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(54) **Title**: CONCAVE BEARING OUTER RACE FOR ROBOTIC JOINTS

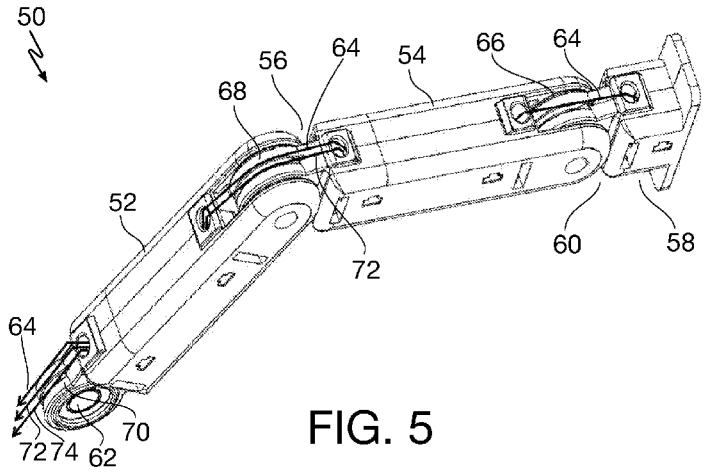

FIG. 5

(57) **Abstract**: A robotic manipulator includes an actuator, a first link and a second link coupled together at a joint, and a bearing rotatably disposed in the joint and having a concave outer race. At least one tendon is coupled between the actuator and the second link, the at least one tendon passes between the first link and the second link, and is routed over the concave outer race of the bearing when passing between the first link and the second link.

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CONCAVE BEARING OUTER RACE FOR ROBOTIC JOINTS

[0001] This international patent application claims the benefit of United States Provisional Patent Application No. 62/041,332 for "Cable Guide System for Robotic Mechanical Manipulator Structure," filed August 25, 2014; Provisional Patent Application No. 62/087,664 for "Tendon Configuration for Under-Actuated Robotic Manipulator With Progressive Wrapping Links," filed December 4, 2014; Provisional Patent Application No. 62/165,080 for "Tendon Configuration for Under-Actuated Robotic Manipulator With Progressive Wrapping Links," filed May 21, 2015; and Provisional Patent Application No. 62/165,074 for "Apparatus and Method for Attaching Apparatus to Robotic Fingers," filed May 21, 2015 the contents of all of which are incorporated in this disclosure by reference in their entirety.

BACKGROUND

Field of the invention

[0002] The present invention relates in general to mechanical manipulators and appendages for use in robotics applications.

The Prior Art

[0003] The mechanical manipulator of an industrial robot is made up of a sequence of link and joint combinations. The links are the rigid members connecting the joints. The joints (also called axis) are the movable components of the robot that enable relative motion between adjacent links.

[0004] One method of providing force for rotating a link around a joint in robots is to utilize artificial tendons that provide tension between a remote actuator and a link. These tendon-based structures are often found in robotic grippers where the links and joints make up the fingers, palm and wrist of the robotic grippers.

[0005] These tendons need to be routed through the links and joints to the remotely located actuators. The tendons move in the links and joints when the mechanical manipulators are moving. The tendons must move through the links and joints and must change direction at

various points between where they are anchored in the links or joints and their anchor at the actuator.

[0006] There are many variations of how the cables can be routed through the joints of a manipulator. Some designs route the tendons over the outer race of the bearings used in the joints. In these designs, it is important to keep the tendon centered on the smooth, low friction race rather than have the tendon rub against the physical structure enclosing the bearing which may be more abrasive to the tendon or susceptible to wear from the tendon. In addition, it is often better to keep the tendon centered on the joint to minimize twist on the fingers.

[0007] The most advanced method to align the tendon onto the bearing race is to have ceramic or metal guides where the tendon both leaves and enters the links that are spanned by the joint. These guides provide an inherent alignment of the tendon onto the center of the outer bearing race. However, the narrow channel between the supporting structure holding the bearing in the joint may be narrower than the alignment tolerance provided by the tendon guides.

SUMMARY

[0008] According to a first aspect of the invention, in robotic manipulators that use tendons to move the links where the tendons are routed through the outer race of a bearing when passing between two links in the robot, the outer race of the bearing is concave to create a self-centering force on the tendon when it is passing over the outer race of the bearing.

[0009] According to a second aspect of the invention, standard bearings are available with flat, concave and v-groove outer races. Depending on the particular application, specially shaped tracks on the outer races can be optimized for improving the alignment of the tendon and separation of the tendon from the bearing supporting structure.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0010] FIG. 1 through FIG. 4 are drawings that present end views of exemplary bearings suitable for use in a tendon based robotic finger in accordance with the present invention.

[0011] FIG. 5 is an isometric view of a robotic finger assembly having two links, and shows tendons passing over the center lines of three joints in the assembly.

[0012] FIG. 6 is a drawing showing a cutaway side view of the links showing the tendon passing over the outer race of one of the joint bearings to illustrate the path a tendon takes at a joint as it slides over the outer race of a bearing.

[0013] FIG. 7 shows a standard ball bearing and a variety of concave bearing shapes.

DETAILED DESCRIPTION

[0014] Persons of ordinary skill in the art will realize that the following description of the present invention is illustrative only and not in any way limiting. Other embodiments of the invention will readily suggest themselves to such skilled persons.

[0015] Referring first to FIG. 1, FIG. 1 a series of drawings present end views of exemplary bearings suitable for use in a tendon based robotic finger in accordance with the present invention. FIG. 1 is a drawing showing an end view of a bearing 10 having a curved concave outer race 12. FIG. 2 is a drawing showing an end view of a bearing 20 having an outer race with a v-shaped indentation 22 disposed between opposing shoulders 24. FIG. 3 is a drawing showing an end view of a bearing 30 having a concave outer race 32 disposed between opposing shoulders 34. FIG. 4 is a drawing showing an end view of a bearing 40 having a concave outer race 42 terminating in end walls 44 that extend outward from the outer race at the inner edges of shoulders 46.

[0016] Referring now to FIG. 5, an isometric view shows a robotic finger assembly 50 including link 52 coupled to link 54 by joint 56. The link 54 of the robotic finger assembly 50 is coupled to a flat end link 58 at a second joint 60. A third joint 62 is shown for coupling link 52 to another link or to a gripper base (not shown). A first tendon 64 is shown passing over the centerlines of the joints 56, 60, and 62 on the outer races of bearing 66 in joint 60, bearing 68 in joint 56, and bearing 70 in joint 62. A second tendon 72 is shown passing over the centerlines of the joints 56, and 62 on the outer races of bearing 68 in joint 56, and bearing 70 in joint 62. A third tendon 74 is shown passing over the centerline of the joint 62 on the outer race of bearing 70 in joint 62. The tendons 64, 72, and 74 will eventually terminate in actuators (not shown) that will operate to move the various links to which the tendons are coupled as is known in the art.

[0017] Bearings 66, 68, and 70 are of the types shown in FIGS. 1 through 4, in order to maintain the tendons in positions centered over the ones of joints 56, 60 and 62 through which they pass. By maintaining the tendons 64, 72, and 74 aligned at the centers of bearings 66, 68, and 70 in their joints 56, 60 and 62, there is reduced wear and friction between the tendons 64, 72, and 74 and the adjacent structures in the joints 56, 60, and 62 that hold the bearings 66, 68, and 70 in place. Also by centering the tendons 64, 72, and 74, twists and torques are minimized on the robotic finger assembly caused by misaligned tendons.

[0018] Referring now to FIG. 6, a drawing shows a cutaway side view of the links 52 and 54 and shows the tendon 64 passing over the outer race of the joint bearing 68. As can be seen from FIG. 6, tendon 64 is shown passing through a plurality of cable guides 76. Other cable guides 78 are provided for another tendon (not shown). Because of the relative angles of links 52 and 54, the tendon 64 is engaged by the outer race of bearing 68 on the left-hand side of FIG. 6, whereas the tendon 64 is shown as not being engaged in the outer races of bearings 66 and 70.

[0019] Referring now to FIG. 7, a top view of the link 54 shows how the tendon 64 passes through cable guides in the form of ceramic eyelets 76 over the top of the concave race of bearing 68. According to an illustrative embodiment of the present invention, the support structure 80 for the bearing 68 is made out of plastic or other material and it is desired not to have the tendon 64 rub against the support structure 80 to minimize wear and resistance. The axle 82 for the joint at the right hand side of FIG. 7 is shown without its bearing mounted.

[0020] The benefit of this invention is that it provides robust centering alignment of the tendon over the bearing race which provides reduced wear and friction between the tendon and the adjacent structure holding the bearing in place. Also by centering the tendon, it minimizes twists and torques on the manipulator link structure caused by misaligned tendons.

[0021] Although the invention has been described in detail by illustrative embodiments, it is to be understood that such detail is solely for that purpose and that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover modifications and equivalent arrangements. For example, it is to be understood that the present invention contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.

What is claimed is:

1. A robotic manipulator comprising:

an actuator;

a first link and a second link coupled together at a joint;

a bearing rotatably disposed in the joint and having a concave outer race;

at least one tendon coupled between the actuator and the second link, the at least one tendon passing between the first link and the second link, the at least one tendon engaged by the concave outer race of the bearing when passing between the first link and the second link.

2. The robotic manipulator of claim 1 wherein the concave outer race of the bearing has a curved cross section.

3. The robotic manipulator of claim 1 wherein the concave outer race of the bearing has a v-shaped cross section.

4. The robotic manipulator of claim 1 wherein the concave outer race of the bearing has a curved cross section bounded by opposing shoulders.

5. The robotic manipulator of claim 1 wherein the concave outer race of the bearing has a curved cross section terminating in end walls that extend outward from the outer race at the inner edges of opposing shoulders.

6. The robotic manipulator comprising:

an actuator;

a gripper base;

a first link coupled to the gripper base at a first joint;

a first bearing rotatably disposed in the first joint and having a concave outer race;

a second link coupled to the first link at a second joint;

a second bearing rotatably disposed in the second joint and having a concave outer race;

a first tendon coupled between the actuator and the first link, the first tendon engaged by the concave outer race of the first bearing when passing between the gripper base and the first link; and

a second tendon coupled between the actuator and the second link, the second tendon engaged by the concave outer race of the first bearing when passing between the gripper base and the first link, the second tendon engaged by the concave outer race of the second bearing when passing between the first link and the second link.

7. The robotic manipulator of claim 6 wherein the concave outer race of the bearing has a curved cross section.

8. The robotic manipulator of claim 6 wherein the concave outer race of the bearing has a v-shaped cross section.

9. The robotic manipulator of claim 6 wherein the concave outer race of the bearing has a curved cross section bounded by opposing shoulders.

10. The robotic manipulator of claim 6 wherein the concave outer race of the bearing has a curved cross section terminating in end walls that extend outward from the outer race at the inner edges of opposing shoulders.

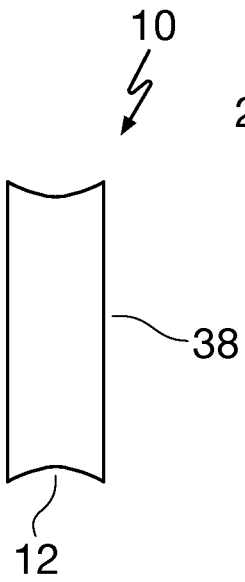

FIG. 1

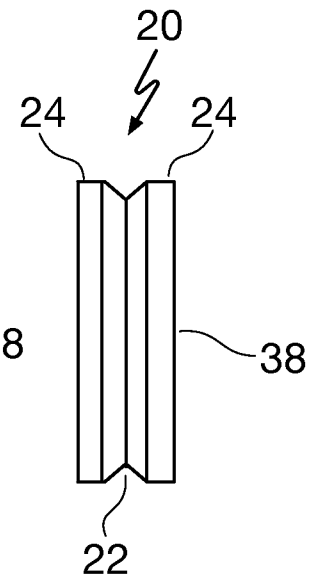

FIG. 2

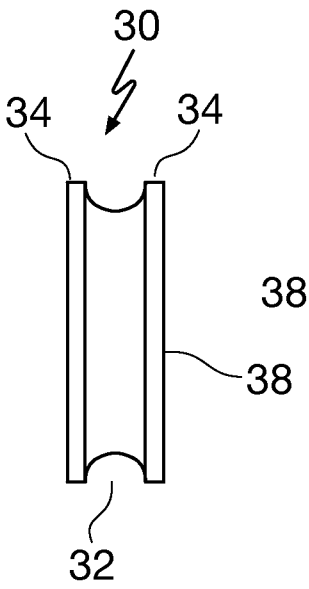

FIG. 3

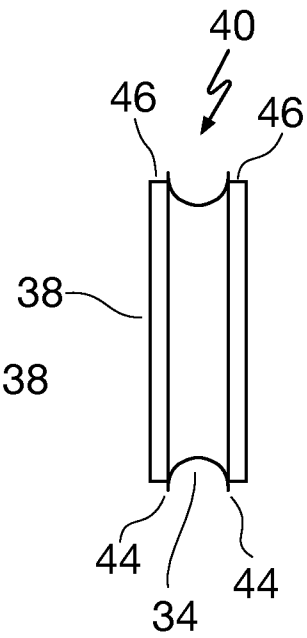

FIG. 4

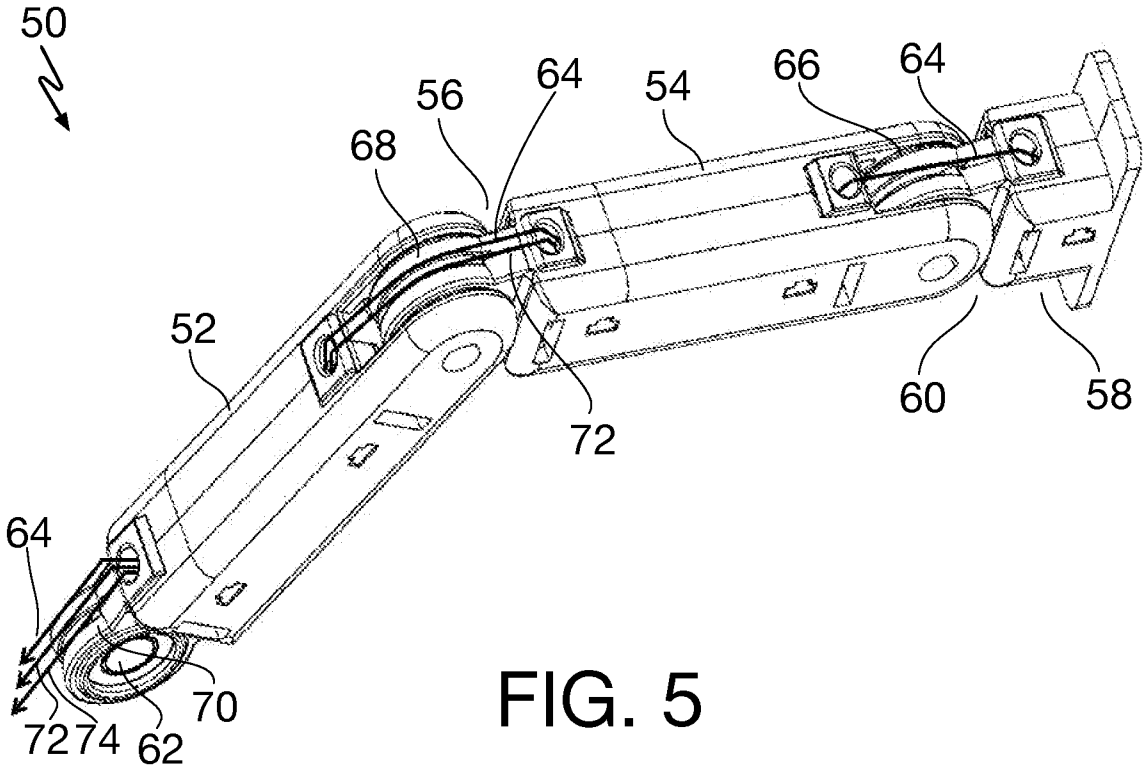

FIG. 5

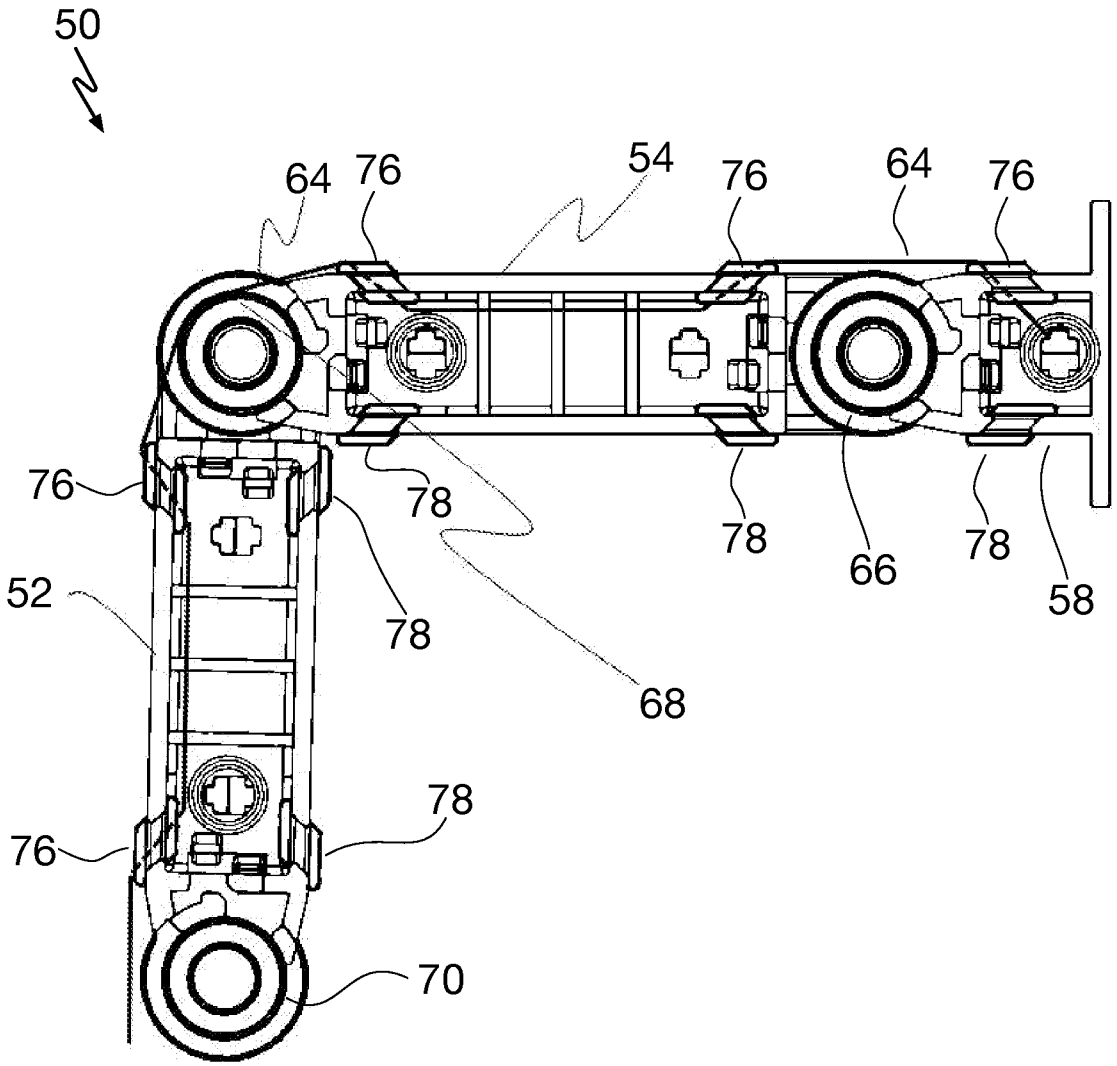

FIG. 6

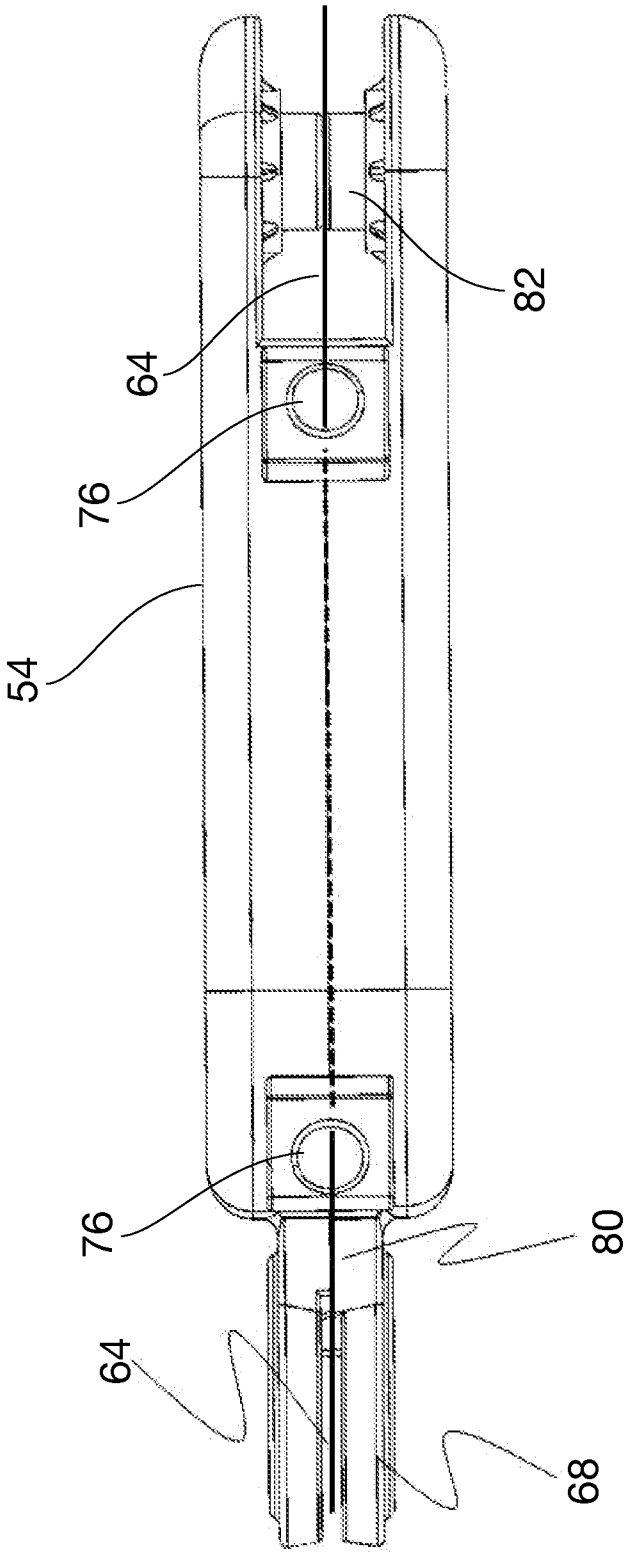

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/046606

A. CLASSIFICATION OF SUBJECT MATTER

B25J 15/08(2006.01)i, B25J 15/02(2006.01)i, F16C 33/58(2006.01)i

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 15/08; F16H 55/36; B25J 15/10; F16H 7/18; F16H 55/50; B25J 15/02; F16C 33/58

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: robotic, manipulator, actuator, link, bearing, joint, concave outer race, and tendon

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2006-0131908 A1 (TADANO, HIROYUKI) 22 June 2006 See paragraphs [0032], [0050]-[0053] and figures 5-6.	1-10
Y	US 2010-0061835 A1 (SIM, HYUN SIK) 11 March 2010 See paragraphs [0005], [0042], [0047], [0061] and figure 3.	1-10
Y	JP 2005-351476 A (GATES UNITTA ASIA CO.) 22 December 2005 See paragraphs [0037]-[0038] and figure 5.	4-5,9-10
A	US 2006-0142102 A1 (RADOCAJ, MIJO) 29 June 2006 See paragraphs [0025]-[0028] and figures 7-13.	1-10
A	US 5570920 A (CRISMAN et al.) 05 November 1996 See column 5, lines 1-20 and figures 4-6.	1-10

☐ 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
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"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
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"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
27 October 2015 (27.10.2015)	**03 November 2015 (03.11.2015)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2006-0142102 A1	29/06/2006	None	
US 5570920 A	05/11/1996	None	