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

"Journal of Economics and Social Sciences"

Equipping excavators with distance sensors to pipelines

Tomsk Polytechnic University

Alexander Rybin [a]

[a] School of Core Engineering Education

Abstract

This effort shares the analysis of problem solving associated with mechanical damage to pipelines. It proposes the method of prevention accidental oil spills during earth excavation using electromagnetic sensors. The advantages of this method versus alternative options are described herein. It presents the review of existing sensors and methods of their installation on the operating member of excavation equipment. An optimal design solution has been developed that ensures trouble-free earth excavation. It shows the economic effect of implementation of this technology into the production processes of the oil and gas sector companies. The conclusions are formulated and summed up on the data presented.

Keywords: Excavator, tracer, accident, excavation; electromagnetic sensors;

1. Introduction

Extraction and exploitation of the oil and gas sector: construction and laying of new pipelines, as well as the recultivation of disturbed soils are accompanied by excavation efforts carried out by heavy excavation equipment. Despite the fact that the most common reason of accidental oil spills is the loss of pipeline integrity, and according to the failure statistics for 2017-2019, 4% of all incidents on interfield pipelines occurred due to mechanical damage to the pipeline during earth operations. Thus, the studies that are able to computerize key production processes and enhance compliance with the high environmental and industrial safety standards in oil and gas sector companies are now becoming more relevant.

Scientific developments of foreign and domestic researchers conclusively prove that improvement of any method, development of any kind of measures aimed to computerize production processes shall begin with the clarification, identification and assessment of the actual status, i.e., with the process of diagnostics and comparison of alternative methods developed [1, 4,7,12]. Considering that innovation and automation of production processes [3,5,8,10] is a major factor of competitiveness of oil and gas players under the present-day market conditions, and determination of its development directions as well as and development of reasonable organizational modifications means to create a stable basement for the companies to further develop and fulfil the main strategic goals. However, it should be noted that finalization of the innovative solutions portfolio is directly associated with the economic assessment of implementation of this solution into production processes. Therefore, the purpose of this study is an economic analysis and the operation of prevention of accidental oil spills during earth excavation operations through equipping the operating members of field support vehicles with the range-finding sensor to the pipeline.

To satisfy this goal, the following tasks have been set:

1. Consider the relevance of use of 2D and 3D leveling systems, analyze their advantages and disadvantages, as well as the possibility and degree of their applicability during excavation;

2. Analyze the ways to solve the problem of mechanical damage of pipeline during earth excavation, give an overview of various types of existing sensors and methods of their installation on the operating members of field support vehicles;

3. Offer the best design option how to install sensors on the operating members of an excavator.

2. Material and Methods

The work is based on the statistic data related to pipeline ruptures in the area of Alexandrovskoye and Kargasok localities of Tomsk Oblast and Nizhnevartovsk area of the Khanty - Mansiysk Autonomous Okrug - Ugra. The survey item is the method of excavation operations using electromagnetic sensors. The review of existing approaches was carried take into account foreign experience in scientific and technical solutions in ensuring safe of operations and commonly accepted occupational safety requirements. The economic effect of implementation of the proposed design was carried out by evaluating the investment projects based on the cash flow discount method (calculation of NPV, IRR, PP, DPP).

3. Results

2D and 3D levelling systems may be outlined [2,6,9,11] among the existing automation equipment for excavation.

The main functions of such systems:

1. Control of depth and deviation during excavation of the pit: the operator puts the ladle on the benchmark (elevation) and enters a design elevation into the software indicating the tangent of the angle of slope. The system analyzes these parameters and displays actual and design values. Once the data is received, the operator performs work based on the readings displayed on the screen, tracks high-altitude position of the ladle relative to the bench mark in real-time mode. When the set level is reached, an audio signal sounds, and a green diode lights up on the panel;

2. Excavation of cutout or backfilling of a complex profile embankment;

3. Setting a “dead zone”, and the hydraulic controls are blocked, when the same is reached - used to protect the excavator (possibility of digging is excluded), protect utilities against the ladle that has misdriven below the digging depth, etc.

The simulation analysis figured out that an initial position of the ladle for a 2D control system may be fixed against some point with a known mark or against a laser plane. In 3D systems, the excavator is determined in absolute coordinates against the digital model of the required surface (Figure 1).

The use of the described 2D systems for safe conduct of earth excavation operations seems to be inexpedient as long as the complexity of synchronization of a pipeline location, parameters of the pit and location of the excavator fails to allow us to complete the task.

The use of 3D systems for seems to be inexpedient due to their high cost (6 million rubles), as well as the need to engage pre-train engineering staff to develop a digital model.

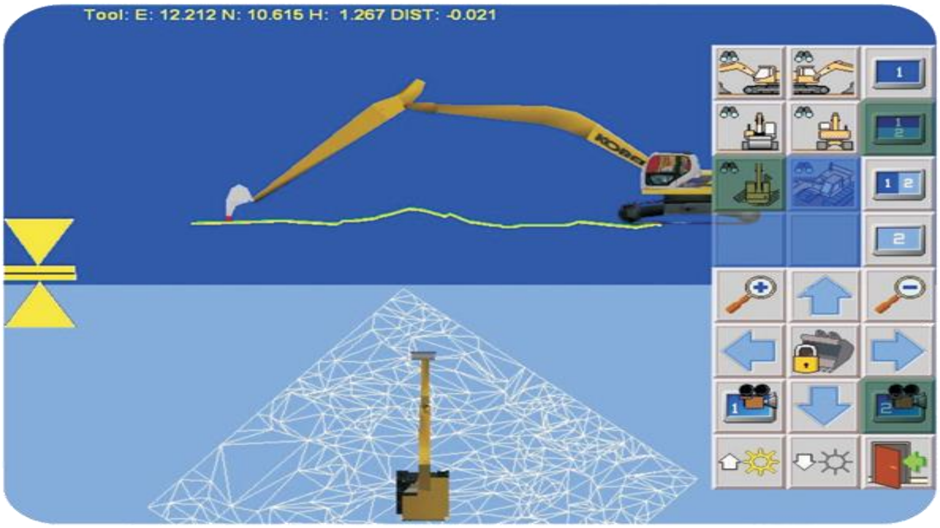

Fig. 1. Digital model of the 3D levelling system

The most high-quality technical model is the development of the package for warning approach of the ladle to underground utilities by EZiDIG (Italy). Warning is in real-time mode, the sensitive control s fixture on excavator handle. The fixture is designed to search for signal cables and power cables in the basic configuration. But when the signal generator is connected, you may control position of other utilities that do not independently generate the electromagnetic signal. EZiDIG is not available on the Russian market, and has no domestically produced equivalents. This complicates the implementation of this equipment, increases the risks and the cost of its maintenance. Thus, there is no ready-made offer for a high-quality solution how to mitigate damage to the pipeline during excavation efforts operations on the domestic market.

The other approach to problem solving may be the use of the sensors capable to detect the pipeline. The sensors due to optical earth opacity are not applicable in earth excavation.

It seems promising to apply electromagnetic sensors used in pipeline finders and georadars. One of the main advantages of magnetic displacement sensors is that a magnetic field may penetrate through all non-magnetic materials without loss of the accuracy of sensing the distance to the object. This means that what no matter what kind of obstacle is available between the sensor and the object: stainless steel, aluminum, brass, copper, plastic, stone or wood, the distance between them will be detected almost immediately. Another advantage of magnetic sensors is that they may operate in harsh environmental conditions and corrosion resistant, as both detectors and objects, if necessary, are coated with inert materials that do not have any effect on magnetic fields.

The use of electromagnetic sensors is complicated by the proximity of massive metal parts of the excavator itself, as well as their mobility. An obvious difficulty is how to select sensors installation location. To ensure proper operation, there should be no any metal objects in the vicinity of the unshielded eddy current sensor. A similar disadvantage may be remedied by shielding the sensor. Two eddy current sensor configurations are shown: with shielding and without shielding (Fig. 2).

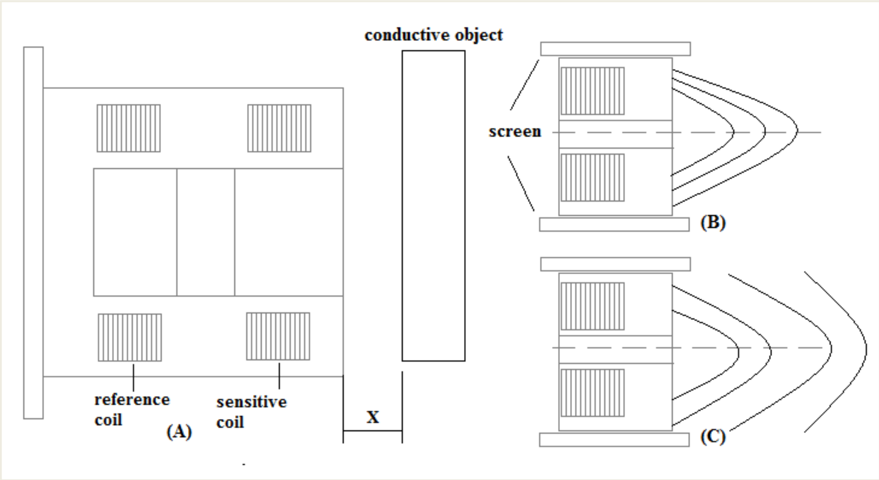

Fig. 2. A - Electromagnetic proximity sensor, B - shielded sensor, C - unshielded sensor

The shielded sensor consists of a metal sheath around the ferrite core and coils. It focuses the electromagnetic field on the front side of the sensor. This allows them to be integrated into metal structures without changing the measuring range. The unshielded sensor is sensitive to movement not only from the front end, but also from the sides.

Thus, the technical result of implementation of this method is improvement of the accuracy of determining a critical distance between the excavator ladle and the pipeline wall surface.

A common practice for the above described systems is the installation of equipment on the handle of the excavator. This position of the sensors prevents from considering a position of the ladle during movement. The sensors installation ensuring safety of the pipeline is fix at the ladle teeth (Fig. 3).

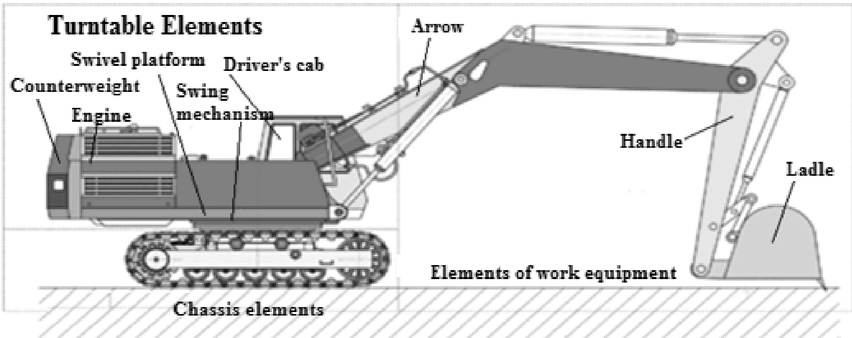

Fig. 3. The layout of the elements of the excavator

Installation of even small sensors at the teeth is a difficult task, as these locations experience pressure and wear during operation of the excavator. Therefore, installation of the sensor on the skid fixed to the handle and reproducing the ladle perimeter may become a fairly simple option. Considering the prevalence of use of magnetic sensors and the existence of tools similar, which operation principle is similar to the designed ones, the development of a prototype of the required electronic equipment is not associated with extensive risks and costs.

The economic calculation of costs associated with localization and remedy of an accidental oil spill was carried out based on the real case of oil and oil products leakage as a result of the loss of oil field pipeline integrity k.2X-vr.2K “Oil Field N” (Table 1).

Table 1. The economic effect of the project

Parameter	Unit of measurement	Parameter Definition	Total indicator
NPV	million rubles	Net present value	1 950 030
IRR	%	Internal rate of return	100
PP	year	Payback period simple	<1
DPP	year	Discount payback period	<1

Considering the cost of geolocators and pipeline finders, it may be assumed that the cost of equipment for one excavator will not exceed 468,000 rubles (excluding VAT). Therefore, the economic effect of the project with the specified macro parameters (annual discount rate of 20%, estimated period of 10 years) pays off the preliminary costs of adoption of the technology in less than 1 year, and it will cost about 601,835.5 rubles to rectify the consequences of only one incident associated with the damage of pipeline surface by an excavating equipment (excluding the cost of remediation).

4. Conclusion

The incidents during excavation due to damage to the pipeline by the excavator ladle lead not only to economic losses, but also cause great harm to the environment.

Among the existing solutions for excavation equipment, we can highlight the 2D and 3D levelling systems, as well as the EziDig excavator system. The use of 2D systems for safety conduct of earth operations works seems to be inexpedient, due to the complexity of synchronization of the pipeline location, the parameters of the pit and the location of the excavator. The use of 3D systems for safe conduct of excavation works is not an ultimate solution due to their high cost (6 million rubles), as well as the need to engage pre-train engineering staff to develop a digital model. Adaption of the sensors developed by EZiDIG into the production processes does not seem possible, as models and their analogues are not available on the Russian market. These factors complicate the adaption of this equipment, increase the risks and costs associated with adaption and maintenance.

The most promising is the development of a pipeline detection tool based on the electromagnetic sensors used in the pipeline finders and georadars. The implementation of such tool is complicated by the proximity of the massy metal parts of the excavator, as well as their mobility. Installation of sensors on a special skid fixed to the handle and reproducing the ladle perimeter may become a fairly simple option. Adaption of such sensors is of current concern and very economically viable solution that does not require significant capital investments, labor costs, and will also allow sensors complete elimination of the human factor and will fully computerize the process of earth excavation operations works.

References

1. Blinkov, I.O., Blinkov, O.G., Serikov, D.Yu. (2019). Evaluation of the effect of innovations adoption as a factor of the competitive immunity of an industrial enterprise. *Equipment and technologies for the oil and gas complex*. Vol. 4. pp. 48-51. DOI: 10.33285/1999-6934-20194(112)-48-51

2. Bukreev, I. (2012). 3D leveling systems as applicable to excavators [Sistema nivelirovaniya v 3D v primenenii k ekskavatoram]. *Roads and people: Moscow*. Vol. 11. pp. 14-16.

3. Evans, E.P., Coulbeck, B. (1992). Pipeline Systems. [Available at https://link.springer.com/book/10.1007%2F978-94-017-2677-1#about] [Viewed on 13.02.2020]
4. Lisanov, M.V. (2010). The risk analysis of trunk oil pipelines when substantiating the design solutions that compensate for the deviations from the existing safety requirements. *Industrial safety: Moscow*. Vol. 3. pp. 58-66.
5. Lisanov, M.V., Shanina, E.L., Savina, A.V., Taran, A.I., Sumskaya, S.I., Naumovich, I.V., Lesnyak, A.E. (2010). The risk analysis of trunk oil pipelines when substantiating the design solutions that compensate for the deviations from the existing safety requirements. *Industrial safety*. Vol. 3. pp. 58-66.
6. Saponenko, U.I. (2008). Single ladle excavator operator [Mashinist ekskavatora odnokovshovogo]. Moscow: Academiya..
7. Seredina, V.P., Kolesnikova, E.V., Kondykov, V.A., Nepotrebnyi, A.I., Ognev, S.A. (2017). Features of the effect of oil pollution on soils of the middle taiga of Western Siberia. *Oil industry*. Vol. 5. pp. 9-20.
8. Seredina, V.P., Sadykov, M.E. (2011). Soils of oil fields in the middle taiga of Western Siberia and a predictive assessment of the danger of pollution by organic pollutants. *Siberian Journal of Ecology*. Vol. 5. №. 18. pp. 617-623.
9. Seredina, V.P., Sadykov, M.E. (2011). The soils of West Siberia middle taiga oil deposits and a predictive estimate of contamination hazard with organic pollutants. *Contemporary Problems of Ecology*. Vol. 4. №. 5. pp. 457-461.
10. Tararychkin, I.A., Blinov, S.P. (2017). Simulation modeling of the damage process of the network pipeline structures. *The world of transport*. Vol. 15. №. 2. pp. 6-19.
11. Ustavich, G.A., Kostina, G.D. (1983). Geodetic surveys during construction and operation of large-scale power supply facilities [Geodezicheskie raboty pri stroitel'stve i ekspluatatsii krupnykh energeticheskikh ob"ektov]. Moscow: Nedra.
12. Yashin, S.N., Koshelev, E.V., Makarov, S.A. (2012). Analysis of the effectiveness of innovative activity. SPb: BHV.