Optimal geometric parameters selection of walking rig individual elements

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Abstract
The main types of rigs with which it is possible to conduct geological exploration under water are listed. Their disadvantages are indicated. For geological exploration of the seabed surface, it is proposed to use the double-support drilling rig with stepper propulsion engine developed in 2016. A technique for selecting the optimal geometric parameters of the cantilever sections of the walking rig bearing frame is presented.

1. Introduction
Caterpillar, wheel and auger thrusters can be used as vehicles on the bottom. The study and industrial development of the seabed resources is impossible without technical means - primarily without underwater mining equipment. An important role among underwater vehicles is assigned to bottom units that carry mining and exploration working bodies in the form of suction tips, rippers, buckets, pick-ups, dumps, soil pumps, airlift heads, probes, drilling rigs. [1] - [5].

It is known that the passability of the wheel is limited by a ledge with a height of one third of its radius and a trajectory width of two thirds. The wheel, the auger and the caterpillar deform the soil, creating a continuous gauge, which in turn leads to environmental damage and additional energy consumption. The walking propulsor is most suitable for operation in the seabed conditions, which allows overcoming obstacles while leaving a discrete gauge. [6] - [10].

The underwater platform is known, which includes a sampler connected to a floating cable, mounted on a vertical frame movably, which, in turn, is rigidly mounted on the frame (see certificate of authorship USSR 920438, E 02 D 1/04, 1984 ). The main disadvantage of the known technical solution is the possibility of its overturning during a storm and the drift of the craft, which leads to the loss of the device.

A device for rotary underwater drilling is known, comprising a support frame, a rotator including a shaft-drum with a rope wound on the drill pipe, an actuator and a tension mechanism (certificate of authorship SU 1139818 A, Bull. No. 6, 15.02.85). The disadvantage of the considered device is that it cannot independently move from the drilled well to a new drilling site.

Known drilling machine, including a support frame, on which is installed the drive of the core pipe, made in the form of a coil with coils wound on it of a flexible element. One end of the flexible element is connected to the float of the other element with the lifting mechanism of the maintenance vessel. The coil has a profile axial bore to accommodate the driving rod, which is rigidly connected to the core tube (certificate of authorship N 1701884, M. Kl6, E 21 B 7/12, 1990). The disadvantages of this
underwater drilling machine is the impossibility of its use at great depths, large energy costs when embedding the float when lifting a flexible element on the vessel.

It is also known machine for underwater drilling exploration wells (Russian Federation Patent No. 2260664; E21B 7/124 publ. September 20, 2005, Bull. No. 26). The disadvantage of this device is inaccurate positioning of the machine when setting on the point of drilling.

To carry out geological exploration on the seabed, it is proposed to use a two-support walking unit (utility model patent No. 166446 “Walking drilling rig”, utility model priority: 07/04/2016). (Figure 1). The installation includes a farm, supports with platforms, hydraulic cylinders of supports, working body, control system. The support frame is made of two parallel tubes with longitudinal guides and is equipped with earrings pivotally connected to the platforms of the supports, while transverse beams rigidly interconnect the ends of the tubes with blocks placed on them. The working body is made in the form of a trolley with rollers that interact with the longitudinal guides of the truss, with a drilling machine rigidly attached to it and two winches equipped with flexible traction elements enclosing blocks of transverse beams, one end of which is fixed on the winch drum and the other on the worker's trolley body. [11]; [12].

![Figure 1. Constructive scheme of the walking rig][12].

2. Methods
To determine the minimum weight of the machine, it is necessary to build the dependence of the counterweight on the length of the cantilever section of the supporting frame. The equation of moments of forces acting on the installation relative to point A [13] - [16] was compiled (Figure 2).
Figure 2. Design scheme.

\[ M_A = G_{PL}K + 2q \frac{K^2}{2} + 2q \frac{(L + K)^2}{2} + G_{ST}L; \]

\[ G_{PL}K = q(L + K)^2 + G_{ST}L - qK^2; \]

\[ G_{PL}K = q((L + K)^2 - K^2) + G_{ST}L; \]

\[ G_{PL} = q \frac{(L + K)^2 - K^2}{K} + G_{ST}L; \]

\[ G_{PL} = q \frac{(L^2 + 2LK + K^2 - K^2)}{K} + G_{ST}L; \]

\[ G_{PL} = q \frac{L(L + 2K)}{K} + G_{ST}L; \]

\[ G_{PL} = q \frac{L(L + 2K)}{K} + G_{ST}L; \]

\[ \Gamma_{oe} \text{ : } q \text{ is the pipe linear mass, (kg/m);} \]

\[ K \text{ is the length of the cantilever frame, (m);} \]

\[ L \text{ is the section length between pts. A and B, (m);} \]

\[ G_{PL} \text{ is the platform weight (counterweight), (kg);} \]

\[ G_{CT} \text{ is the weight of the sup port table, (kg);} \]

\[ G_{PL} = \alpha_{PL}q + \beta_{PL}G_{ST} \text{.} \text{[17]} \]

Where: \( \alpha_{PL} \) is the angular equation coefficient*;

\( \beta_{PL}G_{ST} \) is the initial ordinate.

\[ \gamma_{PL} = \frac{\alpha_{PL}}{L}; \]

\[ \alpha_K = \frac{K}{L}; \]

\[ G_{PL} = \gamma_{PL}qL + \beta_{PL}G_{ST} \frac{1}{L}; \]

\[ g_{PL} = \gamma_{PL}q + \beta_{PL}G_{ST}; \]

\[ \gamma_{PL} = \frac{1 + 2\alpha_K}{2\alpha_K}; \]

\[ \beta_{PL} = \frac{1}{\alpha_K} \text{.} \]

\( g_{PL} \) and \( g_{PL} \) are specific gravity values of the counterweight and the support table per unit length of the working section of the bearing frame;

\( \alpha_K \) is the console coefficient, which characterizes consoles length relative to the length of the working section of the frame (when \( \alpha_K = 0 \) there are no consoles, when \( \alpha_K = 1 \) the length of the console is equal to the length of the working section). [18] - [20].

\[ g_{PL} = q \frac{1 + 2\alpha_K}{\alpha_K} + 5q \frac{1}{\alpha_K}; \]

\[ q = 276,4 \text{ (kg/m); } L = 10 \text{ (m).} \]

\[ g_{PL} = q \frac{1 + 2\alpha_K}{\alpha_K} + 5q \frac{1}{\alpha_K}; \]

\[ g_{PL} = q \frac{1 + 2\alpha_K}{\alpha_K}; \]

\[ g_{PL} = q(2 + \frac{6}{\alpha_K}); \]

\[ G_{PL} = qL(2 + \frac{6}{\alpha_K}). \]
Specific gravity of the counterweight depending on the console coefficient.

With an increase in the length of the cantilevers ($\alpha_k$ coefficient), the counterweight decreases sharply. The specific mass of the counterweight should be selected depending on the ratio of the length of the console to the length of the working section of the supporting frame. The criterion for choosing the coefficient $\alpha_k$ is the minimum of the drilling rig mass:

$$G_{Total} = 2G_{ST} + G_{Frame} + G_{PL};$$
$$K = \alpha_k L;$$
$$G_{Total} = 10qL + 2qL + 4\alpha_k qL + qL(2 + \frac{6}{\alpha_k});$$
$$G_{Total} = qL(14 + 4\alpha_k + \frac{6}{\alpha_k}).$$

3. Results
Dependencies \( G_{Total}(\alpha_K) \) show that the minimum mass of the installation is achieved with the following \((\alpha_K)\) values:

\[
G_{Total}(\text{Min}) = 65783,2 \text{ (kg)} \quad \text{when} \quad \alpha_K = 1,2
\]

\[
G_{Total(1,2)} = qL(14 + 4\alpha_{K(1,2)} + \frac{6}{\alpha_{K(1,2)}}) = 2764 \cdot 23,8 = 65783,2 \text{ (kg)}.
\]

Table 1.

| \(\alpha_K\) | \(G_{Frame}, \text{kg}\) | \(G_{PL}, \text{kg}\) | \(G_{Total}, \text{kg}\) |
|---|---|---|---|
| 0,1 | 6633,6 | 171368 | 205641,6 |
| 0,2 | 7739,2 | 88448 | 123827,2 |
| 0,3 | 8844,8 | 60808 | 97292,8 |
| 0,4 | 9950,4 | 46988 | 84578,4 |
| 0,5 | 11056 | 38696 | 77392 |
| 0,6 | 12161,6 | 33168 | 72969,6 |
| 0,7 | 13267,2 | 29219,43 | 70126,63 |
| 0,8 | 14372,8 | 26258 | 68270,8 |
| 0,9 | 15478,4 | 23954,67 | 67073,07 |
| 1,0 | 16584 | 22112 | 66336 |
| 1,1 | 17689,6 | 20604,36 | 65933,96 |
| 1,2 | 18795,2 | 19348 | 65783,2 |
| 1,3 | 19900,8 | 18284,92 | 65825,72 |
| 1,4 | 21006,4 | 17373,71 | 66020,11 |
| 1,5 | 22112 | 16584 | 66336 |
| 1,6 | 23217,6 | 15893 | 66750,6 |
| 1,7 | 24323,2 | 15283,29 | 67246,49 |
| 1,8 | 25428,8 | 14741,33 | 67810,13 |
| 1,9 | 26534,4 | 14256,42 | 68430,82 |

4. Conclusions
To determine the minimum weight of the rig, the mass of the counterweight was determined as a function of the cantilever section length of the bearing frame. Counterweights and carrier frames weights were determined for different console coefficients. The rig total mass depending on the console coefficient shows that the minimum mass is achieved when the value \(\alpha_K = 1.2\). It is economically feasible to choose console sections with a coefficient equal to 1.2.

The walking rig is important to use for geological exploration at the sea bed and ocean bed because of economic feasibility, high efficiency, high permeability and environmental friendliness.

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