

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
24 April 2008 (24.04.2008)

PCT

(10) International Publication Number
WO 2008/048111 A1

(51) International Patent Classification:

H05B 6/10 (2006.01) **B08B 7/00** (2006.01)
H05B 6/02 (2006.01) **B44D 3/16** (2006.01)
H05B 1/02 (2006.01)

(21) International Application Number:

PCT/NO2007/000372

(22) International Filing Date: 19 October 2007 (19.10.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

20064745 19 October 2006 (19.10.2006) NO

(71) Applicant (for all designated States except US): **RPR TECHNOLOGIES AS** [NO/NO]; Postboks 81, N-1334 Rykkinn (NO).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **BAANN, Tom Arne** [NO/NO]; Avstikkerveien 52, N-3960 Stathelle (NO).

(74) Agent: **OSLO PATENTKONTOR AS**; P.O. Boks 7007M, N-0306 Oslo (NO).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, 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, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, 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, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

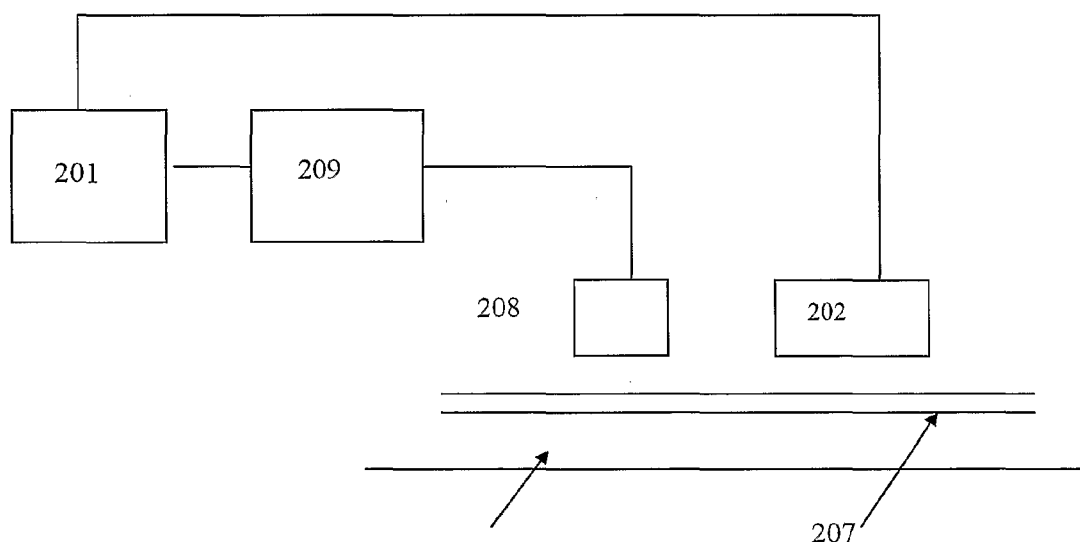
Declaration under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

— with international search report
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

(54) Title: A METHOD AND DEVICE FOR REMOVING COATINGS ON A METAL STRUCTURE



(57) Abstract: A device for removing layers of corrosion and other coatings (205) from a metal surface (204) is disclosed. Said device includes a signal generator (202) driving an induction coil (201) that is positioned on the structure (204). A control unit (206) includes a temperature sensor sensing the temperature in the metal structure (204). The control unit is adapted to control the power output of the signal generator (202) in accordance with the temperature in the metal structure (204).

WO 2008/048111 A1

Description

A METHOD AND DEVICE FOR REMOVING COATINGS ON A METAL STRUCTURE

Technical Field

[0001] The present invention relates to a device and method for removing rust and coatings from the surface of metal structures. The invention may find applications in the oil and gas industry for the maintenance of pipelines, offshore oil platforms and chemical and petroleum tanks, in civil engineering for removing rust on bridges or other large metal structures, or in the maritime sector, e.g. on ships.

Background Art

[0002] From Norwegian patent NO 314296 owned by the present applicant, there is known a device for removing rust and paint on ships' hulls using induction heating. A portable induction heater unit is placed on the hull plate. Said unit includes an induction coil driven by a powerful signal generator. The magnetic field from the induction coil will set up eddy currents in the steel plate, which will be transformed to heat by the ohmic losses in the steel. The heat will lift the paint layers and rust due both to the temperature and differences in expansion coefficients. The supplied heat should be sufficient to lift the paint. However, overheating must be avoided to prevent scorching of the paint and the emission of unpleasant and unhealthy gases. Overheating may also be harmful for objects on the inside of the plates, in particular if there are any inflammable gases present, and may even anneal the steel and change its properties in a undesirable way. Thus, it is very important to accurately control the supplied heat. The unit disclosed in NO 314296 is moved manually over the hull, and will naturally be moved with an uneven speed. To control the supplied heat, a tachometer wheel is mounted on the unit. The wheel traces the movement and controls the induction field, i.e. the unit is adapted to supply a controlled amount of energy per area. While the prior art system will control the supplied heat in a proper way under ideal conditions, it has a couple of shortcomings. Initially, the system must be manually set to the conditions prevailing on the ship in question, i.e. a

mean value must be set that is adapted to the mean thickness of the paint layer. As the workers move to another part of the ship, these conditions may change due to changes in the thickness of the rust and paint, the thickness and the conductivity of the steel.

[0003] It is known from the German patent application DE 199 40 732 A1, to remove the outer layer of coatings from transmission towers using high frequency inductive heating. An infra red sensor is used for measuring the surface temperature; the measured temperature is used as an input for controlling output power of the inductive heating device.

[0004] It is further known from a French patent application, FR 2 843 316 A1, to use inductive heating to heat magnetic structures on vehicles. An anticorrosive painting, wax or the like is applied to said structure and the structure is heated using the inductive heating thereby causing the anticorrosive painting or wax to be less viscous, this lowered viscosity makes penetration of anticorrosive easier. The use of inductive heating will also ensure a more rapid heating with use of less power which implies a rapid cooling compared to what is achieved using heating with radiation or forced heated air.

Disclosure of Invention

[0005] It is an object of the present invention to provide an improved device for the removal of rust and coatings on metal plates that avoids the shortcoming of prior art devices.

[0006] This object is achieved in the invention as claimed in the appended claims. In particular, according to a first aspect, the invention relates to a device for removing coatings from a metal structure, said device including a signal generator driving an induction coil that is adapted to be positioned on the structure and a control unit including a temperature sensor and which is adapted to control the power output of the signal generator in accordance with the sensed temperature. Where the temperature sensor is adapted to measure the temperature in the metal structure beneath layers of corrosion and the other coatings and the power output of the signal generator is a function of the temperature in the metal structure

- [0007] According to a second aspect, the invention relates to a method for removing coatings on a metal structure. Said method includes inducing alternating currents in the structure, determining a temperature and controlling the power of the induced current in accordance with said temperature. Further the method includes measuring the temperature in the metal structure beneath layers of corrosion and the other coatings, and controlling the power output of the signal generator (201) as a function of the temperature in the metal structure beneath the layers of corrosion and the other coatings.
- [0008] Other advantageous embodiments of the invention appear from the appended dependent claims.

Brief Description of Drawings

- [0009] The invention will now be described in relation to the appended drawings, in which
- [0010] Fig. 1 is a schematic block diagram showing the main components of a prior art device for removal of rust and coatings,
- [0011] Fig. 2 is a schematic diagram over a corresponding device according to the present invention,
- [0012] Fig. 3 is a diagram showing a temperature sensor for use in the device in Fig. 2,
- [0013] Fig. 4 is an alternative embodiment of the temperature sensor in Fig. 3,
- [0014] Fig. 5 is an alternative temperature sensor for use in the device illustrated in Fig. 2.

Detailed description

- [0015] A prior art device for removing rust and paint is shown in Fig. 1. In use, the device is positioned on a metal surface that is coated with a layer of paint and rust 107. This layer may of course include other coatings as well, such as epoxy coatings, rubber, fire-retardant and other various coatings for preventing fouling of ships hulls, etc. A power supply unit 101 drives a coil 102. The power supply unit 101 acts as a power signal generator delivering a strong AC signal. The coil 102 will set up an alternating magnetic field in the metal structure. The magnetic field will induce an eddy current in the metal sheet 106 which will heat the metal. To control

the heat induced in the steel, e.g. if the device is held stationary for a moment, a tachometer 104 or other motion sensor measures the rate of displacement of the device. A logic unit 105 reads the output from the tachometer 104 and the power delivered from the power supply unit 101. A control signal is produced and sent to the power supply unit. 101. This prior art device is adapted to supply a constant amount of heat per area of the metal surface.

[0016] Fig. 2 shows a corresponding device designed according to the present invention. The device includes a power supply unit 201 driving a coil 202, as in the prior art device. However, this device includes a temperature sensor 208 that senses the temperature in the metal sheet 206 beneath the device. A microcontroller 209 reads the output from the temperature sensor 208 and the power delivered from the power supply unit 201. An algorithm is used to find the appropriate power required, which is compared with the actual power output. A control signal is produced and sent to the power supply unit 201. Then the temperature in the plate always may be held within a window of acceptable values, irrespective of local variables such as the thickness of the plate or the presence of objects at the inside of the sheet.

[0017] The temperature sensor 208 must be able to measure the temperature in the metal sheet 206 beneath the coating 207. This precludes the use of devices based on measuring temperatures on the surface, such as off the shelf infrared ray detectors. This requirement has dictated the development of temperature sensors suited for this application.

[0018] Fig. 3 illustrates an inductive temperature sensor circuit. The sensor includes an oscillator circuit whose frequency is determined by a resonant circuit made of a coil L_{COIL} and a parallel capacitance C_{OSC} . The oscillator circuit is connected to the microcontroller 312.

[0019] The coil L_{COIL} is a conventional air-cored inductor, which when driven by a signal, couples electromagnetically to the sheet of metal. If the sensor is placed in close proximity of a steel structure, the oscillator coils will be affected by the steel corresponding to an iron core in a common resonator

coil, increasing their inductivity. The invention is applicable for other metals as well provided they have magnetic properties.

[0020] The oscillator circuit consists of the corresponding coil L_{COIL} , connected via shielded cable to a parallel capacitance C_{OSC} and a very high gain non-inverting amplifier 310. The circuit oscillates at the natural resonant frequency of the LC combination, where the loop phase shift is zero and thus positive feedback occurs.

[0021] The output of the oscillator is nominally a digital square wave with frequency:

$$f = \frac{1}{2\pi} \sqrt{\left(\frac{1}{L_{COIL} C_{OSC}} - \frac{R_{COIL}^2}{L_{COIL}^2} \right)}$$

[0022]

[0023] where L_{COIL} is the inductance of the coil, R_{COIL} is the loss in the circuit and C_{OSC} is the capacitance of the external capacitor. C_{OSC} has of course also some internal losses, but they are generally negligible compared with the losses in the coil and is not included in the formula.

[0024] L_{COIL} is affected by the metal sheet, as is R_{COIL} . The oscillator will induce a weak eddy current in the metal and the losses in this circuit are also included in R_{COIL} . The losses in the metal sheet are dependent on temperature, and therefore the actual frequency of the oscillator will change in response to the temperature. The proximity of the metal sheet will also affect the inductance of the coil and thus the frequency of the oscillator, but the distance to the metal is here assumed to be constant, why this parameter may be ignored.

[0025] The fact that the inductance also is dependent on the proximity to the metal implies that this circuit may also be used to measure the distance to the metal sheet, provided that the temperature is held constant.

[0026] For best performance, heavy gauge wire should be used in the coil to reduce the internal R_{COIL} . In addition, C_{OSC} should have a small temperature coefficient. These measures provide for low temperature drift in the oscillator.

[0027] The resistance R_{LOOP} in the feedback loop is ideally set such that it is equal to the impedance of the LC tank at resonance, thus giving the

largest possible signal at the amplifier input and thereby minimising the effect of noise.

- [0028] Noise at the amplifier input is translated into timing jitter in the square wave output, affecting both the frequency and the duty cycle of the output. Therefore the oscillator output signal is passed to a Phase Locked Loop IC 313, which effectively removes the jitter.
- [0029] The microcontroller 312 observes the outputs from the PLL 313. The microcontroller is adapted to calculate the temperature of the metal from these data.
- [0030] To improve the noise immunity, the microcontroller may average several temperature readings.
- [0031] To improve the stability and accuracy of the temperature sensor, a reference oscillator may be incorporated in the circuit, as illustrated in Fig. 4. This circuit includes a first oscillator 407 and a second oscillator 410 with resonance circuits 406 and 409, respectively. The oscillators are positioned on the metal; the first oscillator is placed in the hot zone beneath or near the induction heater, while the second oscillator is placed in the cold zone outside the area affected by the induction heater. The signal from each oscillator is sent to a microcontroller unit 412 that counts and compares the frequencies of the oscillators. For each signal it measures the time required for 200 oscillations to occur. The time is measured in processor clock cycles. The microcontroller 412 then displays these data on a display device 414. This is the microcontroller denoted as 209 in fig. 2, and 312 in Fig. 3. The microcontroller is adapted to produce an output signal that is used to control the signal generator in the induction unit, as explained above. The circuit may include phase locked loops 413 a, b for removing jitter.
- [0032] An alternative method for measuring the temperature in the metal is illustrated in Fig. 5. The method is based on measuring the propagation speed of ultrasonic waves in the metal.
- [0033] The applied signal at the transducer A is creating an ultrasound wave travelling from A to the detector at point B. The applied signal could either

be a single pulse or a signal with a frequency swept between the two frequencies f_{a1} and f_{a2} .

[0034] This ultrasound wave is passing under the heating coil which is creating the temperature T . The detected signal at B is measured either in the time domain as a time delay from A to B or in the frequency domain.

[0035] The delay or the measured frequency spectrum will be an unambiguous function of the average temperature T in the heated area under the coil.

[0036] The methods used for determining the temperature in the metal sheet may find other applications than in devices for removing coating on metal. In the industry, there may often be a need for determining temperature in a metal structure that is not readily visible, i.e. being beneath a covering or coating of some kind, where these methods may be used with advantage.

Claims

1. 1. A device for removing coatings (207) from a metal structure (206), said device including a signal generator (201) driving an induction coil (202) that is adapted to be positioned on the structure (206),
a control unit (209, 312, 412) including a temperature sensor (208) and which is adapted to control the power output of the signal generator (201) in accordance with the sensed temperature (206, 306, 406)
characterized in that the temperature sensor is adapted to measure the temperature in the metal structure beneath layers of corrosion and the other coatings and the power output of the signal generator (201) is a function of the temperature in the metal structure .
2. A device as claimed in claim 1, wherein said device includes:
an oscillator (307) with a resonance circuit (306) including a coil and a capacitor, the resonance circuit being positioned on a heated part of the metal structure,
said control unit (312) being adapted to determine the oscillation frequency of the oscillator and produce a controlling signal which is a function of said frequency.
3. A device as claimed in claim 1, wherein said device includes:
a first oscillator (407) with a first resonance circuit (406) including a first coil and a first capacitor, the first resonance circuit being positioned on a heated part of the metal structure,
a second oscillator (410) with a second resonance circuit (409) including a second coil and a second capacitor, the second resonance circuit being positioned on an unheated part on the metal structure,
said control unit (412) being adapted to determine the difference between the frequencies of the first and second oscillators and produce a controlling signal which is a function of the difference between said frequency values.
4. A device as claimed in claim 3, wherein the control unit (412) includes a clock, and is adapted to estimate said frequencies by counting a predefined number of oscillator periods in clock cycles.
5. A device as claimed in claim 4, wherein the device includes first and second phase locked loops arranged to receive an output signal from the first and

- second oscillator, respectively, and deliver cleaned up versions of the signals to the control unit.
6. A device as claimed in claim 5, wherein the control unit is adapted to sum a number of readings of frequency differences, and compute an average of said frequency differences.
 7. A device as claimed in claim 1, wherein said device includes:
a first transducer (A) adapted to transmit an ultrasonic signal into the metal structure, a second transducer (B) adapted to receive said ultrasonic signal, a processor unit connected to said first and second transducers and which is adapted to determine the temperature in the metal structure.
 8. A method for removing coatings (205) on a metal structure (204), said method including inducing alternating currents in the structure (204) and determining a temperature (204) and controlling the power of the induced current in accordance with said temperature,
characterized in that the sensor measures the temperature in the metal structure beneath layers of corrosion and the other coatings, and controlling the power output of the signal generator (201) as a function of the temperature in the metal structure beneath the layers of corrosion and the other coatings.
 9. A method as claimed in claim 8, wherein the method includes:
positioning a first coil of a first resonance circuit on a heated part of the metal structure, said first resonance circuit controlling a first oscillator,
positioning a second coil of a second resonance circuit on an unheated part of the metal structure, said second resonance circuit controlling a second oscillator,
determining the difference between the frequencies of the first and second oscillators, and determining the temperature in the metal structure beneath said layers as a function of the frequency difference.
 10. A method as claimed in claim 9, the method including cleaning up signals from the first and second oscillator with first and second phase locked loops, respectively.
 11. A method as claimed in claim 9, the method including summing a number of readings of frequency differences, and compute an average of said frequency differences.

12. A method as claimed in claim 8, wherein the method includes:
- positioning a first transducer on said metal structure, positioning a second transducer on the metal structure, transmitting an ultrasonic signal between said first and second transducers, and determining the temperature in the metal structure beneath said layers as a function of a propagation speed of the ultrasonic signal.

1/3

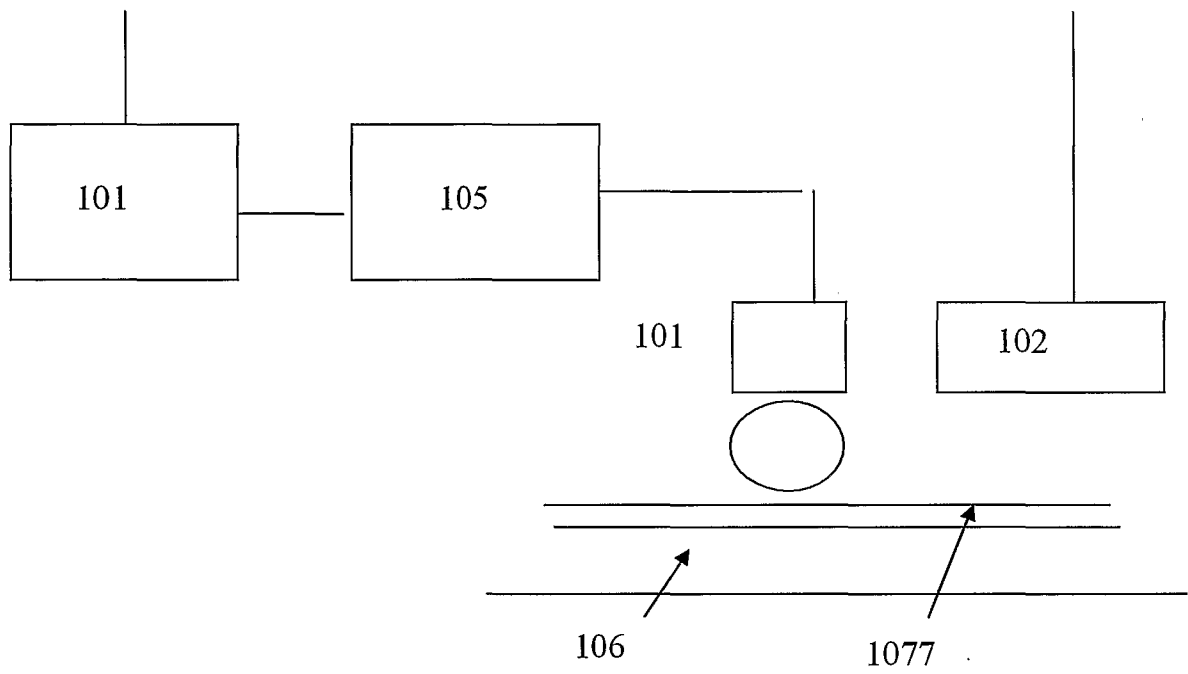


Fig. 1

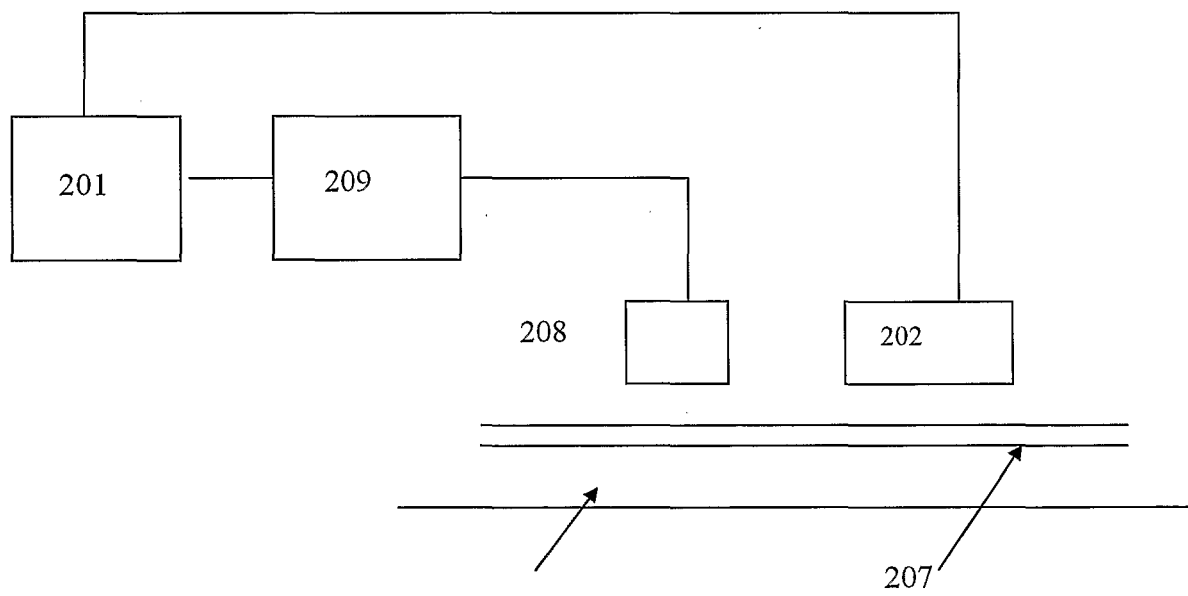
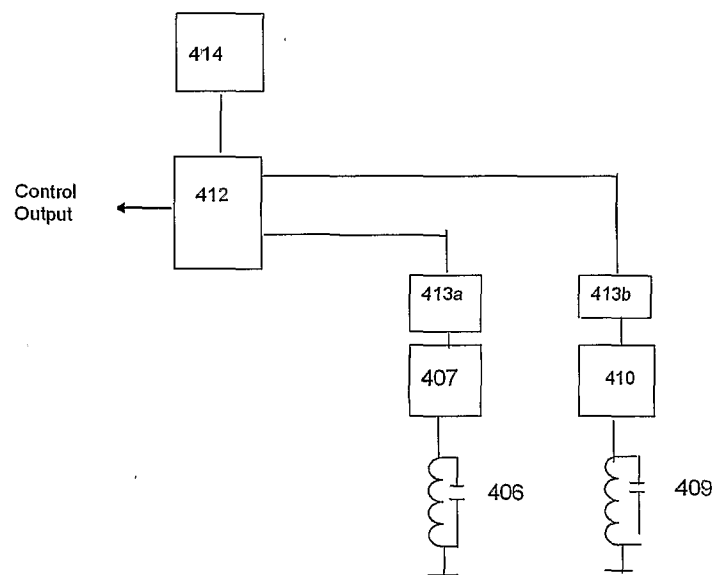
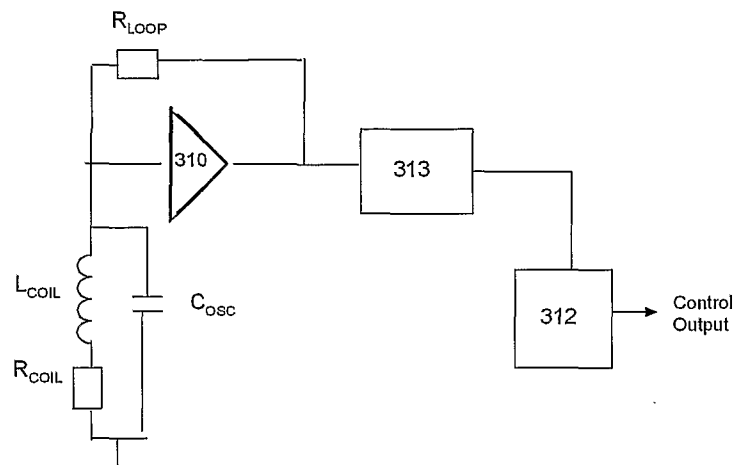
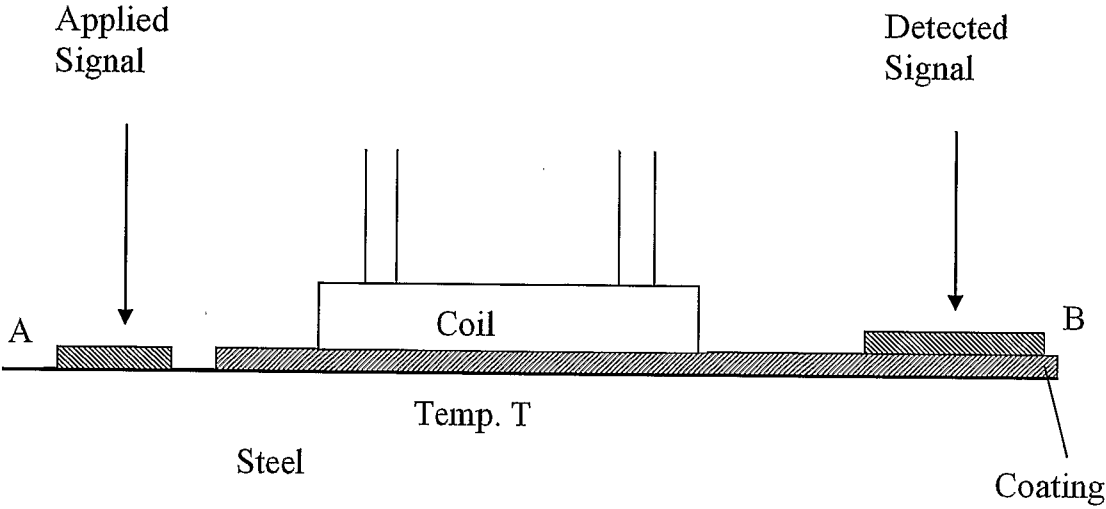


Fig. 2

2/3





INTERNATIONAL SEARCH REPORT

International application No
PCT/NO2007/000372

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05B6/10 H05B6/02 H05B1/02 B08B7/00 B44D3/16

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)

H05B B44D B08B

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 practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 843 316 A (RENAULT SA [FR]) 13 February 2004 (2004-02-13) cited in the application page 6, line 8 - line 22; figure -----	1
A	DE 199 40 732 A1 (STARKSTROM ANLAGEN GMBH [DE]) 1 March 2001 (2001-03-01) cited in the application column 2, line 45 - line 59; figure -----	1-12
A	WO 01/32443 A (JAK J ALVEBERG AS [NO]; ALVEBERG BJOERN ERIK [NO]; BAANN TOM ARNE [NO]) 10 May 2001 (2001-05-10) cited in the application page 4, line 28 - page 5, line 7; figure 1 ----- -/--	1-12

☒ Further documents are listed in the continuation of Box C.

☒ 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 document but published on or after the international filing date

L document which may throw doubts on priority claim(s) or which 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

6 February 2008

Date of mailing of the international search report

14/02/2008

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Gea Haupt, Martin

INTERNATIONAL SEARCH REPORT

International application No

PCT/NO2007/000372

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 4 845 332 A (JANCOSSEK DAVID G [US] ET AL) 4 July 1989 (1989-07-04) column 6, line 57 - column 7, line 16; figure 3 -----	1-12
A	US 5 250 776 A (PFAFFMANN GEORGE D [US]) 5 October 1993 (1993-10-05) column 7, line 1 - line 15; figure 1 -----	1-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NO2007/000372

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
FR 2843316	A	13-02-2004	NONE	
DE 19940732	A1	01-03-2001	AT 413022 B AT 14442000 A FR 2797805 A1 HU 0003374 A2	15-10-2005 15-03-2005 02-03-2001 28-04-2001
WO 0132443	A	10-05-2001	AU 754402 B2 AU 1180501 A BG 65053 B1 BG 106751 A BR 0015206 A CA 2389665 A1 CN 1407931 A CZ 20021872 A3 EA 4780 B1 EE 200200232 A EP 1268222 A1 HK 1052905 A1 HR 20020476 A2 HU 0203341 A2 JP 4014409 B2 JP 2003512961 T MX PA02004407 A NO 995353 A NZ 518958 A PL 355421 A1 SK 7822002 A3 US 6794622 B1 ZA 200204287 A	14-11-2002 14-05-2001 31-01-2007 31-03-2003 31-12-2002 10-05-2001 02-04-2003 12-03-2003 26-08-2004 16-06-2003 02-01-2003 10-06-2005 28-02-2005 28-05-2003 28-11-2007 08-04-2003 10-09-2004 03-05-2001 28-02-2003 19-04-2004 04-03-2003 21-09-2004 11-03-2003
US 4845332	A	04-07-1989	NONE	
US 5250776	A	05-10-1993	US 5373143 A	13-12-1994