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TRACKED ROBOT FOR CLEANING OF PIPE

Urgency of the research. *Service robot is as device which is currently used for standard works as cutting the grass or vacuum cleaning and also teleoperation robot which is remote controlled by human for special tasks as exploring, bomb removing, rescue action etc. Tendency is substitute human in dangerous or monotonous works via using of robots.*

Target setting. *Tracked robot is designed for cleaning of pipe, which has inner pipe wall covered by sediments. The typical example is chimney, where carbon particles cover the pipe wall. Carbon particles can start burning process with result of total damaging of chimney and also building. Pipe robot can be used as practical aid for cleaning and inspection of pipes.*

Actual scientific researches and issues analysis. *Other similar task is repairing of damaged inner pipe wall. Robot which repair pipe from inside pipe saves the costs for site excavation works.*

Uninvestigated parts of general matters defining. *The questions of the design of pipe repairing robots are uninvestigated, because the next research will be focused to this.*

The research objective. *In-pipe robot is as device for locomotion inside pipe with aim to make inspection or cleaning of inner surface of pipe wall. Tracked robot is designed because of better properties as overcoming of problematic places inside pipe and also lower normal force between the tracks and inner pipe wall.*

The statement of basic materials. *Tracked segments are pressed to inner pipe wall and normal force is controlled by controller on the base of measurement of normal force. Cleaning brush module is connected to robot for dirties removing. CCD camera for inspection can be also connected to robot.*

Conclusions. *The cleaning robot is important device for service of pipe systems as prevention of pipe damage of other negative phenomena. Contribution of this robot is significant, because it saves money and time.*

Keywords: *Mobile robot; locomotion; pipe; cleaning; parallelogram; chimney.*
Fig.: 10. References: 17.

Introduction. Service robotics are often used for various activities as cutting the grass, vacuum cleaning, swimming pool cleaning, mine exploring, mars exploring, bomb destroying etc. It is activities which are very monotonous, tiring, very difficult or dangerous for human. The main idea is to help us with hard work. Special case is when robots work in highly dangerous application as munition destroying, nuclear power plant, defensive mine countermeasures [1-10].

There are many various application, where is a need of any cleaning and inspection of pipe wall as prevention of accident with great impacts. The pipe is used for transporting of any medium inside pipe. The problem is when a sediments occur on inner pipe wall. Also if pipe is made from a corrosive material, it is necessary to inspect state of inner pipe wall. Chimney is also as pipe, which has to be cleaned and checked for cracks. Steam generators in nuclear power plants consist of many pipes, which have to be periodically inspected for micro cracks as prevention of radioactivity leaks. Heat exchanger also includes bended pipes, which have tendency to be covered by sediments.

Exploring of these pipes can be executed via using of in-pipe robots (fig. 1). In-pipe robot is able to locomote inside pipe with any aim.

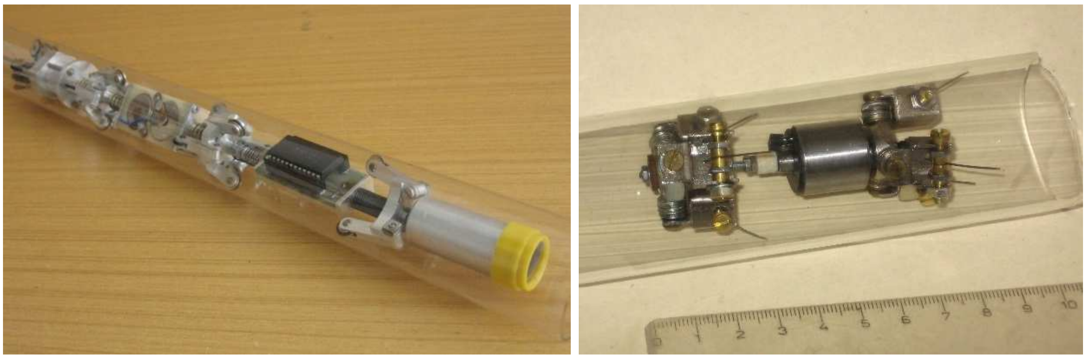

Fig. 1. In-pipe robots

1. Design of robot concept. Pipe systems also has technological changes of inner pipe diameter and also construction barriers as diameter reduction, elbow, T-joint etc. All these mentioned factors are as problem for design of in-pipe robots.

Situation is also complicated when pipe is underground. Using of in-pipe robot decreases the need of site excavation works, which cause the problems for our streets, for traffic, for people, for environment etc. So using of in-pipe robots reduces costs for earth works.

The main subject of this paper is pipe cleaning robot for inner pipe diameter in range from 130mm up to 200mm. The main concept of robot is shown on (fig. 2). The concept proposes the adjustable in-pipe robot, which is able to adapt to inner pipe diameter for optimal locomotion inside pipe. Robot is loaded with own weight. Normal force between the wheels and inner pipe wall should be controlled for achieving of optimal tracking velocity and force. If normal force is low, then friction force is low and wheels slipping occur and also completely falling down of robot can occurs. When normal force is too large, then friction force is very large and robot is blocked and it cannot locomote inside pipe.

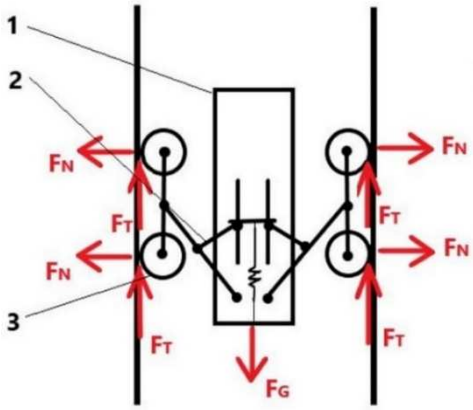

Fig. 2. Concept of wheeled in-pipe robot:
1 – robot body; 2 – adjusting mechanism; 3 – wheels

Increasing of normal force can damage inner pipe wall, because contact area is too small. This problem can be solved via using of tracked in-pipe robot (fig. 3). Tracked segments have bigger contact area and local stress on inner pipe wall will be less and it reduces risk of pipe damage.

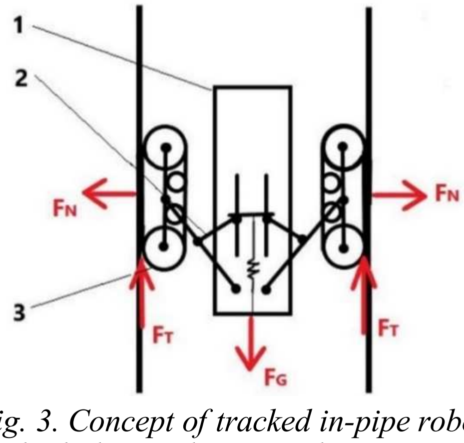

Fig. 3. Concept of tracked in-pipe robot:
1 - robot body; 2 – adjusting mechanism; 3 – tracks

Tracked concept (fig. 3) has been selected, because of mentioned reasons. Figure 3 shows concept only with two arms pressed against the wall. For higher stability is better to design three arms (fig. 4). If angle between arms is 120°, then forces between pipe wall and arms are the same. It is result from static force analysis.

$$-R_2 \cdot cos30° + R_3 \cdot cos30° = 0$$
$$-R_1 + 2 \cdot R_2 \cdot sin30° = 0 \qquad (1)$$

Result from this set of equation is:

$$R_1 = R_2 = R_3 \qquad (2)$$

It means that in every case these forces are in balance and this concept is self-centered inside pipe defined with contact points on inner pipe wall.

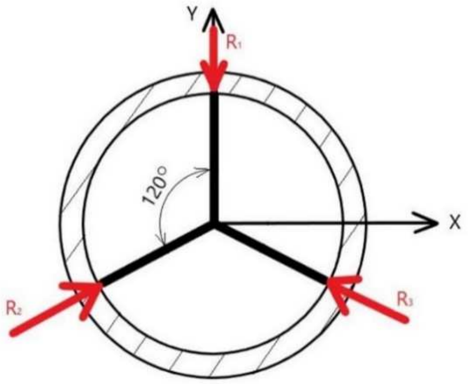

Fig. 4. Arrangement of tracked arms on robot body

2. Kinematic of robot arms. The main requirement is that normal force on pipe wall should be adequate. Second point is need of adjustability to inner pipe diameter. Parallelogram mechanism has been selected for design of arms on robot body. The proposed mechanism is able to adapt to inner pipe diameter in range from 120 mm up to 200 mm.

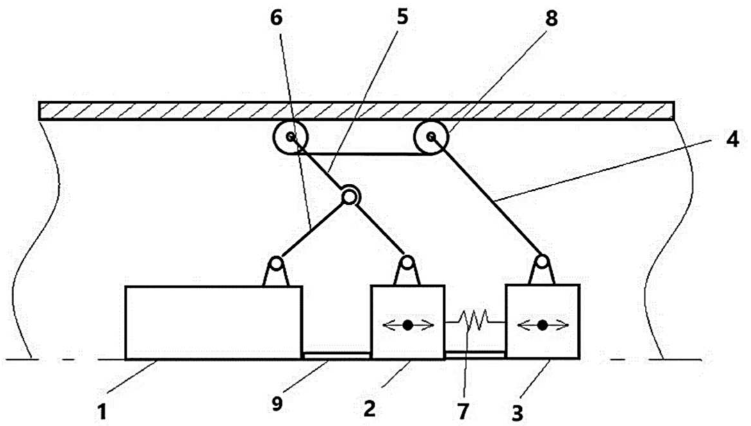

Fig. 5. Kinematic of arms on robot body:
1-robot body; 2, 3 – sliding body; 4, 5, 6 – parallelogram arms;
7 – spring; 8 – tracked segment; 9 – sliding guide

The proposed kinematic (fig. 5) works as follow. Sliding guide (9) is fixed to robot body (1) and sliding bodies (2) and (3) are able to move on this guide. Moving of sliding bodies (2) and (3) cause the movement of arms (4), (5) and (6). Sliding bodies are connected with spring (7), which can compensate the irregularities on inner pipe wall.

Basic dimensions of mechanism is shown on figure 6.

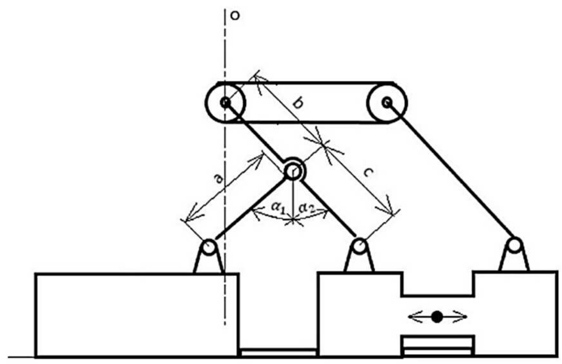

Fig. 6. Basic dimensions of mechanism

Functionality of proposed mechanism is based on fact that arms (4) and (5) on figure 5 are equal. For obtaining of right position of centre of gravity is proposed that members $a = b = c$ (fig. 6).

If robot locomotes to the up, then the requirement is that friction force between tracks and pipe wall should be higher than gravity. In other case robot will fall down.

$$F_t > G \tag{3}$$

3. Design of parallelogram arms. Parallelogram mechanism (fig.7) consists of several parts. It is used for change of displacement of track segments and also change of normal force between the track segments and inner pipe wall. Short arm (1) is connected by joint to basic frame (3). Guiding slide rods (4) are also connected to basic frame (3). Sliding members (6) and (8) can move on sliding rods (4). Sliding members (6) and (8) are placed on thin pipe (7) which can move on screw rod (2). Member (6) has inner thread which interacts with screw rod (2). Rotating of screw rod (2) causes the moving of the member (6) together with member (8). End of slide rods (4) are fixed on flange (9). Arms (5) are connected via joint to the members (6) and (8). Consequently, rotating of screw rod (2) causes the moving of the arms (5) and desired displacement of track segment.

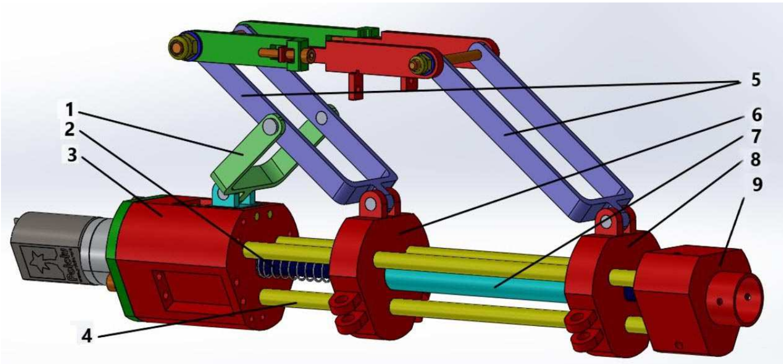

Fig. 7. Parallelogram mechanism

Track segment (fig. 8) is contact system between robot body and inner pipe wall. Plates (1) and (3) together with adjusting screw (2) compose the setting up mechanism for adjusting of distance between axes of track wheels (4).

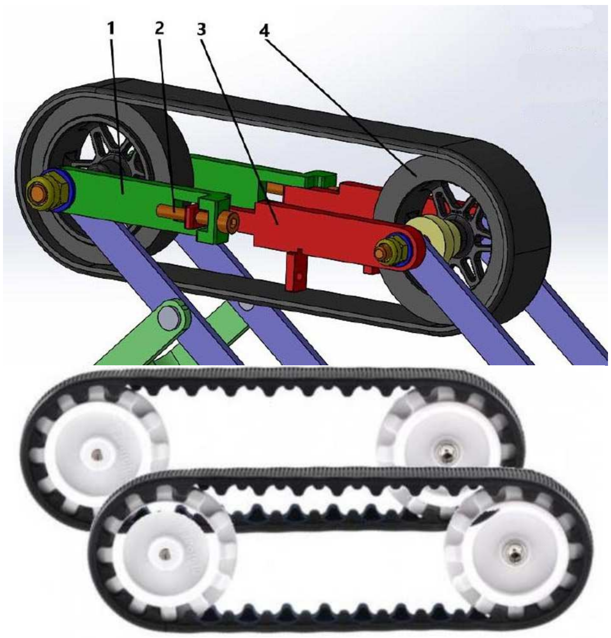

Fig. 8. Track segment

Servomotors are used as drive unit for adjusting of parallelogram and also as drive for tracked segments. The robot also can carry the cleaning brush (fig. 9) for cleaning of inner pipe wall. It is connected on the end of flange. This brush also helps to improve the stability inside pipe. This cleaning module can be dismounted and camera module can be placed on the flange. The robot also includes sensors for detection of inner pipe wall and also collision sensors and sensors for detection of normal force between the pipe wall and track segments.

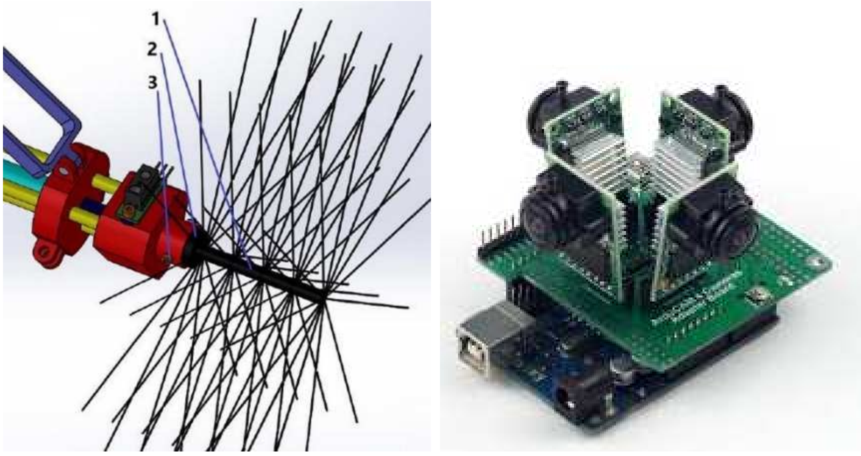

Fig. 9. Cleaning brush and camera module

4. Overall composition of pipe robot. Completed robot can consist of two or more segments with adjustable track segment as it shown on fig. 10. Connecting of more modules ensures the better overcoming of T-joint and other obstacles inside pipe.

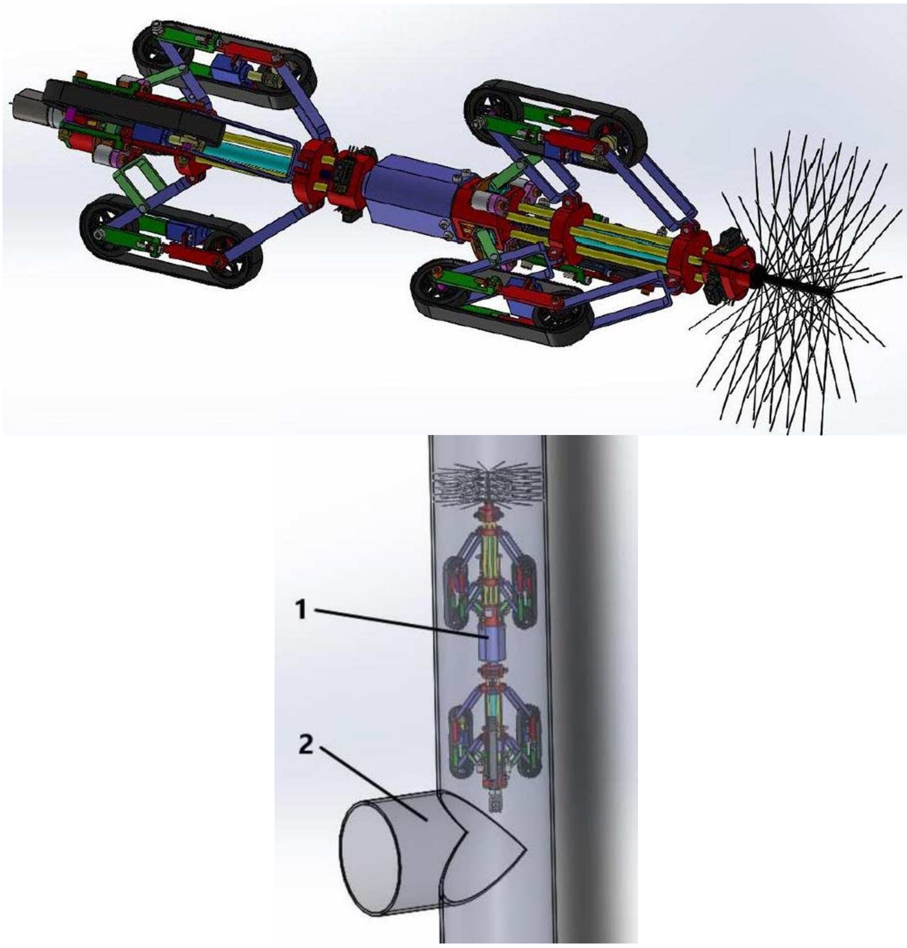

Fig. 10. Composition of robot

5. Final robot realization. Robot is controlled as teleoperation system but it has also automatic function as overcoming of T-joint, self-protection against the falling down, automatic adjusting of normal force on inner pipe wall, etc.

Conclusion. Proposed robot has important role for chimney sweeper as assistive device for cleaning and also inspection. The main contribution is lied on fact that it is applicable from service door entry on chimney and human doesn't need to go on house-top. This is a typical example where robot helps to make dangerous work instead of human. Human became as application technician [11-16].

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ГУСЕНИЧНИЙ РОБОТ ДЛЯ ОЧИЩЕННЯ ТРУБ

Актуальність теми дослідження. *Службовий робот – це такий пристрій, який в даний час застосовується як для стандартних робіт, таких як підстригання трави або вакуумне очищення, так і в якості телеопераційного робота, що дистанційно керується людиною для виконання спеціальних завдань, зокрема, дослідження, знешкодження бомб, рятувальні дії тощо. Задумом є заміна людини у небезпечних або монотонних роботах через використання робота.*

Постановка проблеми. *Гусеничний робот призначений для очищення труби, яка має покриту осадами внутрішню стінку. Типовий приклад – димохід, де частинки вуглецю покривають стінку труби. Частинки вуглецю можуть спричинити процес горіння разом із повним пошкодженням димоходу, а також будівлі загалом. Трубний робот може бути використаний як практичний засіб для очищення та огляду труб.*

Аналіз останніх досліджень і публікацій. *Іншим подібним завданням є ремонт пошкодженої внутрішньої стінки труби. Робот, який ремонтує трубу зсередини, економить витрати на проведення робіт по викопуванню майданчика.*

Виділення недосліджених частин загальної проблеми. *Питання проектування роботів з ремонту залишається невивченим, тому наступне дослідження буде зосереджено саме на цьому.*

Постановка завдання. *Робот-очисник труб є пристроєм для переміщення всередині труби з метою огляду або очищення внутрішньої поверхні стінки труби. Гусеничний робот розроблений завдяки кращим властивостям, оскільки долає проблемні місця всередині труби, а також знижує нормальну силу між доріжками та внутрішньою стінкою труби.*

Виклад основного матеріалу. *Гусеничні сегменти притискаються до внутрішньої стінки труби, а сила контролюється контролером на основі вимірювань нормальної сили. Модуль щітки для чищення підключений до робота для видалення бруду. Для огляду до робота можна також підключати CCD-камеру.*

Висновки відповідно до статті. *Очисний робот є важливим пристроєм для обслуговування трубних систем для запобігання пошкодженню труб іншими негативними явищами. Внесок цього робота є вагомим, оскільки він економить фінанси та час.*

Ключові слова: *мобільний робот; переміщення; труба; очищення; паралелограм; димохід.*
Fig.: 10. References: 17.

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