

SELF-PROPELLED VEHICLE FOR USE IN PIPES

The present invention relates to self-propelled vehicles for use in pipes of piping systems for performing work, for example, for cleaning or
5 coating the inner surface of the pipe.

For purposes of safety, sanitation and work efficiency, vehicles are used within pipes of various piping systems such as oil cargo pipes for oil tankers,
10 and water supply pipes, sewers and gas pipes under the ground or above the ground for performing work, for example, for cleaning or coating the inner surface of the pipe. For instance, pipes are cleaned by placing into the pipe a vehicle carrying a cleaning spray
15 device and moving the vehicle axially of the pipe. Pipes are coated similarly using a vehicle having a coating spray device mounted thereon.

According to this invention there is provided a self-propelled vehicle employing compressed air as
20 power source and adapted for use in performing work in the interior of a pipe of a piping system wherein the vehicle comprises a vehicle body, at least three parallel-link assemblies arranged at approximately equal angular spacings about a central axis of the
25 vehicle body and each comprising parallel first and second links pivoted by one end to the vehicle body and carrying jointly and pivotally at their opposite ends a travelling assembly, the travelling assemblies
operating to move the vehicle along an inner surface of the pipe to be worked on, an extending and retracting
30 mechanism connected to the link assemblies for moving the travelling assemblies towards and away from the inner surface of the pipe, a drive unit mounted within the vehicle body for driving the travelling assemblies,
35 transmissions for transmitting a drive to the respective travelling assemblies, and a rotary nozzle

assembly removably attached to a front portion of the vehicle body for enabling a nozzle to apply a liquid to the pipe inner surface while rotating the nozzle, said extending and retracting mechanism comprising a screw-threaded rod rotatably supported in the body to extend
 5 lengthwise of the body and to be movable lengthwise of the body, an internally threaded block engaged on said rod, support struts pivotally connected at one end to the threaded block and at the other end to the second
 10 links of the respective link assemblies at a point intermediate the ends of said second links, said support struts being telescopingly extensible and being capable of being fixed in selected positions of extension, and an air cylinder and piston connected
 15 between the body and the screw-threaded rod for moving the rod axially of itself.

One embodiment of the invention will now be described by way of example with reference to the accompanying drawings in which:

20 Fig. 1 is a view partly broken away and showing a self-propelled vehicle embodying the invention;

25 Fig. 2A is a view showing a travelling assembly as moved toward the body of the vehicle by a collapsing assembly;

Fig. 2B is a view showing the same as moved away from the vehicle body by the collapsing assembly;

30 Fig. 3 is a diagram showing travelling assemblies as moved toward or away from the inner surface of the pipe to be worked on;

Fig. 4 is a view showing another embodiment of rotary nozzle assembly; and

35 Fig. 5 is a circuit diagram showing an embodiment of pneumatic system for the vehicle of the invention.

The self-propelled vehicle of the invention

for use in pipes will be described with reference to the accompanying drawings.

Figs. 1 to 3 show an embodiment comprising three travelling assemblies 1. The travelling assemblies 1 are connected to a vehicle body 9 by parallel link assemblies 8, 8, 8 and driven along the inner surface of the pipe to be worked on by the operation of a drive

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unit 3 and transmissions 5, 5, 5 while being pressed against the inner surface of the pipe P by a collapsing assembly 2. A rotary nozzle assembly 4 has a rotary shaft 47 and a nozzle 43 positioned generally perpendicular to the shaft 47. During travel, the nozzle 43 rotates. When required, four or more traveling assemblies 1 can be provided.

The vehicle of the invention employs compressed air as its power source so as to be usable for cleaning or coating selectively. The reason is that since volatile solvents are used for coating, the use of electricity as the power source involves an explosion hazard and is therefore undesirable.

The parallel link assemblies 8 serve to connect the traveling assemblies 1 to the vehicle body 9. With reference to Figs. 1 and 2, each link assembly 8 comprises a pair of first link 81 and second link 83 having the same length. The first link 81 comprises opposed first link bars 81a, 81a spaced apart by a predetermined distance and has a base end rotatably attached to a rotary shaft 55 of the transmission 5 mounted on the vehicle body 9. The other end of the link 81 is rotatably attached to a front rotary shaft 14 of the traveling assembly 1. The second link 83 comprises opposed first link bars 83a, 83a spaced apart by a

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predetermined distance and has a base end rotatably attached to another rotary shaft 55 of the transmission 5. The other end of the link 83 is rotatably attached to a rear rotary shaft 15 of the traveling assembly 1.

5 The three link assemblies 8 are arranged at an angular spacing of about 120 degrees about the axis of the vehicle body 9. The force from the collapsing assembly 2 and the drive force of the drive unit 3 are transmitted to the traveling assemblies 1 through the link assemblies 8.

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Each traveling assembly 1 travels along the inner wall surface of the pipe P to be worked on axially of the pipe to thereby move the vehicle. The assembly 1 comprises two opposed frame plates 11, 11 having approximately the same shape and connected together by a plurality of connecting pins 12, the front (first) and rear (second) rotary shafts 14, 15 fitted respectively in the front and rear portions of the frame plates, a pair of main pulleys 16, 16 rotatably mounted on the respective ends of the first rotary shaft 14, a pair of main pulleys 17, 17 rotatably mounted on the respective ends of the second rotary shaft 15, auxiliary pulleys 19, 19 rotatably mounted on the respective ends of the connecting pins, and belts 18, 18 endlessly reeved around the main pulleys and the auxiliary pulleys.

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The collapsing assembly 2 is adapted to move the traveling assemblies 1 toward or away from the inner surface of the pipe to be worked on and to pneumatically press the assemblies 1 against the tube inner surface. The collapsing assembly 2 comprises an air cylinder 25 secured to the rear portion of the vehicle body 9, a screw rod 21 provided inside the vehicle body 9, an internally threaded block 22 screwed on the threaded portion of the screw rod, support frames 23 pivoted to the block 22, and support bars 24 connected to the respective traveling assemblies 1 and each inserted in the support frame 23, the bar 24 being fixedly positionable relative to the frame 23.

The air cylinder 25 has a piston rod 26 projectable into and retractable from the vehicle body 9. The piston rod 26 has a thrust bearing 20b fitted to its forward end.

The screw rod 21 is rotatably supported by the vehicle body 9 and is movable axially thereof by a specified distance. The screw rod 21 comprises a small diameter portion and a threaded large diameter portion. The threaded portion has at its rear end a flange 21a which is adapted to bear against the thrust bearing 20b face-to-face. An extension rod 27 implanted in the rear end of the thread portion extends through the piston

rod 26 of the air cylinder 25 and is formed with a head
28 at its outer end. The screw rod 21 is rotated by
the head 28. The small diameter portion of the screw rod
21 is fitted in a thrust bearing 20a mounted on a
5 partition wall 95 of the vehicle body 9. The partition
wall 95 has a hole for the screw rod small diameter
portion to pass through.

The support bar 24 is slidably fitted in the
support frame 23. The base portion of the frame 23 is
10 pivoted to the block 22, while the outer end of the
support bar 24 is pivoted approximately to the midportion
of the second link 83 of the link assembly 8. The frame
23 and the bar 24 are formed with a plurality of holes
29 arranged at a specified spacing. By inserting a
15 positioning pin (not shown) through the frame and the
bar at the selected corresponding holes, the length of
projection of the support bar 24 from the frame 23 can
be determined.

When the traveling assembly 1 is in a
20 collapsed position, no air is applied to the air cylinder
25, so that the flange 21a on the screw rod 21 bears
against and is supported by the thrust bearing 20b as
seen in Fig. 2A. When the traveling assembly 1 is
positioned away from the vehicle body 9, air is applied
25 to the air cylinder, causing the stepped end face of

the large diameter portion of the screw rod 21 to bear against the thrust bearing 20a and to be thereby supported as seen in Fig. 2B.

The collapsing assembly 2 is operated in the following manner. First, the angle of inclination of the first and second links 81, 83 of each traveling assembly 1 is so determined that a small clearance (e.g. about 25 mm) will be formed between the outer face of the assembly 1 and the pipe inner surface to be worked on. Next, the support bar 24 is drawn out and fixed to the support frame 23 with the positioning pin so that the links will be fixed approximately at the inclination angle. The piston rod 26 of the air cylinder 25 is then operated, thereby moving the screw rod 21 toward the front end of the vehicle body 9 (for example, by about 100 mm) and further varying the angle of inclination of the link assembly 8 connected to the support bar 24 to bring the outer running face of the traveling assembly 1 into the pipe inner surface. In this state, the assembly 1 is pressed against the pipe inner surface pneumatically. This pressure is further adjustable by rotating the screw rod 21 and moving the internally threaded block 22.

The drive unit 3 serves to move the traveling assemblies 1 axially of the pipe to be worked on.

The drive unit 3 comprises two air motors 31a, 31b which are changeable in the direction of rotation of their output shafts and arranged back-to-back inside the vehicle body 9, with the output shaft made rotatable in
5 directions opposite to each other. Thus, when the first air motor 31a rotates positively, the second air motor 31b rotates reversely, while when the first motor 31a rotates reversely, the second motor 31b rotates positively, with the result that the rotary shafts 14, 15 of each
10 traveling assembly 1 rotate together in the same direction.

Each of the transmissions 5 is adapted to transmit the drive force of the drive unit 3 to the traveling assembly 1 through first belts 57 and second
15 belts 50. The transmission is coupled to the output shafts 32a, 32b of the respective air motors 31a, 31b.

With reference to Figs. 1 and 3, at positions dividing the circumference of the vehicle body 9, which is in the form of a hollow cylinder, into three equal
20 portions, three shafts 53, 53, 53 extend from the inner surface of the vehicle body 9 toward its axis. A pulley 54 and a bevel gear 52 are mounted on the forward end of each of these shafts 53. The shaft 53 is in parallel to the aforementioned rotary shaft 55 which is supported
25 by suitable bracket means 55a on the outer side of the

vehicle body 9. The rotary shaft 55 has mounted thereon a pulley 56 positioned in the same plane as the plane of rotation of the pulley 54. Pulleys 58, 59 are mounted on the rotary shaft 55 and the rotary shaft 14 of the traveling assembly 1, respectively. The belt 57 is endlessly reeved around the pulleys 54 and 56. The belt 50 is endlessly reeved around the pulleys 58 and 56. Bevel gears 51a, 51b are mounted on the respective output shafts 32a, 32b of the air motors 31a, 31b. The bevel gear 52 is in mesh with the bevel gear 51a or 51b. Consequently, the rotation of the air motor 31a is transmitted from the bevel gear 51a to the rotary shaft 53 via the bevel gear 53, then to the rotary shaft 55 through the belt 57 and further to the front rotary shaft 14 of the traveling assembly 1 through the belt 50. Similarly, the rotation of the air motor 31b is transmitted to the rear rotary shaft 15 of the traveling assembly 1. When the first air motor 31a rotates positively, the second air motor 31b rotates reversely, and the two motors are arranged back to back, so that the rotary shafts 14 and 15 rotate in the same direction to advance each traveling assembly 1. The assembly 1 retracts when the direction of rotation of the two air motors is changed.

The rotary nozzle assembly 4 is adapted to

clean or coat the pipe inner surface. With reference to Fig. 4, the nozzle assembly 4 includes a nozzle pipe mount 42 on a base 41, a nozzle pipe 45 projecting from the forward end of the forementioned rotary shaft 47 on the mount 42, and the aforementioned nozzle 43 attached to the forward end of the nozzle pipe 45 perpendicular to the nozzle pipe for spraying a liquid onto the pipe inner surface. An air motor 44 attached to the mount 42 is coupled to the rotary shaft 47 for drivingly rotating the nozzle pipe 45. The nozzle pipe 45 is connected to an unillustrate liquid source by a conduit member 49. The base 41 is provided at its bottom with a flange 40 which is removably attached to a flange 93 at the front end of the vehicle body 9 by fastening means such as bolts. This embodiment is suited chiefly to coating work.

To assure an improved cleaning effect when the vehicle is used for cleaning, it is desirable to use an increased number (at least two) of nozzle pipes. With reference to Fig. 1, four nozzle pipes 45 (one not shown) are arranged at an angular spacing of approximately 90 degrees about the rotary shaft 47 rotatably in a plane intersecting the shaft 47 perpendicular thereto.

Fig. 1 further shows a nozzle reciprocating assembly 6 for achieving a further improved cleaning

effect. A nozzle pipe mount 42 is separable from the base 41 and reciprocatingly movable by the assembly 6 axially of the vehicle body 9, such that the nozzles 43 on the shaft 47 can be reciprocatingly movable forward and rearward axially of the pipe be worked on while being revolved by the air motor 44.

The nozzle reciprocating assembly 6 has a rotary shaft 64 supported within the vehicle body 9 in parallel to the rotary shaft 55 of the transmission 5. A belt 61 is endlessly reeved around the rotary shafts 64 and 55. An air cylinder 65 fixed to the base 41 has a piston rod 66 with its forward end attached to the nozzle pipe mount 42 to move the mount 42 axially of the vehicle body. A cam 62 mounted on the rotary shaft 64 is rotatable by the drive force of the drive unit air motor 31a transmitted to the rotary shaft 64 through the belts 57, 61. When rotated, the cam comes into contact with a limit switch 63 on the base 41 to produce a signal, in response to which the piston rod 66 of the air cylinder 65 advances or retracts.

Fig. 5 shows an embodiment of pneumatic circuit for the self-propelled vehicle of the present invention. Although the present embodiment is made entirely operable by a single air duct in view of the efficiency of work inside pipes, the motors and air cylinders are of course

made operable or controllable individually by a plurality of air ducts.

Fig. 5 shows as the elements which require the supply of air the air cylinder 25 of the collapsing assembly 2, the air motors 31a, 31b of the drive unit 3, the air motor 44 of the rotary nozzle assembly 4, and the air cylinder 65 of the nozzle reciprocating assembly 6. Air is also supplied to an air cylinder 106 coupled to a five-port limit switch 112 and serving to change the direction of rotation of the air motors 31a, 31b, and to an air cylinder 100 for controlling the operation of the air cylinder 106. The air cylinder 100 has incorporated therein a compression spring 101 and a piston 102, which advances against the action of the spring when air is supplied to the cylinder to change over a cross cam 103. The air cylinder 106 has coupled thereto two-port switches 108 and 110 which are turned on or off by the rotation of a cam 104 coupled to the cross cam 103.

Each traveling assembly 1 adapted to advance or retract selectively in the following manner. When air is supplied to the circuit to rotate the motor 31a forward and the motor 31b reversely, the traveling assembly 1 moves forward. When the supply of air is discontinued, the motors 31a, 31b stop, and the piston

rod 102 of the air cylidner 100 is retracted by the action of the compression spring 101. When air is supplied subsequently, the piston rod 102 of the air cylinder 100 advances to rotate the cross cam 103 through 90
5 degrees. The rotation of the crc cam is delivered to the cam 104 to change over the limit switches 108, 110. Through the air cylinder 106, the limit switch 112 is further changed over, whereby the direction of rotation of the motors 31a, 31b is changed. The motor 31a
10 therefore rotates reversely and the motor 31b forward to retract the traveling assembly.

When performing work inside a pipe, the vehicle is first placed into the pipe, the screw rod 21 and the support bars 24 are moved, and the air cylinder 25 is
15 operated, whereby the outer running faces of the traveling assemblies are pressed against the pipe inner surface as seen in Fig. 3 to fixedly position the vehicle body 9 in the interior space of the pipe. Next, the air motors 31a, 31b are driven to advance or retract
20 the vehicle. During the travel of the vehicle, the nozzle pipes 45 of the rotary nozzle assembly 4 are rotated to cause the nozzles 43 on the forward ends of the pipes 45 to spray a liquid to the pipe inner surface. When the nozzle reciprocating assembly 6 is operated at
25 the same time, the liquid can be applied repeatedly to

the pipe inner surface by the forward-rearward movement of the nozzles.

Fig. 3 shows a mount 91 attached to the outer periphery of the vehicle body 9. When a television camera, for example, is attached to the mount 91, the desired work can be performed while observing the interior of the pipe.

If the pipe to be worked on has a branch pipe, the opening portion of the branch pipe is likely to impede the travel of the vehicle. Accordingly, each of the traveling assemblies 1, when provided with an elongated slide assisting plate 7, can be driven smoothly.

The vehicle of the invention is adapted to perform work, such as cleaning or coating, inside pipes while running within the pipe by itself. Accordingly, there is no need to move the vehicle with a pulling rope as conventionally practiced or to extend the rope through the pipe for preparation. Moreover, even if the worker can not enter the pipe, the desired work can be performed inside the pipe without removing the pipe from the piping system.

The traveling assemblies are movable by the collapsing assembly radially of the pipe to be worked on toward or away from the pipe inner surface, so that the

vehicle is usable for work within pipes having varying diameters.

The traveling assembly is pressed at its outer running face against the pipe inner surface pneumatically and therefore has a cushioning action. Accordingly at a location where the pipe has a reduced inside diameter owing to a deposit or the like, the screw rod 21 moves rearward against the air pressure of the air cylinder 25 to diametrically diminish the arrangement of the traveling assembly, permitting the vehicle to travel with very high stability.

The rotary nozzle assembly is removably provided, so that the desired work such as coating or cleaning can be performed selectively merely by changing the assembly.

Since air is used as the drive source for running the vehicle, work can be done free of any explosion hazard with high safety even if volatile solvents are used.

CLAIMS

1. A self-propelled vehicle employing compressed air as power source and adapted for use in performing work in the interior of a pipe of a piping system wherein the vehicle comprises a vehicle body, at least
5 three parallel-link assemblies arranged at approximately equal angular spacings about a central axis of the vehicle body and each comprising parallel first and second links pivoted by one end to the
10 vehicle body and carrying jointly and pivotally at their opposite ends a travelling assembly, the travelling assemblies operating to move the vehicle along an inner surface of the pipe to be worked on, an extending and retracting mechanism connected to the
15 link assemblies for moving the travelling assemblies towards and away from the inner surface of the pipe, a drive unit mounted within the vehicle body for driving the travelling assemblies, transmissions for
20 transmitting a drive to the respective travelling assemblies, and a rotary nozzle assembly removably attached to a front portion of the vehicle body for enabling a nozzle to apply a liquid to the pipe inner surface while rotating the nozzle, said extending and retracting mechanism comprising a screw-threaded rod
25 rotatably supported in the body to extend lengthwise of the body and to be movable lengthwise of the body, an internally threaded block engaged on said rod, support struts pivotally connected at one end to the threaded block and at the other end to the second links of the
30 respective link assemblies at a point intermediate the ends of said second links, said support struts being telescopingly extensible and being capable of being fixed in selected positions of extension, and an air cylinder and piston connected between the body and the
35 screw-threaded rod for moving the rod axially of itself.



2. A self-propelled vehicle as claimed in claim 1 further comprising a nozzle reciprocating assembly for reciprocatingly moving the nozzle axially of the vehicle body.

5 3. A self-propelled vehicle as claimed in claim 1 or claim 2 wherein each of the travelling assemblies comprises two parallel frame plates connected together by connecting pins, first and second rotary shafts mounted at opposite ends of the frame plates, a pair of
10 first main pulleys rotatably mounted on opposite ends of the first rotary shaft, a pair of second main pulleys rotatably mounted on respective ends of the second rotary shaft, a pair of auxiliary pulleys rotatably mounted on opposite ends of each connecting
15 pin, and first and second endless belts reeved around the main pulleys and the auxiliary pulleys.

4. A self-propelled vehicle as claimed in any one of the preceding claims wherein the drive unit comprises two air motors arranged back-to-back and rotatable in directions opposite to each other.
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5. A self-propelled vehicle as claimed in any one of the preceding claims wherein each of the transmissions comprises a first rotatable shaft supported at one end by the vehicle body and extending
25 from an inner surface of the vehicle body toward the central axis, a pulley mounted on the first rotatable shaft, a bevel gear mounted on the other end of the first rotatable shaft, a second rotatable shaft supported on an outer side of the vehicle body and disposed in parallel to the first rotatable shaft, a
30 pulley mounted on the second rotatable shaft, a first endless belt reeved around the first and second rotatable shafts, and a second endless belt reeved around the second rotatable shaft and the first or
35 second rotary shaft of the travelling assembly.

6. A self-propelled vehicle as claimed in any



one of the preceding claims wherein the rotary nozzle assembly comprises a base attached to the vehicle body, a nozzle pipe mount attached to the base, a rotary shaft supported at one end by the mount and projecting in the same direction as the central axis of the vehicle body, a nozzle pipe projecting from a forward end of the rotary shaft, said nozzle attached to a forward end of the nozzle pipe and disposed perpendicular to the nozzle pipe, and an air cylinder fixed to the mount and coupled to the rotary shaft.

7. A self-propelled vehicle as claimed in any one of claims 1 to 5, wherein the rotary nozzle assembly comprises a base attached to the vehicle body, a nozzle pipe mount attached to the base, a rotary shaft supported at one end by the mount and projecting in the same direction as the central axis of the vehicle body, at least two pipes attached to a forward end of the rotary shaft and arranged at approximately equal angular spacings about the shaft in a plane intersecting the shaft perpendicular thereto, a nozzle attached to an outer end of each nozzle pipe coaxially therewith, and an air cylinder fixed to the mount and coupled to the rotary shaft.

8. A self-propelled vehicle as defined in claim 7 which further includes a nozzle reciprocating assembly comprising a rotatable shaft supported on the vehicle body in parallel to a second rotary shaft of at least one of the transmissions, a cam mounted on the rotatable shaft, a belt reeved around the rotatable shaft and the second rotary shaft of the transmission, a limit switch attached to the base for contact with the cam, and an air cylinder having a body portion fixed to the base and a piston rod fixed at a forward end thereof to the nozzle pipe mount, the mount being separably attached to the base and reciprocatingly movable relative to the base by the operation of the



transmission.

9. A self-propelled vehicle as claimed in any one of the preceding claims wherein a television camera is mounted on an outer periphery of the vehicle body for observing the interior of the pipe to be worked on.

10. A self-propelled vehicle as claimed in any one of the preceding claims wherein an elongate slide assisting plate is attached to a front portion of each travelling assembly.

11. A self-propelled vehicle substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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