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International application number:		**PCT/EP2019/083198**
International filing date:		**29 November 2019 (29.11.2019)**
Document type:		**Certified copy of priority document**
Document details:	Country/Office:	**GB**
	Number:	**1911844.7**
	Filing date:	**19 August 2019 (19.08.2019)**
Date of receipt at the International Bureau:		**21 December 2019 (21.12.2019)**

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a),(b) or (b-*bis*)

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Application number GB1911844.7

1.	Your reference	**27086**
2.	Full name, address and postcode of the applicant or of each applicant	**Köppen, Rob** **Anton Philipslaan 125** **Eindhoven 5616 TW** **Netherlands**
	Patents ADP number *(if you know it)*	12373965001
	Full name, address and postcode of the applicant or of each applicant	**van der Stel, Sander** **Annabijnspad 55** **Middelharnis 3241 DP** **Netherlands**
	Patents ADP number *(if you know it)*	12373973001
3.	Title of the invention	**REMOTE CONTROLLED CRAWLING DEVICE**
4.	Name of your agent *(if you have one)*	
	"Address for service" to which all correspondence should be sent. This may be in the European Economic area or Channel Islands (see warning note below) *(including the postcode)*	**Gallafents Ltd** **1 Sans Walk** **London EC1R 0LT** **United Kingdom**
	Patents ADP number *(if you know it)*	11699626001 ~~0000729001~~

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Country	Application number	Date of filing	PDAS Access Code
United Kingdom	**1819511.5**	**30 Nov 2018**	**A6E1**

6.	Divisionals etc: Is this application a divisional application, or being made following resolution of an entitlement dispute about an earlier application. If so, please give the application number and filing date of the earlier application	Number of earlier UK application	Date of filing *(day / month / year)*
7.	Inventorship: (Inventors must be individuals not companies)		
	Are all the applicants named above also inventors?	**Yes**	
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Description:	**12**
Claim*(s)*:	**3**
Abstract:	**1**
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Request for search (Patents Form 9A):	**1**
Request for substantive examination (Patents Form 10):	**1**
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11. I/We request the grant of a patent on the basis of this application.

Date: **19 Aug 2019**

12. Name, e-mail address, telephone, fax and/or mobile number, if any, of a contact point for the applicant

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REMOTE CONTROLLED CRAWLING DEVICE

The present invention relates to a remote-controlled device capable of crawling along elongated cylindrical members, such as cables, pipes and cylindrical rods or bars (hereinafter ECMs) to enable testing or treatment operations to be effected on such members by means embodied in or attached to the device. The device should be able to crawl relative to an ECM, whether positioned horizontally, vertically, or at an incline, and should simultaneously be capable of pushing or pulling significant amounts of weight in the form of accessories or appendages as it does so.

The present invention is particularly directed to crawlers for remote inspection and optionally cleaning or lubrication of tensioned steel cables. Examples of such are cables that add stability to free-standing structures, such as towers, masts or poles, chimneys and flare stacks, which are often referred to as “guys”. Guys are continuously under considerable stress and are exposed to harsh environmental conditions for the duration of their use. Periodic examination and maintenance are essential to ensure a guy safely fulfils its maximum service life.

BACKGROUND

Traditional guy maintenance used to consist of a visual inspection and simultaneous lubrication by a technician suspended from the guy in a man-basket. This unsafe method was replaced by employing a rope access technician or a technician suspended in a basket from a crane. Aside from the high degree of risk posed to the technician, as well as the considerable expense of using a crane, this inspection method has proved to be of limited efficacy. First, these methods make it difficult for a technician to inspect the full circumference of a guy; secondly, the guy can only be inspected from the outside, meaning approximately ninety percent of the guy is missed.

Furthermore, if the guy was attached to a gas flare stack, this had to be shut down during the work.

A method was developed which uses two manual winches to pull cleaning, lubrication, and Magnetic Flux Leakage (MFL) inspection devices up and down a guy. Whilst this approach saves the expense of using a crane, it is very labour intensive and, if the guy was attached to a flare stack, the flare still has to be shut down while such activities were going on. Known lubrication devices are also prone to cause excess grease to spill from the guy as it proves almost impossible to match the correct flow of grease with the winch speed. Whilst MFL devices can inspect one hundred percent of a guy (exterior and interior), they need to be driven along the guy at a constant speed for accurate results. This is extremely difficult to achieve using manual winches.

Attempts have been made using a motorised wheeled robot to drive an MFL inspection device along an ECM at a steady speed. This greatly improves the inspection results, but wheeled robots suffer from some limitations, including not having enough contact area with the surface of the ECM, and so enabling any grease deposit on the ECM to render the robot immobile. Additionally, known wheeled robots are restricted in the amount of torque they can generate, so cleaning and lubrication devices which need to engage the surface of the ECM, and where the friction between the operative parts of the cleaning or lubrication device and the surface of the ECM can be quite high still have to be moved using a labour intensive, manual winch system. A remote-controlled device capable of inspecting, cleaning and lubricating large ECMs such as guys has not previously been developed.

PRIOR ART PATENT DISCLOSURES

Published US Patent specification 2015360736 describes a mobile robot that employs three equally spaced or more multiple caterpillar type movements to

drive along the surface of a cable for the purposes of maintenance and inspection. The tracks are toothed belts driven by sprockets to prevent slippage. The caterpillars are positioned at equal circumferential angles to ensure the robot is held onto the cable. The tracks are made from rubber and have tensioners that keep the belts taut. There is a polyethylene resin panel that supports the caterpillar to maintain constant contact between the full length of the belt and cable. There is a distance adjuster that maintains sufficient contact between caterpillars and the cable, which can also be adjusted to allow different sized cables to be driven along. The main advantage of a tracked design over a wheeled one is that the caterpillars provide more contact between the drive mechanism and cable, thereby improving traction. However, the traction this existing robot design generates is limited, and so can only carry a maximum payload of 30 kg, which limits its ability to push and pull appendages.

French Patent specification 2526842 describes a device for the maintenance of guys on radio communications pylons, with wire brushes for cleaning and painting operations within two hinged semi-cylindrical assemblies, and where the device is pulled along a guy manually by a winch cable.

The present invention is directed to a crawler which, operating by remote control, acts as a tractor capable of pushing and/or pulling large payloads along an ECM such as a cable, for example appendages for inspecting, cleaning and lubricating guys.

GENERAL DESCRIPTION OF THE INVENTION

The features of the improved crawling device according to the present invention are set out in the main claim. Further details and preferred features are identified in the sub-claims appendant thereto.

In the present invention, the crawler comprises two diametrically opposed continuous track systems (upper and lower) that, when assembled together, have a channel through the centre which partially envelops the ECM. This channel maximises the track contact surface and also has a layer of material to increase grip. A single motor may provide direct drive to the lower track and indirect drive to the upper track, or two motors may provide direct drive to the upper and lower halves. Tension adjustment between the upper and lower halves allows the clamping force - and therefore traction - to be increased or decreased. This can either be established in advance and fixed by use of spacers between upper and lower housings, or alternatively the tension can be adjusted as the crawler moves along the ECM by installing linear actuators between the upper and lower halves.

The crawler is preferably constructed so that the majority of its weight or the weight of an assembly of a crawler and an appendage is underneath the ECM, which maintains the crawler in an upright position as it moves along. The crawler is typically dimensioned to enable it to move along an ECM of any diameter greater than 20mm. The nature of the continuous track drive mechanism is such that each crawler is capable of moving along ECMs of a range of diameters, above or below which a larger or smaller sized continuous track is needed.

Certain crawler component characteristics may vary slightly depending on the required application. For instance, the size and/or quantity of the track shoes may vary depending on the requirement. The track shoes may be aluminium on smaller diameter ECMs, or steel on larger sizes. The saddled track pad material may need to be harder or softer, thinner or thicker, more hard wearing, or oil resistant. The track drive chain typically consists of a double chain; however, a larger sized ECM may necessitate triple or quadruple chains. For smaller diameter ECMs and/or crawlers carrying light weight payloads, motors can be electric with power supplied by hard wired cable or battery, whereas hydraulic motors are suitable for all diameter

ECMs and light or heavy payloads. The linear actuators may be hydraulic, pneumatic, or electric powered.

By way of illustration, the following is a detailed description of one embodiment of a crawler according to the present invention, the embodiment being specifically designed for remote inspection and optionally cleaning or lubrication of tensioned steel cables. The description is of the embodiment illustrated in the accompanying drawings, in which:

Figure 1 shows schematically a steel structure 1 supported by a guy 2, on which a crawler 3 is being driven by a technician 5 using a hydraulic power pack 4 that is connected to the crawler 3 by hydraulic hoses 6;

Figure 2 shows a hydraulic-powered crawler according to the invention on a guy; and

Figures 3 and 4 show the crawler of Figure 2 with one side or part of one end respectively removed so some of the internal components are visible.

The crawler shown in the Figures comprises two separate identical housings 1, 2 accommodating drive mechanisms that, when the housings are fixed together, clamp around a guy 25 and allow the crawler to move along it. The material used for the housings should be lightweight and so aluminium is preferred. Each housing contains a drive mechanism comprising a continuous track, the two tracks being positioned facing each other when the housings 1 and 2 are assembled together.

Mounted inside each housing 1, 2 are a drive shaft 4 and an axle 6, on each of which is positioned a track sprocket 15, over which run endless track chains 16. One end of the drive shaft is connected to a motor 3 mounted on the side of the housing 1. The opposite end of the drive shaft 4 is fitted into a plain bearing 27 in the housing, and the drive shaft 4 is fixed in position by a

locking plate 5. Each end of each axle 6 is set in a ball bearing 8, adjustably fixed to the side of the respective housing. The motor 3 which is diagrammatically shown may be a hydraulic motor or it may be a pneumatic or electric motor.

The housings 1, 2 are mounted together around the guy 25 by four aluminium guide rods 10 which pass through apertures in guide members fixed in each housing (two lateral 11 and two longitudinal 12). The guide rods are secured in place above the upper housing and below the lower housing by lock pins 14. The guide rod 10 and guide members 11, 12 constrain the movement of the two housings relative to one another to a single direction and maintain proper alignment between the two continuous track drives. The pressure exerted on the guy by the tracks can be adjusted by moving the two housings closer together or further apart. The guide rods 10 increase the overall rigidity of the crawler, and this leads to a more stable motion as it is driven along the ECM, which reduces wear on the components of the drive system, and at the same time increases the accuracy of measurement or inspection apparatus.

Connected to the track chains 16 are a number of brackets 17, to which are connected track shoes 18 on which are bonded track pads 19 that have a saddled shape to increase the surface area in contact with the guy. The track pads are made from a material that improves traction, such as rubber, polyurethane, or silicone, and their edges have rounded corners 20 so as to minimise the jolting that occurs when each track pad 19 first contacts the guy 25, thereby making the crawler motion along a guy smoother, which also assists in accurate measurement or inspection when the crawler is being used. When the crawler is in use, the continuous track system mounted in the lower housing acts together with the continuous track system mounted in the upper housing so that the track saddles simultaneously clamp onto the guy from opposing sides, and the motors drive both continuous track systems, progressively pulling the crawler along the guy.

The tension in the track chain in each of the housings 1 and 2 is adjustable by means of four track tensioning bars 21. Each tensioning bar 21 is threaded and passes through a plate 22 projecting from the wall of housing 1 or 2, and has an eye 28 at one end. The eye 28 is aligned with a hole 29 in the ball bearings 8. The holes 29 are aligned with slots 30 in each wall of the housing 1 or 2, which in turn are aligned with fixing holes 31 in a locking plate 24 positioned on the outside of each housing. A bolt (not shown) is passed through each of the eye 28, hole 29, slot 30 and hole 31 and is held in place with a nut (not shown) adjacent plate 24. Nuts (not shown) are subsequently screwed on to the threaded ends 23 of each tensioning bar 21 so that when both nuts are tightened, the axle 6 is pulled away from the drive shaft 4, thereby tensioning the track chain 16. After the correct tension is reached, holes are drilled in the wall of housing 1 or 2 via two of five pilot holes 32 located in the locking plate 24. Bolts (not shown) pass through the pilot holes 32 and the holes drilled in housing 1 or 2 and are secured in place with nuts (not shown) to hold locking plates 24 against the sides of the housings 1, 2, and because they cannot then move, the track chain 16 remains currectly tensioned. Selection of which two of the pilot holes should be used depends on achieving as much distance between the two drilled holes as possible whilst ensuring the bolts passing through them and the nuts holding them in place on the inner side of the housing do not interfere with other internal components.

In the space between the track sprockets 15, under the portion of each track chain 16 that contacts with the guy, is an idler sprocket 7 that is connected to an axle passing through plain bearings in each side of the housing 1 or 2 and which serves to keep the portion of the track chain running over it pressed against the guy, thereby maintaining a constant clamping force over the full length of each continuous track portion in contact with the guy.

A key function of the crawler is the ability to adjust the distance between the upper and lower housings 1,2 and thereby alter the amount of grip the continuous tracks exert on the guy 25.

In the illustrated embodiment, the distance between the two housings 1,2 can be adjusted prior to the crawler being installed on the guy. The distance may be determined by establishing the guy diameter and the amount of grip required, which depends on the diameter of the channel created when the two tracks are assembled together, typically being 0.5 mm to 3.0 mm less than the guy diameter. The upper and lower housings are fastened together by toggle latches 9, with correctly sized spacers 13 positioned on the guide rods 10 in between the two housings to achieve the desired spacing.

Guys may be narrower in some places than in others, and narrowness below a certain threshold will cause the crawler to lose grip and can prevent it from traversing further. Grease on the guy will also reduce traction and may prevent the crawler traversing. Conversely, guys may be slightly thicker or rougher in some locations than in others, which means the grip could become too great and the crawler would be unable to traverse further.

To overcome the above potential issues, in another embodiment, the distance between the upper and lower housings can be varied during a traverse by employing four linear actuators connected to both housings. This is achieved by increasing the amount of power (hydraulic, pneumatic or electrical) to the linear actuators so the piston rods forming part of the actuators are withdrawn to increase the clamping force between the upper and lower housings, and thus compress both continuous drive tracks against the guy, thereby increasing traction and allowing the crawler to continue traversing the guy.

A guy is a rope that is formed by weaving individual wire strands in a single direction, which means when an individual wire on the surface breaks, a

loose end may rise up a few millimetres and point in the weave direction, which could prevent the crawler from traversing further. By reducing the power to the actuators, the piston rods will extend and release the clamping effect of both continuous drive tracks against the guy, thereby reducing the clamping force and allowing the crawler to continue traversing along the guy. Additionally, in case of engine failure or other problem rendering the crawler immobile, the tension can be fully released, allowing it to be retrieved for repair.

In the illustrated embodiment, where the crawler uses a hydraulic drive, hydraulic motors fitted to the outside of each housing are connected by hoses to a manifold fitted underneath the lower housing to which hydraulic hoses connect to a hydraulic power pack on the ground. The power pack contains a series of valves that regulate the flow of hydraulic fluid, which the technician uses to determine the speed and direction the crawler traverses.

In another embodiment, where the crawler uses electrical drive, the motor power is chosen in dependence on the size of the guy and the crawler itself. The electrical box containing the programmable logic and frequency controllers is fixed under the lower housing, and the electrical cables connect the electrical box to an on board battery or to a power connection located on the ground.

A control box may be fitted underneath the lower housing containing a PLC, frequency controllers and Wi-Fi transmitter, to enable the operation of the crawler to be controlled by a control unit on the ground containing the same components, enabling commands executed by a technician on the ground to be replicated in the control box on the crawler.

The control unit on the ground typically has the following functions:

- Button for crawler power On/Off;

- Button to switch motor phase and reverse the direction the crawler is traversing in;

- Frequency controller to adjust the motor speed and thus the crawler traversing speed;

- Linear actuator controller to vary the degree of grip exerted by the crawler on the guy.

In both hydraulic and electric drive embodiments, the combined weight of the lower housing and components attached to it is substantially more than that of the upper housing, so that once the crawler is fitted onto a guy, with its centre of mass directly underneath the guy, the crawler is able to maintain its orientation relative to the ground when moving along the guy with its centre of gravity below the guy which offsets any tendency for the crawler to rotate around the guy circumference, even if the surface of the guy because of its twisted wire construction, is slightly uneven with grooves and ridges forming a twisted helical textured surface.

Guys sometimes have hardened grease, debris and/or other types of deposit on the surface, which could cause an obstruction to the crawler movement. Significant guy surface damage would mean multiple loose wire strands form an obstruction that could potentially get caught in the drive mechanism, thereby rendering the crawler immobile and potentially unable to be retrieved. For these reasons scraper plates 26 are added to the front and rear of the crawler to remove surface debris and prevent the crawler from passing over an obstruction. The scraper plates are changeable so as to match the semi-circular cut out in each plate to the guy diameter. If desired a camera may be to each of the front and rear of the crawler and to any appendage attached thereto, enabling video images of the guy surface to be wirelessly streamed to a screen on the ground so the technician has a live

visual as the crawler traverses, which allows the technician to identify potential unpassable obstructions and avoid the crawler becoming irretrievably stuck.

The front and rear ends of the crawler and of any appendage may have return switches fitted which signal the motor to go into reverse. Fitting such switches may enable the crawler motor automatically to go into reverse when the crawler reaches the end of a guy.

Inspection and maintenance appendages may be connected to the front of the crawler by a quick release coupling, and include a non-destructive testing appendage that is used on its own; a lubricating appendage that pumps a fixed amount of grease onto the guy and removes any excess; and a cleaning appendage to remove grease, fouling deposits painted and preservative coatings, and lubricants, that can be used simultaneously with the lubricating appendage to pump degreasing agent, if required.

In the drawings, the numbering of the components of the crawler illustrated is as follows:

1. Upper housing
2. Lower housing
3. Motor
4. Drive shaft
5. Drive shaft locking plate
6. Axle
7. Idler sprocket
8. Ball bearing
9. Toggle latch
10. Guide rod
11. Lateral guide meter
12. Longitudinal guide meter

13. Guide rod spacer
14. Guide rod lock pin
15. Track sprocket
16. Track chain
17. Track bracket
18. Track shoe
19. Saddled track pad
20. Rounded-corner of track pad
21. Track tension bar
22. Track tensioning plate
23. Track tension bar thread
24. Track tension lock plate
25. Guy
26. Scraper
27. Plain bearing
28. Tensioning bar eye
29. Ball bearing fixing holes
30. Slots in housing wall
31. Locking plate fixing holes
32. Locking plate pilot holes

CLAIMS

1. A remotely controlled crawler device for use on elongated cylindrical members (ECMs) comprising a pair of housings, each housing including a continuous looped track, part of the track being arranged to run along one side of the housing, means for driving the track, and wherein the track includes a series of shoes and where the outwardly facing side of each shoe includes a generally semi-circular recess of diameter corresponding to that of the ECM, and means for holding the two housings together with the portions of the track running along one side of each housing being engaged on opposite sides of the ECM, whereby driving the circulating tracks causes the crawler to move along the ECM, and means for connecting the crawler to an external control unit remote from the crawler.

2. A remotely controlled crawler device according to Claim 1 wherein the means for driving each continuous looped track is a hydraulic motor.

3. A remotely controlled crawler device according to Claim 1 or 2 wherein each of the two housings includes an independently controllable drive unit connected to the circulating looped track.

4. A remotely controlled crawler device according to Claim 1 wherein one of the housings incorporates a drive motor and means are provided to enable the drive motor to drive the continuous looped track in both housings.

5. A remotely controlled crawler device in accordance with any of Claims 1 to 4 wherein the power to move the crawler along the cable is an electrical or hydraulic supply.

6. A remotely controlled crawler device according to any of Claims 1 to 5 wherein the spacing between the two portions of the crawler may be

adjusted to vary the degree to which the tracks are urged against opposite sides of the ECM.

7. A remotely controlled crawler device in accordance with any of Claims 1 to 6 wherein one housing is materially heavier than the other whereby to enable the force of gravity to keep the crawler on the ECM with its heavier housing located directly below the lighter housing.

8. A remotely controlled crawler device according to any of Claims 1 to 7 and including or at least one of the housings a quick release coupling to enable a separate device to be affixed to the crawler.

9. A remotely controlled crawler device according to any of Claims 1 to 8 and including one or more scraper units at one or both ends of the housing and positioned to engage on, and by scraping remove deposits from, the external surface of the ECM.

10. A remotely controlled crawler device according to any of Claims 1 to 9 and including sensor devices to enable the detection of when the crawler device approaches one end of an ECM and which is arranged on such detection to cause the direction of movement of the crawler on the ECM to be reversed.

11. A remotely controlled crawler device according to any one of Claims 1 to 10 and including one or more camera units mounted on one or both housing units and enabling the view in the neighbourhood of the crawler to be visually monitored by a technician on the ground.

12. A remotely controlled crawler device according to any one of Claims 1 to 11 where each circulating looped track runs on turnround sprockets at each end, one of which is driven via a drive shaft connected to the drive means, and where one or more outer sprockets are provided between the

ends of the loop to ensure that all portions of the track facing the ECM are pressed against it.

13. A remotely controlled crawler device according to any one of Claims 1 to 12 and including guide rods linking the two housings to increase the rigidity of the crawler and to provide a more stable motion along the ECM.

14. A remotely controlled crawler device according to any one of Claims 1 to 13 where the track shoes have rounded corners to promote a more stable motion along the ECM.

ABSTRACT

REMOTE CONTROLLED CRAWLING DEVICE

A cable crawling device is disclosed which can be driven along a tensioned cable (25) for the purpose of maintenance, inspection or treatment of the cable by means of appropriate units attached to the crawler. The device has two housings (1, 2) each of which includes an endless track loop each link of which includes a shoe (19) with a central relief portion for engagement against one side of the cable. The two housings are arranged opposite one another so that the cable lies between the two tracks in the respective housings. Drive means such as an hydraulic motor (3) are connected to drive the tracks to cause the crawler to move along the cable.

Figure 4

Figure 1

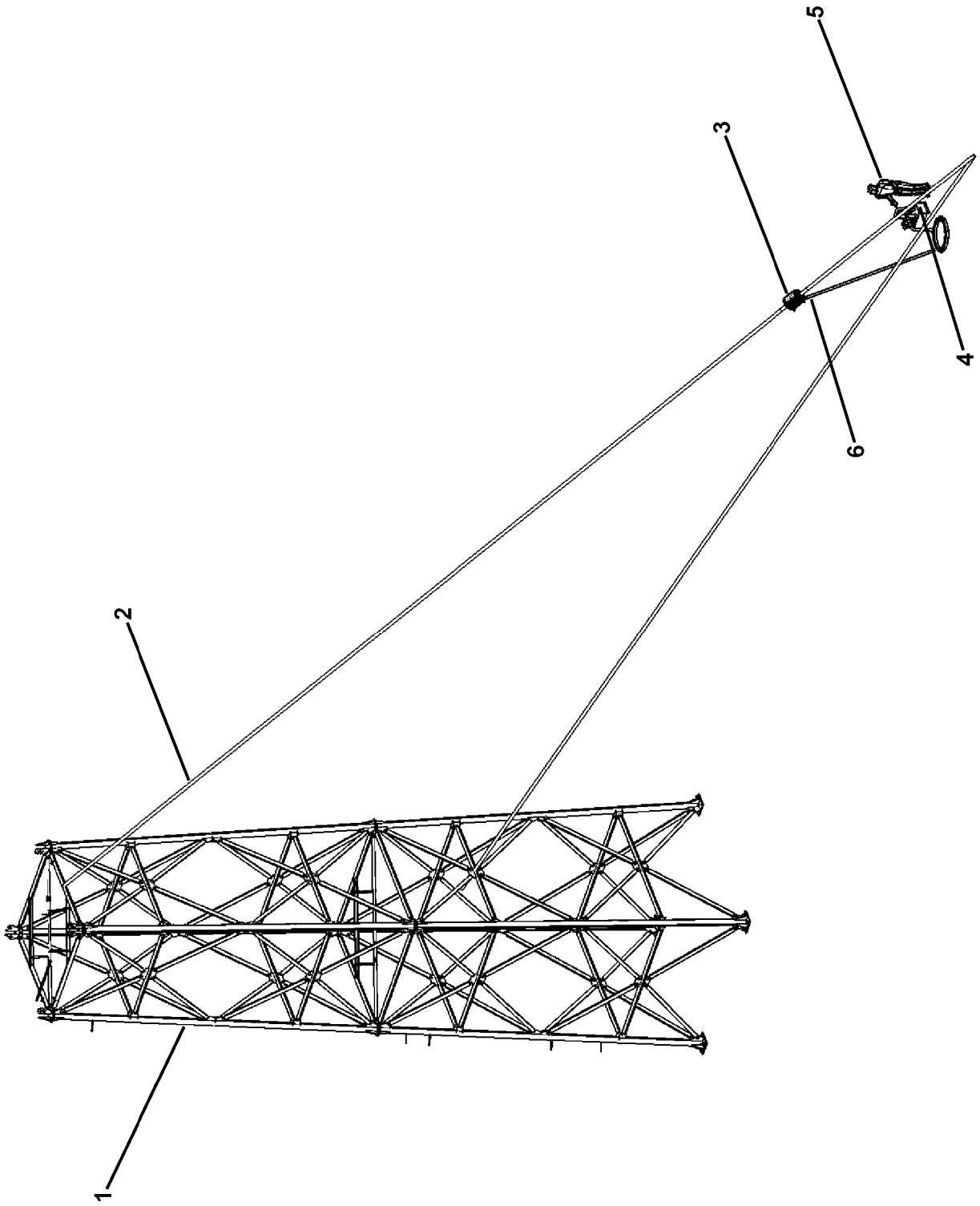

Figure 2

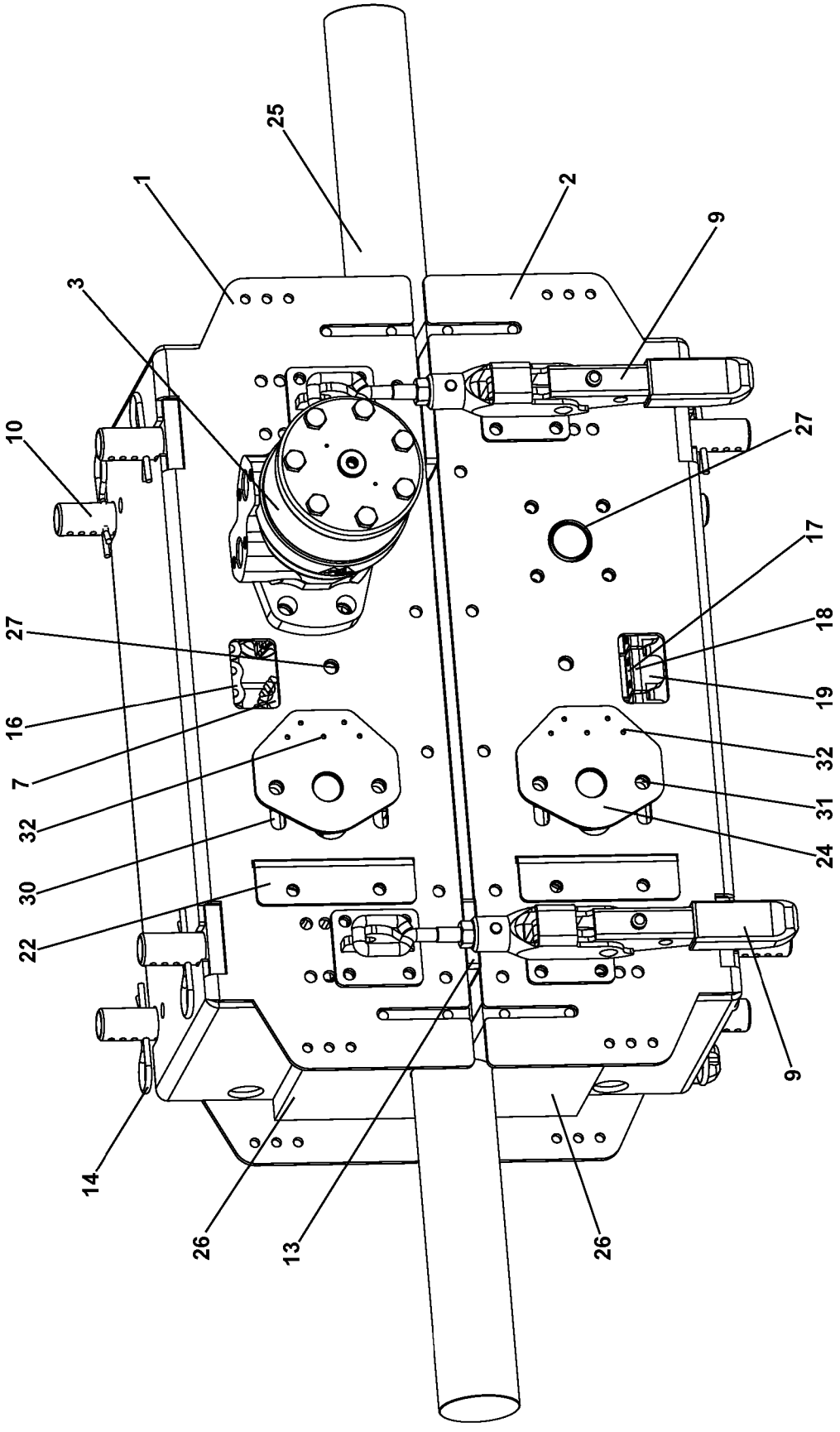

Figure 3

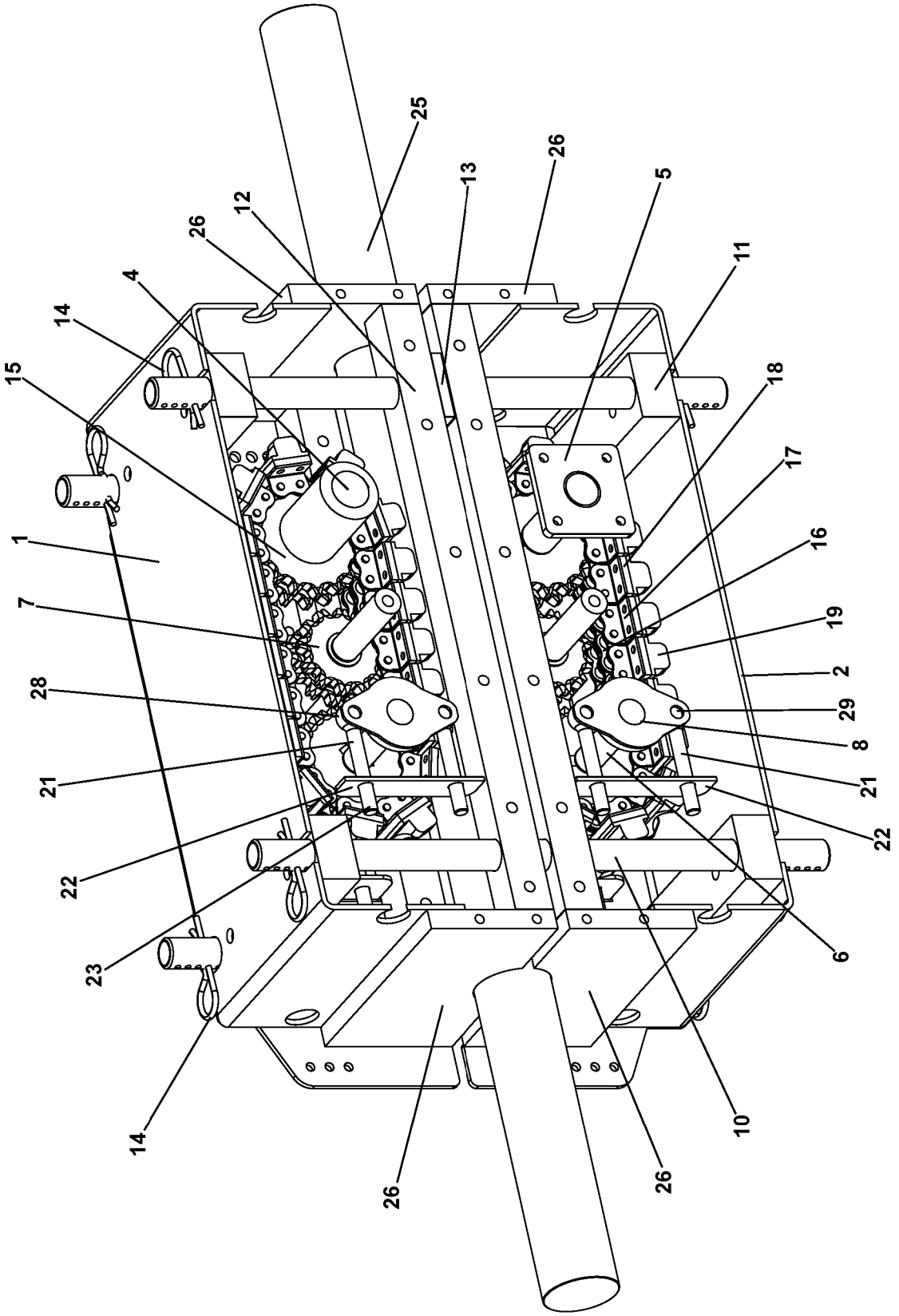
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Figure 4