Abstract: A synthetic rope arrangement (24) is disclosed for use with a construction machine (10). The synthetic rope arrangement may have a synthetic rope (58) with an end (53), and an anchor (60) having an opening (53) formed therein to receive the end of the synthetic rope. The anchor may be removably connectable to the construction machine. The synthetic rope arrangement may also have a stop (62) coupled to the end of the synthetic rope and configured to inhibit the end of the synthetic rope from passing through the anchor.
Description

CONSTRUCTION MACHINE HAVING SYNTHETIC ROPE ARRANGEMENT

Technical Field

The present disclosure is directed to a construction machine and, more particularly, to a construction machine having a synthetic rope arrangement.

Background

Power shovels and draglines are in a category of construction machines that are used to remove large amounts of overburden and ore during a mining operation. The power shovels typically include a boom, a dipper handle pivotally connected to a mid-point of the boom, and a shovel bucket (also known as a dipper) pivotally connected to one end of the dipper handle. Cables extend from a hoist drum over a pulley at a distal end of the boom to an end of the dipper handle supporting the dipper. The cables are reeled in or spooled out by electric, hydraulic, and/or mechanical motors connected to the hoist drum to selectively raise and lower the dipper. The draglines typically include a mast or tri-structure, a boom, and a bucket assembly connected by hoist cables and drag cables. The hoist cables extend from the top of a dragline housing to the end of the boom, and further down to the bucket assembly. Drag cables extend from a front base of the dragline house to the bucket assembly. These cables are reeled in or spooled out by electric and/or mechanical motors connected to the hoist drum and drag drum to selectively raise and lower the bucket assembly.

In most power shovels and draglines, the cables are connected to the drums by way of anchors mounted to an outer surface of the drum. In particular, a cylindrical collar or ferrule is brazed to an end of each cable. The anchors are then welded around their perimeters to the outer surface of the drum, and the ferrule of each cable is placed within a corresponding anchor. The cables extend through the anchors to wrap around the drum. An exemplary hoist drum is disclosed in DE Patent 10 2005 004 0816 that issued to Schneider et al. on August 10, 2006.
Although conventional cables used in construction machines may be acceptable in some applications, the cables can also be problematic. For example, the cables must be replaced frequently because of limited bending fatigue resistance. Because the cables are heavy and stiff, replacement can be difficult, time consuming, and expensive. In addition, as the cables abrade, strands of the ropes can break and create snag hazards. Further, the cables have a very large bending radius that require large drums and sheaves on the machine.

The construction machine and synthetic rope arrangement of the present disclosure solve one or more of the problems set forth above and/or other problems in the art.

**Summary**

In one aspect, the present disclosure is directed to a synthetic rope arrangement for a construction machine. The synthetic rope arrangement may include a synthetic rope with an end, and an anchor having an opening formed therein to receive the end of the synthetic rope. The anchor may be removably connectable to the construction machine. The synthetic rope arrangement may also include a stop coupled to the end of the synthetic rope and configured to inhibit the end of the synthetic rope from passing through the anchor.

In another aspect, the present disclosure is directed to a method of connecting a synthetic rope to a construction machine. The method may include passing an end of the synthetic rope through an anchor, and coupling a stop to the end of the synthetic rope to inhibit the synthetic rope from slipping through the anchor. The method may further include connecting the anchor to the construction machine.

In yet another aspect, the present disclosure is directed to a construction machine. The construction machine may include a base, and a tool operatively connected to the base. The construction machine may also include a drum mounted to the base, a motor configured to drive the drum, and a synthetic rope arrangement operatively connecting the drum to the tool. The synthetic rope arrangement may have a synthetic rope with a first end and a second end, a first anchor having an opening formed therein to receive the first end of the synthetic rope, and a second anchor having an opening formed therein to receive the second end of the synthetic rope. The first anchor may be removably
connectable to the drum, and the second anchor may be removably connectable to the tool. The synthetic rope arrangement may also have at least one stop coupled to each of the first and second ends of the synthetic rope and configured to inhibit the first and second ends of the synthetic rope from passing through the first and second anchors.

**Brief Description of the Drawings**

Fig. 1 is a diagrammatic illustration of an exemplary disclosed construction machine;

Fig. 2 is an isometric illustration of an exemplary disclosed synthetic rope arrangement that may be used in conjunction with the machine of Fig. 1; and

Figs. 3-13 are isometric illustrations showing exemplary anchors that may form a portion of the synthetic rope arrangement of Fig. 2.

**Detailed Description**

Fig. 1 illustrates an exemplary embodiment of a machine 10. Machine 10 may perform some type of operation associated with an industry such as construction, mining, or any other industry known in the art. For example, machine 10 may embody an earth moving type of construction machine, such as the rope shovel depicted in Fig. 1. As a rope shovel, machine 10 may include a crawler 12, a base 14 operatively connected to crawler 12, and a gantry (also known as an A-frame) 16 rigidly mounted to a top side of base 14 opposite crawler 12. Machine 10 may also include a boom 18 pivotally connected to a leading end of base 14, a dipper handle 20 pivotally connected to a midpoint of boom 18, a tool (e.g., a dipper or shovel bucket) 22 pivotally connected to a distal end of dipper handle 20, and one or more synthetic rope arrangements ("arrangements") 24 connecting gantry 16 and/or base 14 to boom 18 and/or tool 22. It should be noted that the term "construction machine" is being used in a general sense to include construction machines, mining machines, landscaping machines, etc. It should also be noted that the rope shovel depicted in Fig. 1 is exemplary only, and intended to illustrate only one possible application of synthetic rope arrangement 24. Other machines (e.g., draglines, cranes, pipe layers, off-highway haul trucks, etc.) could similarly be
equipped with the same or a variation of the disclosed synthetic rope arrangement 24, as desired.

Crawler 12 may be a structural unit that supports movements of machine 10. In the disclosed exemplary application, crawler 12 is itself movable, having one or more traction devices such as feet, tracks, and/or wheels that are driven to propel machine 10 over a work surface 26. In other applications, however, crawler 12 may be replaced with a stationary platform configured for direct engagement with work surface 26.

Base 14 may pivot relative to crawler 12 about a vertical axis 28. As base 14 is pivoted about axis 28, attached gantry 16, boom 18, dipper handle 20, tool 22, and/or arrangements 24 may likewise pivot to change a radial engagement angle of tool 22 with work surface 26. Base 14 may house, among other things, a power source (e.g., a combustion engine) 30 and an internal drum (e.g., a hoist drum, a drag drum, etc.) 32 that is driven by power source 30.

Gantry 16 may be a structural frame, for example a general A-shaped frame, which is configured to anchor one or more of arrangements 24 to base 14. Gantry 16 may extend from base 14 in a vertical direction away from crawler 12. Gantry 16 may be located rearward of boom 18 relative to tool 22 and, in the disclosed exemplary embodiment, fixed in a single orientation and position. Portions of arrangement(s) 24 may extend from an apex of gantry 16 to a distal end of boom 18, thereby transferring a weight of boom 18, tool 22, and a load contained within tool 22 into base 14. These arrangement(s) 24 may generally be static.

Boom 18 may be pivotally connected at a base end to base 14, and constrained at a desired vertical angle relative to work surface 26 by one or more of arrangements 24. Additional arrangements 24 may extend from drum 32 over a pulley mechanism 34 located at the distal end of boom 18 and around a pulley mechanism 36 of tool 22. These arrangements 24 may generally be dynamic, having portions that are selectively reeled-in and spooled-out by drum 32 to affect the height and angle of tool 22 relative to work surface 26. For example, when drum 32 is driven in a first direction, the effective length of the static arrangements 24 may be shortened to cause tool 22 to rise and tilt backward away from work surface 26. In contrast, when drum 32 is driven in a
second direction, the effective length of the static arrangements 24 may be
lengthened to cause tool 22 to lower and tilt forward toward work surface 26.

Dipper handle 20 may be pivotally connected at one end to a
general midpoint of boom 18, and at an opposing end to a corner of tool 22
adjacent pulley mechanism 36 (e.g., rearward of pulley mechanism 36). In this
position, dipper handle 20 may function to maintain a desired distance of tool 22
away from boom 18 and ensure that tool 22 moves through a desired arc as the
effective lengths of the dynamic arrangements 24 change. In the disclosed
embodiment, dipper handle 20 may be connected to boom 18 at a location closer
to the base end of boom 18, although other configurations are also possible. In
some configurations, dipper handle 20 may be provided with a crowd cylinder
(not shown) that functions to extend or retract dipper handle 20. In this manner,
the distance between tool 22 and boom 18 (as well as the arcuate trajectory of
tool 22) may be adjusted. It should be noted that other linkage configurations
may additionally or alternatively be used to connect base 14 to tool 22, if
desired.

Drum 32 may be rotatably mounted within a pedestal 38 that is
fixedly connected to base 14, and operatively connected to power source 30 via a
gear train (not shown). As shown in Fig. 2, drum 32 may include a body 40 that
is generally cylindrical and hollow. In the disclosed embodiment, body 40 is a
forged component, although a cast or rolled component may also be used. A
first end 42 of body 40 may be connected (e.g., bolted or welded) to a
component (e.g., to a spider - not shown) of the gear train and function as an
input end that receives torque sufficient to rotate body 40. A second and
opposing end 44 of body 40 may include a hub 46 that rests inside a bearing of
pedestal 38 (referring to Fig. 1). Body 40 may have a central axis 47 that passes
through hub 46 and an outer annular surface 48. A plurality of annular grooves
50 may be formed within outer annular surface 48. Grooves 50 may spiral
around body 40 and be configured to receive and guide portions of arrangement
24.

At least one mounting feature 52 may be recessed within outer
annular surface 48 of drum body 40 and configured to receive one or more ends
53 of arrangement 24. Although the disclosed mounting feature 52 is shown as
being located at an axial end of drum 32, it is contemplated that mounting
feature 52 could alternatively be centered in an axial direction of body 40. And if more than one mounting feature 52 is included, the mounting features 52 may be located symmetrically around the periphery of body 40 to improve the balance of drum 32. For example, when two mounting features 52 are included, the mounting features 52 may be located opposite each other relative to body 40.

Mounting feature 52 may be a forged or cast component that is subsequently connected (e.g., bolted or welded) at a corresponding location on body 40 (e.g., within a corresponding hole or recess in body 40) of drum 32. In the disclosed example, mounting feature 52 is generally arcuate and hollow, having a pocket 54 configured to internally receive the end of arrangement 24. One or more retainers 56 may extend inward a distance at an end of pocket 54 to retain the associated arrangement end 53. In this configuration, retainers 56 may function as collars for end 53. It is contemplated that mounting feature 52 could have a different female configuration or, alternatively, a male configuration (e.g., a hook, a stud, etc.) that is configured to engage and constrain end 53 of arrangement 24, if desired. It is also contemplated that mounting feature 52 could be integrally formed with body 40. It should be noted that other ends 53 of the same or other arrangements 24 may connect to other portions of machine 10 (e.g., to base 14, to gantry 16, to boom 18, to dipper handle 20, to tool 22, etc.) in the same or in a similar way that end 53 is shown as connecting to mounting feature 52 of drum 32 in Fig. 2. Accordingly, the engagement of arrangement end 53 with mounting feature 52 shown in Fig. 2 should be considered exemplary only and equally applicable to any other portion of machine 10.

As shown in Fig. 2 (and in the different examples of Figs. 3-13), each arrangement 24 may include, among other things, a synthetic rope ("rope") 58, an anchor 60 located at one or both ends 53 of arrangement 24 and that is removably connectable to machine 10 (e.g., to mounting feature 52 of drum 32), and a stop 62 coupled to an associated end of rope 58. Anchor 60 may be configured to receive rope 58, while stop 62 may be configured to inhibit the associated end of rope 58 from passing through anchor 60. In this manner, any tension in rope 58 may be transmitted to machine 10 (e.g., to drum 32) by way of stop 62, anchor 60, and mounting feature 52.
Rope 58 may be an ultrahigh-molecular weight polyethylene type of rope fabricated from many smaller diameter fibers. Rope 58 may have a density less than water (e.g., about 15% the density of water), with high resistance to tension fatigue, bending fatigue, ultraviolet light, and chemical erosion. Rope 58 may be more flexible than a steel cable, allowing for ease of handling, reeling by drum 32, and installation. In some embodiments, a coating 63 may be applied to rope 58. Coating 63 may be applied to only some portions (e.g., to only an end) of rope 58 or to the entire length of rope 58. Coating 63 may have a particular coloring and/or provide a particular property to rope 58.

For example, when coating 63 is applied only at the end of rope 58 wrapped around drum 32, coating 63 may have a bright coloring (e.g., red or orange). In this instance, the color of coating 63 may function as a warning to the operator of machine 10 during unspooling that rope 58 is nearing a maximum unspooled length. In another example, coating 63 may increase a grip of rope 58 on outer annular surface 48, such that mounting feature 52 is required to hold less of the tension load from rope 58. In this instance, coating 63 could be made from a flexible synthetic material, such as polyurethane, polychloroprene, polyethylene, or another tribological nonmetallic materials, and may or may not have an abrasive additive (e.g., sand) distributed therein.

As shown in Figs. 3 and 4, anchor 60 may be a single-piece wedge having an opening 65 configured to receive the associated end of rope 58, or a wedge made from two pieces that are configured to sandwich rope 58 there between. In either configuration, internal surfaces of anchor 60 may be tapered, such that anchor 60 opens up to a greater cross-sectional area as the associated end of rope 58 is pulled the further into anchor 60. After pulling rope 58 completely through anchor 60, stop 62 may be formed within or otherwise connected to the end of rope 58. Thereafter rope 58 may be pulled back out of anchor 60 the way it came in, until stop 62 engages the tapered inner surfaces of anchor 60 to a sufficient degree that further pulling of rope 58 is restricted by the engagement.

In the example of Fig. 3, stop 62 may be formed by back-braiding the end of rope 58. That is, stop 62 may be an enlargement or increased concentration of fibers at the end of rope 58 that is the result of the back-braiding.
As shown in the alternative embodiment of Fig. 4, anchor 60 may be formed by the associated end of rope 58, itself. Specifically, anchor 60 may be a loop or eye formed by doubling the end or rope 58 back over itself. Thereafter, stop 62 may be formed by back-braiding the loose end of rope 58. In this example, anchor 60 may be placed over a male-type mounting feature 52.

Anchor 60 of Fig. 5 may be similar to that of Fig. 4. In particular, anchor 60 of Fig. 6 may include a loop formed by doubling the end of rope 58 back over itself and then back-braiding. However, in contrast to the embodiment of Fig. 4, anchor 60 of Fig. 6 may also include a metallic insert 67 placed inside of the loop. Insert 67 may help to distribute the tension load of the loop around the male-type mounting feature 52, and also help to protect the loop from abrasion caused by engagement with mounting feature 52.

In the example of Fig. 6, stop 62 may also be formed by the end of rope 58, but formed in a different matter to produce a different result. In particular, the end of rope 58 may be frayed, such that the fibers 64 making up rope 58 are spread apart to fill the space inside of anchor 60. In some embodiments, this may be sufficient alone to inhibit rope 58 from being pulled back out of anchor 60. In other embodiments, however, additional retention measures may be taken. For example, a potting material (e.g., a resin) 66 may be put into the space inside of anchor 60, around the loosened fibers of rope 58, and allowed to harden and bond with the frayed fibers. In this example, the loosened fibers and the hardened potting material may together comprise stop 62.

In the embodiment of Fig. 7, anchor 60 may not necessarily have tapered internal surfaces (although that may be possible). For example, anchor 60 could have straight-walled internal surfaces. In this embodiment, stop 62 comprises multiple spikes that are spaced apart from each other around the internal surfaces of anchor 60. The spikes may protrude directly inward and into rope 58 (e.g., about 25-50% through rope 58) or be pointed toward the loose end of rope 58 so as to provide higher resistance against the pulling out of rope 58. It is contemplated that the spikes may be integrally formed with anchor 60 or attached to anchor 60 after formation, as desired.

As shown in Fig. 8, anchor 60 may again have relatively straight-walled internal surfaces. In this example, stop 62 may be a clamp that is
engaged with the loose end of rope 58 and that has a greater external cross-sectional area than an internal cross-sectional area of anchor 60. In this way, stop 62 may create a mechanical interference with anchor 60. In some instances, additional retention means may need to be combined with the stop 62 and anchor 60 of Fig. 8. For example, nails 68 may pass through rope 58 and engage anchor 60. In one instance, after anchor 60 and stop 62 are connected to rope 58, nails 68 may be driven from opposing sides of anchor 60 completely through rope 58 and into the other sides of anchor 60.

Stop 62 shown in Fig. 9 may have characteristics in common with stop 62 of Fig. 3. In particular, stops 62 of both of Figs. 3 and 9 may be fabricated by back-braiding the loose end of rope 58 so as to enlarge the end. In Fig. 9, however, anchor 60 is further fabricated by winding a filament 70, which is separate from the fibers of rope 58, around the enlarged end of rope 58. It is contemplated that filament 70 could be made of the same material as rope 58 or from a different material, as desired. The configuration of Fig. 9 may produce a lighter-weight and/or less-expensive option, when compared to the configuration of Fig. 3.

In the embodiment of Figs. 10A and 10B, anchor 60 may be a clamp or swage clip that is compressed around rope 58 near the loose end. In the depicted example, the swage clip is flattened during compression, such that a width of the compressed clip (shown in Fig. 10B) becomes greater than a thickness (shown in Fig. 10A). As the swage clip is compressed and flattened, rope 58 at the location of the swage clip also becomes compressed and flattened, resulting in a fanning out of rope 58 at the opposing ends of the clip. In this configuration, the fanning out of rope 58 may function as stop 62.

Anchor 60, in the embodiment of Fig. 11 is horseshoe-shaped and includes a similarly shaped internal passage. It is contemplated that anchor 60, in this embodiment, could be formed (e.g., cast or printed) as a single integral component, or formed as two halves that are then joined together (e.g., bolted or welded together). After passing the loose end of rope 58 through the internal passage of anchor 60, a clamp-style stop 62 may be applied to the end. Similar to the embodiment of Fig. 8 described above, stop 62 of Fig. 11 may have a greater external cross-sectional area than the cross-sectional area of the internal
passage, thereby inhibiting stop 62 (and rope 58) from being pulled through anchor 60.

In the embodiment shown in Fig. 12, anchor 60 may be a ferrule, having a generally ring-like shape with a plurality of annularly arranged openings 65. In this configuration, the fibers of rope 58 may be separated from each other and passed through openings 65. It should be noted that the fibers of rope 58 may still be arranged in natural groupings, each of which may pass through separate openings 65. The loose ends of each grouping of fibers may then be engaged with a separate stop 62. In this example, stops 62 may comprise knots, back-braiding, clamps, swage clips, or any other type of stop 62.

In a final embodiment illustrated in Fig. 13, anchor 60 may again be a single- or dual-piece wedge (similar to the embodiments of Figs. 3 and 4), and stop 62 may again comprise spikes (similar to the embodiment of Fig. 7). However, additional retention means may be employed in the embodiment of Fig. 13. Specifically, an additional multi-part (e.g., four part) wedge 72 may be positioned within a fray at the end of rope 58 and function to push the frayed fibers outward into the spikes and against the internal tapered walls of the wedge. In the depicted example, wedge 72 may be an adjustable wedge. In particular, a cam-like lock 74 may pass through a center of wedge 72 and be rotatable to increase a diameter of wedge 72. For example, lock 74 may have a threaded external surface that is tapered, such that the further that lock 74 is screwed into wedge 72, the more lock 74 causes wedge 72 to expand radially outward. In some embodiments, after wedge 72 has been expanded to a desired position, a potting material may be injected into the frayed ends of rope 58 to increase the retention capability of anchor 60 and stop 62. In the disclosed embodiment, lock 74 includes one or more injection ports 76 that communicate with corresponding ports 78 in wedge 72. Ports 76 and 78 may provide a way for the potting mixture to be evenly distributed through the frayed fibers.

It should be noted that one or more features of each of the different embodiments of end 53 may be combined, as desired. For example, any one of the different end embodiments could include spikes, nails, potting materials, back-braiding, looping, fraying, swaging, etc.
Industrial Applicability

The disclosed synthetic rope arrangement may be used in any construction machine application where component longevity, reliability, cost, and ease of use are desired. The disclosed synthetic rope arrangement may be particularly applicable to rope shovels and draglines. The disclosed synthetic rope arrangement may have improved longevity and reliability due to increased abrasion and bending fatigue resistance, a lighter weight, and improved means of connection to machine 10. The disclosed synthetic rope arrangement may also require less inspection and replacement. And when the disclosed synthetic rope arrangement does require replacement, a decreased density and increased flexibility may reduce a cost and hassle of completing the replacement.

It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed synthetic rope arrangement and machine. Other embodiments will be apparent to those skilled in the art from consideration of the specification and practice of the disclosed synthetic rope arrangement and machine. It is intended that the specification and example be considered as exemplary only, with a true scope being indicated by the following claims and their equivalents.
Claims

1. A synthetic rope arrangement (24) for a construction machine (10), comprising:
   a synthetic rope (58) having an end (53);
   an anchor (60) having an opening (65) formed therein to receive
   the end of the synthetic rope, the anchor being removably connectable to the
   construction machine; and
   a stop (62) coupled to the end of the synthetic rope and
   configured to inhibit the end of the synthetic rope from passing through the
   anchor.

2. The synthetic rope arrangement of claim 1, wherein the stop
   includes at least one of plurality of spikes extending from the opening of the
   anchor into the end of the synthetic rope and nails (68) that pass through the
   anchor and the end of the synthetic rope.

3. The synthetic rope arrangement of claim 1, wherein the stop
   includes at least one of braiding or knotting that increases a size of the end of the
   synthetic rope.

4. The synthetic rope arrangement of claim 1, wherein:
   the stop includes potting (66) formed around the end of the
   synthetic rope; and
   the end of the synthetic rope is frayed inside the potting.

5. The synthetic rope arrangement of claim 1, wherein the stop is
   formed by a filament (70) wound into the end of the synthetic rope.

6. The synthetic rope arrangement of claim 1, wherein the stop
   includes at least one of a clamp compressed over the end of the synthetic rope
   and a wedge (72).
7. The synthetic rope arrangement of claim 6, further including a lock (74) configured to push the end of the synthetic rope radially outward against the wedge when the lock is turned.

8. The synthetic rope arrangement of claim 7, wherein at least one of the lock and the wedge includes a potting injection port (76, 78).

9. The synthetic rope arrangement of claim 1, wherein the stop is ring-like and includes a plurality of holes each configured to receive separate strands of the synthetic rope.

10. The synthetic rope arrangement of claim 1, further including a coating (63) applied to the synthetic rope at the end, the coating having at least one of a color and an abrasive property different from a rest of the synthetic rope.
### A. CLASSIFICATION OF SUBJECT MATTER

INV. E02F3/58 D07B1/00 E02F9/14

ADD.

According to International Patent Classification (IPC) or both national classification and IPC

### B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E02F D07B B66C E02D E21B B66B 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 practicable, search terms used)

EPO-Internal

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>US 2012/102679 AI (DOAN STEPHEN P [US] ET AL) 3 May 2012 (2012-05-03) paragraphs [0002], [0020]; figure 4</td>
<td>1, 10</td>
</tr>
<tr>
<td>Y</td>
<td>KR 2013 0014092 A (GWANG MYUNG BIO INDUSTRY CO LTD [KR]) 7 February 2013 (2013-02-07) figures 2, 3</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>CA 2 914 851 AI (ZHENGZHOU ZHONGYUAN DEFENSE MATERIAL CO LTD [CN]) 24 December 2014 (2014-12-24) abstract</td>
<td>1</td>
</tr>
</tbody>
</table>

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 application or patent 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

**I** 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

**Z** document member of the same patent family

Date of the actual completion of the international search: 8 December 2016

Date of mailing of the international search report: 19/12/2016

Name and mailing address of the ISA:

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

Authorized officer:

Papadimi tri ou, S

Form PCT/ISA/210 (second sheet) (April 2005)
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 2014/090279 A1 (CAMPBELL RICHARD V [US]) 3 April 2014 (2014-04-03) paragraphs [0061], [0063]; figures 8,11</td>
<td>1</td>
</tr>
</tbody>
</table>

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT
<table>
<thead>
<tr>
<th>Patent document cited in search report</th>
<th>Publication date</th>
<th>Patent family member(s)</th>
<th>Publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CA 2550216 A1</td>
<td>08-01-2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CN 1891915 A</td>
<td>10-01-2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ZA 200605595 B</td>
<td>25-04-2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2012102679 A1</td>
<td>03-05-2012</td>
</tr>
<tr>
<td>KR 20130014092 A</td>
<td>07-02-2013</td>
<td>NONE</td>
<td></td>
</tr>
<tr>
<td>CA 2914851 A1</td>
<td>24-12-2014</td>
<td>AU 2013393268 A1</td>
<td>07-01-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2914851 A1</td>
<td>24-12-2014</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CN 205443753 U</td>
<td>10-08-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J P 2016528396 A</td>
<td>15-09-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>KR 20160012198 A</td>
<td>02-02-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 2016145796 A1</td>
<td>26-05-2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WO 2014201653 A1</td>
<td>24-12-2014</td>
</tr>
<tr>
<td>US 2014090279 A1</td>
<td>03-04-2014</td>
<td>NONE</td>
<td></td>
</tr>
</tbody>
</table>