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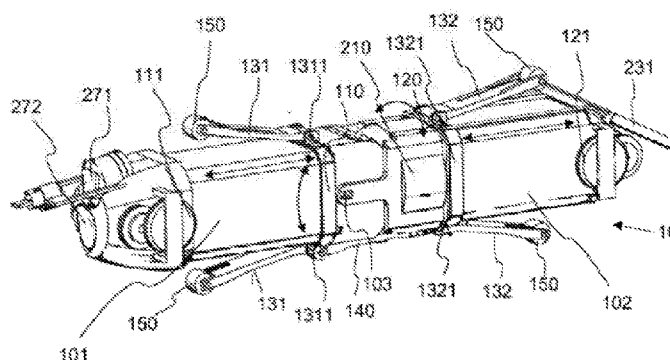


Figure 1

(57) **Abstract:** The invention is a robot (10) for traveling in a first path (510) in a pipe (500). The first path (510) referred to herein refers to an imaginary line passing through the center of the pipe (500) along the pipe (500). A front body (101) comprises a rear body (102) connected with the said front body (101). More specifically, the invention is a spark-proof wireless in-pipe inspection robot (10), which continuously travels autonomously in the natural gas pipeline, detecting internal surface defects of the pipe by image processing and providing position information to the external environment.



WIRELESS INSPECTION ROBOT FOR NATURAL GAS PIPE

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TECHNICAL FIELD

The invention relates to a robot moving along a path in a pipe.

BACKGROUND ART

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The distribution of natural gas in the city is carried using underground pipes of small diameters buried under the 1m-thick sand fill under the streets. Daily traffic on the streets, corrosion, and undetected deformations cause crushes in the urban underground gas distribution pipeline network. The resulting gas leak may cause disasters in the urban areas. These days, the leakages in the gas pipeline in the urban areas are detected by using ground penetrating radars (GPR), which is a very costly and time consuming solution, or by using gas detectors smelling gas leaks on the surface. However, these methods have significant disadvantages such as low positional precision during leak detection, and detecting past problems, and not being able to identify the source of the problem.

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In the academic literature, there are studies on robot designs that perform this process by navigating in the pipe, but there is no product solution since there is no prototype that solves the problem completely. Based on their drive method, they are classified as wheeled snake type, elastic worm type, wheeled screw type, and caterpillar type.

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The patent application US201213605667 discloses a robot in which the arms in the front and rear body touch and hold perpendicular to the pipe and move through the pipe by caterpillar drive.

The patent application US20020094353 discloses a plurality of bodies in the form of multiple wagons arranged one after the other and a robot traveling through the pipe by driving the wheels on the arms extending from these bodies.

One of the common problems in all these robot works is that a robots are connected to the external environment with cables for energy and detection of fault from display. It is a great hazard that the cable must exit through a hole on a pipe filled with explosive gas and the gas leakage at this outlet cannot be completely prevented. Another problem is that these robots are driven by sparking motors,

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therefore, it may be dangerous to use it in the pipes in the presence of flammable gas. These problems make it necessary to make an innovation in the relevant technical field.

5 **SHORT DESCRIPTION OF THE INVENTION**

The present invention relates to a robot in order to eliminate the above-mentioned disadvantages and bring new advantages to the relevant technical field.

10 It is an object of the invention to provide a robot which consumes reduced amount of energy while traveling in the pipe.

Another object of the invention is to provide a robot which can move through connection paths like Tee without overturning in the pipe.

15 It is an object of the invention to provide a robot which reduces the risk of igniting the flammable gases by itself in the pipe in which it moves.

Another object of the invention is to continuously inspect the natural gas pipelines in the urban areas using an autonomous robot without causing any danger and to inform the outside operator
20 about the position of the dents or cracks on the pipe, if any.

The present invention is a robot for moving along a path of progression in a pipe, in order to achieve all the objects mentioned above and which will emerge from the following detailed description. Accordingly, the invention is a robot comprising a front body and a rear body
25 associated with the said front body; comprising a front frame which at least partially surrounds the front body configured to move bi-directionally for a predetermined distance in the direction of the first axis and is parallel enough to the path of advance on front body; comprising at least two front arms, a first end of which is associated with the front frame and extends outwardly from the front frame at an acute angle between itself and the front body, a second end of which holds the
30 inner surface of the pipe; comprising a joint provided between the first ends of the front arms and the front frame for each front arm, the said joint allows the front arms to move so as to change the acute angle between the front arm and front body; comprising at least one front arm drive mechanism associated with the front arms, the said mechanism allows the front arms to move so as to change the acute angle between the front arm and front body; comprising a rear frame which
35 at least partially surrounds the rear body and configured to move bi-directionally for a predetermined distance in the direction of the said first axis;

comprising at least two rear arms, a first end of which is associated with the rear frame and extends outwardly from the front frame at an acute angle between itself and the rear body, a second end of which holds the inner surface of the pipe; comprising a joint provided between the first ends of the rear arms and the rear frame for each rear arm and the said joint allows the rear arms to move so as to change the acute angle between the rear arm and rear body; comprising at least one rear arm drive mechanism associated with the rear arms and the said mechanism allows the rear arms to move so as to change the acute angle between the rear arm and the rear body; comprising a control unit arranged to control the front arm drive mechanism and the rear arm drive mechanism.

A preferred embodiment of the invention is characterized in that the said front arm drive mechanism comprises at least one front arm torsion spring, that exerts force on the front arms to extend the acute angle between the front arms and the front body, for each front arm. Thus, the front arms are allowed to lean against the inner wall of the pipe by extending outward from the body or approaching the body based on the width of the pipe.

Another preferred embodiment of the invention is characterized in that the said front arm drive mechanism comprises at least one front arm pull wire which is associated with the control unit, one end of which is associated with the front arm and the other end is associated with the front body; when voltage is applied by the said control unit, the said front arm pull wire gets shortened at least partially and applies force to the rear arms to narrow the acute angle between the rear arms and the rear body. Thus, the arms are pulled towards the body by consuming less energy.

Another preferred embodiment of the invention is characterized in that the said front arm pull wire is made of a bi-metal fiber material, in particular a shape memory alloy of Ti-Ni.

Another preferred embodiment of the invention is characterized in that the said rear arm drive mechanism comprises at least one rear arm torsion spring, that exerts force on the rear arms to extend the acute angle between the rear arms and the rear body, for each rear arm.

Another preferred embodiment of the invention is characterized in that the said rear arm drive mechanism comprises at least one front arm pull wire which is associated with the control unit, one end of which is associated with the rear arm and the other end is associated with the front body; when voltage is applied by the said control unit, the said front arm pull wire gets shortened at least partially and applies force to the rear arms to narrow the acute angle between the rear arms and the rear body.

Another preferred embodiment of the invention is characterized in that at least one wheel is provided at the second end of the front arms and the rear arms to cling to the inner wall of the pipe; optionally, it comprises a brake mechanism operating in a first state in which the said wheel rotation is prevented and in a second state in which the wheel rotation is allowed.

Another preferred embodiment of the invention is characterized in that it comprises at least one wheel stretch component provided between an outer ring and an inner ring of the said wheel through which rotation is achieved, allowing the outer ring to stretch outwards to ensure that the wheel to cling to a braking surface in the arm to which it is associated; the said wheel stretch component is made of a shape-memory alloy which allows the outer ring to get shortened at least partially when the tension is applied to reduce the stretch distance of the outer ring; the control unit is associated with the expansion component to apply voltage. During travel, the braking situation is active longer than the period when the brake is released. No energy is consumed during braking while energy is consumed when the brake is released. Thus, the amount of energy consumption is reduced.

Another preferred embodiment of the invention is characterized in that the wheel stretching component is provided in the form of a strip extending in zigzag shape between the inner ring and the outer ring.

Another preferred embodiment of the invention is characterized in that it comprises at least one body joint provided between the front body and the rear body, which is driven by a drive element, to allow the front body to bend towards the curved portion.

Another preferred embodiment of the invention is characterized in that it comprises at least one torsion joint provided between the front body and the rear body and which is driven by a drive member to enable the rear body to torsionally move at the center of the first axis relative to the front body. Thus, it allows to pass through curved paths in the pipe.

Another preferred embodiment of the invention is characterized in that it comprises a support arm, the first end of which is connected with a lower surface of the rear body; a wheel provided at the second end of the said support arm and extending from the rear body towards the front body side at an acute angle with the rear body to prevent the rear body from turning over to the front body when the front body bends. Thus, the rear body is prevented from turning over forward while passing through the curved paths in the pipe.

Another preferred embodiment of the invention is characterized in that it comprises a battery.

Another preferred embodiment of the invention is characterized in that said battery is provided in the rear body.

- 5 Another preferred embodiment of the invention is characterized in that it comprises a power generator provided at the rear end of the rear body, comprising a propeller for rotationally generating energy by means of the gas flow in the pipe.

- 10 Another preferred embodiment of the invention is characterized in that the said power generator is associated with the battery.

Another preferred embodiment of the invention is characterized in that it comprises a voltage converter circuit provided between the battery and the power generator.

- 15 Another preferred embodiment of the invention is characterized in that it comprises a propeller orientation adjustment mechanism that allows the propeller orientation to be changed and also ensures the rotation of the propeller by means of gas flow through the pipe while the robot passes through the curved portions of the pipe; and the control unit being configured to control the said propeller orientation adjustment mechanism. Thus, continuous power generation is ensured.

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Another preferred embodiment of the invention is characterized in that it comprises a damage detection device provided at a front end of the front body.

- 25 Another preferred embodiment of the invention is characterized in that the said damage detection device comprises a light source arranged to emit ring-shaped light on the inner surface of the pipe and an image sensor arranged to face the surface where the light is emitted, and it is arranged to transmit the images received by the said image sensor to the control unit.

- 30 Another preferred embodiment of the invention is characterized in that it comprises a communication unit for data transfer between the control unit and a remote terminal.

Another preferred embodiment of the invention is characterized in that the said communication unit is arranged so as to allow ultrasonic communication. This ensures communication without arc flash danger.

Another preferred embodiment of the invention is characterized in that the control unit is configured to perform the following steps to enable the robot to move on a straight path in the pipe:

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- enabling to brake the wheels on the rear arms,
- enabling to release the wheels on the front arms,
- enabling the front frame to move towards the front end of the front body,
- enabling to brake the wheels on the front arms,

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- enabling the front frame to move towards the rear end of the front body, and the rear frame to move towards the rear end of the rear body so as to enable the front body and the rear body travel in the first path.

Another preferred embodiment of the invention is characterized in that the control unit is configured to perform the following steps in order to enable the robot to move in an upward path from a Tee-connection in the pipe:

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- enabling the front body to bend towards the first path,
- enabling the front frame to move towards the front end of the front body,
- enabling to interlock the wheels on the front arms,
- enabling to interlock the wheels on the rear arms,
- enabling the support arm to cling to the surface of the pipe,

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- enabling the front frame to move towards the rear end of the front body, and the rear frame to move towards the rear end of the rear body so as to enable the front body and the rear body travel in the first path.

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BRIEF DESCRIPTION OF THE DRAWING

Figure 1 shows a representative view of the robot.

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Figure 2 shows a representative view of the state of the robot as it travels along a straight path in the pipe.

Figure 3 shows a representative view of the state of the robot as it travels along a straight path in the pipe.

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Figure 4 shows a representative view of the state of the robot as it travels along a curved path through the pipe.

Figure 5 shows a representative view of the state of the robot as it travels along a curved path through the pipe.

5 Figure 6 shows a representative view of an arm.

Figure 7 shows a representative view of the wheel and the braking mechanism.

Figure 8 shows a schematic view of the components of the robot.

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Figure 9 shows a representative view of the turbine, which is in the rear body of the robot, concealed and exposed to the wind.

DETAILED DESCRIPTION OF THE INVENTION

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In this detailed description, the subject matter of the invention is described by using examples only for a better understanding, which will have no limiting effect.

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With reference to Figure 1, the invention is a robot (10) for traveling in a first path (510) in a pipe (500). The first path (510) referred to herein refers to an imaginary line passing through the center of the pipe (500) along the pipe (500). A front body (101) comprises a rear body (102) connected with the said front body (101). More specifically, the invention is a spark-proof wireless in-pipe inspection robot (10), which continuously travels autonomously in the natural gas pipeline, detecting internal surface defects of the pipe by image processing and providing position information to the external environment.

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The front body (101) and the rear body (102) are connected to each other by a body joint (103). The body joint (103) allows the front body (101) to bend in the direction of travel where the pipe (500) is curved, and connected. A rear body (102) torsion joint (210) is provided to ensure that the rear body (102) is twisted relative to the front body (101), that is, to enable rotation around the first axis (520). The torsion joint and the body joint (103) are driven by one DC motor (not shown in the figure).

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A front frame (110) is provided to at least partially surround the front body (101).

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In this possible embodiment, the front frame (110) completely surrounds the front body (101). More specifically, the front frame (110) is configured to move bi-directionally at a predetermined distance on the front body (101) along a first axis (520) parallel to the first path (510).

A front-frame drive mechanism (111) is associated with the front-frame (110) and enables the front-frame (110) to perform the aforementioned movement. The front frame drive mechanism (111) may comprise a motor, pulley assembly (not shown in the figure) associated with the said motor and the front frame (110).

At least two front arms (131) associated with the front frame (110) are provided. A first end of the said front arms (131) is associated with the front frame (110), and a second end extends outwardly from the front body (101) at an acute angle with the front body (101) for clinging to the inner wall of the pipe (500). A front arm joint (1311) is provided between the front frame (110) and the front arm (131). The said front arm joint (1311) allows the front arm (131) to move so as to enable it to increase or decrease the size of the acute angle between the front arm (131) and the front body (101). In this possible embodiment, 2 front arms (131) are provided. In this possible embodiment, the front arms (131) are provided to extend outwardly from opposite sides of the front body (101). In alternative embodiments, more than 2 front arms (131) may be provided. The front arms (131) are arranged on the front frame (110) so as to enable the robot (10) to stand stationary by forming a balance of force when they cling to the inner wall of the pipe (500).

A front arm torsion spring associated with the front arm joint (131) is provided (not shown in the figure). The said front arm torsion spring applies force to the front arm (131) so as to enable it to increase the size of the acute angle between the front arm (131) and the front body (101). A front arm drive mechanism (1312) is provided for reducing the size of the acute angle between the front arm (131) and the front body (101), that is, for applying reverse force to the torsion spring. More specifically, the front arm drive mechanism (1312) comprises a front arm pull wire (not shown in the figure). The said front arm pull wire is made of a material whose length is at least partially reduced as tension is applied. More specifically, the front arm pull wire is made of biometal fiber, in particular Ti-Ni alloy. The front arm drive mechanism (1312) may comprise a pulley (not shown in the figure) and a gearbox (not shown in the figure) in which the front arm pull wire is wound to provide traction at the desired distance.

A wheel (150) is provided at the second end of the front arms (131). A brake mechanism (143) associated with the wheel (150) is selectively actuated between a first state in which the wheel allows rotation and a second state in which the wheel restricts rotation.

A rear frame (120) is provided to at least partially surround the rear body (102). In this possible embodiment, the rear frame (120) completely surrounds the rear body (102). More specifically, the rear frame (120) is configured to move bi-directionally at apredetermined distance on

the rear body (102) along a first axis (520) parallel to the first path (510). A rear frame drive mechanism (121) is associated with the rear frame (120) and enables the rear frame (120) to perform the aforementioned movement. The rear frame drive mechanism (121) may comprise a motor, pulley assembly (not shown in the figure) associated with said motor and rear frame (120).

At least two rear arms (132) associated with the rear frame (120) are provided. A first end of the said front arms (132) is associated with the front frame (120), and a second end extends outwardly from the front body (102) at an acute angle with the front body (102) for clinging to the inner wall of the pipe (500). A rear arm joint (1321) is provided between the rear frame (120) and the rear arm (132). The said rear arm joint (1321) allows the rear arm (132) to move so as to increase or decrease the size of the acute angle between the rear arm (132) and the body. In this possible embodiment, 2 rear arms (132) are provided.

In this possible embodiment, the rear arms (132) are provided to extend outwardly from opposite sides of the rear body (102). In alternative embodiments, more than 2 rear arms (132) may be provided. The rear arms (132) are arranged on the rear frame (120) so as to enable the robot (10) to stand stationary by forming a balance of force when they cling to the inner wall of the pipe (500).

A rear arm torsion spring associated with the rear arm joint (132) is provided (not shown in the figure). The said rear arm torsion spring applies force to the rear arm (132) so as to enable it to increase the size of the acute angle between the rear arm (132) and the rear body (102). A rear arm drive mechanism (1322) is provided for reducing the size of the acute angle between the rear arm (132) and the rearbody (102), that is, for applying reverse force to the torsion spring. In this way, the arms tend to step out spontaneously unless an intervention is made. In this way, even if there is a power failure due to low battery, the robot maintains its position in the pipe and is not dragged. More specifically, the rear arm drive mechanism (1322) comprises a rear arm pull wire (not shown in the figure). The said rear arm pull wire is made of a material whose length is at least partially reduced as tension is applied. More specifically, the rear arm pull wire is made of biometal fiber, in particular Ti-Ni alloy. The rear arm drive mechanism (1322) may comprise a pulley (not shown in the figure) and a gearbox (not shown in the figure) in which the front arm pull wire is wound to provide traction at the desired distance.

A wheel is provided at the second end of the rear arms (132).

Referring to Figures 6 and 7, more specifically, the wheels comprise an outer ring in contact with the inner surface of the pipe (500) and an inner ring (142), in which rotational movement is allowed, in connection with the outer ring. The outer ring is made of a flexible material, in particular, silicone. A wheel stretching component (144) is provided between the inner ring (142) and the outer ring as the brake mechanism (143). The wheel stretching component (144) enables the outer ring to expand outward and to lock the wheel clinging on a braking surface (1301) provided in the arms (130). The wheel stretching component (144) is also made of a material which is shortened in length when tension is applied, in particular Ti-Ni alloy.

The wheel stretching component (144) is provided in the form of a strip extending zig-zagged from the inner ring (142) to the outer ring. In a possible embodiment, a plurality of the wheel stretching components (144) are arranged to extend from the inner ring (142) to the outer ring so as to compensate each other's force.

The brake mechanism (143), the front frame drive mechanism (111), the rear frame drive mechanism (121), the front arm drive mechanism (1312), and the rear arm drive mechanism (1322) are controlled by a control unit (240).

A battery (220) is provided to energize the brake mechanism (143), the front frame drive mechanism (111), the rear frame drive mechanism (121), the front arm drive mechanism (1312), the rear arm drive mechanism (1322), and other electrical components. The battery (220) is preferably located in the rear body (102). A power generator (230) is also provided to charge the battery (220). The power generator (230) is also located at a rear end of the rear body (102).

More specifically, the power generator (230) may comprise a propeller. Thanks to the gas flow in the pipe (500), the rotating propeller enables a 3-phase AC generator (not shown in the figure) to generate electricity by rotating. The power generator (230) is preferably a wind turbine. A voltage converter circuit (250) can be provided between the power generator (230) and the battery (220) to convert the AC voltage to DC voltage. A propeller orientation adjustment mechanism (232) is associated with the propeller (231) of the power generator (230). The control unit (240) controls the propeller orientation adjustment mechanism (232) to move the propeller (231) according to need by hiding the propeller (231) from the wind or exposing the propeller (231) to the wind. In this way, the propeller (231) is directed so as to hide the propeller (231) to avoid drag force in the normal operation of the robot, or to expose the propeller (231) to the wind to charge the battery. More specifically, the propeller (231) is moved by a spring to an angle that exposes it to the wind needed for charging, when energized, it is brought to the hiding position from the wind by the shortened shape memory fiber. Thus, even if there is a power failure due to

low battery in the robot, the propeller (231) is positioned to the angle that exposes itself to the wind needed for self-charging, and thus, the robot (10) charges itself.

A damage detection device (270) is provided at a front end of the front body (101). More specifically, damage detection apparatus (270) comprises a light source which transmits annular light to the pipe (500). In this exemplary embodiment, the light source (271) emits laser beam. An image sensor (272) is provided facing the place where the light source (271) shed light on. The image sensor (272) transmits the captured images to the control unit (240). Thus, if a distortion is detected in a ring form in the images, a defect can be determined in this part of the pipe (500).

The robot also comprises a communication unit (260). The communication unit (260) enables the control unit (240) to send data to an external terminal. In this exemplary embodiment, the communication unit (260) is configured to communicate using ultrasound waves.

A support arm (140) is provided on a lower surface (1021) of the rear body (102). The support arm is also driven by similar components and is controlled by the control unit (240), similar to the front arm (131) and the rear arms (132). The support arm (140) extends outwardly from the lower surface (1021) of the rear body (102) at an acute angle with the lower body. More specifically, the front body (101) extends outwardly to face the side of the front body (101) so that the rear body (102) does not overturn towards the front body (101) when it bends.

Referring to Figure 2 and Figure 3, the control unit performs the following steps to enable the robot (10) to move straightly:

- enabling to brake the wheels on the rear arms (132),
- enabling to release the wheels on the front arms (131),
- enabling the front frame (110) to move towards the front end of the front body (101).
- enabling to brake the wheels on the front arms (131),
- enabling the front frame (110) to move towards the rear end of the front body (101), and the rear frame (120) to move towards the rear end of the rear body (102) so as to enable the front body (101) and the rear body (102) travel in the first path (510).

Referring to Figure 4 and Figure 5, the control unit performs the following steps to enable the robot (10) to move on a path going upwardly from a Tee-connection in the pipe (500):

- enabling the front body to bend towards the first path (510),
- Enabling the front frame (110) to move towards the front end of the front body (101).

- Enabling to interlock the wheels on the front arms (131),
 - Enabling to interlock the wheels on the rear arms (132),
 - Enabling the support arm to cling to the surface of the pipe (500),
 - Enabling the front frame (110) to move towards the rear end of the front body (101), and the
- 5 rear frame (120) to move towards the rear end of the rear body (102) so as to enable the front body (101) and the rear body (102) travel in the first path (510).

In a possible embodiment, the control unit (240) detects the turnings in the pipe (500) according to the images it captures by the image sensor (272), and decides whether to continue straight

10 ahead or to turn at the turning point relative to the determined turning and to carry out the steps required to perform this movement.

Since the bending and torsion movements between two consecutive body blocks are provided by spark-free motors, the energy of the turbine (231) is provided by a spark-free 3-phase AC

15 generator, and other movements are also provided by the shape-memory fiber that shortens when energized and that is not likely to generate sparks, the robot can operate safely in an environment full of flammable gas. Since the shortening ratio of shape-memory fibers relative to their first length is limited, it is not possible to directly provide the long stroke movements necessary for the movement of the frames and arms, therefore, front and rear pulleys and stroke enhancers with

20 metal gearboxes are added to the frames. However, increasing the stroke of movement causes the decrease of the pulling force. To solve this problem, multiple shape memory fibers are operated in parallel to increase the total pulling force.

In other words, the movement of the robot (10) subject to the invention has a special cycle which

25 uses worm and wheel structures together. If it is assumed that the front and rear wheels (150) are braked and the front frame (110) is at the rear and the rear frame (120) is at the front as the initial position, first the front wheels (150) are released and the front frame (110) slides forward, the front wheels (150) are braked, the rear wheels (150) are released and the front frame (110) slides to the rear. Thus the body is moved forward. Then, the rear wheels (150) are braked, the

30 front wheels (150) are released, and the rear frame (120) slides back; thus, the body is moved forward again. Braking of the front wheels (150), release of the rear wheels (150), and sliding of the rear frame (120) makes it return to the initial state.

In other words, when the robot of the invention needs to pass to a pipe perpendicular to the pipe

35 connected with an elbow or Tee-connection, firstly, the lower additional support arm (140) is extended at the connection of the front body (101) and the rear body (102), the front arms (131)

are retracted towards the center, if necessary, the front body block (101) is rotated by the movement of the torsion joint (210) according to the curvature in the lateral directions, the body is moved forward by moving the rear frame (120) backward while the rear wheels (150) are
5 braked, the front frame (110) is moved forward, the front arms (131) are released and hold onto the other side of the elbow, the rear wheels (150) are released and the rear frame (120) is moved forward, the rear wheels (150) are braked and the front (110) and rear (120) frames are shifted back together and in this way the body is moved to the other side of the elbow. When it is to be continued straight forward in the Tee-connection, the lower additional support arm (140) at the
10 junction of the front (101) and the rear (102) body is extended, the front wheels (150) are braked, the rear wheels (150) are released thus sliding the front frame (110) backward to move the body forward, the front arms (131) are retracted back on the body, the front frame (110) is moved forward, the rear wheels (150) move the rear frame (120) to the rear with brakes to move the body forward, the front arms (131) are released and cling to the other side of the Tee-connection, the
15 rear arms (132) are retracted towards the center, the front frame (110) is moved back to move the body forward, the rear frame (120) slides forward and the rear arms (132) are released to cling to the other side of the Tee-connection.

The scope of the protection of the invention is set forth in the annexed claims and certainly cannot
20 be limited to exemplary explanations in this detailed description. It is evident that a specialized one in the art can make similar configurations in the light of the explanations above without leaving the main theme of the invention.

REFERENCE NUMBERS IN THE FIGURE

	10: Robot
5	101: Front body
	102: Rear body
	1021: Lower surface
	103: Body joint
	110: Front frame
10	111: Front frame drive mechanism
	120: Rear frame
	121: Rear frame drive mechanism
	130: Arm
	1301: Braking surface
15	131: Front arm
	1311: Front arm joint
	1312: Front arm drive mechanism
	132: Rear arm
	1321: Rear arm joint
20	1322: Rear arm drive mechanism
	140: Support arm
	150: Wheel
	141: Outer ring
	142: Inner ring
25	143: Brake mechanism
	144: Wheel stretching component
	210: Torsional joint
	220: Battery
	230: Power generator
30	231: Propeller
	232: Propeller orientation adjustment mechanism
	240: Control unit
	250: Voltage converter circuit
	260: Communication unit
35	270: Damage detection device
	271: Light source
	272: Image sensor

5 400: Remote terminal
500: Pipe
510: First path
520: First axis

CLAIMS

1. A robot (10) for moving along a path of travel in a pipe (500) characterized in comprising a front
5 body (101) and a rear body (102) associated with the said front body (101); comprising a front
frame (110) which at least partially surrounds the front body (101) and is configured to move bi-
directionally for a predetermined distance along a first axis (520) parallel enough to the path of
travel on the front body (101); comprising at least two front arms (131), a first end of which is
associated with the front frame (110) and extends outwardly from the front frame (110) at an acute
10 angle between itself and the front body (101), a second end of which clings to the inner surface
of the pipe (500); comprising a front arm joint (1311) provided between the first ends of the front
arms (131) and the front frame (110) allowing the front arms (131) to move to change the size of
the acute angle between the front arm (131) and the front body (101); comprising at least one
front arm drive mechanism (1312) associated with the front arms (131) which allows the front
15 arms (131) to move so as to change the size of the acute angle between the front arm (131) and
the front body (101); comprising a rear frame (120) which at least partially surrounds the rear body
(102) and is configured to move bi-directionally for a predetermined distance in the direction of
the said first axis (520) on the rear body (102); comprising at least two rear arms (132), a first end
of which is associated with the rear frame (120) and extends outwardly from the rear frame (120)
20 at an acute angle between itself and the rear body (101), a second end of which clings to the
inner surface of the pipe (500); comprising a rear arm joint (1321) provided between the first ends
of the rear arms (132) and the rear frame (120) allowing the rear arms (132) to move to change
the size of the acute angle between the rear arm (132) and the rear body (102); comprising at
least one rear arm drive mechanism (1322) associated with the rear arms (131) which allows the
25 rear arms (132) to move so as to change the size of the acute angle between the rear arm (132)
and the rear body (102); comprising control unit (240) which is arranged so as to control the the
front arm (131) drive mechanism and the rear arm drive mechanism (1322).
2. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized
30 in that the said front arm drive mechanism (1312) comprises at least one front arm torsion spring
applying force to the front arms (131) such that the front arms (131) extend the size of the acute
angle between itself and the front arm (101).

3. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that the said front arm drive mechanism (1312) comprises at least one front arm pull wire which is associated with the control unit (240), one end of which is associated with the front arm (131) and the other end is associated with the front body (101); when voltage is applied by the said control unit (240), the said front arm pull wire gets shortened at least partially and applies force to the rear arms (132) to decrease the size of the acute angle between the rear arms (132) and the rear body (102).

4. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that the said front arm pull wire is made of a bi-metal fiber material, in particular, a shape-memory alloy of Ti-Ni.

5. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that the said rear arm drive mechanism (1322) comprises at least one rear arm torsion spring, that exerts force on the rear arms (132) to extend the acute angle between the rear arms (132) and the rear body (102), for each rear arm.

6. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that the said rear arm drive mechanism (1322) comprises at least one front arm pull wire which is associated with the control unit (240), one end of which is associated with the rear arm (132) and the other end is associated with the front body (101); when voltage is applied by the said control unit (240), the said front arm pull wire gets shortened at least partially and applies force to the rear arms (132) to decrease the size of the acute angle between the rear arms (132) and the rear body (102).

7. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that it comprises at least one wheel at the second end of the front arms and the rear arms (132) to cling to the inner wall of the pipe (500); optionally, it comprises a brake mechanism (143) operating in a first state in which the said wheel rotation is prevented and in a second state in which the wheel rotation is allowed.

8. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that it comprises at least one wheel stretch component (144) provided between the said wheel's an outer ring and an inner ring (142) through which rotation is achieved, allowing the outer ring to stretch outwards to ensure that the wheel to cling to a braking surface (1301) in the arm to which it is associated; the said wheel stretch component is made of a shape-memory alloy which allows the outer ring to get shortened at least partially when the tension is applied to reduce the stretch distance of the outer ring; the control unit (240) is associated with the expansion component to apply voltage.

9. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 8, characterized in that the wheel stretching component (144) is provided in the form of a strip extending in zigzag shape between the inner ring (142) and the outer ring.

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10. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 8, characterized in that it comprises at least one body joint (103) provided between the front body (101) and the rear body (102), which is driven by a drive element, to allow the front body to bend towards the curved portion.

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11. A robot (10) in accordance with Claim 8, characterized in that it comprises at least one torsion joint (210) provided between the front body (101) and the rear body (102) and which is driven by a drive member to enable the rear body (102) to torsionally move at the center of the first axis (520) relative to the front body.

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12. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 10, characterized in that it comprises a support arm (140), the first end of which is connected with a lower surface (1021) of the rear body (102); a wheel is provided at the second end of the said support arm and it extends from the rear body (102) towards the front body (101) side at an acute angle with the rear body (102) to prevent the rear body (102) from turning over to the front body (101) when the front body (101) bends.

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13. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that it comprises a battery (220).

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14. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 13, characterized in that the said battery (220) is provided in the rear body (102).

15. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 13, characterized in that it comprises a power generator (230) provided at the rear end of the rear body (102), comprising a propeller for rotationally generating energy by means of the gas flow in the pipe (500).

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16. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 15, characterized in that the said power generator (230) is associated with the battery (220) to charge the battery (220).

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17. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 16, characterized in that it comprises a voltage converter circuit provided between the battery (220) and the power generator (230).

18. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 15, characterized in that it comprises a propeller orientation adjustment mechanism (232) that allows the propeller orientation to be changed and also ensures the rotation of the propeller by means of gas flow through the pipe (500) while the robot (10) passes through the curved portions of the pipe (500); the control unit (240) is configured to control the said propeller orientation adjustment mechanism (232).

19. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that it comprises a damage detection device (270) provided at a front end of the front body (101).

20. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 19, characterized in that the said damage detection device (270) comprises a light source arranged to emit ring-shaped light on the inner surface of the pipe (500) and an image sensor (272) arranged to face the surface where the light is emitted, and it is arranged to transmit the images received by the said image sensor (272) to the control unit (240).

21. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 1, characterized in that it comprises a communication unit (260) for data transfer between the control unit (240) and a remote terminal (400).

22. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 21, characterized in that the said communication unit (260) is arranged to so as to allow ultrasonic communication.

22. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 10, characterized in that the control unit (240) is configured to perform the following steps to enable the robot (10) to move on a straight path in the pipe (500):

- enabling to brake the wheels on the rear arms (132),
- enabling to release the wheels on the front arms (131),
- enabling the front frame (110) to move towards the front end of the front body (101).
- enabling to brake the wheels on the front arms (131),

- enabling the front frame (110) to move towards the rear end of the front body (101), and the rear frame (120) to move towards the rear end of the rear body (102) so as to enable the front body (101) and the rear body (102) travel in the first path (510).

5 23. A robot (10) for moving along a path of travel in a pipe in accordance with Claim 10, characterized in that the control unit (240) is configured to perform the following steps in order to enable the robot 10) to move in an upward path from a Tee-connection in the pipe (500):

- enabling the front body to bend towards the first path (510),
- enabling the front frame (110) to move towards the front end of the front body (101),
- 10 - enabling to interlock the wheels on the front arms (131),
- enabling to interlock the wheels on the rear arms (132),
- enabling the support arm to cling to the surface of the pipe (500),
- enabling the front frame (110) to move towards the rear end of the front body (101), and the rear frame (120) to move towards the rear end of the rear body (102) so as to enable the front
- 15 body (101) and the rear body (102) travel in the first path (510).

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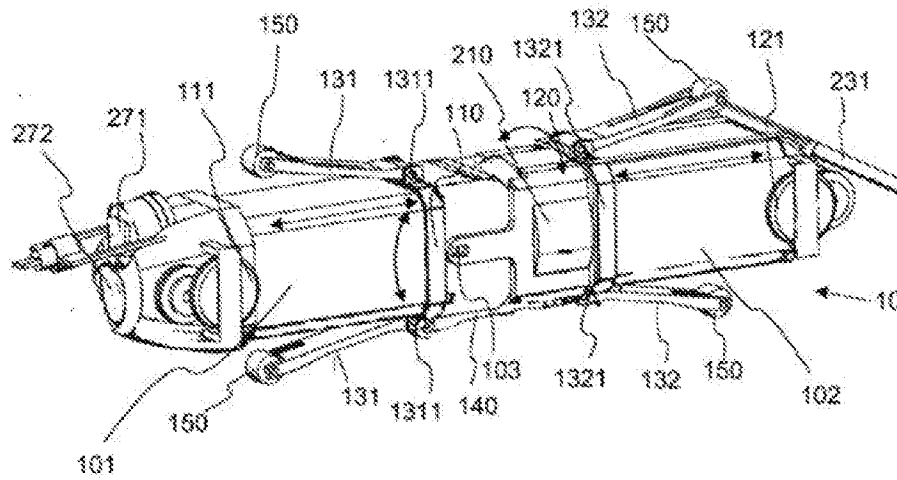


Figure 1

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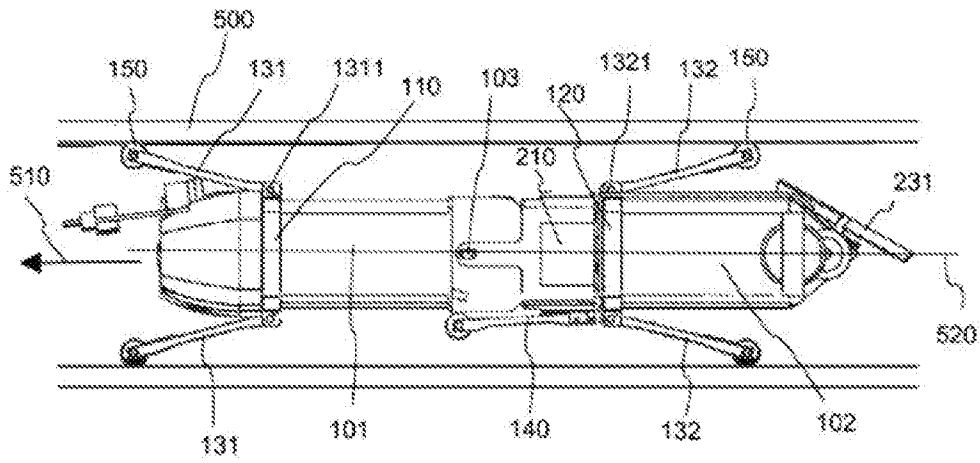


Figure 2

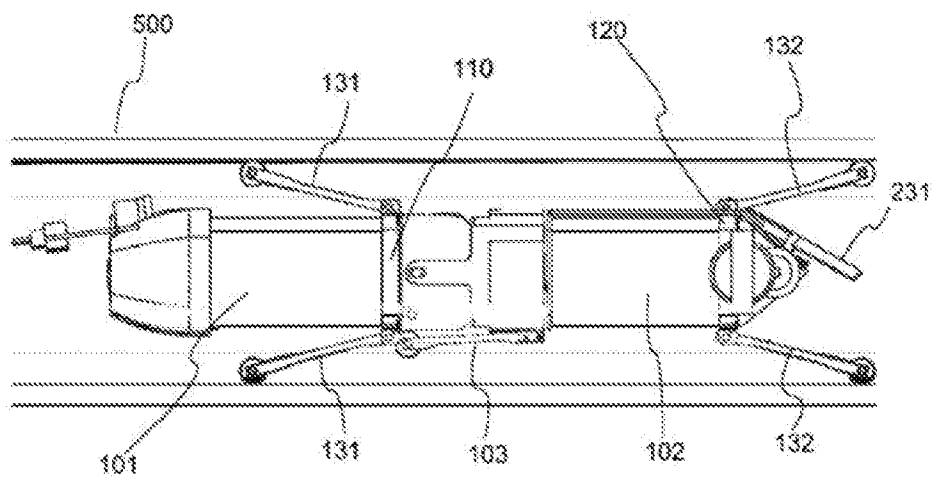


Figure 3

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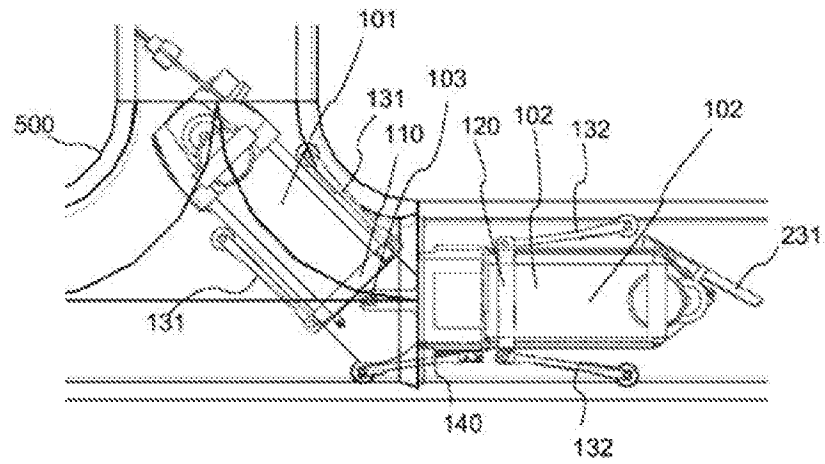


Figure 4

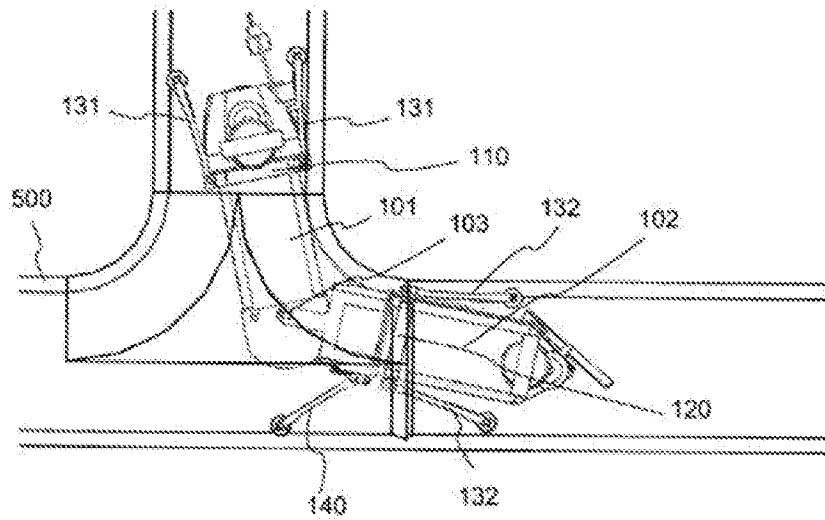


Figure 5

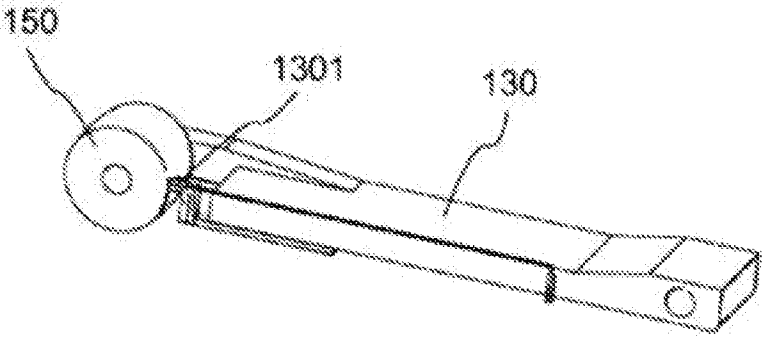


Figure 6

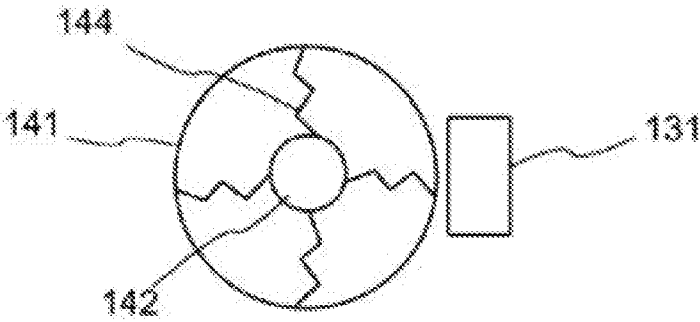


Figure 7

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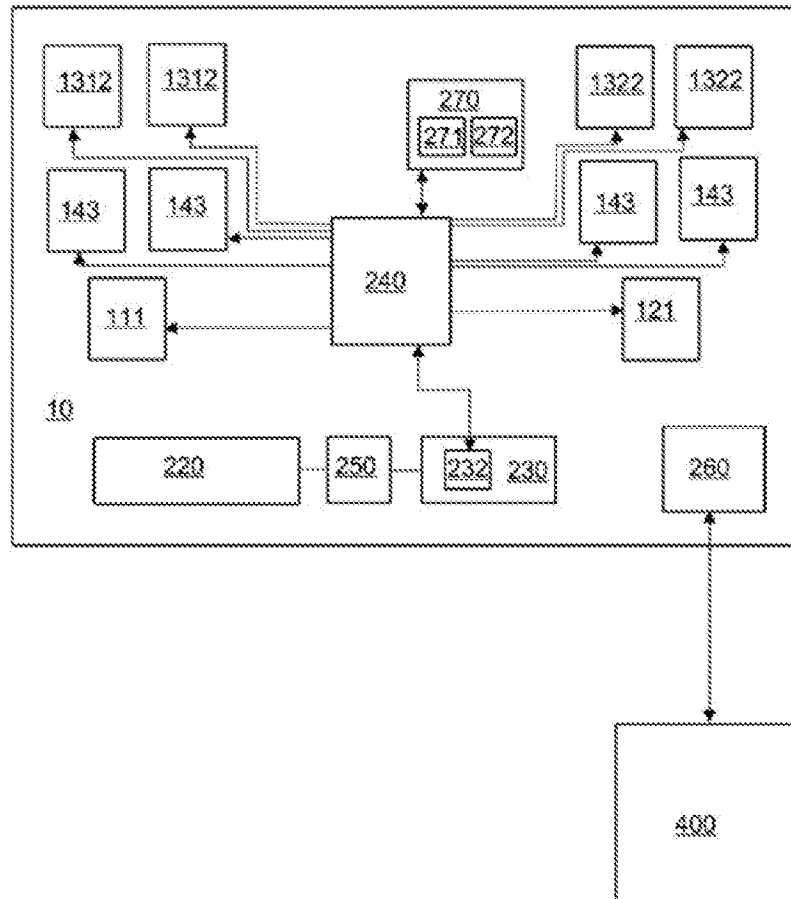


Figure 8

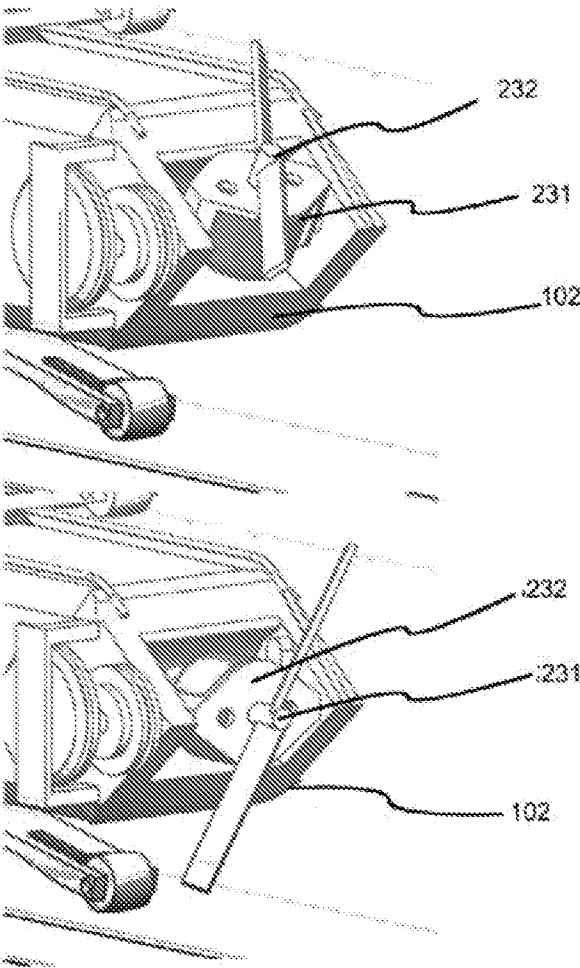


Figure 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/TR2019/051099

A. CLASSIFICATION OF SUBJECT MATTER B25J 11/00 (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 11/00 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) EPODOC,WPI		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 101905584 B1 (KOREA INST ROBOT & CONVERGENCE [KR]) 10 October 2018 (2018-10-10) Whole document	1-23
A	CN 108608399 A (UNIV NANJING SCI & TECH) 02 October 2018 (2018-10-02) Whole document	1-23
A	CN 207833574 U (MASTEEL DESIGN & RES INSTITUTE CO LTD) 07 September 2018 (2018-09-07) Whole document	1-23
☐ 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 "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 "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 "&" document member of the same patent family		
Date of the actual completion of the international search 16 April 2020		Date of mailing of the international search report 16 April 2020
Name and mailing address of the ISA/TR Turkish Patent and Trademark Office (Turkpatent) Hipodrom Caddesi No. 13 06560 Yenimahalle Ankara Turkey Telephone No. (90-312) 303 11 82 Facsimile No. +903123031220		Authorized officer MEHMET ÇAĞDAŞ ÜSTÜN Telephone No. +90 312 3031657