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NEW CONCEPTION OF A MOBILE ROBOT FOR INSPECTING VENTILATION DUCTS

Key words

Mobile robot, ventilation ducts, mechanical construction, inspection robot.

Summary

A robot destined for inspection of ventilation ducts is introduced. The robot consists of two platforms that are able to move in relation to each other. The main problem is to overcome long vertical fragments of ventilation ducts and obstacles such as differently shaped ducts and elbows of various cross sections. Since duct sides are made of steel sheets, the robot climbs vertical parts by using permanent magnets. The structure of the robot applied consists of two platforms placed one above the other. Both platforms are equipped with four immobile columns. At the end of each column a permanent magnet is fixed, driven by servomechanisms, allowing it to descend or lift from the plane of the conduits. An analysis of a minimal number of motions of the upper and lower platform has been carried out, with consideration of obstacles the robot has to overcome. Four motions of the platform meet the requirements mentioned above. Motions of the robot are carried out by using servomechanisms and screw drive mechanisms.

Introduction

In general, mobile inspection robots are becoming more widely used. Robots for industrial pipelines, gas pipes, and sewer inspections all belong to that group. Robots designed to inspect ventilation ducts have to find impurities, corrosion and duct damages, and belong to a specific group of their own. They should override typical obstacles like duct bends and junctions. They also should move along vertical conduits of several meters. To achieve their targets, depending on inspection, the robots are equipped with video cameras, which record and directly transmit pictures to the operator, who evaluates the condition of the ducts based on acquired visual data. In this article, a robot destined for the inspection of ventilation ducts is described. The robot consists of two platforms that are able to move in relation to each other.

1. Initial requirements

A designed constructional solution has to fulfil numerous demands from which part involving mechanical construction of the robot is described below. The robot has to be equipped with appropriate control and data acquisition systems, but this is beyond the scope of this article [1].

The robot will be moving in the ventilation ducts, whose constructional features are determined on PN-B-03434 [2] standard and in the standards related to it. It describes the main dimensions and allowed deviations for rectangular and circular cross sections, and a large number of various shaped connections (tees, elbows, etc.) used in ventilation installations. Assumptions that canals of rectangular cross sections vary from 250 mm to 600 mm and circular cross sections vary from 300 to 600 mm have been made. Material from which the conduits are made is restricted to zinc-coated steel sheets from 1 to 1.85 mm thick.

The robot will have to move around in vertical and horizontal conduits of several meters in dimensions. The main problem is to overcome long vertical fragments of conduits and obstacles such as differently shaped ducts and elbows of various cross sections. The main dimensions of the robot are restricted by the smallest accepted square-duct cross section of 250 mm. Powering of the robot could be solved in two ways. The power can come from batteries placed on platforms or from a remote source connected to the cable coiled on a drum and fixed to the robot.

In the literature, a couple of robots carrying out inspections mainly of pipelines are found: OmniTread, Robot – worm, VersaTrax [3]. Those robots mostly have multi-part structure with joint connections. They mainly move in horizontal conduits and can overcome short vertical parts by supporting rear sections on the horizontal duct.

2. Conception of the robot

Based on an analysis of existing construction of robots, because of the demand of moving in vertical ducts, one can find that the robot called ‘spider’ can meet the requirements [3]. On the other hand, its construction, because of the wide variety of duct diameters and different obstacles, would have to be very complicated.

Since duct sides are made of steel sheets, climbing the robot to vertical parts can be achieved by using permanent magnets or electromagnets. To this end, it is possible to apply wheel or track transmission robots and walking robots [4]. Because of obstacles that robot has to surmount, the best solution is the walking robot with four or more legs. In that case, during the move on the wall, at least three legs of the robot equipped with magnets have to hold it to the wall.

The conception of the robot consists of two platforms placed one above the other (Fig. 1). Both platforms are equipped with four immobile columns. At the end of each column a permanent magnet is attached. A screw mechanism, permits the lowering or lifting of the magnet. When the magnet is lowered, it produces the attractive force acting between the duct wall and the magnet.

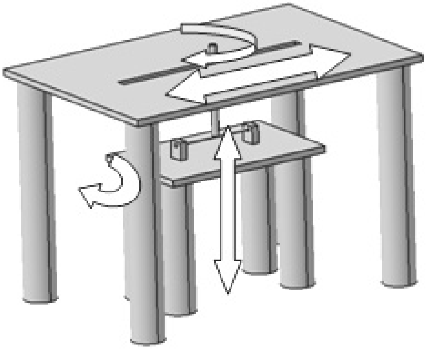

Fig.1. The possible relative displacements of the robot segments

Similar designs to the presented one, which consists of two platforms, are called twin-frame walking machines [5].

Motions of the robot on the vertical wall (or ceiling) are carried out as follows: The magnets placed on the first platform are lowered (supporting the robot), while the second platform with lifted magnets executes a move in relation to the first platform. Afterwards, the second platform lowers the magnets, which cling to the metal wall (supporting the robot), while the first platform moves.

An analysis of the relative motions of the upper and lower platform has been carried out with the consideration of obstacles that robot has to overcome. Fig. 1 presents the relative motions of four platforms, which meet the requirements mentioned above as follows:

- Relative motion of platforms in the vertical direction,
- Relative motion of lower platform in the horizontal direction,
- Relative rotation movement of platforms around the vertical axis, and
- Rotational movement of the lower platform around the horizontal axis.

3. Design solution

Motions of the robot are carried out by the use of servomechanisms (Fig. 2). The screw drive mechanism (3), driven by the servomechanism (4), lifts or lowers the platforms in relation to each other, and, additionally, the screw allows platforms to rotate around vertical axis. A separate servomechanism transmits torque on the passive element of the friction gear (6), allowing the turning of the platforms in relation to one another by ±22º. The linear motion mechanism of the platforms enables the platforms to move in the horizontal direction. The servomechanism (1), fixed to the upper platform, transmits torque on the toothed bar (2) fixed to the lower platform. The platforms can move in relation to one another by 85 mm. The rotation of the lower platform around horizontal axis (5) is executed by two servomechanisms fixed to the platform.

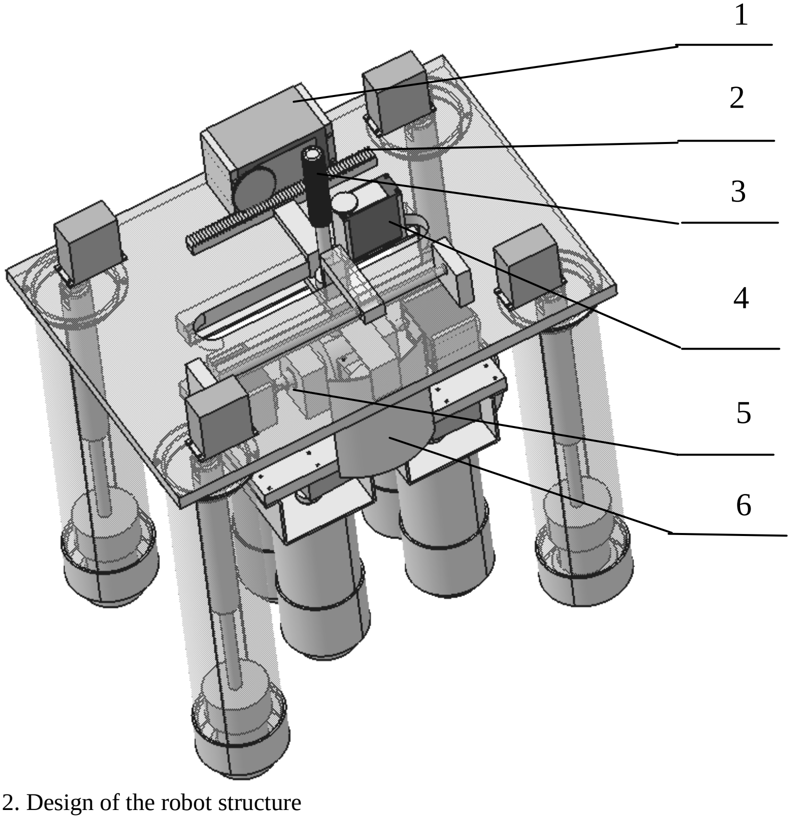

Fig. 2. Design of the robot structure

A displacement of the robot from horizontal wall on vertical side-wall of the ventilation duct is the most complicated manoeuvre of the robot. To do this, the platforms are placed parallel to the wall (Fig. 3). Afterwards, the lower platform is lifted and turned around the horizontal axis, then supported by the magnets to the duct side. Subsequently, the upper platform executes the identical movements as did the lower platform.

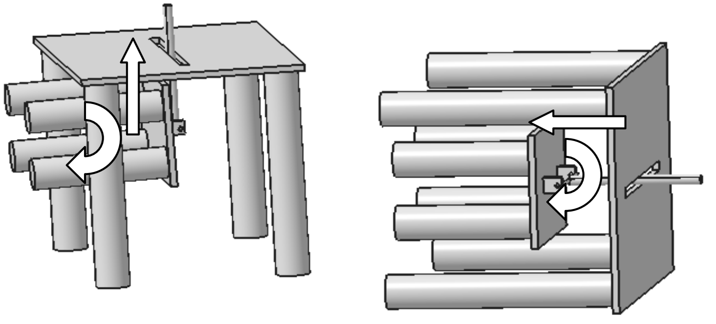

Fig. 3. Motion of the robot on side-wall of the ventilation duct

The column with the magnet lifting mechanism is depicted in Fig. 4. The screw (3) and servo (1) are connected by the clutch (2). The screw is fixed with a ball bearing (4), which restricts its movement just to rotation. On the end of screw, a nut (5) is screwed on. A neodymium magnet (6) is connected with the nut by a ball-and-socket joint. Moment generated in the servo is transmitted to the screw and causes the nut to move upwards or downwards.

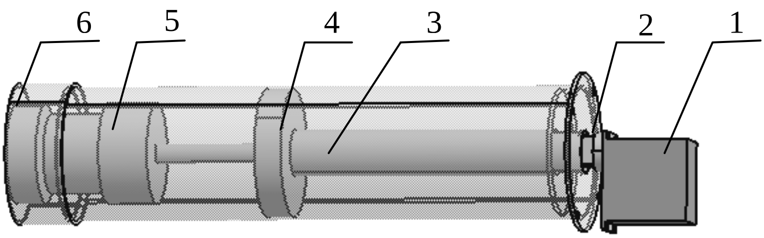

Fig. 4. Column with magnet lifting mechanism

Conclusions

In this paper, a prototype mobile robot for inspecting ventilation ducts is shortly described. The robot takes advantage of magnetic force for moving along steel ducts of a ventilation system.

Neodymium permanent magnets used in the robot can be replaced with electromagnets, which require much less force to take the feet of the robot off the ground, but they are much heavier and demand a stronger source of energy.

References

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Reviewer:
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Nowa koncepcja robota mobilnego do inspekcji przewodów wentylacyjnych

Słowa kluczowe

Robot mobilny, przewody wentylacyjne, robot inspekcyjny.

Streszczenie

W artykule przedstawiono robota przeznaczonego do inspekcji przewodów wentylacyjnych o nietypowym rozwiązaniu konstrukcyjnym. Podstawowym problem jest pokonywanie długich pionowych fragmentów przewodów i przeszkód, jakimi są różnego rodzaju łączniki kształtowe. Ponieważ przewody wentylacyjne wykonywane są z blachy stalowej do utrzymywania robota na pionowych ścianach zastosowano magnesy stałe. Przyjęto konstrukcje robota składającego się z dwóch platform umieszczonych jedna pod drugą, które mogą się wzajemnie przemieszczać. Każda z platform wyposażona jest w cztery nieruchome słupy na końcach, których umieszczone są magnesy stałe, które za pomącą specjalnych napędów przykładane są lub odrywane do ścianki. W oparciu o przeszkody, które pokonywać ma robot dokonano analizy koniecznych ruchów (minimalnej liczby) platformy dolnej i górnej względem siebie, przy których robot będzie mógł pokonać wszystkie przeszkody. Przyjęto cztery ruchy platform spełniające powyższy warunek, które realizowane są przy pomocy serwomechanizmów i mechanizmów śrubowych.