

LOAD INDICATING FASTENER SYSTEMS METHOD AND APPARATUS

Field Of The Invention

This invention relates to load indicating fastener systems that are adapted to indicate loads to which they are subjected and, more specifically, to a non-contact electronic device, such as a reactance capacitor, which measures a changing air gap or form produced when a fastening system is strained, and, more specifically, to a non-contact image processing or laser device, which measures a changing air gap or form produced when a fastening system is strained.

Background

It is desirable that applied fasteners systems should be accurately tightened to the designed load levels in order to ensure the structural integrity of the bolted joint. It is well known that indicating strain gives a true representation of the load induced in the fastener systems. Torque wrenches are commonly used for tightening fasteners to predetermined torque levels, but they are subject to unpredictable friction so that the strain produced can be widely inaccurate. In other words, controlling torque will not lead to accurate loading of a fastener system.

Prior Contact-Type Fastener Extension Measuring Devices

Some measuring devices, for instance linear transducers, need to make physical contact to be functional. These contact methods are inherently difficult to use in the field. The measurements of strain are extremely small and any surface contamination (corrosion, dirt, natural abrasives, in service damage, etc.) leads to significant errors. Accordingly, it is an object of the present invention to measure strain by using a non-contact device and method.

1 formats even though from time to time below for purposes of clarity and brevity applicant will
2 use either one or the other format to describe various aspects and features of the invention.

3 According to the present invention a load indicating fastener system is provided which
4 comprises a body to which strain is applied when the fastener is in use, a load sensing means
5 having parts arranged for relative movement in response to change in length or form of the
6 body or an associated washer design under an applied strain, and a separate non-contact gap
7 measuring device, such as an electronic device including a reactance capacitor, or such as an
8 image processing device, or such as a laser device, (hereinafter collectively and/or separately
9 referred to as "a non-contact gap measuring device") which, when secured adjacent to the
10 fastener, registers the said relative movement of the moving parts by a non-contact method.

11 The fastener system may be in the form of a bolt or stud, a nut and washers, or it may
12 take other forms. In the form of a bolt, the body of the fastener comprises a head and shank
13 which may be of substantially standard form. Similarly, in the form of a stud, the body
14 comprises a shank which may be of substantially standard form. In either of said forms, a
15 washer may incorporate the means of indicating the moving parts being sensed by a separate
16 non-contact gap measuring device of the type described above. In the case of bolt or stud, the
17 load-sensing element responds to a change in length of the shank under the applied strain. In
18 the case of the washer, the load sensing element senses the change of shape in the form of the
19 washer under applied strain. Conveniently, the gap measuring device can be secured at the bolt
20 head, thread end, stud end, or washer where it can easily be secured when the fastener system
21 is in use.

22 The load-sensing element indicates changes in the length of the body of the fastener, or
23 changes in the form of the washer, or changes in the form of the bolt head as the fastener

1 at which the fastener system may be used will not affect the functioning of the load-sensing
2 element.

3 In a preferred embodiment the load-sensing element is a solid diameter bar, one end
4 providing the anchorage part, the other free end to move relative to the fastener. At least part
5 of the load sensing element may be located in a blind bore or passage in the body. When the
6 load sensing means comprises an element, as described above, it may be provided by an insert
7 fitted into the blind end portion of the bore or passage. The anchorage may be anchored into
8 the base of the bore or passage. The bore or passage may have a smaller base portion in which
9 the anchorage part is anchored. Conveniently the non-contact gap measuring device is located
10 at or near the free end of such a bore or passage. There may be direct anchorage of the
11 element to the body, for example by welding, threading or adhesive bonding, or the element
12 may be anchored to the base, which is suitably fixed to the body. The base of the bore or
13 passage may be in the form of a close interference bore into which the element is pressed to
14 provide a secure anchorage.

15 The load-sensing element may be arranged to operate over a given range of changes of
16 length of the body under applied strain. This will usually be by elongation of the body from the
17 unloaded condition up to the material proof load. When the load is applied to strain the body,
18 the load sensing element moves into the body away from the zero datum (datum means the
19 fixed part on the fastener upper head face that does not move). The non-contact gap
20 measuring device attaches to the body and measures the difference between the datum point
21 (reference point or form) on the body and the load sensing element, and the non-contact gap
22 measuring device is calibrated to indicate load.

deflection against a static part of the washer/bolt. The non-contact gap measuring devices are calibrated to indicate the fastener system load as explained above.

In another form, the load sensing may be arranged to register applied loads up to the proof load of the material by measuring the deflection of a specially designed bolt head when the bolt is under strain, the measurement being taken from two parts which are moving relative to each other when the bolt is under strain. The non-contact gap measuring device is calibrated to indicate the fastener system load as explained above.

The method used in the preferred embodiment of the present invention is measurement by reactance which is

$$\begin{aligned} \text{Capacitive reactance} &= \frac{1}{2\pi FC} \\ \text{and capacitance} &= \frac{D \times A}{G} \\ \text{Hence reactance} &= \frac{G}{2\pi FDA} \\ \text{Displacement} &= \text{change in gap} \\ \text{Where } F &= \text{Frequency (hertz)} \\ C &= \text{capacitance (farads)} \\ D &= \text{dielectric constant (air = 1)} \\ A &= \text{area (inch squared)} \\ G &= \text{gap (inch)} \end{aligned}$$

Set forth below are some of the advantages of the present invention:

1. A non-contact gap measuring device comprising all of the necessary electronics measures a changing air gap or form produced when a fastening system is strained without physically coming into contact with the moving parts being measured.
2. Measuring by non-contact minimizes error from contamination or the environment.
3. The distance being measured is determined from the average mean value of the entire surface being measured, which is not the case for contact methods.

1 Fig. 2 is a view similar to Fig. 1 showing the fastener described in Fig. 1 without the
2 portable head.

3 Fig. 3 is a view similar to Fig. 1 showing an alternative option for measuring the gap
4 by using only a cylindrical type reactance capacitor. The portable head is secured to the fixed
5 part of the fastener datum face. The cylindrical type reactance capacitor measures the gap
6 between the face of the cylindrical type reactance and the upper free end of the surface of the
7 measuring element. The non-contact gap measuring device computes the different
8 measurement of the gap and is calibrated to indicate clamping load induced by the fastener
9 when it is in use.

10 Fig. 4 is a view similar to Fig. 1 showing a specially designed washer that deflects
11 when the fastener system is under strain and an non-contact gap measuring device for
12 measuring the gap. The reactance capacitor non-contact gap measuring device, when secured
13 to the bolted joint, measures the gap between the face of the reactance capacitor and the part
14 being measured on the washer.

15 Fig. 5 is a view similar to Fig. 1 showing a specially designed washer that deforms the
16 head of the fastener so that two different parts of the head can be measured relative to each
17 other by the reactance capacitor non-contact gap measuring device when the fastener is under
18 strain.

19 Fig. 6 is a view similar to Fig. 1 showing a further modified form of the present
20 invention with an image processing or laser type gap measuring device fitted for use.

21 Fig. 7 is a view similar to Fig. 1 showing a fastener head which is modified to deflect
22 under load when the fastener is subjected to a tensile force.

23 Fig. 8 is a view similar to Fig. 1 showing a further modification of the present invention

1 face 11 and a lower face 12. The element 8 free end 8A is ground flush with the head 3 upper
2 datum face 11. The element 8 responds to loads applied to the shank 4 by nut 28 when the
3 fastener is in use. The response is related to the extension of the shank 4 under applied loads.
4 It is appropriate for the element 8 to sense applied loads and to indicate said loads up to the
5 proof load for the material of the body 2. Therefore, the element 8 is arranged to respond to
6 the extension of the shank 4 up to the extension caused by the proof load. For this to be
7 achieved the element 8 is set in bore 7 of the body such that the anchorage in counterbore 9
8 moves the element 8 into or out of the body 2 depending on the load being induced into the
9 shank 4. Therefore, the element 8 free end 8A moves relative to the head 3 upper datum
10 surface 11 depending upon whether the shank 4 is being loaded or unloaded. When the shank
11 4 is free from load, the element 8 and the head upper datum surface 11 are flush which
12 indicates no load in the shank 4. Because the shank 4 material obeys Hookes Law, the gap
13 created between the element 8 free end 8A and the head 3 upper datum surface 11 can be
14 calibrated to indicate load by the portable head measuring device 13 up to the proof load of the
15 shank 4 materials. Provided the proof load is not exceeded, the load indication will be always
16 repeatable.

17 The portable head 13 carries the reactance capacitors 15,16 and is constructed to
18 accurately locate onto the head 3 locating spigot 10. The portable head 13 is secured to the
19 head 3 by a magnet 14 mounted on the bottom of portable head 13, or portable head 13 may
20 be secured to head 3 by other known means. The ring type reactance capacitor 16 measures
21 the gap between the face 11B of the capacitor 16 and the head 3 upper datum surface 11. The
22 cylindrical type reactance capacitor 15 measures the gap between the surface 11A of the
23 capacitor 15 and the free end 8A of element 8. The said gaps between the said surfaces and

1 the element 8 are compared by the camera or laser system 34, 35 and calibrated to indicate
2 load that the shank 4 is subjected to during its use. The camera 34 can be replaced by a laser
3 34 and coupled to a processor 35 and to a readout 36 or to a computer (not shown).

4 As seen in Fig.7 an alternative option for measuring the fastener head 40 deflection
5 when the system is under load. The specially designed head 40 is shaped with an annular
6 groove 41, a spigot 10 having an annular outer face 42 surrounding a recess 43 having a floor
7 44 and cylindrical wall 45, and the portable monitor 34A with the camera or laser 34 detects
8 the change in shape of the head when under load. The electronics is calibrated to recognize the
9 load scale from zero to proof load of the material and indicates load induced into the fastener.

10 Fig.8 is the same as that described in Fig.7, but a special washer 21 causes the specially
11 designed head 46, having recess 43 with floor 44 and wall 45 and outboard concave face 47,
12 to deflect.

13 Fig.9 is the same as that described in Fig. 7, but the special washer 22 changing shape
14 due to the fastener system loading up to the material's proof load is detected by either the
15 camera or laser 34 as shown.

16 The foregoing description of a preferred embodiment and best mode of the invention
17 known to applicant at the time of filing the application has been presented for the purposes of
18 illustration and description. It is not intended to be exhaustive or to limit the invention to the
19 precise form disclosed, and obviously many modifications and variations are possible in the
20 light of the above teaching. The embodiment was chosen and described in order to best explain
21 the principles of the invention and its practical application to thereby enable others skilled in
22 the art to best utilize the invention in various embodiments and with various modifications as
23 are suited to the particular use contemplated. It is intended that the scope of the invention be

CLAIMS



1 1. A measuring device characterized by a portable sensing head which, when secured
2 adjacent a fastener system, detects a changing gap or form produced by the fastener when the
3 system is under strain without contacting the sensed portions of the fastener undergoing
4 significant relative movement

1 2. The device of claim 1 further characterized by a reactance capacitor supported in the
2 portable sensing head and detecting the changing gap or form.

1 3. The device of claim 1 further characterized by a camera or laser supported in the
2 portable sensing head and detecting the changing gap or form.

1 4. The device of claim 1 further characterized by the changing gap is produced by an
2 element embodied within the fastener when the system is under strain.

1 5. The device of claim 1 further characterized by the changing gap is produced relative
2 to a deflectable washer of the fastener system when the fastener system is under strain.

1 6. The device of claim 1 further characterized by the changing form is produced by a
2 deflectable bolt head or washer of the fastener system when the fastener system is under strain.

1 7. The device of claim 1 further characterized by the changing form is a bolt head and a
2 washer of the fastener system under strain.

1 8. A device of any one of claims 1-7 used to indicate load of the fastener.

1 9. A device of any one of claims 1-7 used to indicate when the load on the fastener
2 reaches a predetermined load.

1 10. A device of any one of claims 1-7 used to communicate with a fastener tightening
2 mechanism.

1 11. A device of any one of claims 1-7 used to transmit a signal for remote sensing.





2 by:

3 an end portion for mounting the detector head atop a head of the fastener.

1 21. The apparatus of claim 20 wherein the end portion is further characterized by:

2 a recessed opening in the detector head along its longitudinal axis terminating
3 in a flat end face orthogonal thereto for fitting around a spigot of the fastener.

1 22. The apparatus of claim 20 wherein the end portion is further characterized by:

2 a recessed opening in the detector head along its longitudinal axis for receiving
3 a locator peg positionable within the portable head and the fastener head for guiding the
4 detector head into a position relative to the fastener.

1 23. The apparatus of claim 20 wherein the end portion is further characterized by:

2 a magnet mounted therein.

1 24. The apparatus of claim 20 wherein the end portion is further characterized by:

2 a friction fit with the spigot.

1 25. The apparatus of claim 19 wherein the attachment portion is further characterized

2 by:

3 an end portion for mounting the detector head to the side of a head of the
4 fastener.

1 26. The apparatus of claim 15 wherein the detector head configuration and
2 construction for sensing the changing gap or form is further characterized by:

3 at least one reactance capacitor symmetrically mounted in one end of the
4 detector head relative to the longitudinal axis of the detector head.

1 27. The apparatus of claim 26 wherein the at least one reactance capacitor is further
2 characterized by:

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1 34. The apparatus of claim 15 wherein the detector head configuration and
2 construction for sensing the changing gap or form is further characterized by:

3 a central bore through the detector head concentric with a longitudinal axis of
4 the detector head terminating at one of the detector head, and
5 a camera mounted adjacent the other end of the central bore with a longitudinal
6 axis of the camera concentric with the longitudinal axis of the central bore for viewing the
7 changing gap or form.

1 35. The apparatus of claim 15 wherein the detector head configuration and
2 construction for sensing data defining relative movement is further characterized by:

3 a central bore through the detector head concentric with a longitudinal axis of
4 the detector head terminating at one of the detector head, and
5 a laser mounted adjacent the other end of the central bore with a longitudinal
6 axis of the laser concentric with the longitudinal axis of the central bore for viewing the
7 relative movement.

1 36. The apparatus of claim 15 wherein the generating circuit responsive to the sensed
2 changing gap or form for providing an output signal indicative of the clamp load applied to the
3 fastener is further characterized by:

4 said circuit includes a capacitance pre-amplifier.

1 37. The apparatus of claim 15 wherein the generating circuit responsive to the sensed
2 changing gap or form for providing an output signal indicative of the clamp load applied to the
3 fastener is further characterized by:

4 said circuit includes an image processor.

1 38. The apparatus of claim 15 wherein the generating circuit responsive to the sensed

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2 characterized by:

3 the deflection of an outboard annular peripheral portion of the washer.

1 46. The apparatus of claim 45 further characterized by:

2 the changing gap is between a deflected face of the washer and a datum surface
3 of the bolted joint.

1 47. The apparatus of claim 15 wherein the relatively moving portions are further
2 characterized by:

3 first and second portions of the bolt head.

1 48. The apparatus of claim 47 wherein the significant relative movement is further
2 characterized by:

3 a deflection of the first portion of the bolt head relative to the second portion of
4 the bolt head.

1 49. The apparatus of claim 48 characterized by:

2 a head shape including a central recess in an outboard face.

1 50. The apparatus of claim 49 characterized by:

2 a head shape including a concave outboard face.

1 51. The apparatus of claim 15 characterized by:

2 a head shape including an inboard annular groove in the underside of the bolt
3 head and a spigot on the top side of the bolt head with a central recess therein.

1 52. The apparatus of claim 15 further characterized by:

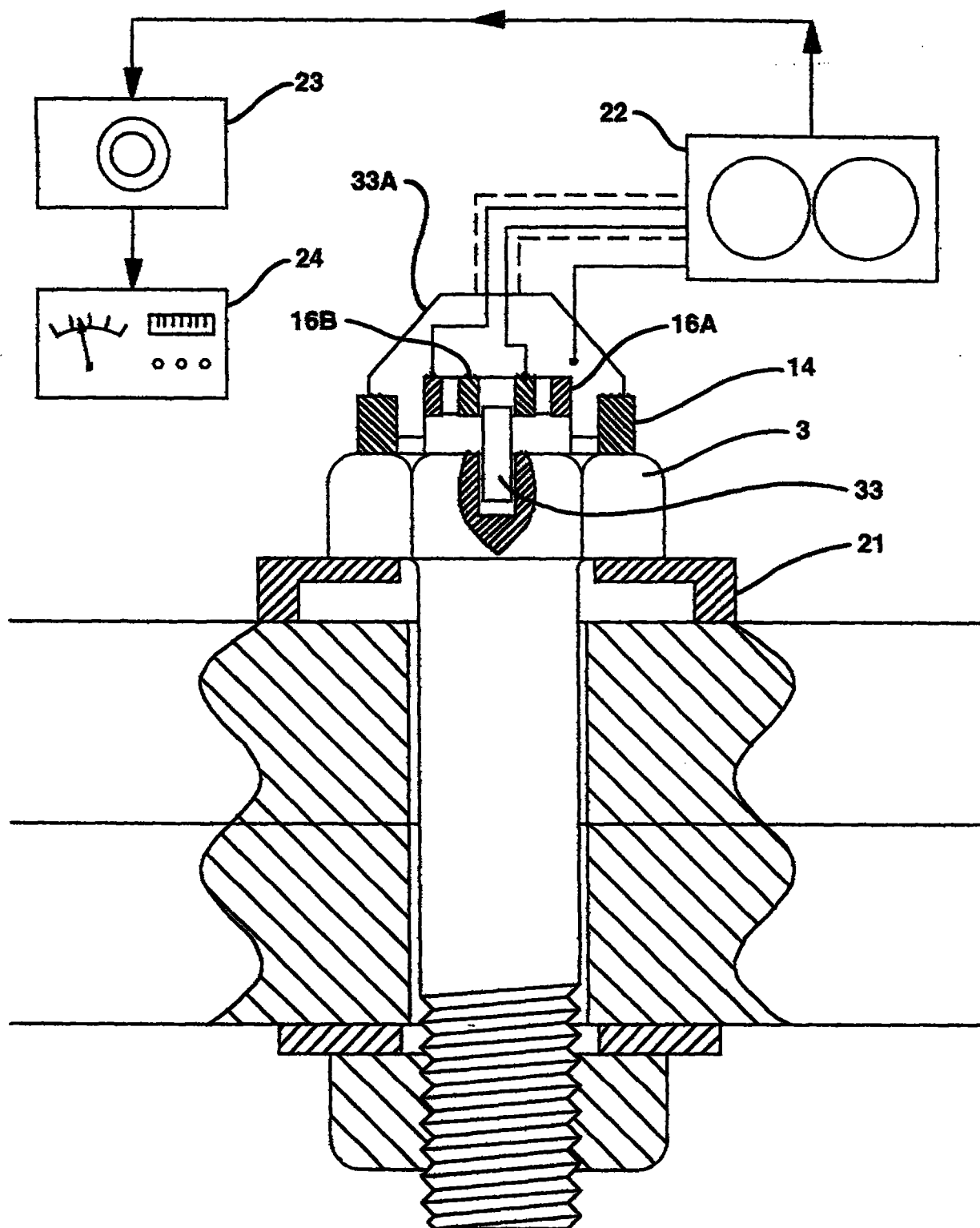
2 the changing form is the bolt head of the fastener system.

1 53. The apparatus of claim 15 further characterized by:

2 the changing form is both a bolt head and a washer of the fastener system.



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FIG. 5

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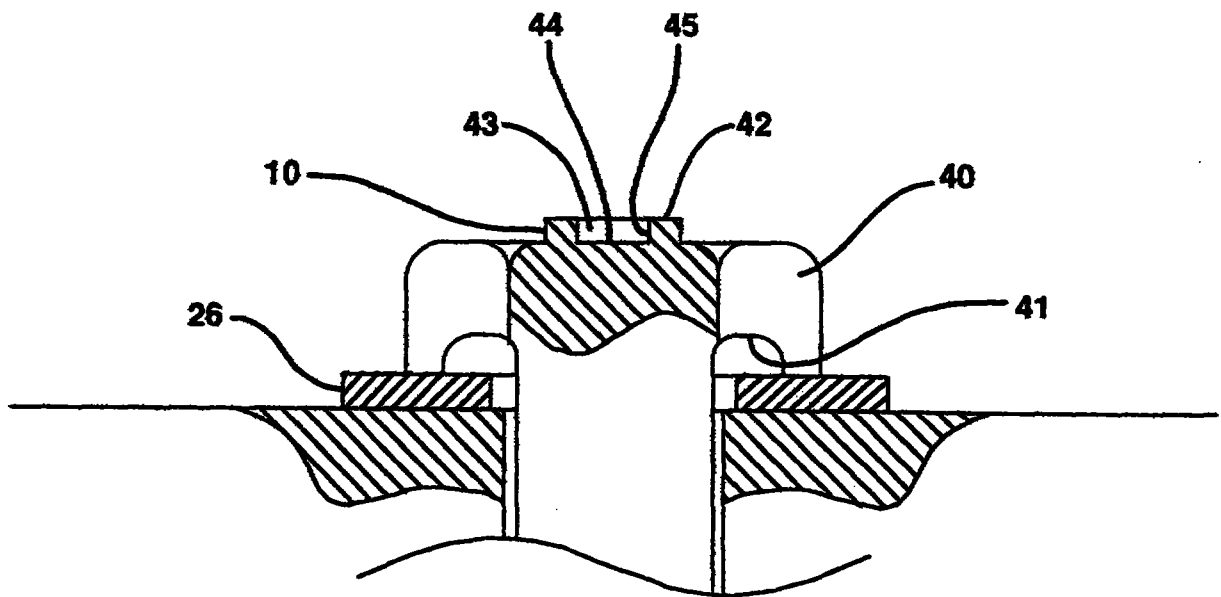


FIG. 7

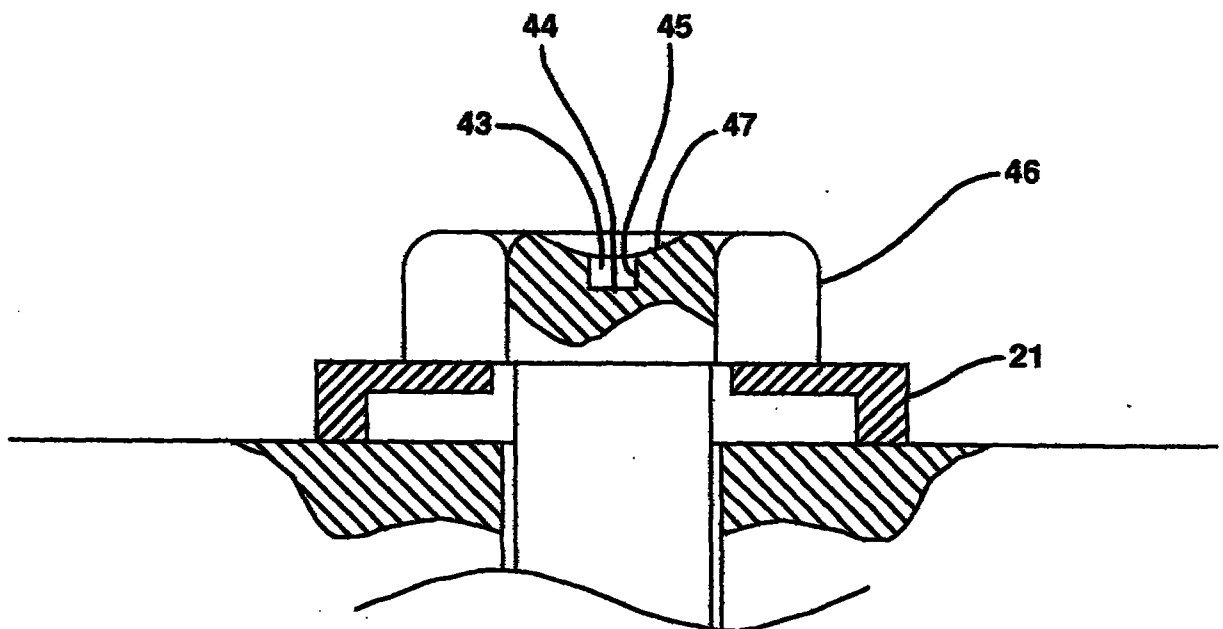


FIG. 8

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- 1 8. A device of any one of claims 62-63, 65-68, 70-74 [1-7] indicate load
2 of the fastener.
- 3 9. A device of any one of claims 62-63, 65-68, 70-74 [1-7] used to indicate
4 when the load on the fastener reaches a predetermined load.
- 5 10. A device of any one of claims 62-63, 65-68, 70-74 [1-7] used to
6 communicate with a fastener tightening mechanism.
- 7 11. A device of any one of claims 62-63, 65-68, 70-74 [1-7] used to
8 transmit a signal for remote sensing.
- 9 12. A device of any one of claims 62-63, 65-68, 70-74 [1-7] used to
10 determine that the fastener system is still within the desired design pre-load window.
- 11 13. A device of any one of claims 62-63, 65-68, 70-74 [1-7] used to
12 indicate load at elevated temperatures.
- 13 14. A device of any one of claims 62-63, 65-68, 70-74 [1-7] used to give a
14 warning or signal when a desired fastener system pre-load is reached.
- 15 20. The device of any one of claims 62-63, 65-68, 70, 72, 73 [20] further
16 characterized by:
- 17 an attachment portion having an end portion for mounting the detector
18 head atop a head of the fastener.
- 19 21. The device [apparatus] of claim 20 wherein the end portion is further
20 characterized by:
- 21 a recessed opening in the detector head along its longitudinal axis

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1 terminating in a flat end face orthogonal thereto for fitting around a spigot of the
2 fastener.

3 22. The device [apparatus] of claim 20 wherein the end portion is further
4 characterized by:

5 a recessed opening in the detector head along its longitudinal axis for
6 receiving a locator peg positionable within the portable head and the fastener head
7 for guiding the detector head into a position relative to the fastener.

8 23. The device [apparatus] of claim 20 wherein the end portion is further
9 characterized by:

10 a magnet mounted therein.

11 24. The device [apparatus] of claims 20 wherein the end portion is further
12 characterized by:

13 a friction fit with the spigot.

14 29. The apparatus of claim 73 [15] wherein the multiple first [at least one
15 reactance] capacitor plates are [is] further characterized by:

16 a cylindrically shaped capacitor mounted concentrically with a ring
17 shaped capacitor.

18 30. The apparatus of claim 29 wherein the cylindrically shaped capacitor
19 mounted concentrically with the ring shaped capacitor is further characterized by:

20 a bottom face of each capacitor is equally spaced from an end plane of
21 the detector head orthogonal to the longitudinal axis of the detector head.

22 31. The apparatus of claim 29 wherein the cylindrically shaped capacitor

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1 mounted concentrically with the ring shaped capacitor is further characterized by:

2 a bottom face of each capacitor is spaced apart from each other and
3 from an end plane of the detector head orthogonal to the longitudinal axis of the
4 detector head.

5 32. The apparatus of claim 72 [15] wherein the at least one reactance
6 capacitor is further characterized by:

7 a pair of concentrically mounted ring capacitors.

8 33. The apparatus of claim 32 wherein the pair of ring capacitors is further
9 characterized by:

10 a bottom face of each capacitor is equally spaced from an end plane of
11 the detector head orthogonal to the longitudinal axis of the detector head.

12 62. A load measuring apparatus characterized by:

13 an externally mounted camera or laser supported in a portable sensing
14 head and configured and constructed for sensing a changing gap, between, on the
15 one hand, an end face of a bar in and anchored to a base of a bore in a bolt head
16 and shank of a fastener system and, on the other hand, a datum face of the bolt
17 head of the fastener system, caused by longitudinal extension of the shank under
18 strain relative to the datum face on the bolt head without contacting the relatively
19 moving portions of the fastener system, and

20 a generating circuit responsive to the sensed changing gap for
21 providing an output signal indicative of a clamp load applied to the fastener system.

22 63. A load measuring apparatus characterized by:

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1 a camera or laser, externally removably positionable and supportable on a portable
2 detector head atop a fastener system to be visually or light beam coupled,
3 respectively, to a bolt head of the fastener system along an axis parallel to the
4 longitudinal axis of the fastener system configured and constructed for sensing a
5 changing form caused by a deflection of a first portion of the bolt head relative to a
6 second portion of the bolt head when the fastener is under strain without contacting
7 the sensed portions of the bolt head, and

8 a generating circuit responsive to the sensed changing form for
9 providing an output signal indicative of a clamp load applied to the fastener.

10 65. The apparatus of claim 63[4] or 70 further characterized by:
11 a bolt head shape including a central recess in an outboard face.

12 66. The apparatus of claim 63[4] or 70 further characterized by:
13 a bolt head shape including a concave outboard face.

14 67. The apparatus of claim 63[4] or 70 further characterized by:
15 a bolt head shape including an inboard annular groove in the
16 underside of the bolt head and a spigot on the top side of the bolt head with a
17 central recess therein.

18 68. The device of claim 63 or 70 further characterized by the changing
19 form is a bolt head and a washer combination of the fastener system under strain.

20 70. A measuring device characterized by a portable sensing head, having
21 a first cylindrical capacitor plate fixedly supported in the portable sensing head,
22 externally removably positionable atop an integral head portion of a fastener



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1 system, and constructed and configured for directly capacitively coupling to a
2 second cylindrical capacitor plate movably supported in the fastener system to form
3 a capacitor for use in a circuit for detecting a changing gap, measured from a
4 reference datum plane of the bolt head of the fastener system, the changing gap
5 being produced in the fastener when the fastener system is under strain and
6 causing a variance in the capacitive reactance of the detection circuit without the
7 portable sensing head contacting the second movable capacitor plate.

8 71. A measuring device characterized by a sensing circuit having a first
9 capacitor plate externally removably positionable beside a deflectable washer
10 mounted between an integral head portion of a fastener system and a workpiece,
11 and constructed and configured for directly capacitively coupling to a second
12 capacitor plate movably supported on the washer of the fastener system to form a
13 capacitor for use in a circuit for detecting a changing gap between the first and
14 second capacitor plates, the changing gap being produced when the fastener
15 system is under strain and causing a variance in the capacitive reactance of the
16 detection circuit without the sensing circuit contacting the second movable capacitor
17 plate

18 72. A measuring device characterized by a portable sensing head, having
19 multiple first capacitor plates fixedly supported in the portable sensing head,
20 externally removably positionable atop an integral head portion of a fastener
21 system, and constructed and configured for directly capacitively coupling each of the
22 first capacitor plates to a common second capacitor plate movably supported on the





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1 fastener system to form multiple capacitors for use in a circuit for detecting a
2 changing form of the bolt head of the fastener system, the changing form being
3 produced in the fastener when the fastener system is under strain and causing a
4 variance in the capacitive reactance of the detection circuit.

5 73. A measuring device characterized by a portable sensing head, having
6 first, spaced apart, capacitor plates fixedly supported in the portable sensing head,
7 externally removably positionable atop an integral head portion of a fastener
8 system, and constructed and configured for directly capacitively coupling the first
9 capacitor plates to a second capacitor plate a portion of which is movably supported
10 in the fastener system to form multiple capacitors for use in a circuit for detecting a
11 changing gap, measured from a reference datum plane of the bolt head of the
12 fastener system, the changing gap being produced in the fastener when the fastener
13 system is under strain and causing a variance in the capacitive reactance of the
14 detection circuit without the portable sensing head contacting the second movable
15 capacitor plate.

16 74. A measuring device characterized by a portable camera or laser
17 which, when externally removably positioned and supported alongside of a bolt
18 head and deflectable washer of a fastener system and visually or light beam
19 coupled, respectively, to the bolt head and washer along an axis cutting the
20 longitudinal axis of the fastener system at a substantial angle, detects a changing
21 gap or form produced in the fastener when the system is under strain without
22 contacting the sensed portions of the fastener undergoing significant relative

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Claims



1. A load measuring apparatus comprising:

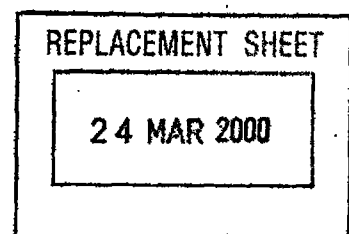
an externally mounted camera or laser supported in a portable sensing head and configured and constructed for sensing a changing gap, between, on the one hand, an end face of a bar in and anchored to a base of a bore in a bolt head and shank of a fastener system and, on the other hand, a datum face of the bolt head of the fastener system, caused by longitudinal extension of the shank under strain relative to the datum face on the bolt head without contacting the relatively moving portions of the fastener system, and

a generating circuit responsive to the sensed changing gap for providing an output signal indicative of a clamp load applied to the fastener system.

2. A load measuring apparatus comprising:

a camera or laser, externally removably positionable and supportable on a portable detector head atop a fastener system to be visually or light beam coupled, respectively, to a bolt head of the fastener system along an axis parallel to the longitudinal axis of the fastener system configured and constructed for sensing a changing form caused by a deflection of a first portion of the bolt head relative to a second portion of the bolt head when the fastener is under strain without contacting the sensed portions of the bolt head, and

a generating circuit responsive to the sensed changing form for providing an output signal indicative of a clamp load applied to the fastener.

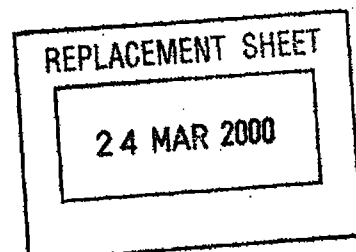




3. A measuring device comprising a portable sensing head, having a first cylindrical capacitor plate fixedly supported in the portable sensing head, externally removably positionable atop an integral head portion of a fastener system, and constructed and configured for directly capacitively coupling to a second cylindrical capacitor plate movably supported in the fastener system to form a capacitor for use in a circuit for detecting a changing gap, measured from a reference datum plane of the bolt head of the fastener system, the changing gap being produced in the fastener when the fastener system is under strain and causing a variance in the capacitive reactance of the detection circuit without the portable sensing head contacting the second movable capacitor plate.

4. A measuring device comprising a sensing circuit having a first capacitor plate externally removably positionable beside a deflectable washer mounted between an integral head portion of a fastener system and a workpiece, and constructed and configured for directly capacitively coupling to a second capacitor plate movably supported on the washer of the fastener system to form a capacitor for use in a circuit for detecting a changing gap between the first and second capacitor plates, the changing gap being produced when the fastener system is under strain and causing a variance in the capacitive reactance of the detection circuit without the sensing circuit contacting the second movable capacitor plate.

5. A measuring device comprising a portable sensing head, having multiple first capacitor plates fixedly supported in the portable sensing head, externally removably positionable atop an integral head portion of a fastener





system, and constructed and configured for directly capacitively coupling each of the first capacitor plates to a common second capacitor plate movably supported on the fastener system to form multiple capacitors for use in a circuit for detecting a changing form of the bolt head of the fastener system, the changing form being produced in the fastener when the fastener system is under strain and causing a variance in the capacitive reactance of the detection circuit.

6. A measuring device comprising a portable sensing head, having first, spaced apart, capacitor plates fixedly supported in the portable sensing head, externally removably positionable atop an integral head portion of a fastener system, and constructed and configured for directly capacitively coupling the first capacitor plates to a second capacitor plate a portion of which is movably supported in the fastener system to form multiple capacitors for use in a circuit for detecting a changing gap, measured from a reference datum plane of the bolt head of the fastener system, the changing gap being produced in the fastener when the fastener system is under strain and causing a variance in the capacitive reactance of the detection circuit without the portable sensing head contacting the second movable capacitor plate.

7. A measuring device comprising a portable camera or laser which, when externally removably positioned and supported alongside of a bolt head and deflectable washer of a fastener system and visually or light beam coupled, respectively, to the bolt head and washer along an axis cutting the longitudinal axis of the fastener system at a substantial angle, detects a changing gap or form produced in the fastener when the system is under strain without contacting the



sensed portions of the fastener undergoing significant relative movement.

8. The device of claims 3, 5 or 6 further comprising:
an attachment portion having an end portion for mounting the detector head atop a head of the fastener.

9. The device of claim 8 wherein the end portion further comprises:
a recessed opening in the detector head along its longitudinal axis terminating in a flat end face orthogonal thereto for fitting around a spigot of the fastener.

10. The device of claim 8 wherein the end portion further comprises:
a magnet mounted therein.

11. The device of claims 3, 5 or 6 wherein the at least one reactance capacitor further comprises:

a pair of concentrically mounted ring capacitors.

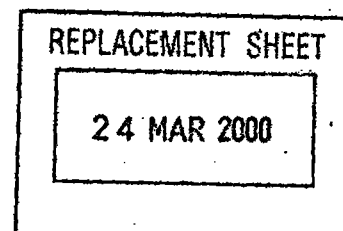
12. The device of claim 11 wherein the pair of ring capacitors further comprises:

a bottom face of each capacitor is equally spaced from an end plane of the detector head orthogonal to the longitudinal axis of the detector head.

13. The device of claims 5 or 6 wherein the multiple first capacitor plates further comprise:

a cylindrically shaped capacitor mounted concentrically with a ring shaped capacitor.

14. The device of claim 13 wherein the cylindrically shaped capacitor





mounted concentrically with the ring shaped capacitor further comprises:

a bottom face of each capacitor is equally spaced from an end plane of the detector head orthogonal to the longitudinal axis of the detector head.

15. The device of claim 13 wherein the cylindrically shaped capacitor mounted concentrically with the ring shaped capacitor further comprises:

a bottom face of each capacitor is spaced apart from each other and from an end plane of the detector head orthogonal to the longitudinal axis of the detector head.

