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(54) **Title**: SYSTEM FOR MOVING A MOBILE TENDON CONTROLLED PLATFORM ROBOT

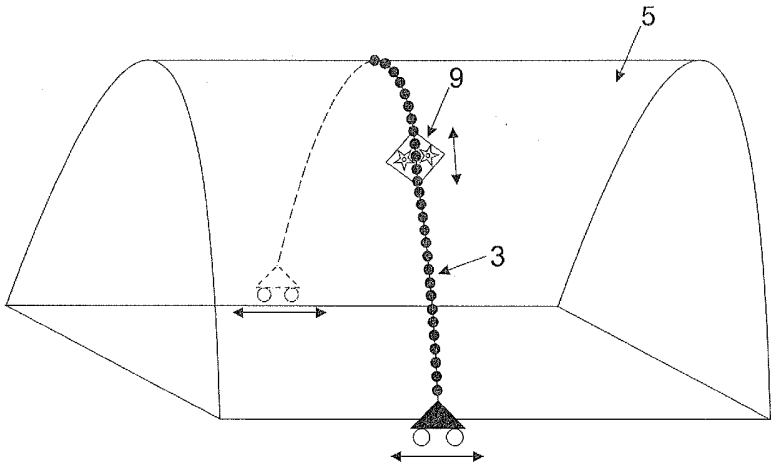

FIG. 3A

(57) **Abstract**: System for moving a mobile tendon controlled plat- form robot, comprising a mobile platform (1), at least one drive means (2', 2", 2'", 2"") and at least one tendon (3', 3", 3'", 3"") connected to the mobile platform (1), wherein the relative position of the at least one tendon (3', 3", 3'", 3"") with respect to the mobile platform (1) is controllable with the at least one drive means (2', 2", 2'", 2""), and wherein the at least one tendon (3', 3", 3'", 3"") is provided with means (4) to enable the tendon (3', 3", 3'", 3"") to move without chafing past a surface (5) of an object (6) external to the mobile tendon controlled platform robot.

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System for moving a mobile tendon controlled platform robot

The invention relates to a system for moving a mobile tendon controlled platform robot, comprising a mobile platform, at least one drive means and at least one tendon connected to the mobile platform, wherein the relative position of the at least one tendon with respect to the mobile platform is controllable with the at least one drive means. The word 'tendon' as used in relation to the invention can relate to any type of flexible cord or member.

Such a system is known from WO95/23053 and from US2012/0043162. In the known system the mobile tendon controlled platform robot operates within a confined workspace and with plural tendons. The tendons then extend from anchor points in selected corners of the confined workspace to motor driven spools, reels or winches that are located on the mobile platform. By a controlled driving of the spools or winches the mobile platform can be accurately positioned within the confined workspace. An end effector mounted on the platform may carry out a specific task, such as grasping loose articles or holding and manipulating a tool.

US2012/0043162 specifically mentions the operations of welding, blasting and painting which need to be performed inside a block, wherein the block is surrounded by structures such as partition walls and stiffners as are present in the hull of a ship. Such a mobile tendon controlled platform robot can also be used to carry out operations on the outside of the ship, notably on the convex hull. To avoid that while the mobile platform is moved the tendons damage the ship's hull, the anchor points for the tendons are placed distant from the ship. This has notable disadvantages considering that the tendons restrict the freedom of movement of other equipment near to the ship and is aesthetically undesirable. Furthermore controlling the mobile platform accurately requires eight cables and a complicated control unit. Also the tendons are relatively long considering the distant placement of the anchor points and therefore prone to vibration, in

part caused by wind. With long distances it is also difficult to maintain a straight connection of the tendons between the anchor points and the robot, which makes accurate positioning difficult.

Similar problems exist when the mobile tendon controlled platform is applied for operations on other types of objects having a surface with a curvature. An object of the invention is therefore to propose a system for moving a mobile tendon controlled platform in which the aforementioned problems are alleviated or addressed.

US-A-3,638,600 teaches a system according to the preamble, wherein at least one tendon is provided that is slidably encased in a nylon tubing for most of the tendon's length to enable the tendon to move without chafing past a surface of an object.

In accordance with the invention a system for moving a mobile tendon controlled platform is proposed having the features of one or more of the appended claims.

In a first aspect of the invention a system is proposed for moving a mobile tendon controlled platform wherein at least one drive means and at least one tendon are connected to the mobile platform, and wherein the relative position of the at least one tendon with respect to the mobile platform is controllable with the at least one drive means, and in which the at least one tendon is provided with means to enable the tendon to move without chafing past a surface of an object that are selected from the group comprising a) tubes that are rotatably provided around the at least one tendon so as to arrange that said tubes rotate during movement of the at least one tendon past the surface transverse to its longitudinal direction, b) beads that are rotatably provided around the at least one tendon, and c) an external friction lowering coating provided on the at least one tendon.

Such tubes and/or beads are very cost efficient and reliable means to prevent that the tendons may chafe during their transversal movement along the surface of the object. The length of the tubes and shape of the beads can be elected

freely as long as they are rotatably provided around the at least one tendon and serve the invention's purpose. The measure that the tendon is at least in part provided with an external friction lowering coating promotes that damage to the surface of the object due to chafing is avoided.

Normally the object is external to the mobile tendon controlled platform robot. With this arrangement of the invention it is enabled to mount the anchor points for the tendons close by or even on the very object along the surface of which the mobile platform is moved. This practically eliminates the problems that are associated with the conventional application of the mobile platform when the anchor points are placed distant from the object.

Although the prior art embodied by WO95/23053 and US2012/00431624 teaches that the drive means or drives are placed on the mobile platform, this is not a requirement in the system of the invention. In a particular embodiment the at least one drive means is external from the mobile platform. In this embodiment a guide reel may be mounted on the mobile platform, around which guide reel the at least one tendon is guided, wherein the at least one tendon connects directly or indirectly to the at least one drive means such that actuation of said drive means results in relative movement of the at least one tendon and the mobile platform. Preferably for this purpose the at least one drive means connects to a winch for storing and/or releasing of the at least one tendon.

In another embodiment the at least one drive means is mounted on the mobile platform and connected to a device selected from the group comprising a winch, and (frictional) engagement means, which selected device is in contact with the at least one tendon so as to arrange that actuation of the at least one drive means results in relative movement of the at least one tendon and the mobile platform. This embodiment can suitably be implemented such that there is only a single tendon.

In another embodiment there are two tendons and two drive means, wherein each tendon cooperates with a device in-

dividual to such tendon and selected from the group comprising a winch, and (frictional) engagement means, which selected device is in contact with its concerning tendon so as to arrange that actuation of the concerning drive means that is operably connected to the selected device results in relative movement of the concerning tendon and the mobile platform.

In still another embodiment there are four tendons and four drive means operably connected to winches mounted on the mobile platform so as to arrange that actuation of a drive means that is operably connected to a winch results in relative movement of the tendon connected to the concerning winch and the mobile platform.

It will be clear that the invention is not restricted to a particular number of tendons; in fact the invention requires only that there is at least one tendon. There may therefore also be five or six, or any other suitable number of tendons.

The invention will hereinafter be further elucidated with reference to the drawing schematically showing the system of the invention in different embodiments. It is to be noted that these schematic examples are not restrictive as to the claims, and are provided merely to elucidate the concept of the invention.

In the drawing:

-figure 1 shows a first embodiment of the system of the invention operating with a single tendon and a drive means external of the mobile platform;

-figure 2 shows a second embodiment of the system of the invention operating with a single tendon and a drive means mounted on the mobile platform;

-figure 3A and 3B show a third embodiment of the system of the invention operating with a single tendon and a drive means mounted on the mobile platform;

-figure 4A and 4B show a fourth embodiment of the system of the invention operating with two tendons and drive means mounted on the mobile platform;

-figure 5A and 5B show a fifth embodiment of the

system of the invention operating with four tendons and drive means mounted on the mobile platform.

Wherever in the figures the same reference numerals are applied, these numerals refer to the same parts.

Common to all embodiments of the system of the invention is a mobile platform 1, at least one drive means 2 and at least one tendon 3 connected to the mobile platform 1, wherein the relative position of the at least one tendon 3 with respect to the mobile platform 1 is controllable with the at least one drive means 2, and the at least one tendon 3 is provided with means 4 to enable the tendon 3 to move without chafing past a surface 5 of an object 6. In this example the object 6 is external to the mobile tendon controlled platform robot 1. The means 4 to enable the tendon 3 to move without chafing past the surface 5 are embodied as tubes or beads 7 that are rotatably provided around the at least one tendon 3. It is also possible that the tendon 3 is at least in part provided with an external friction lowering coating.

Figure 1 shows the embodiment in which a drive means 2 is external from the mobile platform 1. In this embodiment a guide reel 8 is mounted on the mobile platform 1 around which guide reel 8 a tendon 3 is guided. The tendon 3 connects either directly or indirectly to the drive means 2 such that actuation of said drive means 2 results in relative movement of the tendon 3 and the mobile platform 1. If there is an indirect connection to the drive means 2 this may be implemented in that the drive means 2 connects to a winch, reel or spool for storing and/or releasing of the tendon 3.

Figure 2 shows the embodiment in which one drive means 2 is mounted on the mobile platform 1 and the tendon 3 is connected to a winch, reel or spool, so as to arrange that actuation of the drive means 2 results in relative movement of the tendon 3 and the mobile platform 1. As is the case in the embodiment of figure 1, the embodiment of figure 2 is arranged with a single tendon 3. This is also the case in the embodiment of figure 3A/3B.

In figure 3A an embodiment is shown in which a drive means (not shown) is or are mounted on the mobile platform 1

and connected to engagement means 9. The engagement means can be implemented as frictional engagement means, which in the example shown are embodied as star shaped wheels. In the detail of figure 3B is clearly shown that these engagement means 9 are in contact with the single tendon 3 so as to arrange that actuation of the drive means results in relative movement of the tendon 3 and the mobile platform 1.

Yet another embodiment is shown in figure 4A and 4B. Figure 4A and 4B show the embodiment in which there are two tendons 3', 3'' and two drive means 2', 2''; see in particular figure 4B. Each tendon 3', 3'' cooperates with a winch 10', 10'' or another suitable device individual to such tendon 3', 3''. This device may be selected from the group comprising a winch (as is shown in figure 4B), a reel, a spool and (frictional) engagement means. If frictional engagement means are selected means as are shown in the embodiment of figure 3A and figure 3B may be employed. The eventually selected device (winch, reel, spool or (frictional) engagement means) is in contact with the concerning tendon 3', 3'' so as to arrange that actuation of the concerning drive means 2', 2'' that is operably connected to the selected device (such as the shown winches 10', 10'') results in relative movement of the concerning tendon 3', 3'' and the mobile platform 1.

Figure 5A and 5B finally show an embodiment in which there are four tendons 3', 3'', 3''', 3'''' and four drive means 2', 2'', 2''', 2'''' operably connected to winches 10', 10'', 10''', 10'''' mounted on the mobile platform 1 so as to arrange that actuation of a drive means 2', 2'', 2''', 2'''' that is operably connected to a winch 10', 10'', 10''', 10'''' results in relative movement of the tendon 3', 3'', 3''', 3'''' connected to the concerning winch 10', 10'', 10''', 10'''' and the mobile platform 1. Again instead of the winches also reels or spools, or frictional engagement means as employed in the embodiment shown in figure 3A and 3B may be applied.

CLAIMS

1. System for moving a mobile tendon controlled platform robot, comprising a mobile platform (1), at least one drive means (2', 2'', 2''', 2'''') and at least one tendon (3', 3'', 3''', 3'''') connected to the mobile platform (1), wherein the relative position of the at least one tendon (3', 3'', 3''', 3'''') with respect to the mobile platform (1) is controllable with the at least one drive means (2', 2'', 2''', 2''''), wherein the at least one tendon (3', 3'', 3''', 3'''') is provided with means (4) to enable the tendon (3', 3'', 3''', 3'''') to move without chafing past a surface (5) of an object (6), **characterized in that** said means (4) to enable the tendon (3', 3'', 3''', 3'''') to move without chafing past a surface (5) are selected from the group comprising a) tubes that are rotatably provided around the at least one tendon so as to arrange that said tubes rotate during movement of the at least one tendon (3', 3'', 3''', 3'''') past the surface (5) transverse to its longitudinal direction, b) beads (7) that are rotatably provided around the at least one tendon (3', 3'', 3''', 3''''), and c) an external friction lowering coating provided on the at least one tendon (3', 3'', 3''', 3'''').

2. System for moving a mobile tendon controlled platform robot according to claim 1, **characterized in that** said means (4) to enable the tendon (3', 3'', 3''', 3'''') to move without chafing past a surface (5) are beads (7) that are rotatably provided around the at least one tendon (3', 3'', 3''', 3'''').

3. System for moving a mobile tendon controlled platform robot according to claim 1 or 2, **characterized in that** the tendon (3', 3'', 3''', 3'''') is at least in part provided with an external friction lowering coating.

4. System for moving a mobile tendon controlled platform robot according to any one of claims 1-3, **characterized in that** the at least one drive means (2', 2'', 2''', 2'''') is external from the mobile platform (1) and that on the mobile platform (1) a guide reel (8) is mounted around

which the at least one tendon (3', 3'', 3''', 3'''') is guided, and that said at least one tendon (3', 3'', 3''', 3'''') connects directly or indirectly to the at least one drive means (2', 2'', 2''', 2'''') such that actuation of said drive means (2', 2'', 2''', 2'''') results in relative movement of the at least one tendon (3', 3'', 3''', 3'''') and the mobile platform (1).

5. System for moving a mobile tendon controlled platform robot according to claim 4, **characterized in that** the at least one drive means (2', 2'', 2''', 2'''') connects to a winch (10', 10'', 10''', 10''''), reel or spool for storing and/or releasing of the at least one tendon (3', 3'', 3''', 3'''').

6. System for moving a mobile tendon controlled platform robot according to any one of claims 1-3, **characterized in that** the at least one drive means (2', 2'', 2''', 2'''') is mounted on the mobile platform (1) and connected to a device selected from the group comprising a winch, a reel, a spool, and preferably frictional engagement means, which selected device is in contact with the at least one tendon (3', 3'', 3''', 3'''') so as to arrange that actuation of the at least one drive means (2', 2'', 2''', 2'''') results in relative movement of the at least one tendon (3', 3'', 3''', 3'''') and the mobile platform (1).

7. System for moving a mobile tendon controlled platform robot according to claim 6, **characterized in that** there is a single tendon (3).

8. System for moving a mobile tendon controlled platform robot according to claim 6, **characterized in that** there are two tendons (3', 3'') and two drive means (2', 2''), wherein each tendon (3', 3'') cooperates with a device individual to such tendon (3', 3'') and selected from the group comprising a winch, a reel, a spool and preferably frictional engagement means, which selected device is in contact with its concerning tendon (3', 3'') so as to arrange that actuation of the concerning drive means (2', 2'') that is operably connected to the selected device results in relative movement of the concerning tendon (3', 3'') and the mo-

bile platform (1).

9. System for moving a mobile tendon controlled platform robot according to claim 6, **characterized in that** there are four tendons (3′, 3′′, 3′′′, 3′′′′) and four drive means (2′, 2′′, 2′′′, 2′′′′) operably connected to winches (10′, 10′′, 10′′′, 10′′′′), reels or spools mounted on the mobile platform so as to arrange that actuation of a drive means (2′, 2′′, 2′′′, 2′′′′) that is operably connected to a winch, reel or spool results in relative movement of the tendon (3′, 3′′, 3′′′, 3′′′′) connected to the concerning winch (10′, 10′′, 10′′′, 10′′′′), reel or spool and the mobile platform (1).

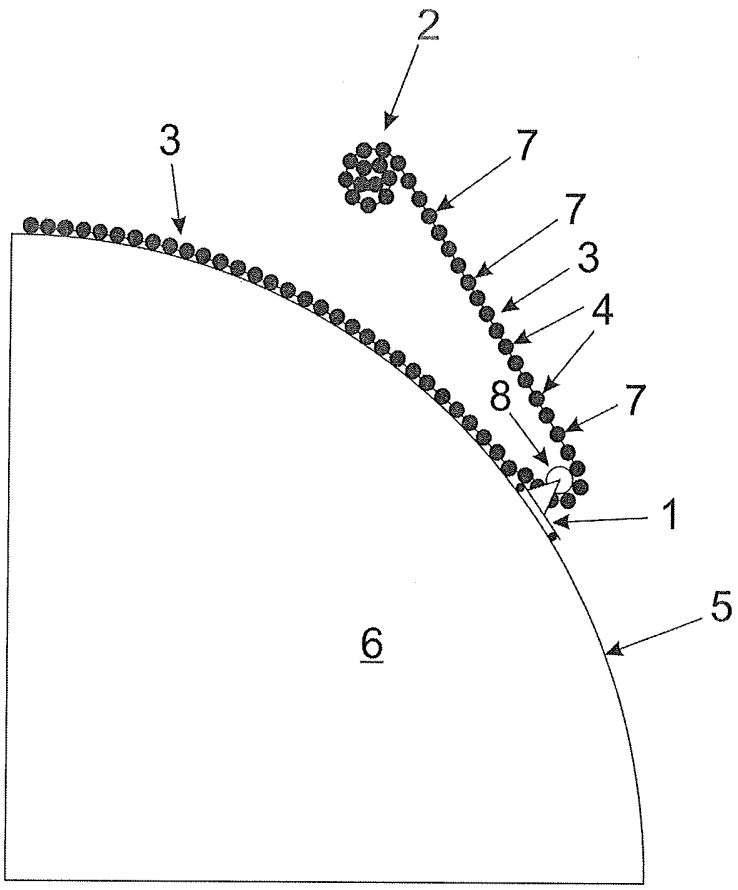

FIG. 1

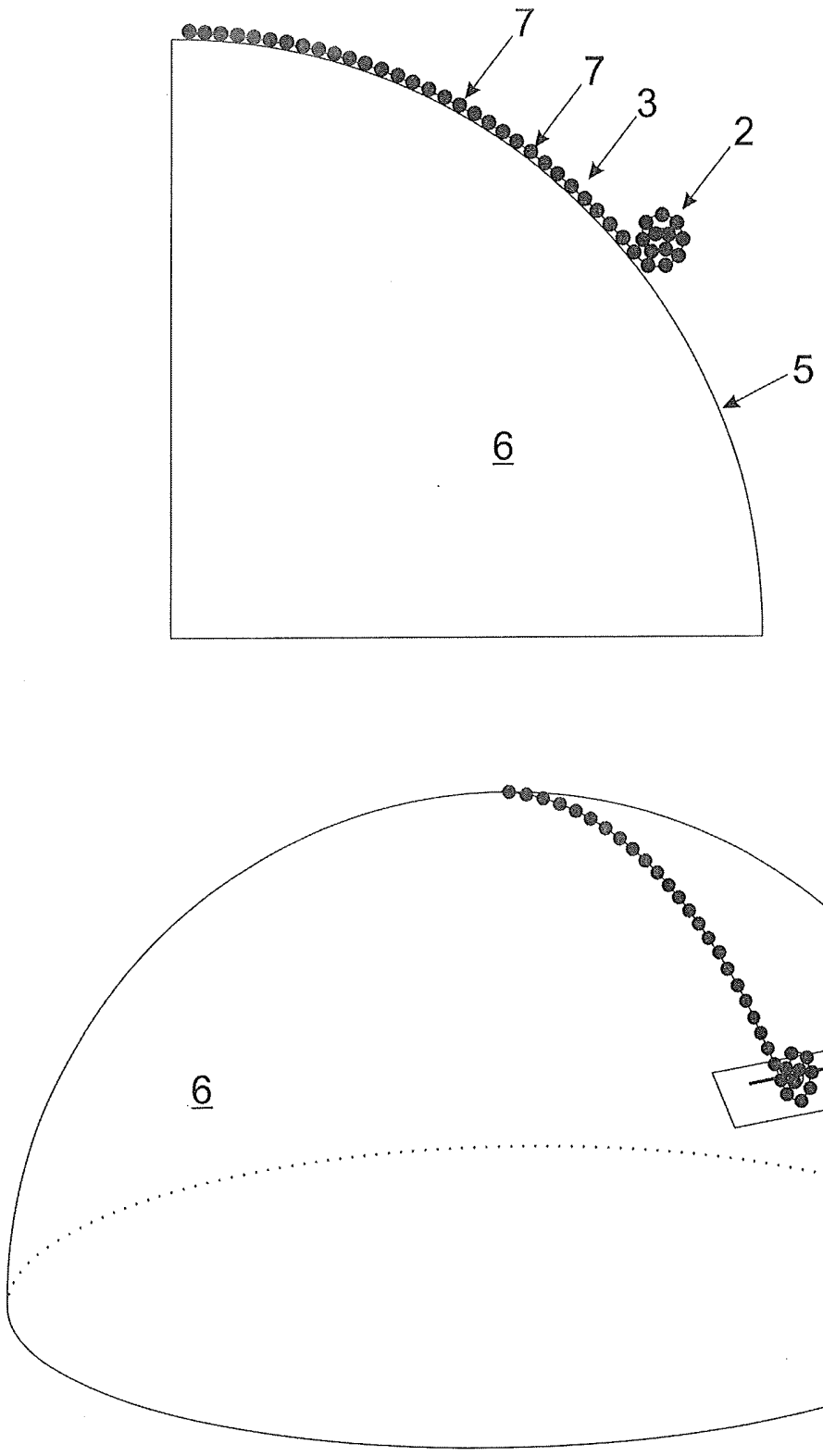

FIG. 2

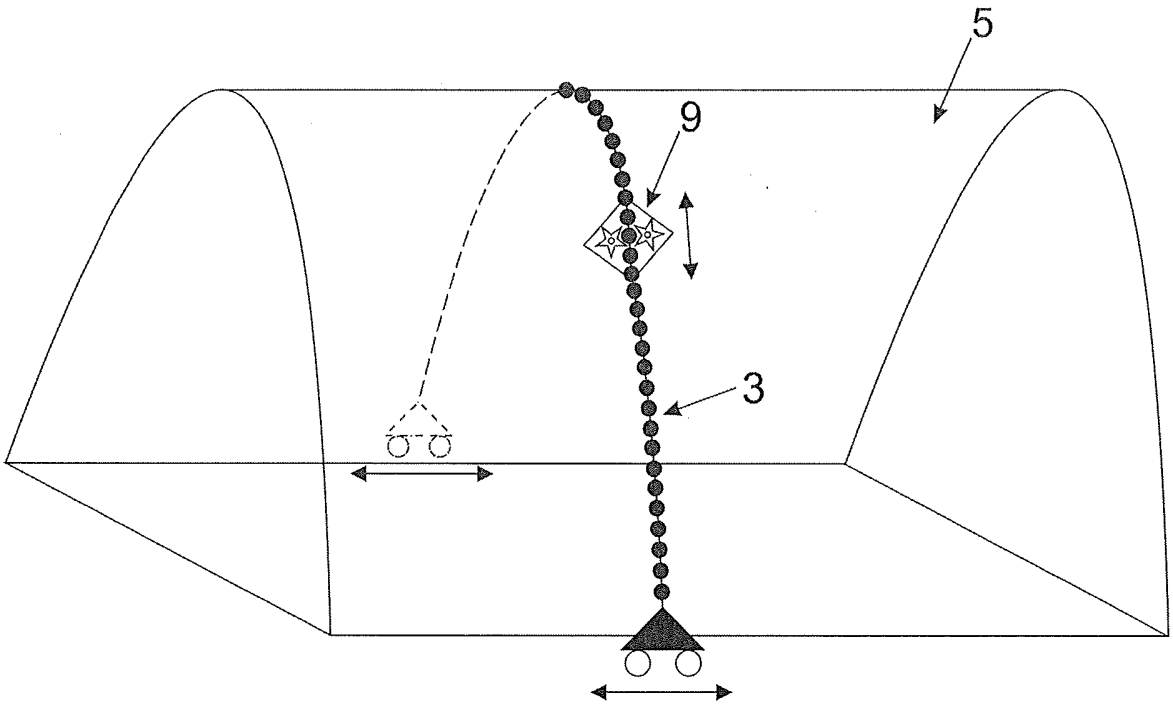

FIG. 3A

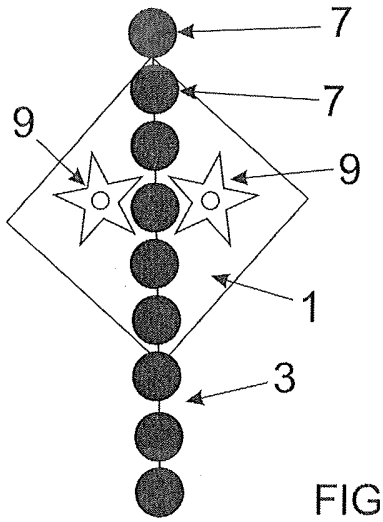

FIG. 3B

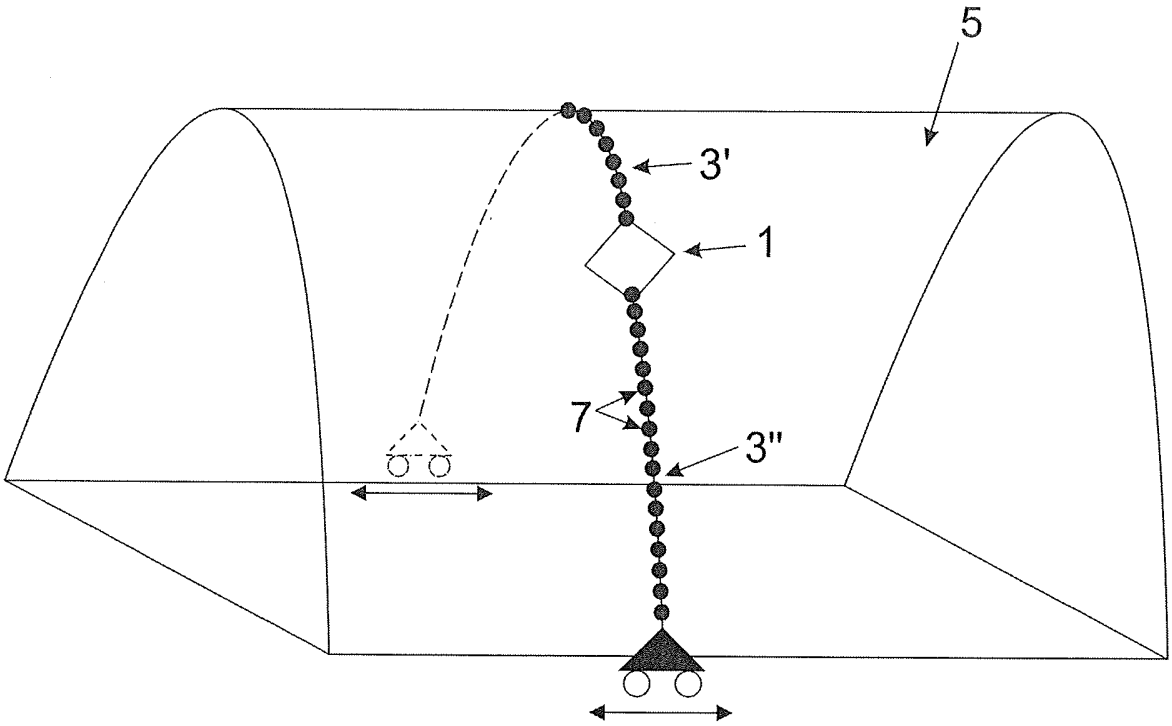

FIG. 4A

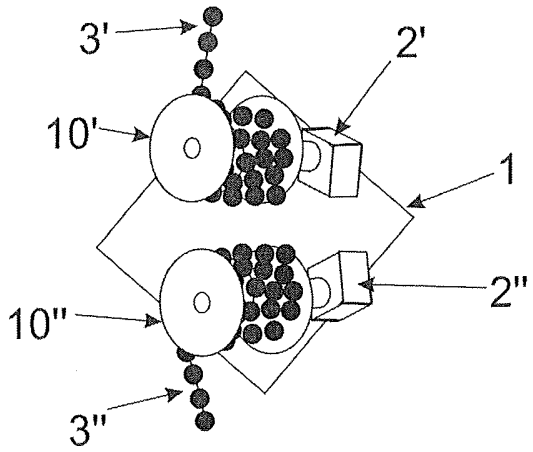

FiG. 4B

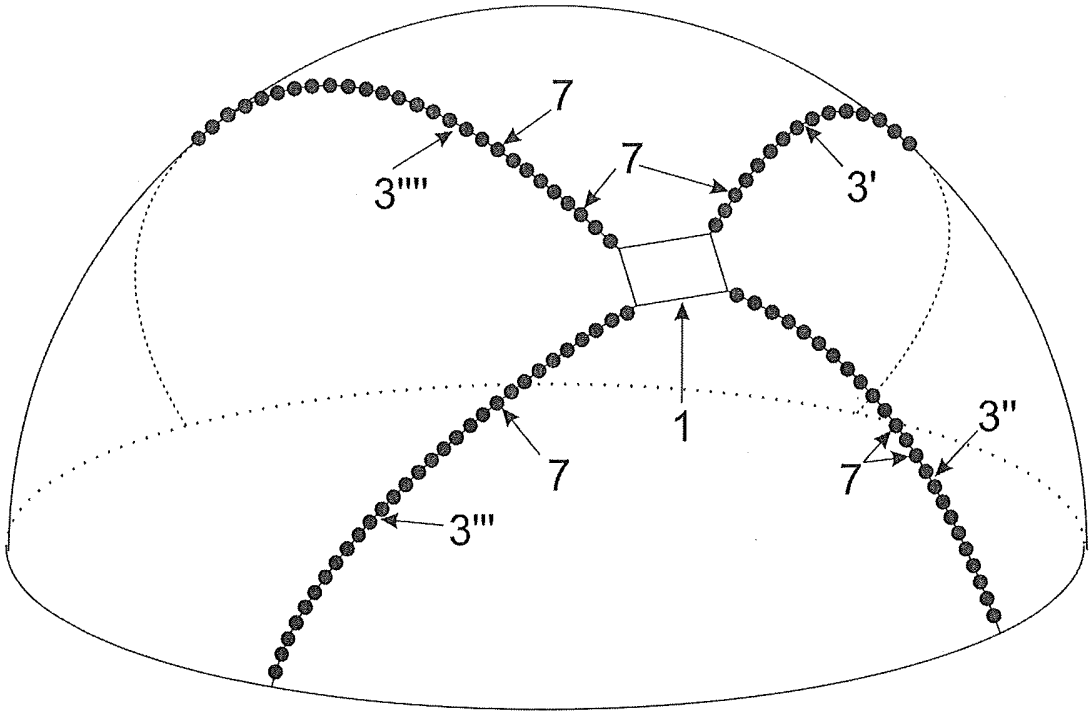

FIG. 5A

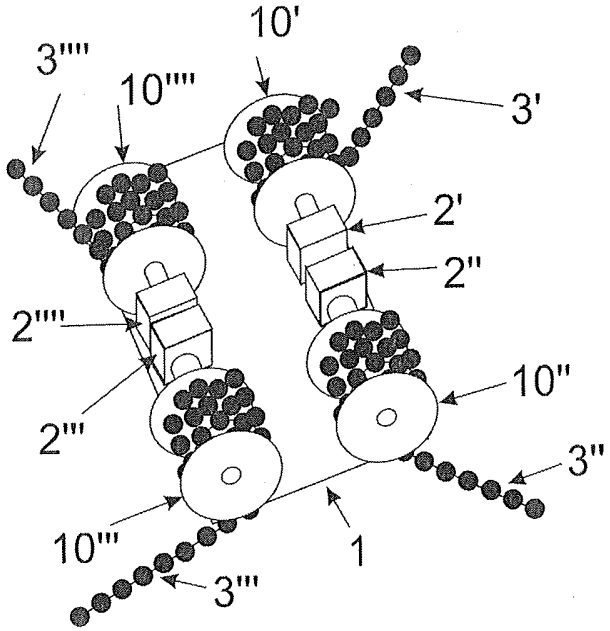

FiG. 5B

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2013/050638

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25J9/00
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)
B25J A47L B08B B63B

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 3 638 600 A (MODREY HENRY J) 1 February 1972 (1972-02-01) figures 1,2,7 column 3, line 60 - column 4, line 2 -----	1,5
A	WO 2011/148004 A1 (FUNDACION FATRONIK [ES]; COLLADO JIMENEZ VALENTIN [ES]; GUSTAVSSON LAR) 1 December 2011 (2011-12-01) abstract; figures 1,9,14 -----	1-9
A	US 5 585 707 A (THOMPSON CLARK J [US] ET AL) 17 December 1996 (1996-12-17) abstract; figure 1 column 1, line 40 - line 50 column 1, line 15 - line 23 -----	1-9

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

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2013	30/10/2013

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	Lumineau, Stéphane

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2013/050638

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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