Available online at http://jess.esrae.ru/

“Journal of Economics and Social Sciences”

A design for a magnetic-wheeled flaw detector platform

Tomsk Polytechnic University

Evgeny Terentyev [a, b]

[a] School of Earth Sciences & Engineering, Tomsk Polytechnic University
[b] Limited Liability Company "Slavneft-Krasnoyarskneftegaz»

Abstract

A transport platform for an in-tube robotic flaw detector has been developed, which is capable of unrestricted manoeuvring in a complex piping diameter from 300 mm, getting on the wheels after overturning and overcoming vertical obstacles.
The absence of an additional mechanism for deactivating the magnetic field in the platform design leaves additional space for technological equipment placement on the platform.
The proposed platform is adequately for designing small-sized pipe flaw detectors on its basis, as well as other technological devices used in various National Economy Sectors. The platform capability to turn over on its wheels independently eliminates the emergency situations occurrence during diagnostic work, and kinematics provides unlimited manoeuvring in a complex pipeline manifold.

Keywords: main gas pipelines, flaw detector, stress-strain state, diagnostics, automation, transportation;

1. Introduction

At the same time, classical solutions for pipeline diagnostics are not suitable for technically complex sections (bends, bends, turns, transitions of different diameters, etc.) and require the development of new technical solutions.

Generally, flaw detection is the focus of both engineers’ and scientists’ interests. At the same time, one of the features of the technical condition monitoring is that about 45% of main gas lines are not adapted for in-line inspection and requires various methodologies development and more advanced inline inspection tools.

Mobile robotic systems development for technical condition diagnostics and non-destructive testing inside field pipelines is one of the directions of the development of modern in-line diagnostics [11]. After all, automation of technological processes significantly increases labor productivity, reduces the number of workers and service personnel, improves working conditions, increases the productivity of equipment, which corresponds to the energy strategy of Russia until 2030 [3].

2. Diagnostic Robotics

Taking into account the significant length of the gas pipeline system (GPS) of the Russian Federation (over 160 thousand km of large-diameter gas pipelines) and its operation in the regions with difficult natural and climatic conditions, the scope of diagnostic works has fundamental features compared to the diagnosis of small gas pipeline systems in European countries (Germany, Italy, Holland, etc.).

With increasing the GPS service life, the problem of evaluating performance and improving reliability based on diagnostic results becomes one of the top priorities and the main factors are as follows:

- most of the field and gas transportation systems are constructed and designed in regions with difficult climatic, and natural-geological conditions. Therefore, higher standards are used for the design of gas transportation equipment;
- most pipelines (about 56%) have a service life of 33 years and 20% of gas pipelines operate at reduced pressure. Therefore, we need constant monitoring, and assessment of their conditions [10];
- the domestic industry differs significantly from the foreign one.

Failures, accidents and destruction of the GPS facilities can cause huge damage to the natural environment, infrastructure and humanity. Despite modern technologies development for manufacturing pipeline transport, accidents are still not excluded. However, in order to reduce their number, non-destructive testing methods are applied. According to GOST 16504-81 "Nondestructive testing is a method used for evaluating the properties of a material, component or system without causing damage and which doesn't disturb the suitability of the object" [1]. The most widely used methods are magnetic, acoustic, electrical, and optical nondestructive testing.

Classical solutions for pipeline diagnostics are not suitable for technically complex sections (bends, bends, turns, transitions of different diameters, etc.) and require the development of new technical solutions [13]. Generally, flaw detection is the focus of both engineers' and scientists' interests.

The robotic application rate is currently quite high in the industry. This is due to the fact that the operations performed have a high level of repeatability and are easily implemented in algorithms. Many operations have been replaced by automated systems. But in the oil and gas industry, the robotics rate is not enough, and it only comes into use. In this case, the process of detecting, selecting types, and measuring parameters of defects in the pipe base metal and welded defects during in-line diagnostics is automated. So, the question of A2072 IntroScan scanner-flaw detector effectiveness compared to its analogues arises.

Modern robotic systems are high-tech devices that provide pipeline monitoring using several non-destructive testing methods at once. The combination of methods helps to more accurately determine the location of defects, their size, shape, and allows assessing the technical condition of the pipeline being diagnosed with a high degree of accuracy and its remaining life in order to ensure the pipeline safe operation.

One of the well-known robotic devices of in-line diagnostics is the robot tractor of CJSC Gazproekt (Figure 1) works mainly as a thickness gauge that detects pit corrosion [5].

Fig. 1. Remote-controlled diagnostic complex TDK-400-ML

At the same time, the rotating electromagnetic-acoustic sensor provides a low efficiency of detecting defects caused by corrosion: at best, it detects cracks deeper than 30-40% of the pipe wall thickness. Placing the robot tractor into the pipeline requires testing disclosure of the ground and firing operations to cut several coils in the process pipelines. In addition, the device is not able to pass vertical tees and this limits the scope of its application.

The robot magnetic-wheeled scanner of CJSC "Introscan Technology" [6] detects cracks formed due to corrosion, with a depth of 15% of the pipe wall and can be placed into the pipeline through a manhole or check valve, and can pass vertical tees (Figure 2). On the one hand, the small size of the robot gives an advantage, allowing to perform inline diagnostics of small diameter pipelines, and, on the other hand, to increase significantly the inspecting time of a given distance.

Fig. 2. Robotic complex A2072 "IntroScan"

Another version of the robotic flaw detector is the robotic diagnostic tool of CJSC "Orgenergogaz" [4], designed specifically to diagnose defects caused by corrosion (Figure 3). It can detect cracks with a depth of 5 % of the pipe wall thickness. It is placed into a manhole or check valve without cutting the pipeline and can pass any vertical tees and sections. For one loading into the pipeline, this flaw detector can perform a continuous scan of 250 linear meters of pipe without the batteries recharging with the passage of several vertical sections or tees [2].

Fig.3. Robotic system of OAO "Orgenergogaz»

A comparison of the above-mentioned flaw detectors is presented in Table 1.

Table 1 Comparative analysis of robotic flaw detectors

Developer	CJSC "Introskan technology"	CJSC "Orgenergogaz"	CJSC "Diakont»
Item	flaw detector A2072 " IntroScan»	flaw detection complexity of technological pipelines	*TK-400-ML*
Nominal diameter of the inspected pipelines, mm	DN 500-1400	DN 700-1000	DN 500-1400
Weight, kg	12	85	100
Monitoring distance from the loading point, m	up to 1500	up to 1000	up to 550
Speed of movement of diagnostic tools m/min	5	10	12
Communication line	wireless connection (Wi-Fi channel) up to 8 hours of battery life	wireless connection (Wi-Fi channel) up to 3.5 hours of battery life	connecting cable
Loading and unloading	inspection hatch DN400 mm, check valve, process cut	inspection hatch DN 700 mm, check valve, process cut	check valve DN 700 mm, process cut
Sensitivity of acoustic monitoring	15 % of the wall thickness; 30% of the welded joint thickness.	depth of 5 % of the pipe wall thickness	more than 30-40 % of the pipe wall thickness

In the future, the probability of detecting corrosion via the above-mentioned devices will make it is possible to detect analogous defects in the diagnostic support of technological pipelines general repairs. Moreover, another very important advantage of such devices is the elimination of the defects caused by human error [12].

3. A design for a magnetic-wheeled flaw detector platform Introscan A2072

Despite the revealed advantages in experimental and industrial exploitation, the flaw detector platform 's drawbacks Introscan A2072 have been identified as well.

They are as follows:

- maneuvering with DN 300 mm tees is not possible due to significant radius of rotation and dimensions;
- not overcoming vertical obstacles due to the platform configuration;
- when tipping, the platform becomes unrecoverable due to metal debris sticking to the magnetic wheels while moving on the pipe side surface [7].

This invention provides novel means for a small-sized platform of a magnetic-wheeled pipe flaw detector. It allows:

- performing unlimited maneuvering in a complex pipeline manifold with DN ≥ 300 mm;
- overcoming vertical obstacles in a pipeline manifold without being equipped with a mechanism to deactivate magnetic wheels;
- automatically turning over on its wheels after-possible tipping.

The invention concept lies in the fact that the presented flaw detector platform containing magnetic motor-wheeled modules comprises a longitudinal axis interconnecting the platform chassis with rotation limiters via longitudinal joints. In addition, the longitudinal axis has a transverse joint and extreme bushes of the longitudinal axis are connected to the gear motors shafts mounted on the extreme chassis of the platform longitudinally.

Figure 4 shows the platform for a magnetic-wheeled pipe flaw detector, where: 1 - chassis; 2 – a gear motor; 3 - longitudinal axis; 4 - an intermediate bush; 5 – a wheel; 6 – a ring magnet; 7 – a non-magnetic plate; 8 – a bush; 9 – a stop; 10 – a transverse joint; 11 – the technique of the trolley; 12 – a video camera; 13 - non-magnetic inserts.

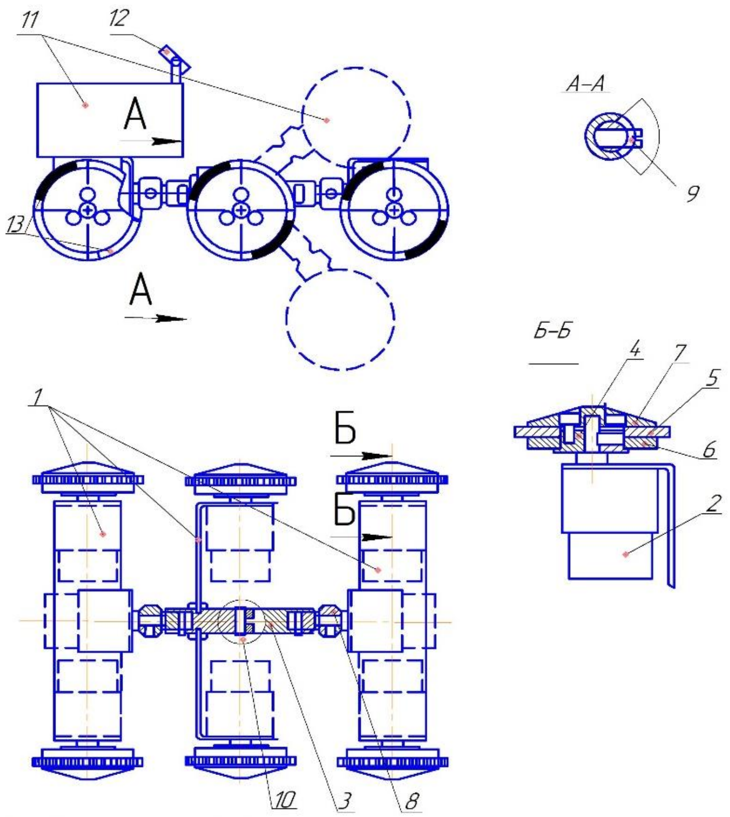

Fig. 4. A platform for a magnetic-wheeled pipe flaw detector

In terms of design, the platform for a magnetic-wheeled pipe flaw detector consists of three chassis 1 with mounted gear motors 2 and interconnected with a longitudinal axis 3. Wheels 5, ring magnets 6 and non-magnetic plates 7 are installed on side gear motor axis 2 via intermediate bushes 4. Mounted on the shafts of the longitudinally mounted gear motors 2, the extreme bushes 8 of the longitudinal axis 3 are fixed by the stop 9. The longitudinal axis 3 has a transverse joint 10. The extreme chassis 1 have some space for technique of the trolley 11 and a video camera 12 to be installed. The platform wheels 5 are equipped with non-magnetic inserts 13 equally spaced around the perimeter.

This platform for a magnetic-wheeled flaw detector works as follows.

The platform is installed on the inside surface of the steel pipe to be examined. Ring magnets 6 made of electrical steel with high magnetic properties, provide magnetization of the platform to the examined steel pipe. The provision on the longitudinal axis 3 of the bush 8 having capability of rotation limited by the stop 9 in sector C and of the transverse joint 10, ensure a complete fit of all platform wheels 5 to the curved surface. Then, power is supplied to the side gear motors 2. If the platform wheels 5 rotate clockwise (Figure 4), the platform moves forward. If the platform wheels 5 rotate in the opposite direction, the platform moves back. The rotation of the left and right wheels

5 in opposite directions ensures the platform rotation in place. The shafts of longitudinally mounted gear motors 2 in normal operation are not rotated due to the design of their gears [8].

When the platform of the magnetic-wheeled flaw detector tips on its side or roof, the operator working remotely through a video camera 12 and longitudinal gear motors 2, will turn over the platform. Switching on longitudinally mounted gear motors 2 in turn, the operator achieves the parallel position of the central and right chassis 1 (Figure 4) to the surface onto which the platform has tipped over with the wheels 5 down. When placing the platform on wheels 5, the provision of the stop 9 on the longitudinal axis 3 ensures the forced rotation of all three chassis 1 relatively to each other. Moreover, after the above-mentioned adjustments, the provision of a transverse joint 10 ensures the placing the right chassis 1 wheels 5 (Figure 4) on the surface of the pipe. The magnetization force of the right chassis 1 wheel 5 and relative rotation of the adjacent chassis 1 allows putting the entire platform on the wheels 5. When putting the platform on the wheels 5, the non-magnetic plates 7 on the wheels 5 allow reducing the rotation torque. As the platform tipped sideways, the wheels 5 magnetization to the pipe surface is excluded.

If the platform runs into a vertical obstacle, the wheels 5 will slip up until the non-magnetic inserts 13 of the middle wheels 5 will reach the desired position, i.e. the non-magnetic inserts will be downward. In this position, due to the non-magnetic plates 7, the magnetization force of the front wheels 5 to the vertical surface of the obstacle F_1 is greater than the force of their magnetization to the horizontal surface F_2. The traction force Ft of the front wheels along the vertical obstacle is determined by the formula: $F_t = k_{aw} \cdot F_1$, where k_{aw} - a wheel-to the support surface friction coefficient; F_1 – the magnetization force.

Under the condition $F_t > F_2$, the front wheels 5 of the platform begin to move upward along the vertical obstacle. The back wheels 5, also equipped with non-magnetic plates 7, slip after running into a vertical obstacle until the non-magnetic plates 7 of the back wheels 5 occupy the desired position. Thus, the platform overcomes the vertical obstacle. Similarly, the platform goes down from the vertical obstacle. With the front and then the back wheels 5 locked in a horizontal section, non-magnetic inserts should be parallel to the vertical surface due to slipping of the wheels 5. (Figure 5).

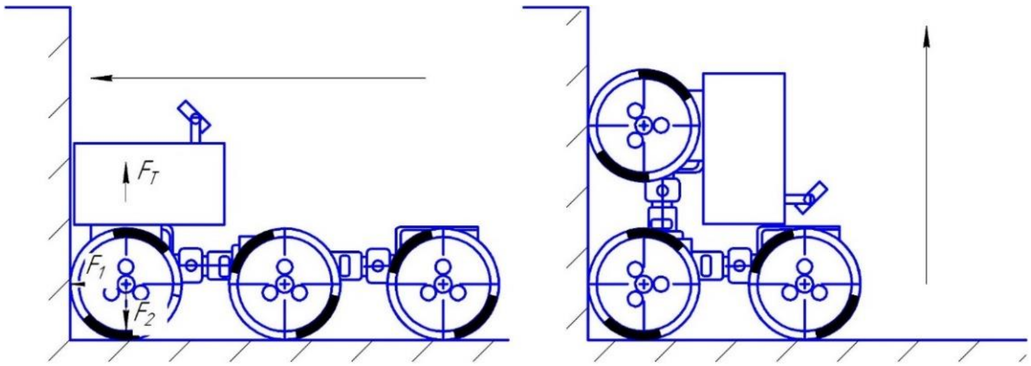

Fig. 5. Overcoming a vertical obstacle

It is worth noting that the ring magnets 6 should be selected so that their forces will be sufficient to hold the platform in any position in relation to the examined object, even despite the provision of non-magnetic plates 7 on the front wheels 5 [9].

4. Conclusion

The absence of an additional mechanism for deactivating the magnetic field in the platform design leaves additional space for technological equipment placement on the platform, and kinematics provides unlimited maneuvering in complex piping.

The proposed platform is adequately for designing small-sized pipe flaw detectors on its basis, as well as other technological devices used in various National Economy Sectors. The platform capability to turn over on its wheels independently eliminates the emergency situations occurrence during diagnostic work, and kinematics provides unlimited maneuvering in a complex pipeline manifold.

References

1. Afanasyev, V.B., Chernova, N.V. (2011). Modern methods of non-destructive testing. *Advances in modern natural science*. No. 7. pp. 73-74

2. Kline, R. A., Hsiao, C. P., Fidaali, M. A.(1986). Nondestructive evolution of adherently bonded joints. *Trans. ASME: J. Eng. Mater and Technol*. 108. N 3. pp.214-217.

3. Order of the Government of the Russian Federation of 13.11.2009 N 1715-R "On the Energy strategy of Russia for the period up to 2030".

4. Patent RU 2418234 "in-Line vehicle". JSC "ORGENERGOGAZ". [Available at http://www.findpatent.ru/patent/241/2418234.html] [accessed 19/10/2020].

5. Patent RU 118739 U1 ROS. Federation. Self-propelled in-tube projectile-flaw detector / S. G. Naumov; No. 2012117670U; application 27.04.2012; publ. 27.07.2012.

6. Patent RU 2369783 C1 ROS. Federation. Internal pipe inspection facility-defectoscope with variable speed of movement/ chebotarevskiy Y. V., A. I. Sinev, P. K. Plotnikov; No. 2008127949A; Appl. 08.07.2008; publ. 10.10.2009, bull. No. 28.

7. Patent RU 2647173 "Platform for an in-line magnetic flaw detector on wheels." – URL: https://yandex.ru/patents/doc/RU2647173C2_20180314 [accessed 23/10/2020].

8. Patent RU 2051058 "Vehicle for moving on ferromagnetic surfaces." – URL: https://yandex.ru/patents/doc/RU2051058C1_19951227 [accessed 01/10/2020].

9. Patent SU 540716 "Self-propelled cart". [Electronic resource]. - access mode to page: https://yandex.ru/patents/doc/SU540716A1_19840123 [accessed 11/09/2020].

10. Poezzhaeva, E.V., Fedotov, A.G., Glyadov, P.V. (2015). Development of a robot for pipeline control. *Young scientist*. No. 16. pp. 218-222.

11. Shmakov, V.A., Smirnov, Yu.N., Gizzatullin, R.R. (2007). Planning repairs of main pipelines based on the results of in-line diagnostics. The Role of science in the development of the fuel and energy complex. *Matera. scientific-practical Conf. October 24, 2007*.Ufa. pp. 90-92.

12. Vasiliev, N.N., Isaakian, N.O., Smolyansky, V.A. (1951). Defectoscope. *Technical Railway dictionary*. M., State transport railway publishing house.

13. Zubailov, G.I., Gumerov, K.M., Gizzatullin, R.R. (2007). Metal Impact strength and pipeline strength. Problems and methods of ensuring the reliability and safety of transport systems. *Matera. scientific-practical Conf. May 22, 2007*. Ufa. pp. 169-171.