(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
27 June 2013 (27.06.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/093399 A1

(51) International Patent Classification:
G01B 7/02 (2006.01) *H03K 17/95* (2006.01)
H01F 27/30 (2006.01)

(21) International Application Number:
PCT/GB2012/000919

(22) International Filing Date:
21 December 2012 (21.12.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1122231.2 23 December 2011 (23.12.2011) GB

(71) Applicant: **QINETIQ LIMITED** [GB/GB]; Cody Technology Park, Ively Road, Farnborough, Hampshire GU14 0LX (GB).

(72) Inventors: **SINGH, Rajinder;** QinetiQ Limited, Cody Technology Park, Ively Road, Farnborough, Hampshire GU14 0LX (GB). **SULLIVAN Jonathan Shamus;** QinetiQ Limited, Cody Technology Park, Ively Road, Farnborough, Hampshire GUM 0LX (GB). **CHANA, Kamaijit Singh;** c/o QinetiQ Limited, Malvern Technology Centre, St Andrews Road, Malvern, Worcestershire WR14 3PS (GB).

(74) Agent: **CLARKE, Alan;** QinetiQ Limited, Intellectual Property, Malvern Technology Centre, St Andrews Road, Malvern Worcestershire WR14 3PS (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available):* AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available):* ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

(54) **Title:** PROXIMITY SENSOR WITH CONDUCTIVE PROTECTIVE SHIELD COMPRISING DISCONTINUITIES SUCH AS SLITS

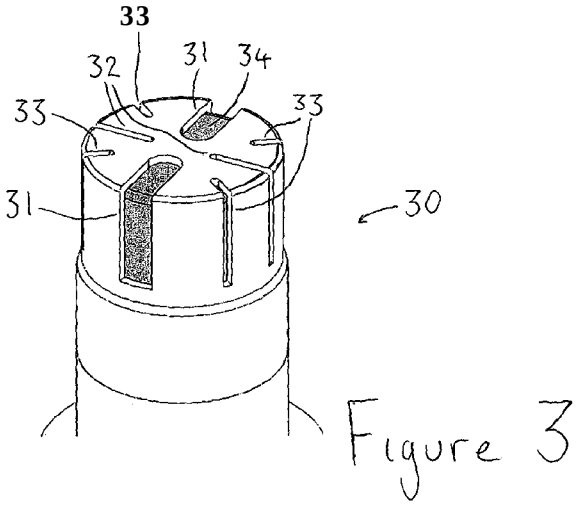


Figure 3

(57) **Abstract:** A proximity sensor includes a sensing element having a sensing tip, wherein the tip has a conductive shield substantially surrounding at least a circumferential portion of the sensing element,, and preferably also the sensing tip, the conductive shield having electromagnetic discontinuities that allow an electromagnetic field to pass therethrough. The discontinuities may be tailored to provide desired electromagnetic field characteristics. The conductive shield provides physical protection to the tip, allowing the sensor to be used in particularly hostile environments such as in hot areas of gas turbine engines. The sensor may typically be an eddy current sensor.

WO 2013/093399 A1

PROXIMITY SENSOR WITH CONDUCTIVE PROTECTIVE SHIELD COMPRISING DISCONTINUITIES SUCH AS SLITS

The present invention relates to proximity sensors, such as eddy current sensors or capacitive sensors used primarily for distance or timing measurement, and in particular relates primarily, but not exclusively, to sensors suitable for use at high and very high temperatures.

Gas turbine engines employ sets of turbine blades mounted on rotatable shafts, typically with one or more sets of blades acting as a compressor, feeding air into a combustion chamber, and one or more sets located behind the combustion chamber, comprising the turbine. Typically there may be between 20 and 200 blades forming a compressor or combustion turbine, and shafts (or spools) may rotate typically at 10,000 revolutions per minute (RPM). To achieve reasonable efficiency and safe operation, it is beneficial in many circumstances for the tips of the turbine blades to be within a certain distance from the cowling surrounding the turbine, this being typically between 0.5 and 5mm. Measurement of this distance while the engine is running is therefore very useful in that the result can be used when adjusting the blade to cowling distance to achieve optimum efficiency, and engine safety. The measurement can also be very useful in detecting (and, if required, compensating for) turbine blade "growth", which occurs due to the centrifugal forces acting on the blades when rotating at high speed, or in detecting overall change in turbine tip to cowling clearance. Defective or incorrectly fitted blades may also be detected, should they unilaterally change height.

Timing information, e.g. the time between successive turbine blades passing a given point, is also valuable in determining engine characteristics such as shaft rotation speeds, and time difference between different blade pairs is useful for detection of faults with, and condition of, the turbine blades.

Eddy current sensors are commonly in use for making the measurements described above. The sensors *contain* one or more coils, and are typically driven with an electrical current to create a magnetic field. The field extends into the region through which the objects to be sensed pass. The field can be created either with the electrical current, or by using a permanent magnet (for example a rare-earth magnet). The field may be either DC or AC. A permanent magnet or a DC current creates a non-uniform DC field. Alternatively, an AC current creates an AC field. Eddy currents are induced in a conducting object as it experiences changes in the magnetic field that surrounds it. In the case of a DC field, the object experiences field changes as it moves through the non-uniform excitation field. The faster the object moves, the greater the rate of change of field, hence higher currents are induced at higher speeds. In the case of an AC illuminating field, the object experiences a changing field whether it is moving or not.

The eddy currents flowing in the conducting object being sensed result in a secondary field. The secondary field can be sensed by various means, such as by detecting the induced voltage in a separate detection coil, or by sensing impedance or apparent inductance changes in the drive coil.

Factors other than the distance between the sensor and object being measured also affect the measurements made, an important one being temperature. Gas turbine engines are subject to extremes of temperature, both hot and cold. Temperature changes in the sensors can change the resistance or other electrical properties of the sensors, which can appear to be a distance change to the electronic systems connected to the sensor. It is important therefore to reduce the effects of temperature on the measurements in such applications.

US patent No. 5942893 describes an eddy current sensor that may be used in measuring turbine blade clearance. In use, the sensor is located in the cowling so that it is in close proximity to the outer edge of the turbine blades.

The sensor has conductive shielding on its sides to prevent unwanted fringing fields.

Other types of proximity sensor exist. These include capacitive types, such as those produced by Tyco Thermal Controls LLC, which measure the capacitance between two conductors within the sensor, or between a conductor in the sensor and the object being measured; for the former type proximate objects will tend to alter the capacitance, by changing a dielectric within the fringes of the electric field between the conductors, whereas for the latter the capacitance is inversely proportional to the distance between the sensor and the object. Such sensors may also be used in place of eddy current sensors in many applications.

According to the present invention there is provided a proximity sensor comprising a sensing element having a longitudinal axis, a sensing tip at an end of the element, and a conductive, protective shield substantially surrounding at least a circumferential portion of the sensing element, characterised in that the protective shield comprises at least one electromagnetic discontinuity around its circumference.

The present invention allows sensors to be made that have significant benefits in terms of allowing them to be operated repeatedly at elevated temperatures due to the additional thermal protection provided by the conductive protective shield. The shield may be arranged to cover some or all of the sensor tip according to the needs of the environment into which it is to be put.

Shielded sensors are known, as mentioned above. However, such shields as employed in the prior art provide a continuous magnetic or electric conduction band around the sensor that acts to "short out" to some degree

magnetic or electric fields generated by the sensor. The use of electromagnetic discontinuities on the shield reduces this problem and provides for a more efficient sensor (in terms of allowing the electric or magnetic fields to pass more freely through a shielded sensor than would otherwise be the case without said discontinuities).

At least one of said discontinuities is arranged to allow an electric or magnetic field to pass through the shield between the sensor and an object being sensed. Other discontinuities may be present on the shield for the sole purpose of preventing electric or magnetic currents to flow around the circumference (or other conductive paths) of the sensor. The form of the discontinuity may be found using electromagnetic modelling software, or may be designed by empirical means, or by any other suitable method. The form of the at least one discontinuity may be arranged to provide a magnetic or electric field having a particular desired shape, suitable for a particular application.

The at least one discontinuity may comprise a slot cut into the shield. The discontinuity may have an axial component. Preferably the discontinuity is arranged to run in an axial direction to the principal energising field, which will typically be axially along the shield.

The at least one discontinuity may also comprise one or more channels cut into the shield that do not pierce the shield. Such channels can present a discontinuity to AC fields and currents, and generally present a greater discontinuity at increasing operating frequencies. Similarly, the at least one discontinuity may comprise a change in material resistivity, by, for instance, incorporating different materials in regions of the shield.

The shield may itself have a protective coating, such as a thermal barrier coating applied thereto to help protect the sensor and shield from extremes

of temperature. Such coatings are known, and may comprise for example yttrium stabilized zirconia, or other suitable coating.

The invention will now be described in more detail, by way of example only, with reference to the following Figures, of which:

Figure 1 diagrammatically illustrates a first embodiment of the present invention, employing a castellated shield;

Figure 2 diagrammatically illustrates a second embodiment of the present invention, with a capped shield having two slots;

Figure 3 diagrammatically illustrates a third embodiment of the present invention, with a capped shield, slots and slits;

Figure 4 diagrammatically illustrates a fourth embodiment of the present invention with a capped shield with axially running slots; and

Figure 5 diagrammatically illustrates a fifth embodiment of the present invention with a capped shield, circular apertures and slits.

Figure 1 shows a first embodiment of the present invention. An eddy current sensor (1) comprises a ceramic sensing tip (2, shown shaded) enclosed within which is a single conducting coil having an axial length of 2mm (not shown). The coil is connected to two pins of a connector (3) on the back end of the sensor (1). Circumferentially surrounding the tip (2) is a shield (4) made from titanium, and which extends almost to the end of the tip (2), leaving 2mm of the sensor tip protruding. The overall diameter of the shield is approximately 11mm, and is designed to hold a sensor of approximately 10mm diameter. The shield is attached to the main case (5)

of the sensor, both of which are electrically connected to a third pin of connector (3), and which is subsequently connected to electrical earth. The case also connects to a thermal sink to allow the sensor to cool.

The shield (4) has a number (eight in this case, but this can vary according to the sensor diameter and frequency of operation) of thin slits (e.g. 6) cut into it, which run axially down the length of the shield for 6mm and which give a generally castellated appearance to the top of the shield.

In use the sensor is driven with an AC current having a frequency of 2 MHz. At this frequency, without the slits present in the shield, a B-field would be induced around the shield, as the conductive material provides a low impedance. This B-field present in the shield reduces the B field extent axially beyond the sensor tip, and hence reduces its measurement sensitivity. The addition of the slits (6) reduces significantly the B-field coupling into the shield, as they act as air gaps providing a much higher impedance to the magnetic B-fields. The slits (6) break the shield's ability to couple with the illuminating field, thereby reducing the attenuating effect of the shield.

The embodiment shown in Figure 1 has been made and tested. A comparison sensor identical to that described above, but without the slits (i.e. having a continuous metallic shield around the circumference) was also produced, so that performance of the slit arrangement could be gauged. The comparison sensor produced, under a certain test condition, a pk-pk output of 66.3mV. Under identical test conditions the first embodiment (i.e. having the slits as described above) produced a pk-pk output of 162mV. Thus it can be seen that the use of slits as described above has a very significant impact on the output achievable, and hence on the sensitivity of the sensor.

The embodiment above has been shown to perform well from an electrical point of view. It does however have the disadvantage that a large region of the ceramic sensor tip is left exposed. Should the ceramic crack from thermal shock, or otherwise become damaged then relatively large pieces of the ceramic can be ingested into the engine or other apparatus being measured, potentially causing damage and malfunction of the sensor.

Although titanium has been used in this embodiment, other materials, such as Inconel or other nickel alloys, or other conductive material able to withstand the mechanical and thermal environment in which it is to be used, may be used for this and other embodiments.

Figure 2 shows a second embodiment of the present invention, wherein the shield is extended to cover the sensor tip. Eddy current sensor (20) is identical to that shown in Figure 1, with the exception of the shield, and so those similar elements will not be described further. Shield (21) is again made from titanium (although, as stated earlier, other materials can be used) and extends beyond the sensor tip and wraps around to form a cap (22). In this way it provides a greater mechanical protection of the sensor tip itself, and of the engine (or other apparatus being measured) should the *ceramic* of the sensor tip break apart. The shield has two relatively wide apertures, or slots (23), cut into it that act both as the electromagnetic discontinuity (at least partially breaking up the B-field circulating around the shield) and the exit path for the eddy current inducing B-field.

The slots extend axially along opposite sides of the shield for a similar distance to that used for the thin slits described in relation to Figure 1 above, but also extend into the orthogonal, radial plain (i.e the face of the cap (22)) at the end of the sensor. The axial portion (24) of the slot is responsible for some B field suppression, as well as providing the magnetic field to the

device under test, while the portion of the slot on the face is mainly responsible for projecting the eddy current field towards the device under test. The slots (23) provide an opening to the sensor that is much reduced as compared to the first embodiment, and so should the ceramic of the sensor become damaged then only much smaller pieces are free to exit the slot into the apparatus being measured, and so are much less likely to cause damage and malfunction of the sensor or device (e.g. engine) being measured.

Figure 3 shows a close-up of the shield (30) of a third embodiment of the present invention, this being similar to the second embodiment in that it comprises a capped shield having two slots (31) (for providing the eddy current field to an object under test) covering sensing tip (34). It differs however in that it has, in addition to the slots, six thin slits to additionally provide a greater resistance to the creation of B fields in the shield. Each of the slits, like the slots, is formed in the face of the shield as well as running axially down its length. The slits run for a similar length to that of the slots in this embodiment, although they may differ in other embodiments.

There are two slightly different types of slit used - a major slit (32) and a *minor* slit (33). The *major* slits extend into the face of the cap a little further than the minor ones, but they are of similar width. Two major slits (32) are present, located opposite each other and equally spaced between the two slots (31), and four minor slits (33) are located at approximately equidistant points around the circumference of the shield, each minor slit approximately equidistant between a major slit and a slot

Note that herein the term "slot" refers to a gap of sufficient size and shape to be capable of providing a practical degree of emission of illumination field sufficient to act upon a nearby conductive object, and hence cause eddy currents to form therein, whereas a slit is a gap that is not designed to

provide a practical degree of emission of B field, but instead is present to break up B fields circulating around the shield. Of course, a slot can, if it is of suitable shape (e.g. generally having a significant axial component), also have the effect of breaking up the circulating B fields.

Table 1 below shows the relative performance of three different embodiments of a capped shield against the castellated embodiment reference as described in relation to Figure 1. The Embodiment Number 1 is that shown in Figure 2, having a capped shield with two slots; Embodiment Number 3 is that shown in Figure 3 (i.e. having two slots, two major slits and four minor slits), while Embodiment Number 2 is similar to that of Figure 3 but instead having only the two slots and two major slits, and no *minor* slits.

Embodiment Number	Measurement from Reference	Measurement from Embodiments	% of reference
1	293	82	28
2	251	119	47
3	247	134	54

Table 1. All measurements are in mV (pk-pk), taken from a standard test rig.

The voltage levels provided in Table 1 are indicative of the eddy current modulation and reception levels generated in a test rig, and so are a good measure of sensitivity of the sensor. It can be seen from Table 1 that the reference sensor (i.e. a castellated embodiment similar to that shown in Figure 1)has the greatest sensitivity, which is not surprising as it does not have the cap on the shield, and so has the largest field available for generating eddy currents. It can be seen that the relative performance of

the capped embodiments improves significantly from embodiment 1 to embodiment 2 with the addition of two major slits that disrupt circulating B-fields, and then improves again (albeit with a reduced improvement) with the addition of four minor slits at embodiment 3.

As has been described above, the electromagnetic discontinuities need not comprise apertures or cuts going completely through the metal. Instead, they may comprise e.g. sectional variations, such as grooves, which act to disrupt the magnetic fields at high frequencies, but which will have little effect at lower frequencies. In this way a sensor, such as an eddy current sensor, can be made that has a completely enclosed, capped shield, but that allows magnetic fields to pass through due to the action of the discontinuities on fields of certain frequencies. Such a cap has advantages in high temperature, pressure, radiating, ionising, or other harsh environments as the enclosed sensor is fully protected.

Figure 4 shows a fourth embodiment of the present invention. A sensor (40) has a capped shield (41), which itself has a pair of slots (42) (note, only one is visible in the projection shown) running axially down the shield (41) a distance of 6mm, and located on opposite sides thereof. The slots in this embodiment do not protrude into the cap of the shield (41). The shield (41) covers sensing tip (43). This embodiment provides good protection for the sensing tip, with the slots (42) acting to disrupt B fields flowing around the shield and also providing an aperture for the illuminating field to exit the sensor (40).

The above embodiments all have slits and/or slots running axially along the shield. The scope of the invention should not be constrained to the use of such forms. For example, the slots and/or slits may be present just in an end

cap of the shield. As described more generally above, other forms and shapes of electromagnetic discontinuity can be used.

Figure 5 shows a fifth embodiment of the present invention. A sensor (50) has a capped shield (51), with the cap (52) having a pair of semicircular cut-outs (53) at opposite sides of the cap (52). An axial portion of the shield (51) has corresponding semicircular cut-outs, each also having a slit (54) running back axially from the cut-out to break up the B-field flowing around the sensor. The cut-outs (53) allow the illuminating field to emanate from the sensor tip (55).

The size and shape of the slots, slits, other apertures, or indeed any of the electromagnetic discontinuities, and of the shape of the shield itself may be found by calculation, by trial and error, or by computer simulation using, for example, an electromagnetic simulator tool, or by any other method. The skilled person will be aware that field strength falls away as a function of the inverse square of the distance from the coil, and so it is advantageous, if a high field strength is desired, to provide electromagnetic discontinuities of a size with this in mind. So, for a 2mm coil, the field will be ¼ that at zero offset at 2mm distance, 1/16th that at 4mm distance, and 1/36th that at 6mm distance. Thus it is advantageous for any of the slits, slots or other electromagnetic discontinuities to extend for these larger distances so that a much reduced level of attenuation of the illuminating B field occurs.

The slits used in the embodiments described are all 0.5mm in width, for purposes of manufacturing convenience. The slots are wider to allow for the projection of the illuminating field, and may typically have a width of around D/5, where D is the diameter of the shield, but may vary according to the requirements of the sensor.

The invention has been described generally in relation to eddy current sensors, and it is believed that this is the prime area for its application. The invention does however have utility with other sensor types, e.g. capacitive sensors, where an electric field is generated between a pair of conductors. The shield in this case incorporates one or more slots or other orifices to allow the electric field to impinge upon an object being measured. The slots or other orifices should be designed to avoid too much attenuation of the electric field, which can be done by trial and error, calculation, or by the use of computer simulation tools as described above in relation to eddy current sensors.

Claims

1. A proximity sensor comprising a sensing element having a longitudinal axis, a sensing tip at an end of the element, and a conductive, protective shield substantially surrounding at least a circumferential portion of the sensing element, characterised in that the protective shield comprises at least one electromagnetic discontinuity around its circumference.

2. A proximity sensor as claimed in claim 1 wherein the at least one discontinuity has an axial component.

3. A proximity sensor as claimed in claim 1 or claim 2 and having at least two discontinuities formed therein.

4. A proximity sensor as claimed in any of claims 1 to 3 wherein the conductive shield acts as a collar along the length of the sensing element.

5. A proximity sensor as claimed in any of the above claims wherein the at least one discontinuity comprises at least one slit in the shield.

6. A proximity sensor as claimed in any of claims 1 to 5 wherein the at least one discontinuity comprises at least one slot in the shield.

7. A proximity sensor as claimed in any of claims 1 to 4 wherein the at least one discontinuity comprises a change in thickness in the shield.

8. A proximity sensor as claimed in any of the above claims wherein the proximity sensor is an eddy current sensor

9. A proximity sensor as claimed in claim 8 wherein the at least one discontinuity is arranged to allow a magnetic field to extend out towards a region proximal to the sensor.

10. A proximity sensor as claimed in claim 8 or claim 9 wherein the shield has a cap that at least partially encloses the end of the sensing element.

11. A proximity sensor as claimed in claim 10 wherein the cap has at least one of a slit according to claim 5, or a slot according to claim 6, located thereon.

12. A proximity sensor as claimed in claim 11 wherein the slot and/or slit is present in both the end cap of the shield as well as the axial portion of the shield.

13. A proximity sensor as claimed in any of claims 1 to 3 wherein the sensor is an eddy current sensor, and the shield totally encloses the sensing element.

14. A proximity sensor as claimed in any of the above claims wherein the shield is made from one of titanium or Inconel.

15. A proximity sensor as claimed in any of the above claims wherein the shield is itself at least partially coated in a thermal barrier coating.

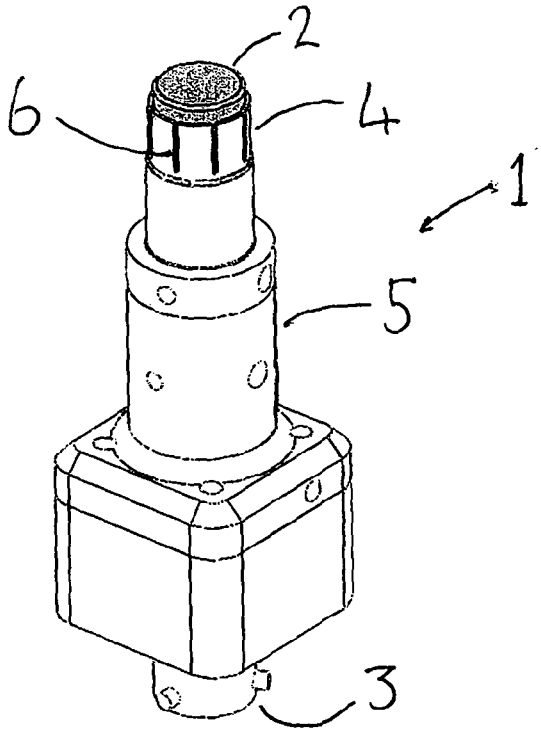


Figure 1

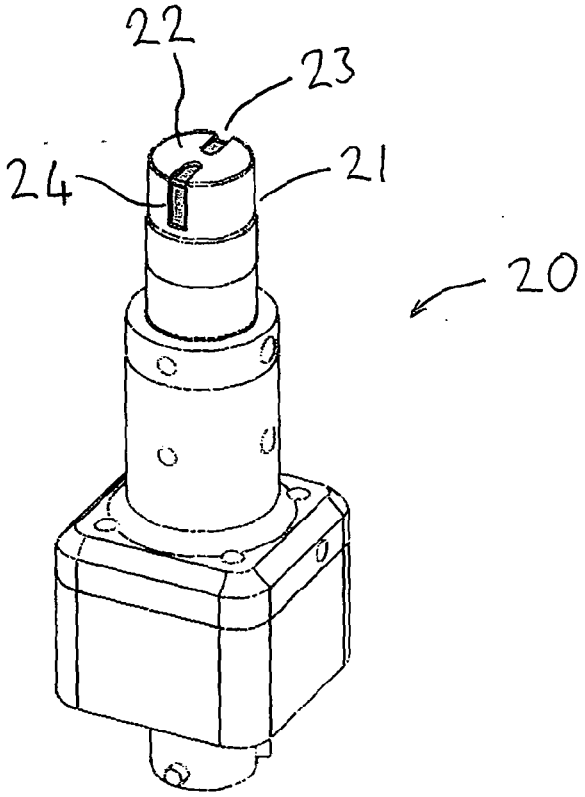


Figure 2

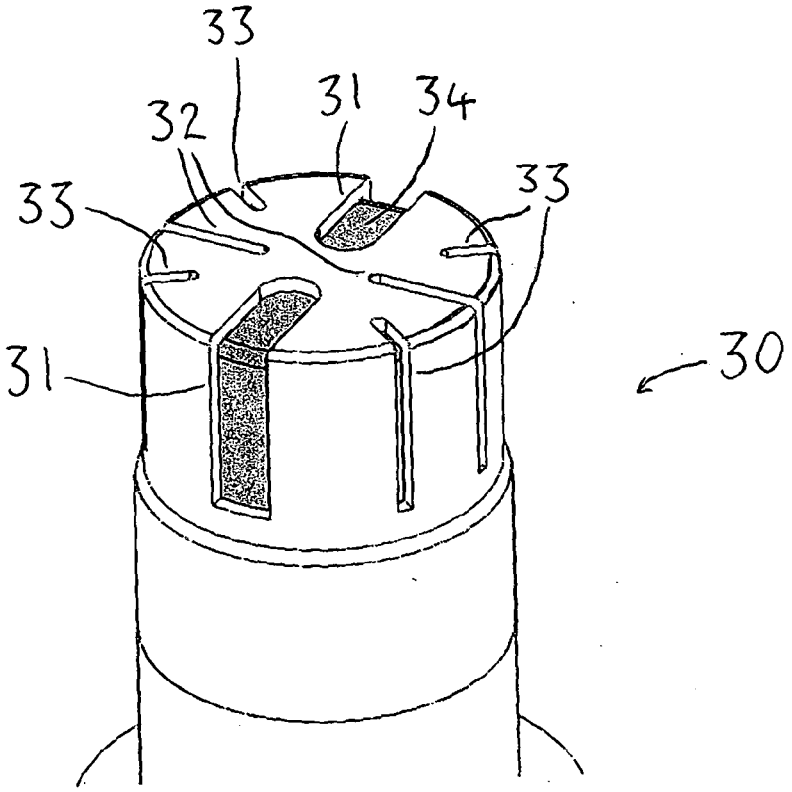


Figure 3

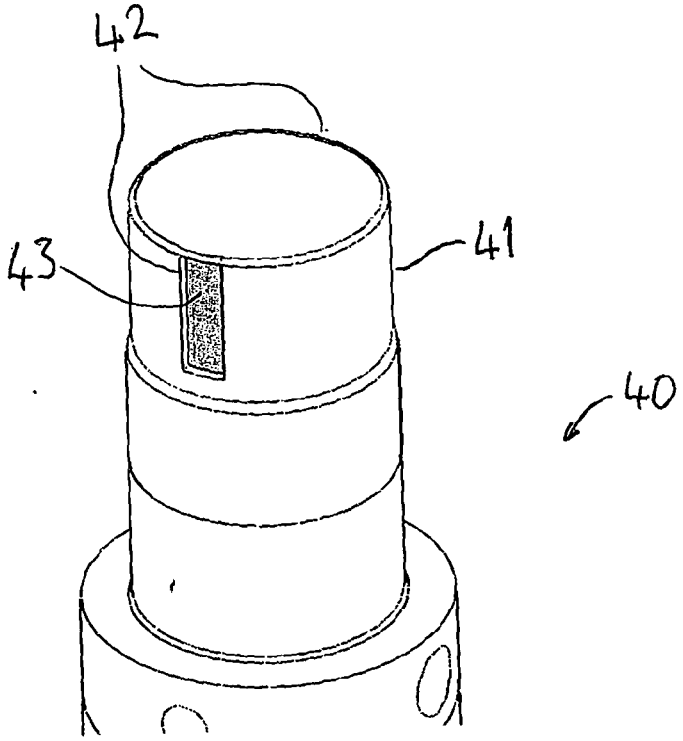


Figure 4

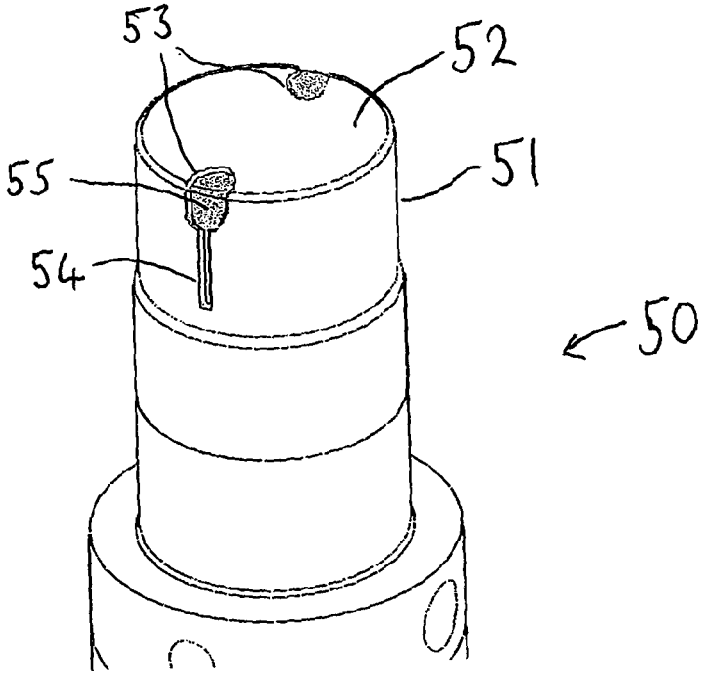


Figure 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2012/000919

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01B7/02 H01F27/30 H03K17/95
ADD.

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)
G01B H01F H03K

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/024275 Al (RUDD ROBERT E I I I [US] RUDD I I I ROBERT EDWARD [US]) 1 February 2007 (2007-02-01)	1-8, 13
Y	abstract pages 1-5 , 6a paragraphs [0001] , [0003] , [0006] - [0013] , [0024] - [0027] , [0029] , [0033] , [0035]	3 ,9-12 , 14

X	EP 1 785 697 Al (MATSUSHITA ELECTRIC WORKS LTD [JP] PANASONIC ELEC WORKS CO LTD [JP]) 16 May 2007 (2007-05-16) abstract paragraphs [0005] , [0006] , [0017] , [0021] , [0023] - [0026] f i gures la, 3a	1-5 , 8

	-/- ·	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" documentwhich may throw doubts on priority claim(s) orwhich is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 March 2013	22/03/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Poi zat, Chri stophe

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2012/000919

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 101 750 009 A (NANJING CIGU LTD CORP; UNIV NANJING AERONAUTICS) 23 June 2010 (2010-06-23) the whole document	1-9
X	US 2001/019262 A1 (WOOLSEY KEVIN [US] ET AL) 6 September 2001 (2001-09-06)	1,2,4-6, 8,13,14
Y	abstract figures 9,12, ,13a, 13b paragraphs [0009] - [0015], [0075] - [0077]	3,7,9-15
X	JP 2002 365007 A (NIPPON S0KEN; TOYOTA MOTOR CORP) 18 December 2002 (2002-12-18)	1-6,8,9, 13
Y	the whole document	7,10-15
X	EP 1 742 362 A1 (SENSTRONIC S A [FR]) 10 January 2007 (2007-01-10)	1-11,13
Y	abstract paragraphs [0006], [0013] - [0018], [0021], [0024] - [0032], [0039], [0044], [0079] - [0081] figures 1-16	12-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2012/000919

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007024275 A1	01-02-2007	NONE	
EP 1785697 A1	16-05-2007	EP 1785697 A1	16-05-2007
		EP 1881298 A1	23-01-2008
		EP 2236989 A2	06-10-2010
		EP 2244067 A2	27-10-2010
		EP 2244068 A2	27-10-2010
		KR 20070054721 A	29-05-2007
		KR 20070069145 A	02-07-2007
		US 2008258739 A1	23-10-2008
		US 2008315868 A1	25-12-2008
		WO 2006121145 A1	16-11-2006
		WO 2006121146 A1	16-11-2006
CN 101750009 A	23-06-2010	NONE	
US 2001019262 A1	06-09-2001	AT 248461 T	15-09-2003
		AU 3996301 A	12-09-2001
		CA 2398689 A1	07-09-2001
		DE 60100669 D1	02-10-2003
		DE 60100669 T2	08-07-2004
		EP 1264404 A2	11-12-2002
		US 6424145 B1	23-07-2002
		US 2001019262 A1	06-09-2001
		WO 0165695 A2	07-09-2001
JP 2002365007 A	18-12-2002	NONE	
EP 1742362 A1	10-01-2007	AT 427585 T	15-04-2009
		EP 1742362 A1	10-01-2007
		ES 2324718 T3	13-08-2009
		JP 2007012608 A	18-01-2007
		US 2007001667 A1	04-01-2007