications of position, and

calculating, with the processor (244), travel distances from the measured time or phase differences and a predetermined value for a propagation speed of the optical radiation, to derive the indications of displacement (ΔY) for each of the gasket surface portions.

~~20~~19. A computer readable medium storing instructions, which when executed by one or more processors (44) that is/are communicatively coupled with a sensor (42) in a sensor system according to any one of claims 1-~~14~~13, cause the one or more processors to derive indications of displacement (ΔY) for each of the gasket surface portions (48) based on indications of position measured by the sensor; to compare the indications of displacement for each of the gasket surface portions to at least one threshold value (Ty), and to generate a warning signal if at least one of the indications of displacement transgresses the at least one threshold value, and optionally wherein the instructions, when executed by the one or more processors (44), cause the one or more processors to execute further processing steps as defined in any one of claims ~~15~~14-~~19~~18.

~~21~~20. A structure (10), for instance a tunnel, adapted to be arranged at least partially within a body of soil and/or water to form part of a road or railroad network, and comprising:

- at least two tubular structural members (20, 21), which are interconnected along adjacent edges (24, 25) and define an internal passageway (18) for passing through traffic;
- a gasket (30) that sealingly interconnects and extends along a path between the adjacent edges (24, 25), and
- a sensor system (40) in accordance with any one of claims 1-~~14~~13.