REMOTE CONTROLLED MOBILE INSPECTION ROBOT

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Abstract

Provision of well-being in rooms is associated with their good ventilation. Good ventilation is influenced by cleanliness of ventilation ducts. The article presents a drive-by-wire version of a mobile inspection robot for ventilation ducts. A handler, which is movable in three axes and ended with a grab, a supporting vertical wheel (to reduce wheel skid) as well as a colour camera, a distance sensor and two light sources (LED and halogen lamp) on a rotary platform have been placed on a circular chassis. Apart from performing the inspection function, the operator of the „Inspector 1" robot may remove bigger pieces of dirt and garbage from a ventilation shaft using the handler and the grab. The device is powered from a 12 V / 5 Ah battery. A robot controlled using a control panel allows accurate illumination of the internal walls of the duct and wireless transmission of a colour image to the operator's monitor. The rotary platform on which the camera with lighting is placed is also capable of tilting up and down. The robot's drive has been resolved in a way that makes it as manoeuvrable as possible. Two front drive wheels operate independently and two rear wheels are easy-running. The robot will also allow recording the following environmental parameters in the ventilation shaft: humidity, temperature, draught force and direction and the presence of gases.

The entire robot's electronic system is based on battery-powered supply (12V/5Ah) which is sufficient for approx. two hours of continuous operation. The voltage of the battery is constantly monitored and should it drop.

Keywords: *mobile inspection robot, ventilation duct, structure of the running system, mobile robot arm, supporting vertical pressure wheel, camera positioner, environmental parameter sensors*

1. Introduction

In the days of common application of technology in various, often difficult works, manual cleaning of ventilation shafts is more and more often replaced by semi-automatic cleaning. The person supervising the machine still decides about everything, but is the robot that performs the activities in conditions which are harmful for people.

Efficient ventilation of rooms provides well-being and health of the people staying in them. Should it be damaged or even non-existent – this will lead to the loss of concentration, the feeling of shortness of breath, headache and even to poisoning carbon monoxide. Care for not only the efficiency of ventilation but also for the quality of clean air – which is also associated with cleanliness of the walls of ventilation ducts [2] - is an extremely important issue.

Modern methods of cleaning of ventilation ducts rely mostly on mechanical cleaning with various kinds of brushes, however, pneumatic cleaning – with air under high pressure - is also applied.

There are many structures and sizes of ventilation ducts. The most frequently found include ducts made of galvanized steel sheets as well as bricked ducts. The size of a duct strongly influences the way it is cleaned. Ventilation shafts with large sections can be cleaned manually, but it is better to use an inspection – cleaning robot in the places where a person cannot fit.

2. Functions and parameters of the robot

The “Inspector 1” robot, used for inspections and cleaning of ventilation ducts, is characterized by specific parameters and is capable of remote performance of the following functions and activities (Tab. 1).

Tab. 1. Basic functions of the inspection-cleaning robot

No.	Function/activity	Function/activity performing elements
1	Mobility, manoeuvrability	Two front wheels with independently controlled electric motors, two rear easy-running wheels (travelling with a small turn angle)
2	Locomotion support	An additional, retractable vertical wheel increasing the adhesion of the robot's wheels to the ground (skid reduction), an ultrasonic distance sensor, and front-wheel revolution sensors will allow to record the covered distance
3	Remote control	The operator controls the robot by wire using a control panel (a wireless version will be developed in prospect)
4	Observation of duct walls	Colour, wireless camera placed on a rotary platform with a positioner
5	Lighting	Basic light source – LED, additional lighting with a halogen lamp
6	Removal of dirt	Mobile, retractable arm ended with a grab. Mobile arm in three axes (the following, different, replaceable arm tips will be developed in prospect: scoop, lengthwise brushes, transverse brush)
7	Monitoring environmental conditions in the duct	In the wireless version with a controlling processor, the robot will be equipped with the following sensors: sound, temperature, humidity, draught force and air flow direction, presence of gases in the duct

The “Inspector 1” robot is built on a steel base, which, along with the motors and the wheels, constitutes a mobile chassis. The robot's executive element is a mobile robot arm with a mounted grab. The robot also features an innovation - a supporting, vertically retractable wheel, which allows increasing the adhesion of the wheels to the ground. The rotary camera platform with a positioner, where, apart from the camera, both light sources as well as an ultrasonic distance sensor have been placed, is mounted on this vertical pillar. The robot's power supply is a 12V/5Ah battery. Everything is controlled by wire by the operator using a control panel. The view of the wire version of the “Inspector 1” robot has been presented in Fig. 1.

3. Structure of „Inspector 1” robot

The mobile „Inspector 1” robot is a complex structure. Its particular components and mechanical parts were first modelled in a 3D form in the Solid Edg ST2 graphic program. Then they were assembled, thanks to which possible collisions during the robot's movement could have been detected as well as the specific shape of the whole could have been seen (Fig. 1.).

The Solid Edge ST2 program allowed generating detailed technical figures of particular parts, which had been made mostly of aluminium materials and profiles as well as thin steel sheets.

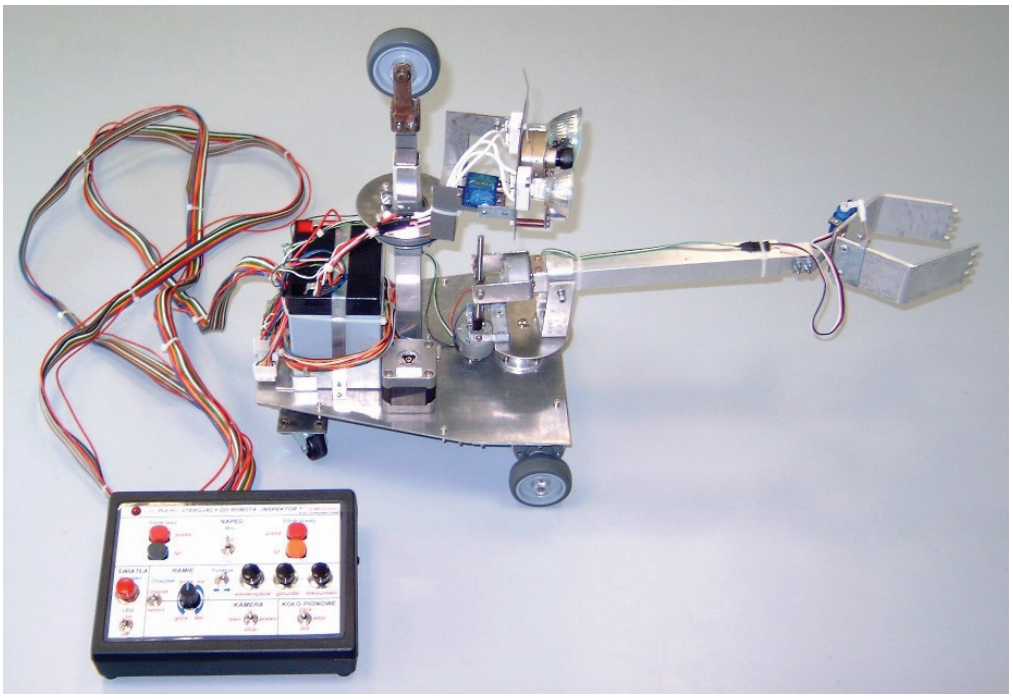

Fig. 1. Wire version of "Inspector 1" robot for ventilation ducts

3.1. Chassis

The chassis of the „Inspector 1" robot (Fig. 2.) is made of galvanized steel sheet strengthened along its girth with aluminium angle bars. The chassis is of the wheel type in which two front rubberised wheels are propelled by RH158-12-200 independently controlled electric motors made by Micromotors. The motors have mechanical transmissions as well as Hall effect revolution sensors. Independent steering allows achieving a small angle during a turn and thus high chassis manoeuvrability.

Two rear wheels are easy-running (can freely rotate in two planes), which provides stability of the chassis and minimum wear of the wheels during a turn.

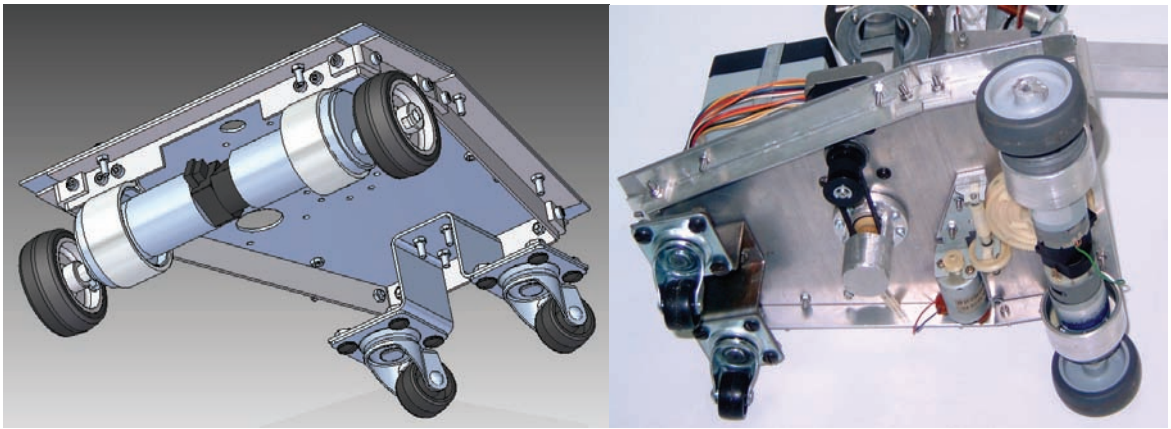

Fig. 2. Model of the robot's chassis and actual view [1]

3.2. Arm

The robot's arm, which is mobile in three axes (Fig. 3), is built of aluminium profiles. Thanks to three motors, it can rotate horizontally, be raised and lowered vertically as well as be pulled out and retracted along the length of the arm. Each of the motors has a wormwheel transmission.

The arm is equipped with a grab, which can be used to remove bigger pieces of dirt from a ventilation duct and is movable as a result of using a servo. It will be possible to replace the grab with a scoop (to remove lingering loose materials) o rotary cleaning brushes (lengthwise and transverse).

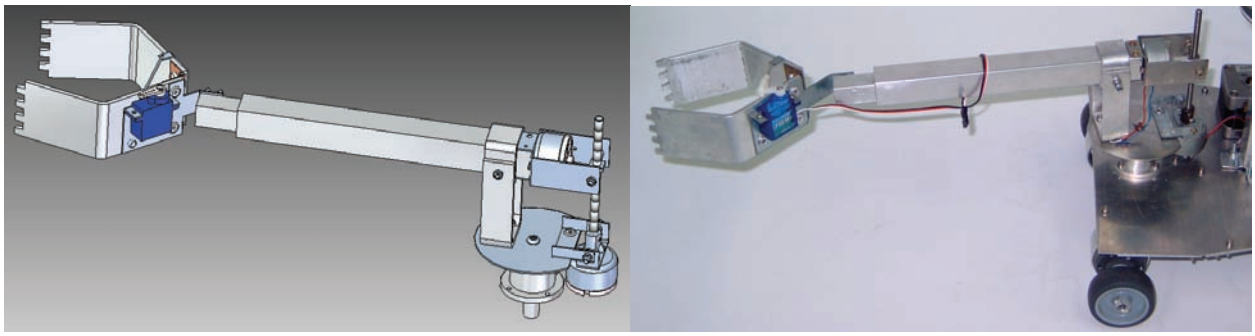

Fig. 3. Modelled arm of „Inspector 1" robot and its actual construction [1]

3.3. Vertical wheel

A vertical wheel which supports the robot's locomotion (Fig. 4.) is an innovation applied in order to increase the pressure of the wheels to the ground – and thus adhesion. This is helpful when the robot moves at a certain inclination.

The structure of the vertical wheel is also made of aluminium and the used wheel is the same as the driving wheel. To increase the adhesion of the wheels to the ground (reduce the skid), the vertical supporting wheel is pulled up (using a stepper motor with a worm gear) and presses the upper wall of a duct with a certain force, causing expansion between the horizontal walls of a duct. The vertical wheel's pressure force is set by the operator, who has a pressure sensor installed in the vertical column at their disposal. When the robot moves in a duct, the system will be controlling the set parameter of the pressure force by itself.

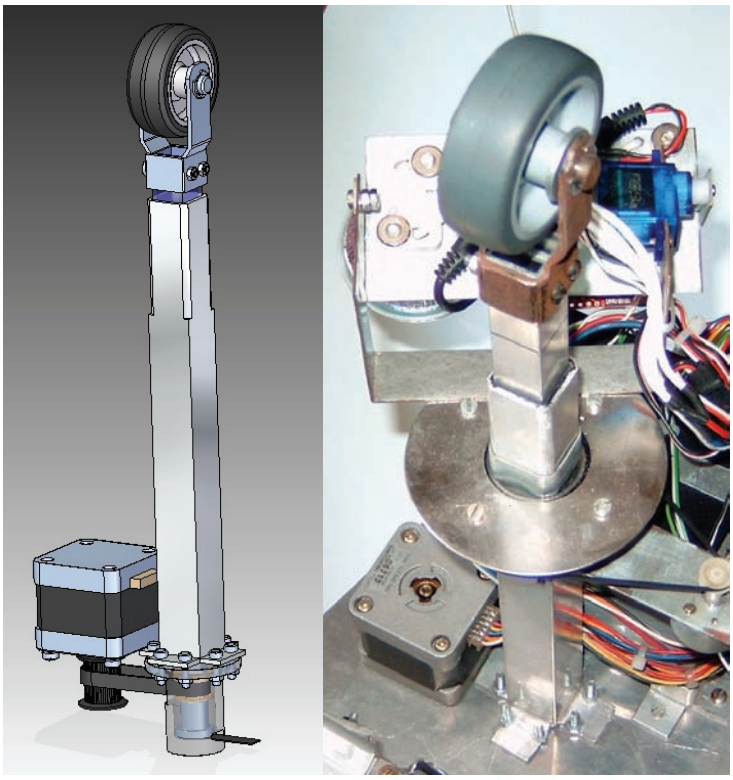

Fig. 4. Vertical supporting wheel as a model and a real structure

3.4. Camera platform with a positioner

The mobile camera platform, along with its positioner, is placed on a vertical pillar of the vertical supporting wheel. A fork, on which steel sheet with the elements installed on it can be turned vertically thanks to a servo, has been fastened to the horizontally placed (on a bearing) wheels made of galvanized steel sheet. A colour, wireless camera, an ultrasonic distance sensor and two light sources: basic LED 12V and additional – halogen lamp 12V - can be found there.

Movements of the entire camera platform in the horizontal plane take place as a result of using a small DC motor, which is also placed at the vertical pillar of the vertical supporting wheel.

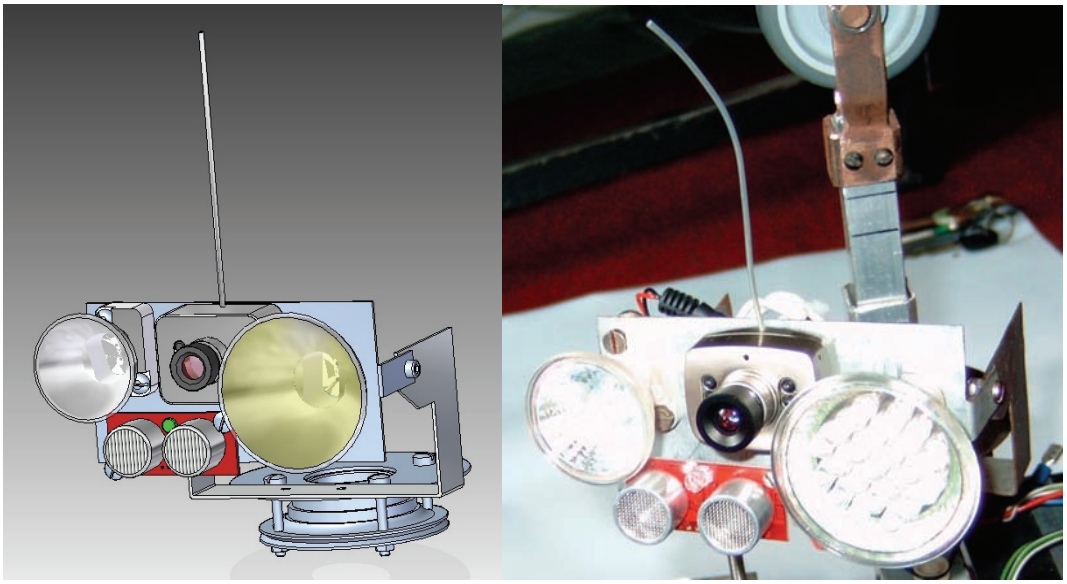

Fig. 5. Model of camera platform with a positioner and actual view

3.5. Control panel

The control panel has been constructed only for the wire version. In the wireless control version, the control panel will be the screen and the keyboard of a laptop.

The presented control panel (Fig. 6.) includes many switches activating particular motors (of the drive, the arm, the grab, the vertical supporting wheel and the camera platform) and lighting. Special controls (placed inside the casing of the control panel) have been used to control the modelling servos as well as the stepper motor.

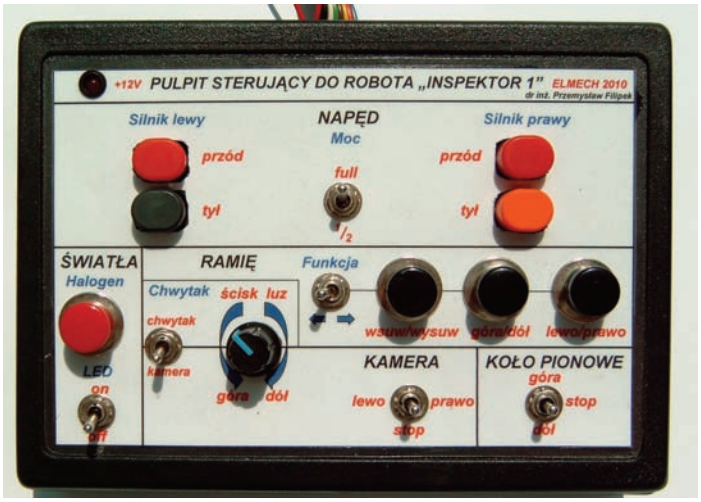

Fig. 6. Built wire control panel

3.6. Other elements

The existing version of the „Inspector 1” robot is driven by wire. In prospect, a AT91SAM7S256 32-bit microprocessor, made by Atmel, handling the sensors and the robot's executive elements as well as wireless control, is planned to be used. Thanks to the microprocessor and the applied mass memory carriers, it will be possible to record parameters of the whole route covered by robot in the ventilation duct. On this basis, a virtual map of ducts can be created as well as this information can be used to move the robot back to the initial point in the event of e.g. a failure of the wireless control or the robot being out of range (autonomous return).

The applied environmental parameter sensors will inform the operator about the working conditions in the ventilation duct. The microprocessor in the robot will be constantly sending information on the temperature, the humidity, the draught and the air flow direction, the presence of poisonous gases as well as the distance from an obstacle or a wall of a duct to the operator. The wireless camera is equipped with a microphone, thanks to which it will be possible to detect the location of a leaking gas.

The entire robot's electronic system is based on battery-powered supply (12V/5Ah) which is sufficient for approx. 2 hours of continuous operation. The voltage of the battery is constantly monitored and should it drop, the operator will be sent a signal indicating depletion in the robot's power supply.

Figure 7 presents the view of the whole „Inspector 1” robot.

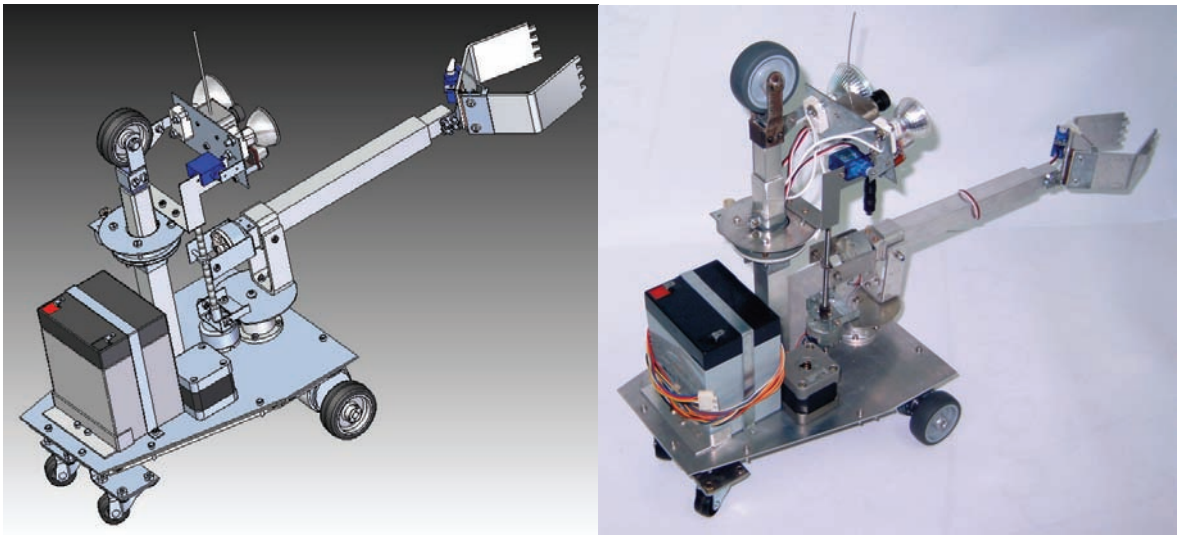

Fig. 7. Model of the whole robot (Solid Edge ST2 program) and view of its real construction [1]

4. Summary

- The robot meets the requirements in terms of functionality, mobility and manoeuvrability which have been set for it.
- „Inspector 1” is an efficient inspection device. Thanks to a mobile, colour camera, a halogen lamp and a LED, the robot's operator may view a clear, actual image on the monitor.
- Application of aluminium profiles in the structure ensures achievement of the required rigidity of the arm while keeping its mass low.
- The robot may work in places not accessible for people, in the conditions which pose a threat to life and health (e.g. air oversaturated with hazardous content of a flammable gas, carbon monoxide, carbon dioxide) or are onerous for health (stench, insects, rodents).
- The device can be distinguished from different robots of this kind with the autonomous return, replaceable tips, a variety of environmental parameter sensors as well as an innovative vertical supporting wheel.

References

[1] Bańczerowski, B., Cyranowski, W, Duda, K, Stachowski, R., Filipek, P, *Inspection-cleaning robot for ventilation ducts*, 2nd Lublin Congress of Student Research Groups - Tygiel 2010, edited by J. Caban and M. Szala, Lublin University of Technology, pp. 285–296, Lublin 2010.

[2] Filipek, P., Kamiński, T., *Structural solutions of driving system and sets remotely controlled vehicle to the inspection of ventilating pipes*, Journal of KONES Powertrain and Transport, Vol. 16, No. 4, p. 75-82, 2009.