The Upgrading of the Technological Process of the Main Pipeline Break by Means of the Bucket with the Improved Running Gear

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Abstract. When doing major repair works on underground main pipelines, there is a need to carry out earthworks. The single-bucket excavators are used today since they are the mostly wide spread. When stripping main pipelines with the single-bucket excavator, the sequence moving from one stop to the other in the longitudinal direction upon completing the working cycle, it was revealed that the trench profile turns out to be enlarged. It is caused by the fact that the bucket is turned at a definite angle in relation to the axis of the pipeline. As a result, a redundant earth volume from the trench is extracted which results in the increasing of work execution process in stripping the main pipeline. Target of the proposed engineering solution is the improvement of the stripping process when carrying out the major repairs of the main pipeline. The research object is a single-bucket excavators equipped with the working element – a back hoe. The observations and a detailed study of technological processes of earthworks have been carried out, and the analysis has been done for the existing problem in the topic under examination. In addition, based on 3D modeling, an innovative simulation spatial model of the device was developed. As a result of the development of the proposed engineering solution, the technological process was improved to strip a main pipeline. On this basis, technical and economic features were improved. The reduction in the extracted soil from the trench impacts directly not only the duration of the stripping process but also the duration of the back filling process made by the bulldozer. This results in the reduction of harmful atmospheric emissions. The proposed single-bucket excavator can be used in places with structurally unstable soils as well as in all the climatic areas of this country. The proposed engineering solution enables to improve and to enforce the equipment of the repair and construction site. Moreover, the application of the excavator helps strip the pipelines of any diameters. The device design can be used in combination with any single bucket excavator.

1. Introduction

Today, most main pipelines in this country have been designed buried underground. The work process of develop a trench is one of the most labor-intensive when building or doing major repairs. Now in this country, several large gas transmission projects are being realized, such as “Bovanenkovo-Ukhta-2”, “North Stream-2”, “Power of Siberia”, “Ukhta-Torzhok-2”. Apart from this, major repairs are being done each year on the existing main pipeline network.
2. Relevance
Presently, there is a single-bucket excavator absolutely in every repair and construction site. Hence, the issue of improving development of the trench using a single bucket excavator is very urgent. The period of work execution or major repairs in general depends upon the duration of the process develop of the trench. Herewith, it is necessary to note that single bucket excavators are machines of cyclical activity. When develop a trench, the operator has to move from one stop to another on and off putting out the develop process, and this increases the duration of earthworks. From the above-said, the improvement of the trench develop process with a single bucket excavator will bring the contemporary techniques of construction and major repair works to a new qualitative level.

3. Formulation of the problem
There are two problems in the process of opening the trench. The first is that each work cycle of a single-bucket excavator consists of the six process operations. To cut the duration of the develop process it is needed to decrease their number, thus, the process reduction can be achieved.

The second problem lies in the fact that when executing the develop process the excavator’s tracks are along the trench, that is there is no possibility of moving the machine in cross direction relative to the trench axis. At that, the working element of the excavator and the bucket correspondingly will be at an angle $\gamma$ to the trench axis 1 (Figure 1) when develop the main pipeline from lateral sides which increases its cross section. As a result the volume of earth to be extracted grows and hence, the period of earthworks.

![Figure 1. Scheme of soil cutting with a single bucket excavator equipped with a work body](image)

Apart from this, when the development the underground main pipeline with a single bucket excavator, the operator has to secure the integrity of the insulation a pipe. The technological operation of cutting soil from one parking lot is carried out with several positions of the working body. The major drawback is in the fact that there is a risk of damaging the pipe wall with the bucket teeth at the turned position of the work body. To prevent damaging the pipe wall, the operator has to develop the pipeline with a soil protective layer not less than 0.2 m from each side.

4. Target
The target is the improvement of the work process of trench developing in construction and major repairs of main pipelines.

To achieve the aim one should solve the following tasks:
- to develop a technical solution that will reduce the non-productive movement of a single-bucket excavator in the process of developing;
- to develop the engineering solution enabling to reduce the profile of the trench;
- to reduce the negative impact on the environment;
- to ensure a maximum automation of the trench developing process with a single bucket excavator;
- to increase the technological capabilities of a single-reach excavator while improving safety during a pipeline opening and maneuverability.
The proposed engineering solution enables to exclude nonproductive movements in the excavator cycles. In addition, the proposed technical solution will make it possible to exclude the excavation of excess soil volume and will improve the safety of developing operations, while excluding damage to the pipeline.

In addition, the proposed technical solution will make it possible to exclude the excavation of excess soil volume and will improve the safety of developing operations, while excluding damage to the pipeline. The extraction of excess soil during the development of the trench leads to an increase in the duration of not only the technological process of opening, but also to an increase in the technological process of backfilling of the trench, after repair and restoration work.

5. Method of scientific research
As a method of scientific research the method of modeling is used. With the help of this method, a spatial 3D imitation model of the proposed device has been developed, a technological scheme for opening the trench has been executed, and thus the problems have been solved.

6. Theoretical part
According to [1], the analysis of statistic data among the applied machines has been executed, the result of which revealed that when designing the factory characterization are considered first of all, that is, the aging of the equipment and probable aggravation of these data are not taken into account. As a result of exploitation due to the aging of equipment many parameters impacting a machine performance can deteriorate.

In construction or major repairing of main pipelines, the earthworks are ones of the most labor-intensive; hence, the maximum mechanization and automation are required [2]. Let us review some of the known engineering solutions to execute trench developing operation.

The excavator [3] is known for pipeline developing mounted laterally to the trench. For better outsee of an operator when developing the cabin is made suitable for its elevation control respective its original position. Apart from this, the excavator's work element is equipped with a grappler enabling to move soil to the dumping area.

Out of the existing technology level, the excavator [4, 5] is known with a truck-like chassis. At that, when developing a trench, the clearance of the excavator's frame with the cabin can be adjusted. The visual range for an operator is improved enhancing the quality of earthworks. This excavator's drawback is that when lifting the frame with the cabin using a special chassis, the wheel base is reduced and the spatial stability correspondingly.

One more excavator [6] is known equipped with an improved work element. The excavator’s boom is made telescopic suitable for expanding which enables to extract more earth from one stand. However, the telescopic boom due to its design grows heavier thus; increasing the total weight and the fuel consumption grows correspondingly. All these factors result in the increase of polluting emissions.

There is a machine [7] for trench developing. With the help of this machine, it is possible to open the trench in one pass. To improve the excavator’s work in [8], an improved design of the chassis is proposed enabling to develop a trench on the uneven ground. However, the given construction requires a total redesign of the machine. So this engineering solution is impossible for using on all repair and construction sites and this is a considerable drawback.

In [9], the methods of reducing environmental emissions are proposed when excavators are operating. Highlighted is the fact that fuel prices grow, so it is needed to cut the consumption. Moreover, great attention is given to the issue of operator’s training [10], because the fuel consumption and the number of nonproduction movements depend largely upon their skills.

There are other engineering solutions to improve economic performance of a single bucket excavator. In [11], an improved construction of the bucket for trench developing is proposed reducing its cross section.
In [12], it is suggested to change the steel material of which the work element is made for the aluminum alloy. Among other things it is proposed to exchange the bucket of standard plant manufacture for more enlarged, made of aluminum too. At that the productivity according to [12] can be increased up to 35%.

To develop trenches, a special trailer [13] is known, on which a chain cutter is mounted. The drawback of the given device is that a base machine is required to move it in its work.

The excavator [14] is also known with the work element in the form of a nozzle through which water is given under pressure for soil erosion. When developing a trench the ground is hydro-washed out under pressure. The drawback of this excavator is that after the developing it is impossible to do repair and construction works until the trench is dry again. Moreover, another drawback is the need in water source which is not everywhere available and that set limits to the application of this excavator.

The use of water results only in the increase in the cost of the trench developing operations.

In [15], a technique to develop a main pipeline is proposed and a special machine having conveyor as a work element. To develop a pipeline, first the ground is being developed down to the lower generating line in a first pass, after that the second pass follows during which the total developing of the pipe body is done from the ground by two lateral mills and by the worm conveyor which is brought under the lower generating line of the pipe. The given machine and the technique have drawbacks:

- the pipe developing has to be done in two passes which increases the time of the process;
- the machine moves in reverse running in the trench made at the first pass which complicates the pipe developing process.

Presently, to improve the trench developing process, the hybrid technologies are applied using the GPS and GLONASS systems [16-21].

The excavator [22] is known with a conveyor for improving the trench developing process. In the process of operating, the ground from the bucket is loaded to the conveyor along which it is moved over the excavator side. However, the machine operation is impossible without a high-sided truck behind the excavator. The excavated ground will be dropped into the machine bed.

There is another machine [23] for a layer-by-layer developing of an underground main pipeline. The work element is designed as two chain mills behind a base machine. The drawback of the given developing technique is that the pipeline has to be developed in two passes along the section under repair which increases nonproduction movements and results in enhancing environmental impact.

The method of pipeline developing is known using two single-bucket excavators moving along the developed trench one by one [24]. The application of two excavators results in the increase of financial expenses.

One should strive for cutting down the number of machines used for earthworks to the minimum. To improve the trench developing process in construction or major repairs of main pipelines, an innovative device is proposed.

The device 1 is composed of two components 2 and 3 (Figure 2a), suitable for a rigid connection between them in the longitudinal direction. Each of the two parts 2 and 3 of the proposed device 1 consists of a spatial metal frame 4 and self-propelled running parts 5 and 6 located front and rear respectively. The components 2 and 3 are designed with definite outline dimensions suitable for their transportation on the roads of regional and federal roads.

The spatial frame 4 consists of a metal base 7 made of perforated plate along the edges of which the metal frames 8 and 9 are mounted rigidly connected. Rails 10 are mounted on the metal base 7 in even intervals along which buggies 11 are moving on metal wheels 12 in to-and-fro motion. Metal plates 13 and 14 are fixed on buggies 11 which rigidly connect when linking parts 2 and 3 thus building one whole platform 15 (Figure 2b). The platform is made suitable for to-and-fro horizontal motion with the help of hydraulic cylinders 16. The horizontal to-and-fro motion of the plates 13 and 14 connected together is done with the horizontally positioned hydraulic cylinders 16. There are metal ramps 19 (Figure 2c) on the spatial frame 4 in order to mount a single bucket excavator 17 with the working body 18 on the platform 15. For the possibility of moving the entire spatial frame 4, in the
process of opening the trench, it is connected to the self-propelled chassis 5 and 6, front and rear, respectively, the running parts of which can be rotated by an angle of 180 degrees. After the connection of parts 2 and 3, the device is ready for mounting the excavator 17 on it. In the case of irregularities in the terrain in the path of the proposed device, the spatial frame 4 is suitable for moving in a vertical direction. For this case, there is a system consisting of hydraulic cylinders 20 fixed on the self-propelled running parts 5 and 6. Each of the pairs of hydraulic cylinders can work independently from one another enabling to equalize the position of the spatial frame 4 with the excavator 17 even if there are sloping sites and sudden level differences.

Figure 2. Simulation three dimensional process schemes of the proposed device where a – general view of the proposed device for transport, b – the proposed device in service position when developing a main pipeline, c – the proposed device (back elevation)

1 – the proposed device, 2 – the first component of the device, 3 – the second component of the device, 4 – spatial metal frame, 5, 6 – self-propelled running parts, 7 – metal base, 8 – longitudinally mounted metal frame, 9 – transversally mounted frame, 10 - rail, 11 – rail riding buggy, 12 – metal wheel, 13, 14 – metal plates, 15 – platform, 16 – horizontally mounted hydraulic cylinder, 17 – single bucket excavator, 18 – working body, 19 – metal ramp, 20 – vertically mounted hydraulic cylinders for positioning the frame of the device, 21 – earth surface, 22 – add-on device, 23 - trailer, 24, 25 – rotary running parts, 26 – trailer frame of the add-on device, 27 - trench, 28 – oil-pumping station, 29 – electric generator, 30, 31 – rigid hitches, 32 – car-body, 33 - storage space, 34 – main pipeline, 35 – trench axis, 36 – upper lines of the trench slopes.

The carrier of the self-propelled running parts 5 and 6 is designed with the independent suspension enabling to freely move the excavator 17 without sharp jerking and shifting in vertical directions relative to the horizontal earth surface 21. The pairs of hydraulic cylinders 20 are on the self-propelled running parts 5 and 6. The management of the hydro-system is done by the remote control which enables to guarantee a level horizontal position of the excavator 17 when developing a main pipeline.
Behind the proposed device, an additional device 22 [1] is installed, consisting of a trailer 23 with rotary running parts 24 and 25. The frame 26 of the trailer 23 is made collapsible in order to increase its size in the longitudinal direction depending upon the trench 27 profile. Moreover, there are an oil-pumping station 28 and a power generator 29 for the add-on device 22 on the frame 26. To move the add-on device 22 following the proposed device 1, the rotary running parts 24 and 25 are connected to it by rigid hitches 30 and 31. The motion of the device in developing the trench is done by remote control. At that, the movement of the whole complex of devices 1 and 22 can be executed both by the excavator 17 operator from the cabin and his assistant who can control the process being at the safe distance from the basic machine. When developing a trench the ground from the excavator bucket goes to the body of the add-on device 22. While filling the car-body 32 in developing the trench 27, the soil goes into the storage space 33. The device works as follows. At first the device 1 and 22 are put at the beginning of the section of the main pipeline 34 under repair. At that, to assemble and the subsequent joining the devices, they are positioned across the developing trench 27. Further, the spatial frames of parts 2 and 3 of the proposed device are connected with one another. The self-propelled running parts 5 and 6 are also joined together with the plates 13 and 14. Hereafter, the metal ramp 19 are laid out along which the excavator 17 goes to the platform 15 of the device 1. Further, using rigid hitches 30 and 31, the add-on device 22 is joined to the proposed device 1, the former is the trailer 23 with the car-body 32. After the above mentioned steps, the trench developing starts. The movable platform 15 is brought into the left end position, at that the excavator 17 moves to the left entirely. In this position, as the operator of the excavator 17 is developing the pipe from the left lateral side of the pipe. As the cutting edge of the excavator 17 reaches the design reference mark at the bottom of the trench 27, the platform with the machine 17 is moved to the mid-position from which the pipe 34 developing starts above its upper generating line. After that, the platform with the excavator is moved all the way to the right, from where the pipe 34 developing is done from the right lateral side. As far as the trench is developed, the soil is loaded from the bucket to the car-body 32 of the device 22 standing in front of the work element 18. Whereby, after the filling of the car-body 32 it is lifted using the hydraulic system shooting the earth to the storage space 33. On the completion of developing from one stand, both devices 1 and 22 with the excavator 17 positioned on one of them are moved to the next stand where all the operations are repeated. For the visual perception of the situation by an operator by the trench position on the site, the line of the axis trench 35 of the pipeline 34 and the upper lines 36 of the trench 27 slopes in the surface plane of earth 21 are fixed by layout. Thus, the developing of all the section under repair is executed.

7. Practical importance
The practical significance of the device is that it can be used on all construction and repair flows without exception, in absolutely any climatic and soil conditions.

8. Conclusion
In terms of practical significance, the advantages of the proposed device are:
- reduction of the excavator’s working cycle duration;
- providing access to the trench from two lateral sides by workers, machines and mechanisms;
- environmental impact reduction due to the cutting working cycle of the excavator;
- reduction of the cross section of the trench, hence cutting labor intensity for the earthwork in general;
- increasing the quality of developing works;
- possibility of the excavator’s quick cross motion relative to the developed trench;
- the special design of the proposed device can be used for sharp sloping sites and topographic inequalities.

Compared to the conventional techniques of developing process, the proposed device enables to exclude the operation of the excavator’s working body at an angle $\gamma$ to the axis of the developed pipeline 1 which will help to cut the labor intensity of the developing process. The developed device...
enables to develop trenches in all climatic regions of this country. The power driven base mounting of the proposed device enables to freely move the overall device with the excavator along the axis of the developed trench. The management of the whole device is done so that the excavator operator can control the motion being in the cabin. When using the proposed device, nonproduction movement of the excavator is reduced. The device 1 is moved electrically, which reduces the environmenta

9. References
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