Excavator implement for pipeline repair

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Abstract. The article presents an option to improve the design of the equipment of an excavator of the 3 dimensional group. The equipment is intended for selective repair of the pipeline by an excavator, without involving other road construction equipment (for example, a pipeline). The proposed version of the design of the working body allows you to increase the speed of repair of the pipeline, by reducing the time required to change equipment, its relocation, which as a result reduces the cost of repair work. The main idea is to supplement the main equipment of the excavator with a structure consisting of three teeth, forming, in conjunction with the bucket, a gripping mechanism. To confirm the operability of the proposed design, theoretical studies were carried out aimed at determining the stability of the machine for the most dangerous design operating positions, and the permissible sizes (pipe sizes) were established, with which the stability of the machine is maintained.

1. Introduction

The creation of an effective energy infrastructure, including pipeline transport, occupies one of the priority places both in the long-term socio-economic development of the country and in the strategic activities of the Ministry of Energy of the Russian Federation. At present, 100% of the gas produced, 93% of the oil produced, and more than 20% of the refined products are transported via trunk pipelines [1,2].

During operation, pipelines and their elements wear out. The nature of wear can be very different and is determined by the operating conditions, the properties of the material from which the pipeline is made, its design features, insulation quality, etc [1].

Overhaul is a repair performed to restore serviceability and complete (or close to complete) restoration of the resource of an object with the replacement or restoration of its components, including base parts. Overhaul of the linear part is divided into the following types: with the replacement of pipes; with replacement of insulating coating; selective repair [3].

Selective repairs include: repair of the pipeline section with the elimination of defects in the pipe wall or with the installation of the coupling; repair of the pipeline section with the replacement of the “coil”, pipe, assembly of linear fittings. [3].

It is possible to reduce the time and financial costs of performing operations on selective repair of the pipeline by improving the equipment of the excavator, which is the basic machine for performing selective repair of the main pipeline [4].

Researching

To improve the design of excavator equipment for selective repair of the pipeline, confirming its operability by checking the machine for stability and making the necessary calculations of the hydraulic system.

In order to increase the speed of repair and reduce the cost of work, the authors developed the design of the equipment of the excavator, which allows selective repair of the pipeline without involving additional equipment (Figure 1).
The proposed design of the working equipment is: 1 – handle; 2 – bucket; 3 – capture; 4 – thrust; 5 – bucket traction; 6 – limiter; 7 – rubber pad; 8 – bucket hydraulic cylinder; 9 – capture cylinder. Welding of all elements of the working equipment is carried out in accordance with GOST 5264-80 [5].

Capture consists of three teeth located in parallel and fixed on one base. The edges of the teeth have a rubberized coating to prevent deformation of the pipe during the lifting [6]. Designed equipment allows you to develop soil in the places of repair of pipelines and to dismantle the opened pipeline using gripping devices. The working equipment allows selective repair of pipelines with a diameter of 720 ...1220 mm [7].

2. Theoretical studies of the design of equipment

Theoretical studies require two tasks:

1. To carry out calculations of the hydraulic system of the equipment;
2. Carry out calculations to determine the stability of the machine [8].

It is possible to determine the forces on the rod of the capture hydrocylinder by projecting onto the y axis equal $y_i = 0$.

$$-G_{c1} + F \cdot \sin 60^\circ - G_{c2} - G_p - G_{k+t} - G_e = 0,$$

where $F$ – force of pressing teeth to the surface of the pipeline, N; $G_{c1}$ – weight of arrow 1; $G_{c2}$ – weight of arrow 2; $G_p$ – handle weight; $G_{k+t}$ – weight of bucket and pipe; $G_e$ – the weight of the excavator.

$$F = \frac{G_{c1} + G_{c2} + G_p + G_{k+t} + G_e}{\sin 60^\circ}.$$  

The net power of the hydrocylinder was determined by the formula [9,10]

$$N = F \cdot V,$$

where $N$ is a useful power developed by a hydrocylinder, W; $F$ – force on stock, N; $V$ – stock speed, m/s.

The actual speed of the stock was determined by the formula [11]

$$V_p = \frac{Q_{fc}}{S_{ef}},$$
where \( V_D \) – actual stock speed, m/s; \( Q_{fc} \) – fluid consumption, m\(^3\)/s; \( S_{ef} \) – is an effective piston area, m\(^2\).

For the piston working cavity, the effective area of the piston was determined by the formula [12]

\[
S_{ef} = \frac{\pi D^2}{4},
\]

where \( D \) is the piston diameter, m.

The payload power of the pump is determined by the formula [11]

\[
N_{pp} = \Delta P_p \cdot Q_s,
\]

where \( N_{pp} \) – useful power of the pump, W; \( \Delta P_p \) – pressure drop across the pump, Pa; \( \Delta P_n = P_{nom} \); \( Q_s \) – pressure supply, m\(^3\)/s.

To confirm the operability of a machine equipped with a modernized equipment, theoretical studies were conducted aimed at determining the stability of the machine and preventing its overturning [13]. This parameter was determined through the stability coefficient, which is determined by the formula [13]

\[
K_y = \frac{M_y}{M_o},
\]

where \( M_y \) – the moment of all the forces holding the excavator from tipping over; \( M_o \) – the moment of all the forces contributing to the overturning of the excavator.

When determining the stability coefficient, the size group of the machine, the type of equipment, the working position of the machine and a number of other parameters are taken into account [2]. For different types of interchangeable equipment and different operating modes, its own limits of stability coefficient are recommended. Under normal conditions, \( K_y = 1.1 \ldots 1.2 \) [14].

The efficiency of the modernized equipment excavator was calculated to work with pipes with a diameter of 720, 1020 and 1220 mm.

3. Research results

The stability of the excavator is checked not only for the conditions under which the working process is performed, but also for the conditions of transportation of the unit, when changing equipment, etc. [15].

Theoretical studies were carried out for two design positions of the excavator, taking into account the variable shoulders of the gravity equipment and the machine, where the running gear is located perpendicularly and parallel to the trench (Figure 2).

Figure 3 shows the graphical dependencies constructed during theoretical studies. It can be seen from the graph that the stability of the excavator is fully preserved for both the first and second working position. The x axis shows that stability is maintained when working with pipes having a diameter of 720, 1020 and 1220 mm.

Also, as a result of research, it was found that the operation of the machine with a pipeline, the diameter of which is 1420 mm, with the use of equipment in combination with a gripper, leads to a rollover. In other words, the stability coefficient of the machine in position II is below the established coefficient for machines of this size category.
Figure 2. The design position of the excavator: a – location of the running gear perpendicular to the trench; b – location of the running gear parallel to the trench

Figure 3. Dependence of the stability coefficient from pipe diameter at excavator positions: P₁ – the location of the running gear perpendicular to the trench; P₂ – arrangement of the running gear parallel to the trench
4. Conclusion

The presented calculated dependences make it possible to determine what engine power of the base machine is required for the productivity of the trencher.

Formulas for calculating the productivity of the machine, taking into account the speed of movement of the base machine and the remote capacity of the equipment, allow you to determine the pace of the repair cycle using the advanced design of the digging machine.

The design of the cutter drum for removing soil from under the main pipeline with a diameter of 720 mm has been developed. The cutter drum is installed on trencher with dual trencher implement, and is mounted perpendicular to a copying tool. This design allows you to exclude a digging machine from the standard fleet of vehicles, which reduces the cost of its operation and relocation.

And it also allows you to dig up the pipeline in one pass, which in turn saves time that was previously spent on installing the digging machine. The proposed technical solution allows for capital repairs of pipelines with the replacement of the outer insulation coating without lifting the pipeline from the trench and maintaining its position.

The design of the equipment of a trencher for opening the pipeline and cleaning the annular space from the ground can significantly increase the productivity of the construction equipment involved in the repair work and reduce the time spent carrying out this kind of work.

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