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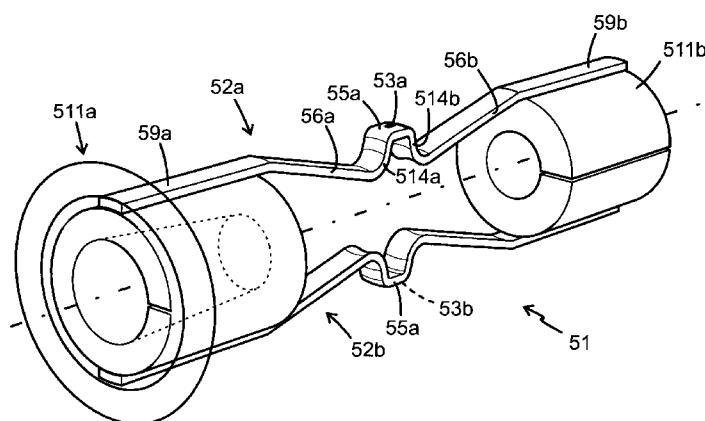


FIG. 1

(57) Abstract: The invention relates to a measuring device for measurement of the load on a hollow shaft perpendicular to the latter's centreline (C). The measuring device comprises a load cell (51) with a fixed element (52a, 52b) on which 5 elongation sensors (53a, 53b) are each fastened on a respective measuring portion (55a, 55b). The fixed element is provided with fastening means (511a, 511b) for fastening it in the shaft. According to the invention the measuring portion (55a, 55b) of the fixed element (52a, 52b) is connected to the respective fastening means via a bending resistance-reducing section (56a, 514a, 56b, 514b) of the fixed element, which section comprises at least one portion which does not run axially. The invention relates also to a method for measurement of the shaft load with such a measuring device.

MEASURING DEVICE FOR MEASUREMENT OF THE LOAD ON A HOLLOW SHAFT AND METHOD FOR SUCH MEASUREMENT

5 **Field of the invention**

The present invention relates in a first aspect to a measuring device for measurement of the load on a hollow shaft, perpendicular to the centreline of the shaft, which measuring device comprises a load cell with at least one fixed element and at least one elongation sensor, such that the fixed element is
10 provided with fastening means for fastening in the hollow shaft and that an elongation sensor is attached to a measuring portion of each fixed element.

The invention relates also to a hollow shaft provided with a measuring device according to the present invention, and to a vehicle provided with such a hollow shaft.

15 A second aspect of the invention relates to a method for measurement of the load on a hollow shaft, perpendicular to the centreline of the shaft, whereby the load is measured by a measuring device with a load cell which comprises a fixed element and at least one elongation sensor, such that the load cell is fastened within the hollow shaft and that the elongation sensor is fastened to a measuring
20 portion of each fixed element.

Unless expressly indicated otherwise, terms such as axial, radial etc. in the present application text relate to the centreline of the hollow shaft for which the measuring device is intended to be used.

25 **Background to the invention**

In many contexts it is necessary to measure shaft loads. This may entail measuring the shaft load of an industrial machine, e.g. a machine tool, a paper machine, a turbine etc. It is particularly necessary to measure the load for a trunnion of a vehicle wheel suspension, e.g. a balance tandem, or of a tilt trunnion
30 on a vehicle. Particularly on a truck, it is important to determine whether prescribed axle load limits are complied with. The invention is primarily intended for applications concerning vehicles, although other kinds of applications are within its scope.

There are many kinds of devices and methods for measurement and calculation of shaft loads, both indirect and direct. A commonly applied method is to use elongation sensors to read off the shaft deflection and use the resulting measured values to determine the load. To this end, the elongation sensors may
5 be fastened directly on the shaft. In the case of a hollow shaft, it is often advantageous for the elongation sensors to be situated inside it, since an external location may be impractical, e.g. for environmental reasons. In such cases the elongation sensors may be fastened directly on the shaft, e.g. by adhesive attachment. However, internal locations are quite time-consuming, and handling a
10 shaft provided with a sensor is troublesome during a production process. This leads to the elongation sensors being fastened to a special load cell which is fitted inside the shaft. Examples of this latter method are described inter alia in US 4203318, US 4429579, US 4526044, US 4576053, US 5402689, EP 227597 and SE7809077-6.

15 A further advantage of a separate load cell is that it can be fitted at a late stage in the production process, it can be post-fitted and it is easy to replace.

A measuring device with such a load cell may therefore perform the function of overload protection and load weigher for a vehicle. It may also be used for load sensing on the brake in the case of rigid suspensions based on leaf
20 springs.

As well as the known measuring devices, the general principle of the patent specifications mentioned above is that measurement is carried out on some other element than the actual shaft and that the elongation sensors are situated on a smaller-diameter cylindrical surface which is concentric with the shaft. When the
25 shaft is deformed by external load, the element with the cylindrical surface will become deformed to a lesser extent than the shaft, resulting in the elongation sensors producing a measured value which is correspondingly downscaled as compared with elongation sensors fastened directly on the shaft.

Prior art concentrically configured load cells require a considerable
30 clamping force for them to function in all operating conditions. This may be complicated to achieve, involving risk of the connection becoming unfastened. To ensure that the connection does not become unfastened or subject to microslip, the diameter of the portion of the measuring element where the elongation sensor is applied may be reduced to reduce the load on the connection, as a result of the

consequently reduced axial forces, but it follows that the measurement signal is greatly reduced since the actual elongation during bending is proportional to the distance from the centreline.

5 **Summary of the invention**

The object of the present invention is to overcome said problems of the state of the art and thereby make it possible to achieve good measurement precision when measuring the load on a shaft by using a measuring cell with elongation sensors, and at the same time to avoid large axial lateral forces which
10 might unfasten the connection.

This object is achieved according to the first aspect of the invention by a measuring device of the kind indicated in the introduction comprising the special features that the measuring portion is connected to the respective fastening means via a bending resistance-reducing section of the fixed element, which
15 bending resistance-reducing section comprises at least one portion of the fixed element which does not run axially.

This configuration means that the fixed element is flexible and deformable so that no major lateral forces are propagated to the fastening means. The resulting built-in weakness eliminates or at least reduces the risk of the fastening
20 means becoming unfastened by large lateral forces. The fact that there is therefore no need to relocate the elongation sensor on a small radius to reduce the lateral forces makes it possible to achieve a good measurement signal. The bending resistance-reducing section with portions directed non-axially serves as a kind of bellows so that the load cell will not present any appreciable resistance
25 when the shaft bends.

According to a further preferred embodiment, the portion running non-axially forms an angle of more than 30° with the centreline.

The greater the obliquity, i.e. the angle to the centreline, the more accentuated becomes the bellows effect, i.e. the reduction in bending resistance.
30 At obliquities beyond the angle value indicated, the effect becomes obvious, still more so if the angle is at least 45°.

According to a further preferred embodiment, said portion or portions are perpendicular to the centreline. This is optimum from the above point of view, so a

perpendicular arrangement is appropriate if the application does not involve special conditions calling for compromise with other constructional requirements.

According to a further preferred embodiment, the measuring portion is adapted to being situated at a distance from the inside periphery of the hollow shaft which is shorter than the distance from the measuring portion to the centreline.

The further away from the centreline the measuring portion is situated, the more accurate the measured value becomes. Positioning according to this embodiment is therefore advantageous.

According to a further preferred embodiment, the measuring portion is adapted to being situated at a distance from the inside periphery of the hollow shaft which is shorter than 10% of the inside diameter of the hollow shaft.

The fact that the measuring portion with the elongation sensor is thus situated close to the inside periphery of the shaft where the deformation is greatest enhances still more markedly the accuracy of the measurement signal. For maximum accuracy, said distance is preferably shorter than 5% of the inside diameter, or perhaps shorter than 2%. The bending resistance-reducing section does in fact result in such optimum positioning without large lateral forces being generated in relation to the fastening means.

According to a further preferred embodiment, the measuring portion runs axially and is connected at each end to a radially directed portion of the fixed element.

This is a constructionally simple configuration which also effectively achieves the desired flexibility of the fixed element.

According to a further preferred embodiment, the fixed element takes the form of an axially oriented elongate element with at least one radial bulge which comprises the measuring portion.

This embodiment likewise combines constructional simplicity with effective flexibility. The bulge may be radially outwards or inwards. It is preferably oriented outwards, since this results in coming closer to the inside periphery of the shaft, with the consequent advantages described above.

According to a further preferred embodiment, the load cell comprises two diametrically opposite fixed elements each provided with an elongation sensor.

The result is complementary measured values, one representing an elongation and the other a contraction. In combination they result in greater accuracy of the measured value.

According to a further preferred embodiment, the fixed element takes the form of a planar panel adapted to being fitted in a hollow shaft in such a way that the panel is in a plane which comprises the centreline of the shaft.

This version provides the fixed element with constructional simplicity resulting in simple and distinct fitting in a correct position in the shaft. The embodiment also affords manufacturing advantages in that the fixed element is easy to stamp or cut from a metal plate.

According to a further preferred embodiment, the fastening means of the fixed element comprise pressing surfaces situated at each end of it and a press device for pushing the pressing surfaces radially outwards.

This version makes it easy for the load cell to be fastened within the shaft without the shaft having to be provided with special fastening devices. This means that the load cell can be used on shafts which are not prepared for load measurement in this way. Fitting the fixed element in the shaft also becomes distinct and safe so that the relation between deflection of the shaft and the bending pattern of the fixed element becomes clear.

According to a further preferred embodiment, the press device comprises a conical male element and a conical female element adapted to cooperating with one another, such that the female element has its outside connected to the fixed element radially within the pressing surfaces and that the press device further comprises an axial movement mechanism for axial movement of the male element in the female element.

This constructional solution combines simplicity of fitting the load cell with secure fastening of it. The axial movement mechanism takes the form with advantage of an axial screw.

According to a further preferred embodiment, the male portion is hollow to allow a shaft to pass through it.

The measuring cell is thus suitable for an application where there is need for such an inner shaft, e.g. a driveshaft.

According to a further preferred embodiment, at least the bending resistance-reducing section of the fixed element is made of material with an elasticity modulus which is less than half of the elasticity modulus of steel.

The elasticity modulus is therefore less than 100 GPa. The fact that said
5 section has a relatively low elasticity modulus increases its bendability and the consequent reduction of the lateral forces. A suitable material may be aluminium or a polymer. The whole fixed element is preferably made of such material, as it facilitates manufacture.

The invention relates also to a hollow shaft provided with the invented
10 measuring device. According to a preferred embodiment, the invented hollow shaft is a hollow shaft for a vehicle. The invention relates also to a vehicle provided with a hollow shaft according to the invention.

The second aspect of the invention achieves the stated object in that a method of the kind indicated in the introduction comprises the special measures
15 that the measuring portion is connected to the respective fastening means via a bending resistance-reducing section of the fixed element and that the bending resistance-reducing section is provided with a portion which runs non-axially.

According to a preferred embodiment of the invented method, the method is applied on a hollow shaft for a vehicle.

20 According to further preferred embodiments of the invented method, it is applied by means of a measuring device according to the invention, particularly according to any of its preferred embodiments.

The invented hollow shaft, the invented vehicle and the invented method afford advantages of similar kinds to the invented measuring device and its
25 preferred embodiments, advantages described above.

The preferred embodiments of the invention indicated above are indicated in the dependent claims. It should be noted that further preferred embodiments of the invention may take the form of every possible combination of the preferred
30 embodiments indicated above and every possible combination of them and features mentioned in the description of examples below.

The invention is explained in more detail by the detailed description of embodiment examples of it set out below with reference to the attached drawings.

Brief description of the drawings

Fig. 1 is a perspective view of the load cell for a measuring device according to the invention.

Fig. 2 is a section through the load cell for a measuring device according to another embodiment example of the invention.

Fig. 3 is a schematic illustration of a detail of the load cell in Fig. 1.

Fig. 4 is a schematic illustration of a detail corresponding to Fig. 3 but according to an alternative embodiment example.

Fig. 5 is a perspective view of the load cell for a measuring device according to a further embodiment example of the invention.

Fig. 6 is a side view of the load cell in Fig. 5.

Fig. 7 is a hollow shaft provided with a load cell according to Figs. 5 and 6.

Fig. 8 is a vehicle provided with a shaft according to the invention.

Figs. 9-11 illustrate schematically further alternative embodiment examples of a load cell according to the invention.

Description of embodiment examples

Fig. 1 illustrates the load cell 51 for a measuring device according to the invention. The load cell 51 has two fixed elements 52a, 52b arranged diametrically relative to the centreline C of the hollow shaft (not depicted) in which the load cell is fitted. The fixed elements are clamped in the hollow shaft by fastening means 59a, 59b, 511a, 511b. Each fixed element 52a, 52b has an elongation sensor 53a, 53b attached to it.

The upper fixed element 52a in the diagram takes the form of a striplike element running substantially axially and made of, for example, aluminium, with an outward bulge at the middle. Each end portion of the fixed element 52a is provided with a pressing surface 59a, 59b. The pressing surfaces 59a, 59b are pressed to contact with the inside of the hollow shaft by a conical clamping connection 511a, 511b at each end. The configuration of the conical clamping connections is described in more detail with respect to the embodiment example illustrated in Figs. 5 and 6. The fixed element 52a thus has its ends clamped in the hollow shaft.

The fixed element 52a has running from each contact surface 59a, 59b a respective portion 56a, 56b which is slightly angled inwards so as to be clear of

the inside of the hollow shaft. At each inner end of the slightly angled portions 56a, 56b, the fixed element 52a continues with an almost radially directed portion 514a, 514b leading to a central portion 55a which constitutes the fixed element's measuring portion 55a. The latter is situated a short distance inside the hollow shaft and runs axially. This measuring portion 55a has the elongation sensor 53a attached to it. The lower fixed element 52b in the diagram is configured in the same way.

When the shaft in which the load cell 51 is fitted is subjected to load from above, the shaft will bend downwards. The measuring portion 55a will undergo corresponding downward bending, resulting in a contraction of the elongation sensor 53a which serves as a measurement of the load. The downward bending of the measuring portion 55a results in an axial force in each direction. The bellows-like geometry of the fixed element 52a makes it readily capable of elastic bending on either side of the measuring portion 55a, which largely absorbs these axial forces so that only a relatively small proportion of them is passed on to the fastening devices. In this load situation, the measuring portion 55b on the corresponding fixed element 52b will be stretched, resulting in a corresponding stretching of its elongation sensor 53b. The device depicted in Fig. 1 may alternatively be provided with fixed elements on only one side.

Fig. 2 depicts an embodiment example which mainly differs from that in Fig. 1 in the configuration of the conical clamping connection, which in this case is hollow to allow an inner shaft 102, e.g. a driveshaft, to pass through. The clamping connection comprises a conical female part 611a and a conical male part 612a which are pressed together between an inner flange 617a of a sleeve 615a and a nut 616a which is tightenable on an external thread on the sleeve 615a. Tightening the nut 616a causes the pressing surface 69a of the fixed element 62a to press against the inside surface of the hollow shaft 101.

Fig. 3 illustrates schematically and exaggeratedly how the fixed element 52b in the device in Fig. 1 is deformed by bending of the shaft, in this case by a load directed upwards.

Fig. 4 similarly illustrates deformation of the fixed element 72a in a modified version. The fixed element 72a differs from that previously illustrated in that the measuring portion 75a with elongation sensor 73a is situated radially within the portions which run towards the sides, i.e. on an inward bulge instead of

on an outward bulge as illustrated above. The inward bulge needs to be relatively small so that the bending of the measuring portion 75a does not deviate so much from the bending of the hollow shaft, i.e. the dimension h needs to be small. The diagram also illustrates lateral forces F which occur when the fixed element is bent. As described in more detail above, these lateral forces are relatively small owing to the geometry of the fixed element.

The measuring device illustrated in Figs. 5 and 6 is provided with a load cell 1 comprising a fixed element 2, elongation sensors 3a, 3b and fastening means 11, 12, 9a, 9b, 10a, 10b. The fixed element 2 is a thin panel 2 stamped out from sheet aluminium. The panel 2 is intended to be fitted within a hollow shaft so that it is situated diametrically in a plane through the centreline C of the shaft in which it is fitted.

The panel 2 has a centrally situated measuring portion 5 flanked by two side portions 4a, 4b. The measuring portion 5 is a narrow strip which is perpendicular to the centreline C and has its ends almost reaching the inside periphery of the hollow shaft. An elongation sensor 3a, 3b is attached to each axial side of the middle portion 5. The elongation sensors 3a, 3b are connected by undepicted lines to a recording unit for recording measured values from the elongation sensors and processing those values to produce information about the load to which the shaft is subjected.

The measuring portion 5 has its one end connected to one side portion 4a and its other end connected to the other side portion 4b. Immediately adjacent to the middle portion 5, each side portion has a triangular section 6a, 6b converging towards the measuring portion 5. Each side part 4a, 4b has outside the triangular section a rectangular section 7a, 7b with consequently parallel outer edges 9a, 10a, 9b, 10b which form part of the fastening means. Each side portion has in the rectangular section 7a, 7b a recess 8a, 8b.

The recesses 8a, 8b are each adapted to accommodating a respective separating/parting device 11, 12 (only one of which appears in the drawings). Each of these devices comprises a slit sleeve 11 with a conical inside surface which narrows towards the middle of the fixed element, and a conical plug 12 with an outside taper corresponding to the inside taper of the sleeve 11. An axial movement mechanism 15 in the form of a screw mechanism 15 can be used to press the plug 12 into the sleeve 11. Screwing the plug 12 in causes the sleeve

11 to expand and push outwards the tips of the rectangular section 7a, 7b on either side of the respective recess 8a, 8b. Thus the pressing surfaces 9a, 10a, 9b, 10b formed by the edges of the panel 2 on the respective rectangular sections 7a, 7b will be pressed against the inside of the hole in the shaft so that the panel is
5 fixed in position.

The fastening of the fixed element 2 may of course be effected in many other alternative ways than by clamping cones such as described above, e.g. it may be fastened by shrink fit.

On each triangular section 6a, 6b of the respective side portions 4a, 4b,
10 the edge 13a, 13b which is opposite to the edge which runs obliquely is somewhat countersunk relative to the respective adjoining edges which form the pressing surfaces 9a, 9b. This means that the measuring portion 5 does not have its ends fixed to the shaft, making it easier for it to deflect. The deflection is also facilitated by the fact that the web section 14a, 14b connecting the measuring portion 5 to
15 the respective triangular section is narrow.

Fig. 7 depicts a hollow shaft 101 in which a load cell 1 of the kind depicted in Figs. 1 and 2 is fitted. The load cell may instead be taken to be of the kind illustrated in any of Figs. 1-4.

Fig. 8 depicts schematically a truck 103 provided with a shaft 101 which
20 has a load cell 1 of the kind depicted in Fig. 7 fitted in it.

Some further alternative embodiment examples of the load cell for a measuring device according to the invention are depicted schematically in Figs. 9-11, which each show the load cell fitted in a hollow shaft 101.

In Fig. 9, the fixed element 22 of the load cell 21 takes the form of a thin
25 panel similar to that in Figs. 5 and 6. Its measuring portion 25 to which the elongation sensors 23a, 23b are fastened forms in this case an angle of 45° with the shaft centreline C and therefore extends diagonally between the two side portions 24a, 24b.

In Fig. 10, the measuring portion 35 is perpendicular to the centreline C,
30 as in Figs. 5 and 6. Unlike Figs. 5 and 6, however, the side portions have no triangular section immediately adjacent to the measuring portion 35 but are in this case of rectangular configuration. The measuring portion 35 is connected to each side portion 34a, 34b by a respective web section 314a, 314b.

In Fig. 11 the load cell takes the form of a short tube 42 with zigzag profile and the elongation sensors 43a, 43b are situated on opposite obliquely positioned sides of a ridge of the tube profile. The tube 42 has both of its ends fixed to the shaft 101.

CLAIMS

1. A measuring device for measurement of the load on a hollow shaft (101), perpendicular to the centreline (C) of the hollow shaft, which device comprises a
5 load cell (1, 51, 61) with at least one fixed element (2, 52a, 52b, 62a) and at least one elongation sensor (3a, 3b, 53a, 53b, 63a), which fixed element is provided with at least one fastening means (9a, 10a, 9b, 10b, 11, 12, 59a, 59b, 511a, 511b, 69a, 611a, 612a, 615a, 616a) for fastening in the hollow shaft (101), and which at least one elongation sensor is attached to a measuring portion (5, 55a, 55b, 65a)
10 of each fixed element, **characterised** in that the measuring portion (5, 55a, 55b, 65a) is connected to the respective fastening means via a bending resistance-reducing section (6a, 6b, 14a, 14b, 56a, 56b, 514a, 514b, 66a, 66b, 614a, 614b) of the fixed element, which bending resistance-reducing section comprises at least one portion which does not run axially of the fixed element.
- 15 2. A measuring device according to claim 1, **characterised** in that each said portion not running axially forms an angle of more than 30° with the centreline (C).
3. A measuring device according to claim 2, **characterised** in that each said portion not running axially is substantially perpendicular to the centreline (C).
4. A measuring device according to any one of claims 1-3, **characterised** in
20 that the measuring portion (55a, 55b, 65a) is adapted to being situated at a distance from the inside periphery of the hollow shaft which is shorter than the distance between the measuring portion and the centreline (C).
5. A measuring device according to claim 4, **characterised** in that the measuring portion (55a, 55b, 65a) is adapted to being situated at a distance from
25 the inside periphery of the hollow shaft which is shorter than 10% of the inside diameter of the hollow shaft.
6. A measuring device according to any one of claims 1-5, **characterised** in that the measuring portion (55a, 55b, 65a) runs axially and is connected at each end to a portion directed radially inwards (514a, 514b, 614a, 614b) of the fixed
30 element.
7. A measuring device according to any one of claims 1-6, **characterised** in that the fixed element (52a, 52b) takes the form of an axially oriented elongate striplike element with at least one radially directed bulge (55a, 514a, 514b) which comprises said measuring portion (55a)

8. A measuring device according to claim 7, **characterised** in that said bulge (55a, 514a, 514b) is directly radially outwards.
9. A measuring device according to any one of claims 1-8, **characterised** in that the load cell (51) comprises two diametrically opposite fixed elements (52a, 52b) each provided with an elongation sensor (53a, 53b).
10. A measuring device according to any one of claims 1-6, **characterised** in that the fixed element (2) takes the form of a planar panel (2) adapted to being fitted in a hollow shaft (101) in such a way that the panel (2) is in a plane which comprises the centreline (C) of the shaft (101).
11. A measuring device according to any one of claims 1-10, **characterised** in that the fastening means of the fixed element (2, 52a, 52b, 62a) comprise pressing surfaces (9a, 10a, 9b, 10b, 59a, 59b, 69a) of the fixed element which are situated at each end of the fixed element, and a press device (11, 12, 511a, 511b, 611a, 612a, 615a, 616a) for pushing the pressing surfaces radially outwards.
12. A measuring device according to claim 11, **characterised** in that the press device comprises a conical male part (12, 612a) and a conical female part (11, 611a) adapted to cooperating with one another, said female part (11, 611a) having its outside connected to the fixed element radially within the respective pressing surface, and further comprises an axial movement mechanism (15, 615a, 616a) for axial movement of the male part in the female part.
13. A measuring device according to claim 12, **characterised** in that the male part (612a) is hollow to allow a shaft (102) to pass through the male part.
14. A measuring device according to any one of claims 1-13, **characterised** in that at least the fixed element's bending resistance-reducing section (6a, 6b, 14a, 14b, 56a, 56b, 514a, 514b, 66a, 66b, 614a, 614b) is made of material whose elasticity modulus is less than half of the elasticity modulus of steel.
15. A hollow shaft **characterised** in that the hollow shaft (101) is provided with a measuring device according to any one of claims 1-14.
16. A hollow shaft according to claim 15, **characterised** in that it is a hollow shaft for a vehicle (103).
17. A vehicle **characterised** in that the vehicle (103) comprises at least one hollow shaft (101) according to claim 16.
18. A method for measurement of the load on a hollow shaft (101), perpendicular to the centreline (C) of the hollow shaft, whereby the load is

- measured with a measuring device with a load cell (1, 51, 61) with at least one fixed element (2, 52a, 52b, 62a) and at least one elongation sensor (3a, 3b, 53a, 53b), the load cell being fastened within the hollow shaft (101) and the at least one elongation sensor being fastened to a measuring portion (5, 55a, 55b, 65a) of
- 5 each fixed element, **characterised** in that the measuring portion (5, 55a, 55b, 65a) is connected to the respective fastening means via a bending resistance-reducing section (6a, 6b, 14a, 14b, 56a, 56b, 514a, 514b, 66a, 66b, 614a, 614b) of the fixed element and that the bending resistance-reducing section is provided with a portion which does not run axially.
- 10 19. A method according to claim 18, **characterised** in that it is applied for measurement of the load on a hollow shaft (101) for a vehicle (103).
20. A method according to either of claims 18 and 19, **characterised** in that the method involves using a measuring device according to any one of claims 1-14.

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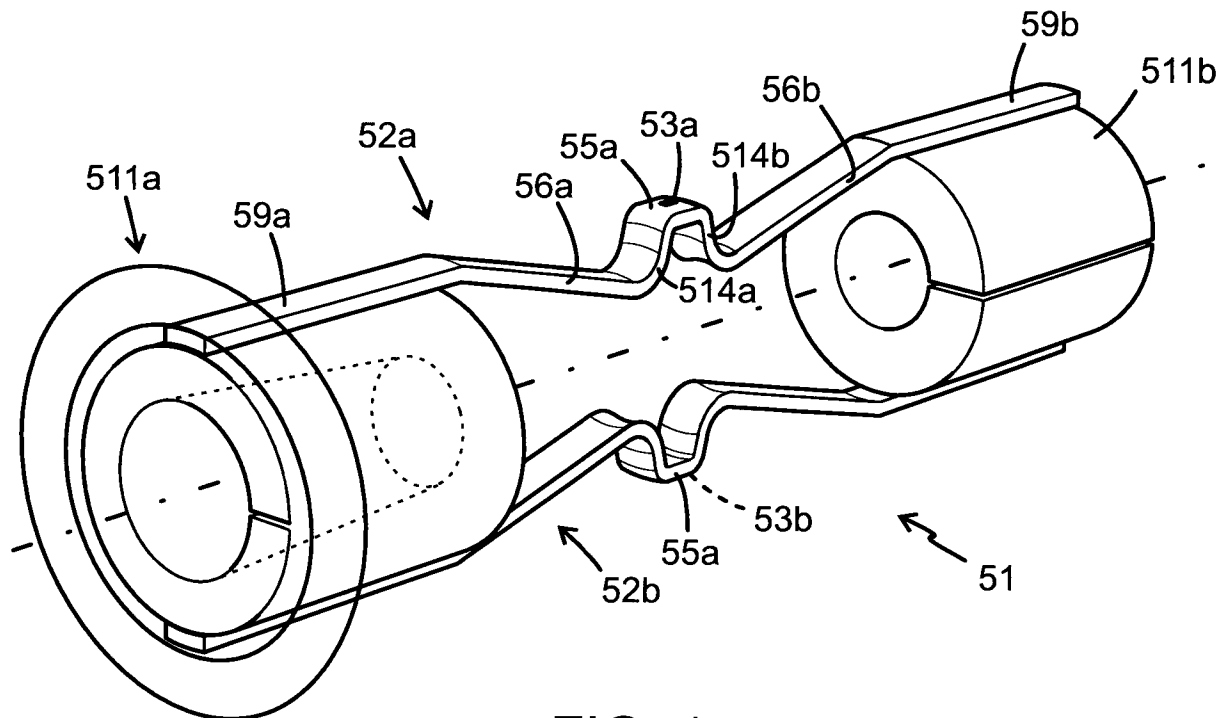


FIG. 1

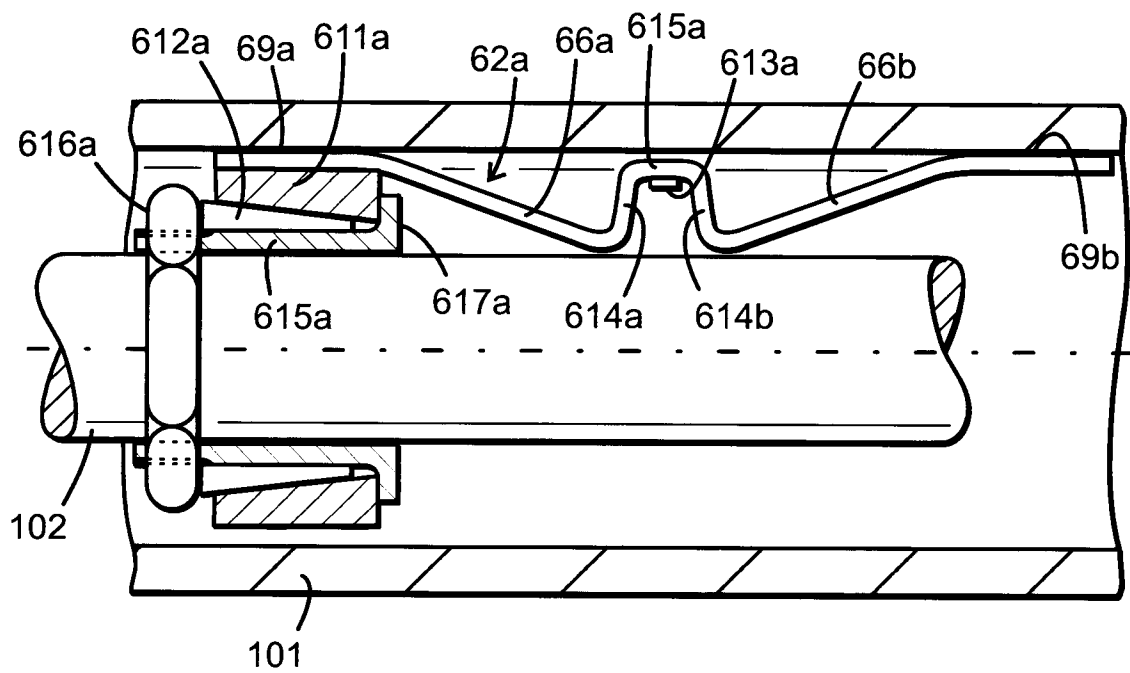


FIG. 2

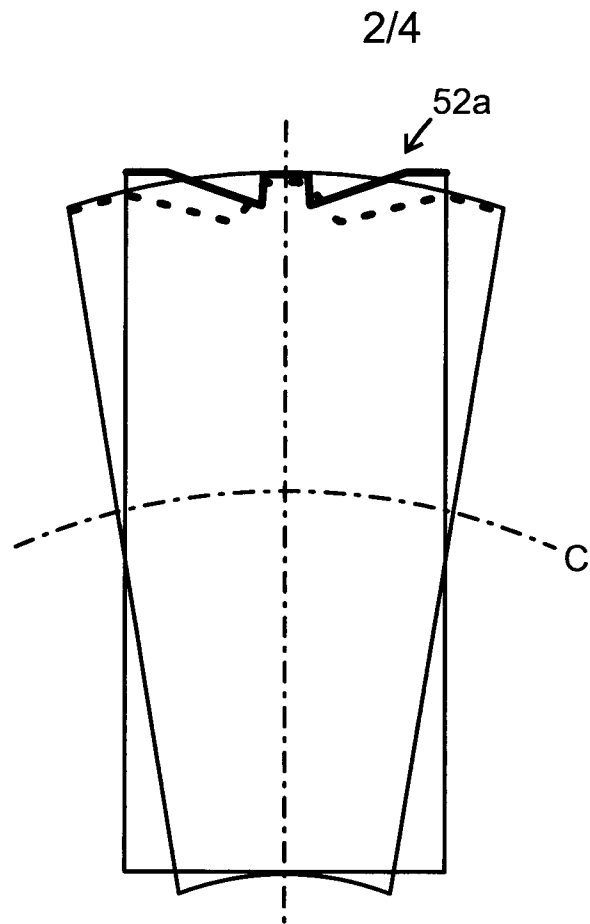


FIG. 3

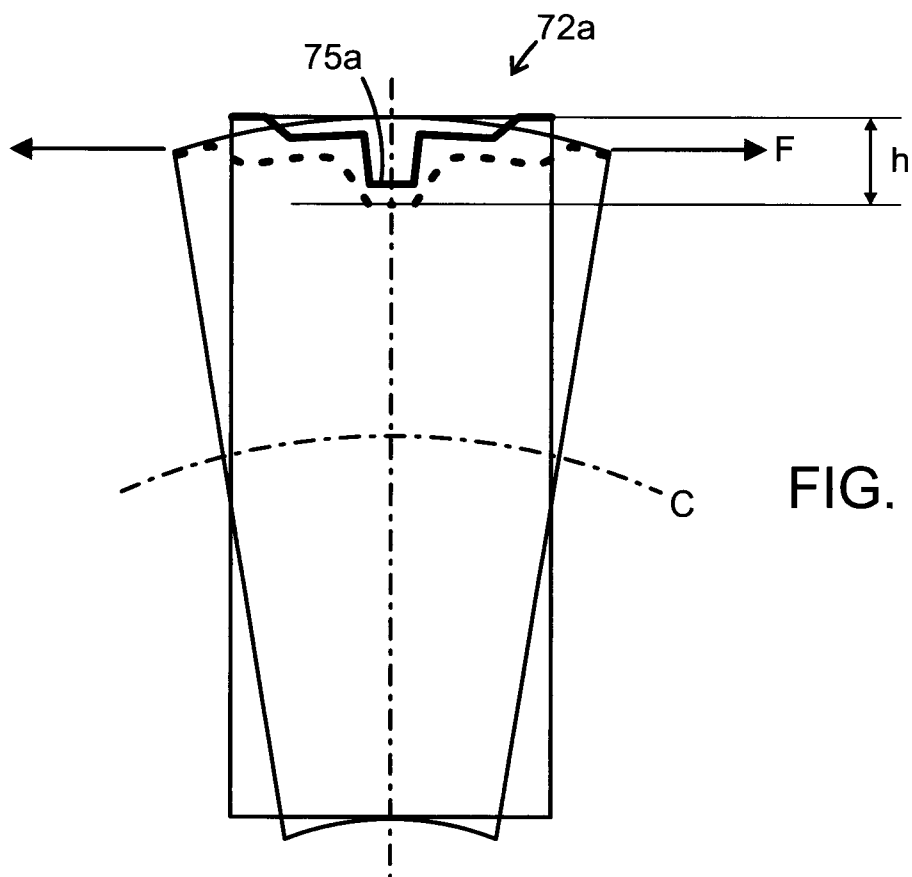


FIG. 4

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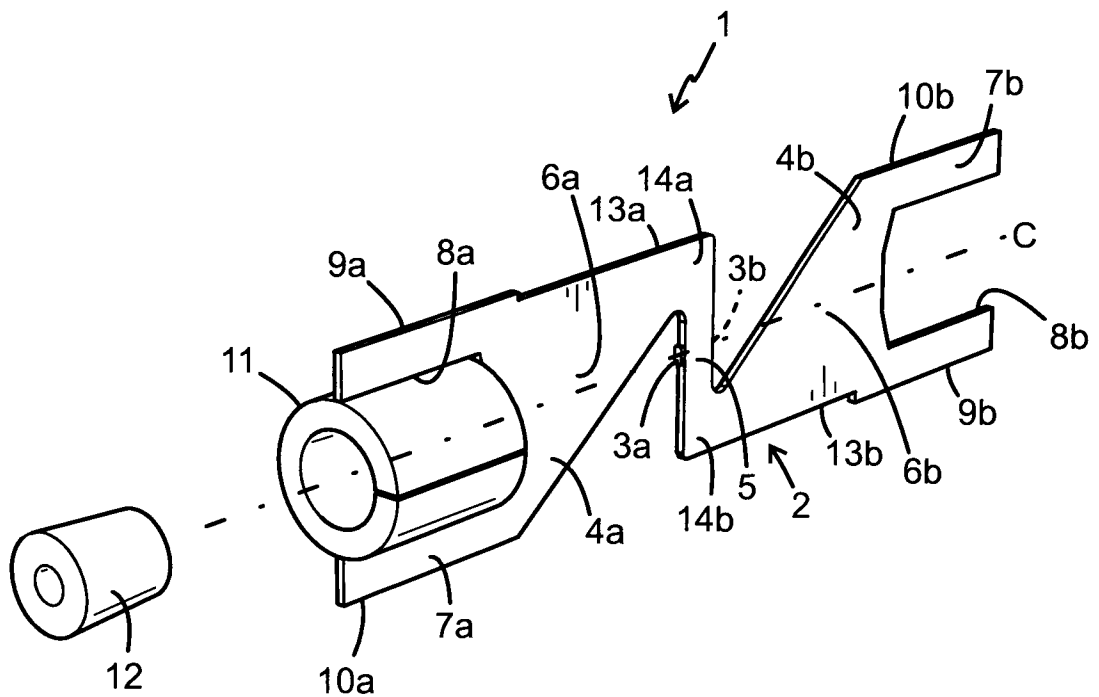


FIG. 5

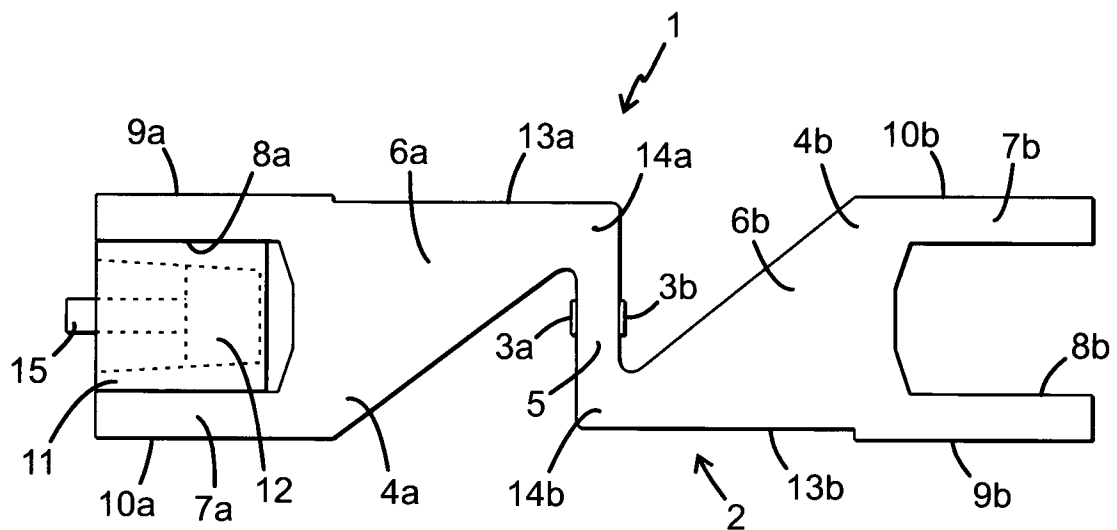


FIG. 6

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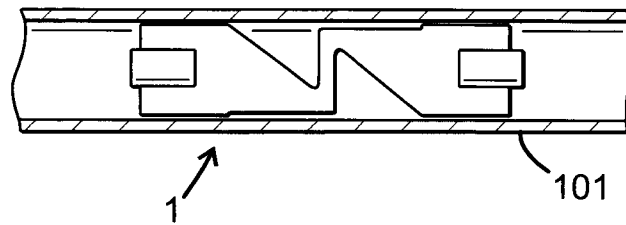


FIG. 7

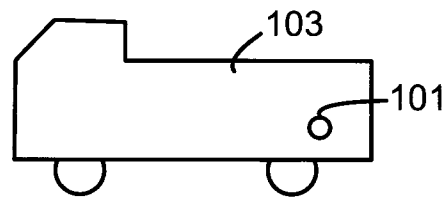


FIG. 8

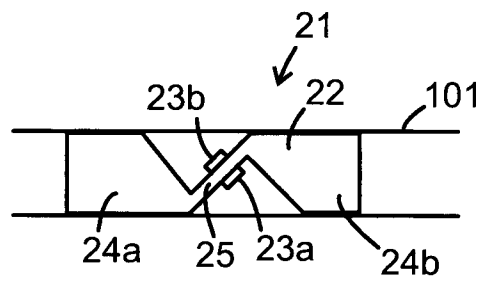


FIG. 9

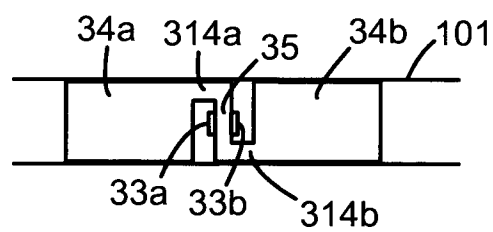


FIG. 10

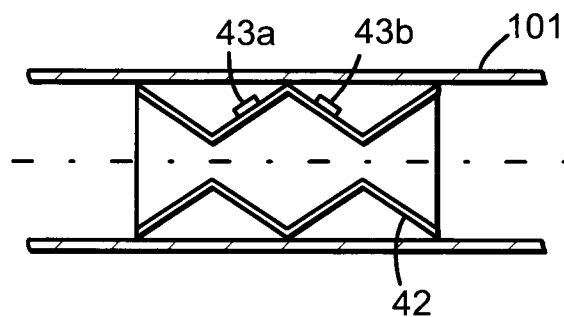


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2011/050319

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: G01G, G01L

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5456119 A1 (NAKAZAKI YOJI ET AL), 10 October 1995 (1995-10-10); abstract; figure 6 --	1-20
A	US 4203318 A1 (YORGIADIS ALEXANDER), 20 May 1980 (1980-05-20); abstract; figures --	1-20
A	GB 2030300 A (JOHANSSON K), 2 April 1980 (1980-04-02); abstract; figure 2 --	1-20
A	US 4526044 A1 (MOSER ROBERT L ET AL), 2 July 1985 (1985-07-02); abstract; figures --	1-20



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

16-05-2011

Date of mailing of the international search report

23-05-2011

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2011/050319

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5402689 A1 (GROGAN RICHARD J), 4 April 1995 (1995-04-04); abstract; figures 1,3 -- -----	1-20

Continuation of: second sheet

International Patent Classification (IPC)

G01L 1/22 (2006.01)

G01G 19/12 (2006.01)

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Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2011/050319

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