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(54) **Title:** METHOD AND DEVICE FOR INSPECTING A RING COMPONENT PRODUCED IN OR FOR A DRIVE BELT MANUFACTURING PROCESS

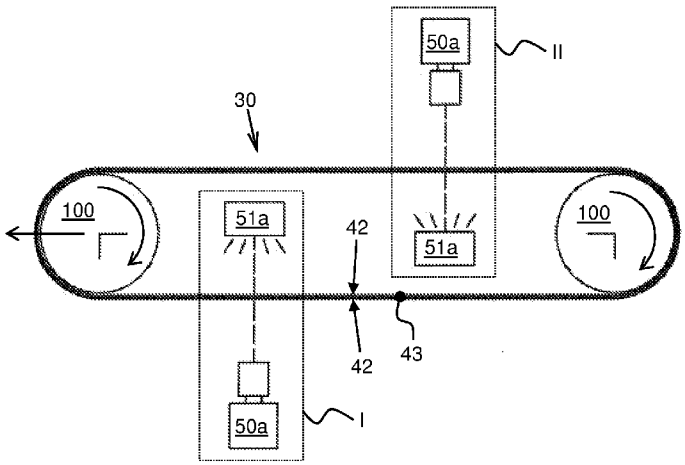


FIG. 3

(57) **Abstract:** The invention provides for a method for inspecting the quality of a ring component (30) produced in or for a drive belt (3) manufacturing process including the steps of: 5 - placing the ring (30) partly between a camera (50a) and a light source (51a) that is directed at the camera (50a), whereby from the vantage point of the camera (50a) the light source (51a) is partly visible and partly obscured by the ring (30) thus revealing at least a part of the contour of an axially facing side surface (43) thereof, - using the camera to take an image of the ring (30), *i.e.* of the said contour part, and 10 of - relating the quality of the ring (30) to the shape of the said contour part by analyzing the image thus taken, in particular by detecting deviations of its actual shape from a theoretically desired shape.

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METHOD AND DEVICE FOR INSPECTING A RING COMPONENT PRODUCED IN OR FOR A DRIVE BELT MANUFACTURING PROCESS

The present invention relates to a method for monitoring the quality of a drive belt manufacturing process, in particular of inspecting ring components manufactured therefor. Such a drive belt is predominantly used as the means for power transmission between two adjustable pulleys of the well-known continuously variable transmission that is a/o applied in motor vehicles.

Several types of drive belt are generally known, one example whereof is described in the European patent publication EP-A-1 554 507 and is composed of a multitude of relatively thin transverse metal elements that are slideably incorporated on two laminated endless tensile means that are each composed of a set of mutually nested flat metal rings, alternatively denoted as continuous bands. The rings are normally made from a maraging steel that combines a/o the properties of great tensile strength and good resistance against tensile stress and bending fatigue. The transverse elements are normally cut, e.g. by blanking, from a strip or plate of basic carbon steel such as 75Cr1. Usually, several further process steps are applied to improve the surface quality and hardness of the elements, such as stone tumbling and quench hardening.

During operation of the drive belt, the said ring component thereof is cyclically loaded to a considerable extend, such that metal fatigue (fracture) is a recognized failure mode of the drive belt, which in practice determines the ultimate functional life thereof. Since it is well known that surface imperfections, such as cracks, scratches, dents and the like, can locally raise stress levels, which in turn may lead to early fatigue fracture, the ring component is produced and handled with great care to avoided damaging of the its outer surface. Even so, such ring damage can not be completely excluded. Therefore, it is common practice to optically inspect the ring surface regarding surface damage as part of its production process and, if imperfections are detected, i.e. if the ring quality does not satisfy a predefined criterion, to reject the respective ring component from the drive belt manufacturing process, or to at least select or mark it for rework. Such optical ring surface inspection may be performed by a duly trained human analyst, but it is preferably performed automatically by first taking a still image of -a part of- the ring surface using a digital camera and then analyzing the camera image using a computer equipped with image analysis software. Indeed, several examples of such optical ring inspection methods have recently been proposed, as provided by, for instance, the

Dutch patent publications NL-A-1028628 and NL-A-1028882.

Although such known inspection methods work adequately per se and represent a significant step forward in terms of inspection efficiency and accuracy compared to the former non-automated inspection by the naked eye, it was found that the ring quality inspection can be improved upon even further. Whereas NL-A-1028628 focuses on the radially facing inner and outer main surfaces of the ring, actually the convexly curved, but predominantly axially facing left and right side surfaces of the ring component and the edges thereof between said main surfaces and such side surfaces are also, if not even more, critical areas in terms of fatigue fracture initiation by surface imperfections. Indeed, NL-A-1028882 focuses on the said side surfaces, however, because the tensile means is inspected as a whole, the rings thereof overlap one another at least partly and the said edges thereof are not completely available for inspection, i.e. are not completely visible to the human analyst or the camera.

It is an object of the present invention to provide for an optical ring inspection method that is at least partly automated and that enables inspection of the whole of the said ring side surfaces. The invention further aims to improve on the sensitivity of the known methods, in particular by also being able to detect surface imperfections that can not be distinguished from undamaged parts of the ring surface merely by analyzing the light reflected of the ring surface in one direction as taught by, for instance, NL-A-1028882.

According to the present invention such a new method for inspecting the quality of the ring component in the drive belt manufacturing process is provided by the following claim 1. Because in this new method the camera is positioned in line with and facing a light source with the ring being placed there between, such that its side surface is back-lit, the contour thereof is made visible with the highest possible contrast and any imperfection therein is optimally recognizable, whether by a human analyzing the camera image or by the said camera image analysis software. In this manner, according to the invention, specifically those types of surface damage that facilitate fatigue crack growth are selectively detectable with remarkable sensitivity.

It is remarked that the said light source can be a lamp, laser or the like directly shining into the camera, but it may also be represented by a mirroring surface that reflects light towards the camera.

According to the invention the ring is preferably rotated to have its entire circumference pass between the light source and the camera. More preferably, at least two such sets of the light source and the camera facing the light source are

employed in the inspection method, each set being installed and used to inspect a respective one of the two side surfaces of the ring simultaneously. In a more detailed embodiment of the inspection method according to the invention that is illustrated in the figures hereof, three such sets of light source and associated camera are employed in respect of a single ring side surface. In this manner, the typical convex shape or contour of said side surface can be accounted for, i.e. the whole of the side surface including the said edges between its main and side surfaces can be analyzed simultaneously and/or without having to move a camera.

Further, in order to avoid that external contaminations, such a e.g. dust particles on the surface of the ring would be erroneously recognized as imperfections of the ring contour, the method according to the invention preferably includes an initial step of cleaning, e.g. cleansing the ring. For the same purpose, the ring is preferably earthed, i.e. ground, at least during the taking of the camera image, but preferably also before. It was found that, otherwise, a static electric charge builds up in the ring when it is rotated as part of the inspection method, which charge would attract dust particles.

The invention is elucidated further with reference to the figures enclosed.

Figure 1 is a schematic representation in a perspective view of a known continuously variable transmission provided with the present type drive belt and two pulleys.

Figure 2 is a cross section of the known drive belt oriented in the longitudinal direction thereof.

Figure 3 illustrates the method according to the invention in a schematic top-view of a possible set-up of an optical ring inspection device also according to the invention.

Figure 4 shows a preferred camera arrangement for the inspection device according to the invention.

Figure 5 provides an image of the drive belt ring component taken in the course of carrying out the method according to the invention by a camera in the figure 4 arrangement.

Figure 1 shows the central parts of a known continuously variable transmission that is commonly applied in the drive-line of motor vehicles between the engine and the drive wheels thereof. The transmission comprises two pulleys 1, 2, each provided with two pulley discs 4, 5, between which a drive belt 3 is present for transmitting a rotational movement M and an accompanying torque from one pulley 1, 2 to the other 2, 1. The pulley discs 4, 5 are shaped generally conical and at least one pulley disc 4

is incorporated in the transmission axially moveable along a respective pulley shaft 6, 7 on which both discs 4, 5 are placed. The transmission normally also comprises activation means that impose on the said at least one movable disc 4 an axially oriented clamping force directed towards the respective other pulley disc 5 such that the drive belt 3 is clamped there between.

The drive belt 3 comprises an endless tensile means 31 and a multitude of relatively thin transverse elements 32 that are provided on the tensile means 31 movable along the longitudinal direction thereof and oriented predominantly transversely thereto. The elements 32 take-up the said clamping force, such that at rotation of a driving pulley 1, friction between the discs 4, 5 and the drive belt 3, causes the elements 32 to be thrust in the said direction of movement M from the said driving pulley 1 to a driven pulley 2 and back again, thereby being guided and supported by the tensile means 31. A geometric transmission ratio of the transmission is determined by the quotient of an effective contact radius R2 of the drive belt 3 at the driven pulley 2 and an effective contact radius R1 of the drive belt 3 at the driving pulley 1, which may be varied continuously in range of values.

Figure 2 provides a cross section of the known drive belt 3, which cross section is oriented in the longitudinal direction of the belt 3. In figure 2 the transverse element component 32 of the drive belt 3 is shown in front elevation. The element 32 comprises three main parts, namely a relatively wide and essentially arrowhead-shaped top part 33, a relatively wide and essentially trapezoidal bottom part 35 and an essentially oblong pillar part 34 of relatively limited width that interconnects the top and bottom parts 33, 35. Further, a projection 38 is provided on a front main face 40 of the transverse element 32, which projection 38 is accommodated in a hole 39 provided in a rear main face 41 of an adjacent transverse element 32. The projection 38 and hole 39 are provided to mutually connect and align adjacent transverse elements 32 of the drive belt 3 during operation in the transmission. At the bottom part 35 of the transverse elements 32 below a so-called tilting edge 37 its thickness tapers-off at least effectively, so as to allow adjacent elements 32 to mutually tilt about the axially oriented tilting edge 37 when clamped between the discs 4, 5 of the pulleys 1, 2.

The transverse elements 32 are incorporated in the drive belt 3 mounted on the endless tensile means 31 thereof, which consists of two laminated parts, each part being formed by a number of thin and flat metal rings 30 that are nested one around the other in the radial direction and each part being accommodated in a respective opening or recess 36 in the transverse element 32, one recess 36 provided on either

side of the pillar part 34 between the element's top and bottom parts 33, 35.

A typical problem that may occur in the manufacture of the ring component 30 of the drive belt 3 is that its outer surface may show imperfections such as cracks, scratches, dents and the like, even though the rings 30 are produced and handled with great care. These surface imperfections can locally raise stress levels that occur during operation of the drive belt 3, which in turn may lead to early fatigue fracture thereof. Therefore, in addition to preventing such ring damage in the first place, it is a general aim in the manufacture of the ring components 30 to be able to identify any ring component 30 that does not satisfy a predefined quality criterion at least in terms of any surface imperfection thereof. The present invention provides for an automated optical inspection method that can be used to monitor such ring quality, which method is schematically illustrated in figure 3 along a top view of a possible embodiment of an optical ring inspection device suitable for carrying such method. In particular the axially facing left and right side surfaces 43 of the ring 30 component including the edges between such side surfaces 43 and the radially oriented inner and outer main surfaces 42 of the ring 30 are the most critical areas in terms of fatigue fracture initiation by surface imperfections.

The optical ring inspection device in figure 3 comprises two rotatable rollers 100, around which rollers a ring 30 is mounted, which ring 30 is viewed from the side, while looking in the axial direction relative thereto and facing one of the said side surfaces 43 thereof. The rollers 100 can be moved apart to -at least slightly- tension the ring 30 and can be rotationally driven to also rotate the ring 30. At least one roller 100 is ground (not shown) to prevent the ring 30 from being statically charged, i.e. to prevent dust particles from being attracted to the ring 30.

The inspection device is provided with two sets I, II of a camera 50a and an associated light source 51a that are positioned mutually in line such that a respective camera 50a faces, i.e. is oriented directly at a respectively associated light source 51a, as is schematically indicated for each set I, II by the dashed line drawn there between. Each such set I, II being associated with and used to inspect a respective, i.e. left or right, side surface 43 of the ring 30.

The device is arranged such that, when mounted around the rollers 100, the ring 30 is placed partly between the camera 50a and the light source 51a of a respective set I, II, such that from the vantage point of each respective camera 50a the light source 51a that is respectively associated with the respective camera 50a is partly visible and partly obscured by the ring 30, thus revealing the said camera 50a at least a part of the contour of a respective side surface 43 of the ring being back-lit

by the said light source 51a. As a result the camera's 50a can accurately record the said contour part of the side surfaces 43 of the ring 30 with the highest possible contrast, thus making any imperfection therein optimally recognizable, whether by a human analyzing the camera image or by the said camera image analysis software. Preferably, both camera's 50a are thereby oriented in a direction essentially perpendicular to the main surfaces 42 of the ring 30.

When the ring 30 is rotated by means of the rollers 100, the entire circumference of the side surfaces 43, i.e. of the contour thereof, can be scanned by the camera's 50a. Any deviation of, or irregularity in such contour that is detected during the scan and that exceeds a predefined magnitude, represents an undesired surface imperfection. If such an undesired surface imperfection is detected, the ring 30 concerned is rejected from the drive belt manufacturing process, or to at least is selected or marked for rework.

According to the invention, preferably two sets I, II of three camera's 50a, 50b, 50c and three associated light sources 51a, 51b, 51c each, are applied in the automated optical ring inspection device. Like before, each such set I, II is associated with a respective, i.e. left or right, side surface 43 of the ring 30. In this particular embodiment of the invention, one camera 50a of a set I, II is oriented essentially in the said direction perpendicular to the main surfaces 42 of the ring 30 for imaging a central part of the respective side surface 43, whereas the other two camera's 50b, 50c are respectively oriented at mutually opposite angles a1, a2 of between 30 and 60 degrees, preferably essentially 45 degrees with such perpendicular direction for imaging the edges between the said respective side surface 43 and the said main ring surfaces 42. This latter, preferred camera arrangement is shown in more detail in figure 4, however, only schematically (a/o the scale of the ring 30 has been greatly exaggerated) and only for one such set I.

The accompanying figure 5 provides an example of a camera image of the contour of a section of the side face 43 of the ring 30 that may be obtained with the inspection device of figure 4. In this particular, but in the practice of ring manufacture relatively rare case, the image clearly shows an imperfection 44 in the form of a notch on the ring side surface 43. This particular ring 30 will thus be rejected from the drive belt manufacturing process.

CLAIMS

1. Method for inspecting a ring component (30) produced in or for a drive belt (3) manufacturing process, in particular for inspecting the quality thereof, which method comprises the steps of:

- placing the ring (30) partly between a camera (50a) and a light source (51a) that is directed at the camera (50a), whereby from the vantage point of the camera (50a) the light source (51a) is partly visible and partly obscured by the ring (30) thus revealing at least a part of the contour of an axially facing side surface (43) thereof,
- using the camera to take an image of the ring (30), i.e. of the said contour part, and of
- relating the quality of the ring (30) to the shape of the said contour part by analyzing the image thus taken, in particular by detecting deviations of its actual shape from a theoretically desired shape.

2. The method according to claim 1, wherein the ring (30) is rejected from the drive belt (3) manufacturing process, or at least is selected or marked for rework, if the said quality, in particular the said contour deviations, does not satisfy a predefined criterion.

3. The method according to claim 1 or 2, wherein the said light source (51a) either is a lamp, laser or the like that shines directly towards the camera (50a), or is represented by a mirroring surface that reflects light towards the camera (50a).

4. The method according to claim 1, 2 or 3, wherein, after the image has been taken, the ring (30) is rotated relative to the camera (50a) and the light source (51a).

5. The method according to any one of the preceding claims, wherein the rings (30) are prevented form being electrically charged, preferably by earthing the rings (30).

6. The method according to any one of the preceding claims, characterized in that, it further includes an initial step of cleaning the rings (30).

7. Device for inspecting a ring component (30) produced in or for a drive belt (3) manufacturing process, in particular for inspecting the quality thereof, which device comprises two rollers (100) for mounting the ring (30) in the device, characterized in that, the device further comprises a camera (50a) and a light source (51a) that faces, i.e. that is directed at the camera (50a).

8. The device according to claim 7, characterized in that the camera (50a) is oriented in a direction essentially perpendicular to a radially facing main surface (42) of the ring (30) when mounted in the device and are positioned such in the device that from the vantage point of the camera (50a) the light source (51a) is partly visible and partly obscured by the ring (30).

9. The device according to claim 7 or 8, characterized in that, the device comprises two sets (I, II) of the camera (50a) and the light source (51a) facing it, each such set (I; II) being associated with a respective axially facing side surface (43) of the ring (30), at least when mounted in the device.

10. The device according to claim 9, characterized in that, each such set (I; II) comprises three camera's (50a, 50b, 50c) and three light sources (51a, 51b, 51c), each light source (51a; 51b; 51c) directly facing a respective camera (50a; 50b; 50c) of the set (I; II), whereof a first camera (50a) is oriented in a direction essentially perpendicular to a radially facing main surface (42) of the ring (30) when mounted in the device and whereof the other two camera's (50b, 50c) are respectively oriented at mutually opposite angles of between 30 and 60 degrees, preferably of essentially 45 degrees with such perpendicular direction.

11. The device according to any one of the claims 7-10, characterized in that the rollers (100) are arranged such that they can be moved apart to tension the ring (30) and that they can be rotationally driven to also rotate the ring (30).

12. The device according to any one of the claims 7-11, characterized in that at least one roller (100) is earthed.

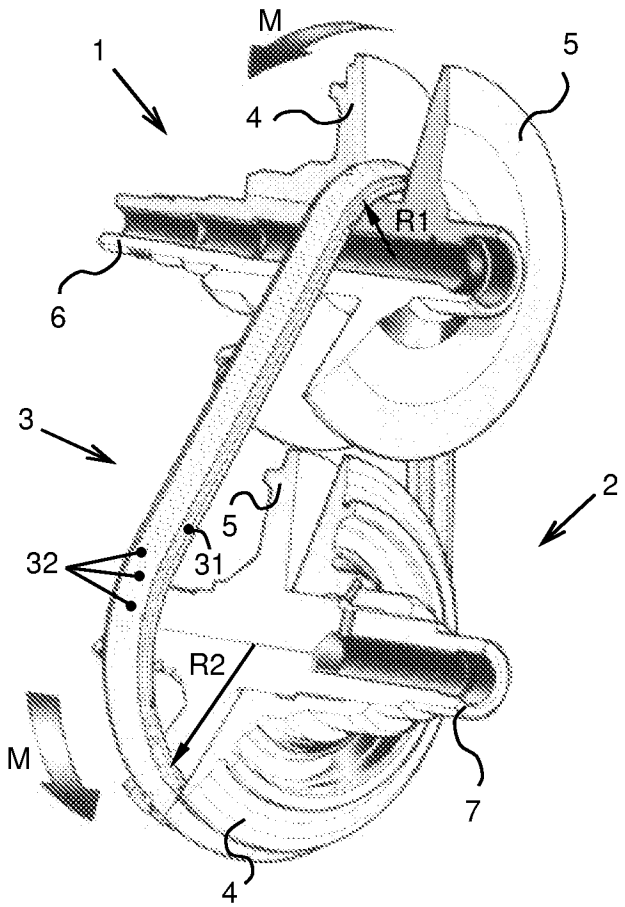

M
1
5
4
R1
6
3
2
5
32
31
R2
M
7
4

FIG. 1

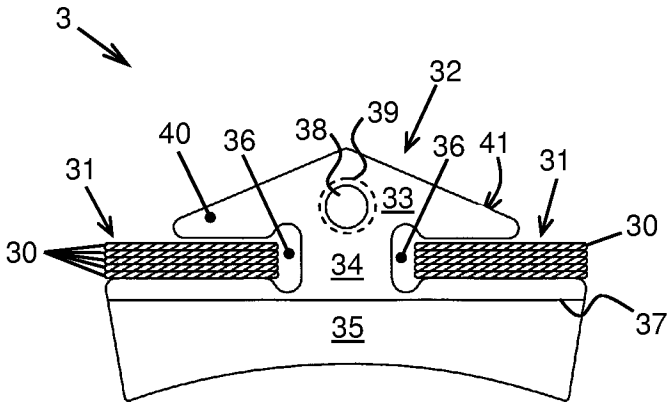

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34
37
35

FIG. 2

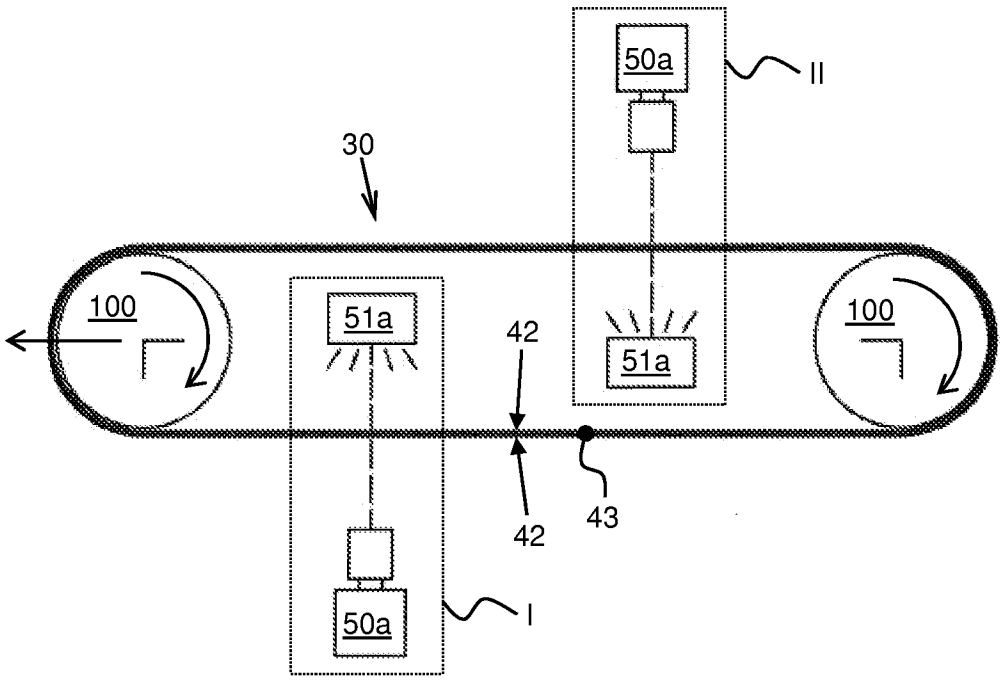

50a
II
30
100
51a
42
51a
100
42
43
50a
I

FIG. 3

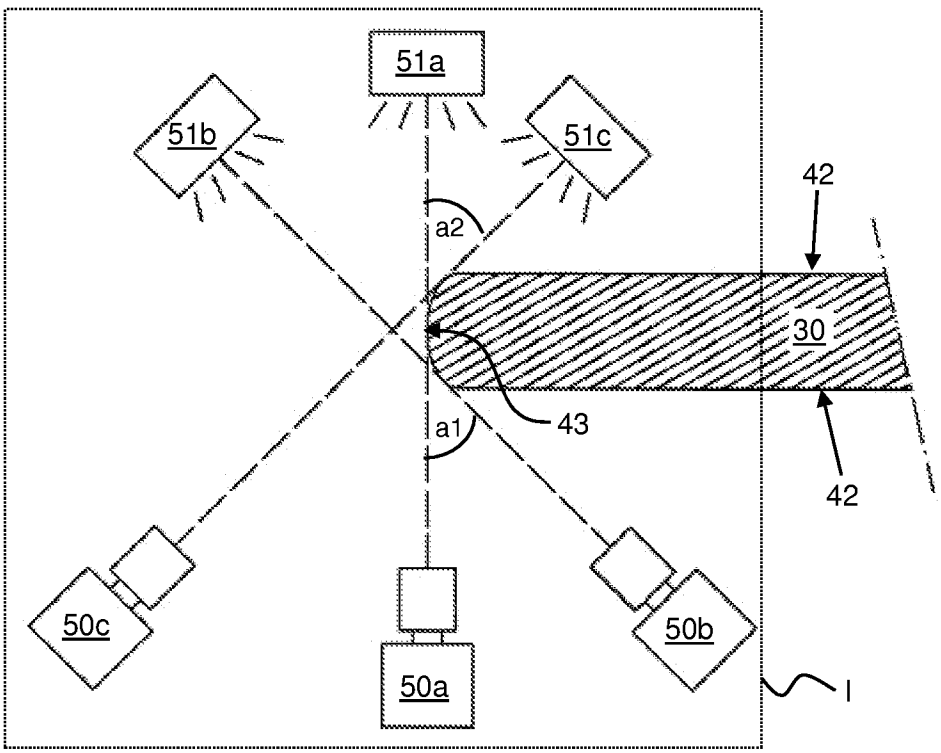

51a
51b
51c
42
a2
30
43
a1
42
50c
50b
50a
I

FIG. 4

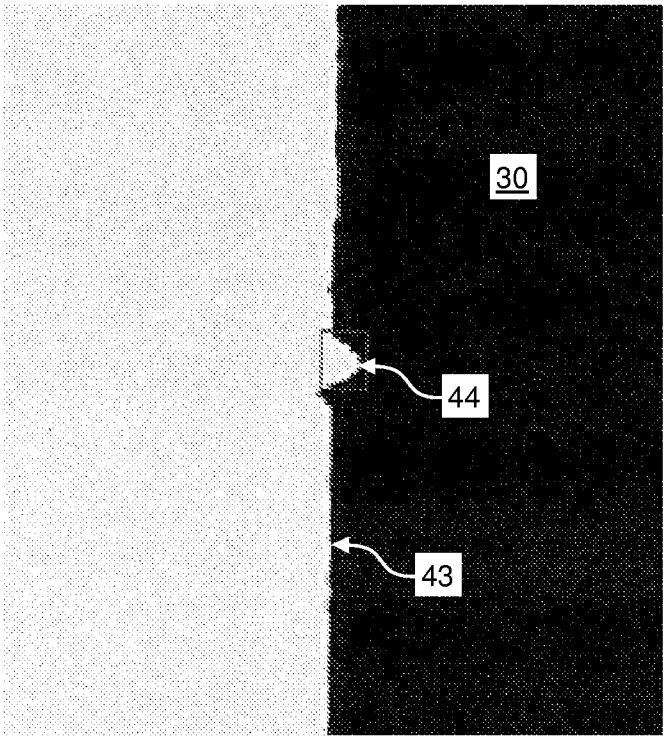


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2007/050709

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N21/89

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)
G01N G01M G01B F16G

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007 187516 A (TOYOTA MOTOR CORP) 26 July 2007 (2007-07-26) paragraphs [0001], [0008], [0010], [0012], [0013], [0027], [0033], [0043] figures 1,2,4-6	1-12
Y	WO 91/15731 A (AUROTEC SYSTEM GMBH INDUSTRIEA [DE]) 17 October 1991 (1991-10-17) abstract page 2 page 4, last paragraph page 12 figure 1	1-12
Y	JP 06 331553 A (HITACHI METALS LTD) 2 December 1994 (1994-12-02) abstract	6

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

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 September 2008	06/10/2008

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, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	D'Alessandro, Davide

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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2007/050709

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 2006 138830 A (NIPPON ELECTRO SENSARI DEVICE) 1 June 2006 (2006-06-01) abstract figure 5	10
A	US 3 715 476 A (WATANABE T ET AL) 6 February 1973 (1973-02-06) column 1, line 40 - line 59 column 3, line 57 - column 4, line 3 figure 3	1-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2007/050709

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