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Research

TUNNELING SYSTEMS FITTED WITH DUPLEX-IMPACT OPERATING MEMBER FOR THE SHORT RELIEVING TUNNELDRIVING WITH TUBBING LINING

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ABSTRACT

The article considers tunnel boring machinery options for mechanization of ancillary workings on loamy soils in the construction of underground networks and reports the following:

-The results of experimental trials for distribution of the impact energy in the Cambrian clay soils, on the bases of which we developed the proposed construction;

-The layout scheme and the operation principle of the impact operating member;

-The graph construction of the tunnelling system's theoretical productivity, equipped with impact operating member that works in the oncoming shear mode, depending on the average value of the mine face hardness, including the presence of solid bed layers;

-The ratio of the tunnelling system's theoretical performance with a new transport scheme proposed for the mines of the St. Petersburg Metro constructiong.

INTRODUCTION

The construction of tunnels networks and workingsof the St. Petersburgunderground is provided by relieving tunnel driving (Isaev, 2015; Gulelmetti, *et al*., 2013) (transport and extrapasses, blind and special blind drifting, production of pit bottom, cameras, etc.) required to connect the stations under construction with vertical shaft, for delivering of broken rock to the surface andall things necessary for stations construction.

The short length of such mine workings does not permit using shields and complex drilling activities, as their work requires the creation of extended mounting and dismountingcameras that totally through their length may exceed the length of the relieving tunnel driving. Therefore, their constructionis most often carried out by mining methods using manual tunnellers labor with hammers and fastening the mine face with timber. Performingof such tunnel works has a relatively low capacity and inevitably leads to the danger, because of possible workers'placement in the loose mine-face zone.

Improving the safety and efficacy of relieving tunnel driving on clay slaughters leads to the necessity of creation the mechanized means for complex mining faces.

METHODOLOGICAL FRAMEWORK

Based For the short relieving tunnel driving in

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difficult mining and geological conditions, for example, during the construction of the St. Petersburg metro, characterized by high heterogeneity and relative complexity, it is advisable to use the impact operating members; however, the hydraulic drills with independent rotation and pulse deal with water removing degradation of mine-face products, which is not appropriate for the clays.

Furthermore, due to the fact that the mine faces of the St. Petersburg underground construction could contain clays with hardness coefficient of f=1-2 based upon the scale of prof. M. M. Protodjakonov or clays containing solids with hardness coefficient f=more than 6, the destruction of such mine faces by incisal tool is practically impossible (Yungmeyster, *et al.*, 2014b).

Thus, the mechanized way of relieving tunnel driving in clay massifs could be based on the use of an operating member unit, an erector tubing-installer or a tunnel boring machine manipulator, for example, the Brokk (Fig. 1a and 1b).

The short tunnel driving complex (Fig. 1b) (Yungmeyster, *et al.*, 2016b) contains a tubing-stacker 1, an under frame 2. Tubing-stacker moving 1 is carried out by hydrocylinders 3 (a mechanism of tubing-stacker moving).

The tubing-stacker 1 is equipped with the rotary telescopic arm 4 mounted on the tubing-stacker under frame 2. At one end of the rotary arm 4, set the fastener 5 for capturing and installation the tubing to the tunnel ring (Fig. 2). At the other end of the fastener 5 on the rotary arm 4 mounted the duplex impact operating member 6. Fastening of metal roof

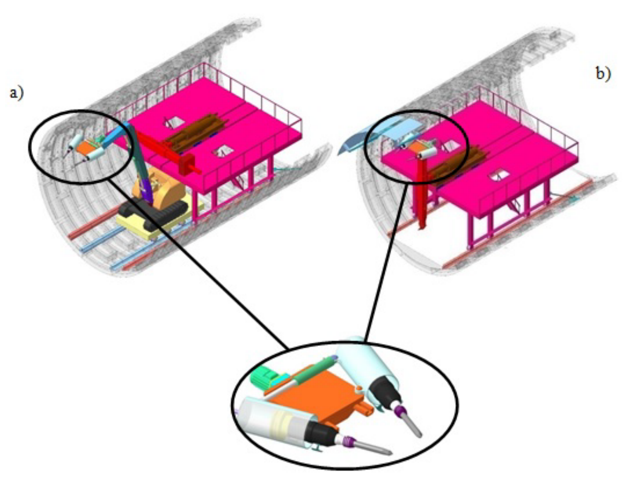

Fig. 1 The tunneling system for relieving tunnel driving a) partially mechanized safety guard with the usage of Brokk, equipped with proposed operating member; b) The tunneling system for the relieving tunnel driving with tubbing lining.

is carried out by segments 7, made of sheet steel 5 mm to 7 mm thick. This construction is set behind a tubbing tunnel framing 8 when installing the first (procarved) rings. Hydraulic cylinders 9 are provided in the construction of the tunnel complex for the further roof holding, in the process of the tunnel development.

Hydraulic cylinders 9 on one side are fastened to the metal segment 7, and on the other to the bracket 10 which should be installed to the mounted tubbing tunnel framing.

The development of mine face is carried out by duplex impact operating member.

The working out of mine face solid is divided into four phases: Phase I to Phase IV (Fig. 2b). As the solid had being working out (Phase I) the crab moves forward, thus pushing the metal segment 7, which provides a holding of the mine face roof. This operation is repeated after completing the left and right parts of the I-st phase.

As the solid had being worked out (Phase I), the telescopic divider 11, presented in the form of round metal pipes with a diameter of 159 mm and 133 mm, is moved to a depth of stope and fixed in a foot holes specially prepared by gad pickers.

The constructions of the divider 11 and the fastened metalroof7 are equipped with special mounting brackets 12, in which the metal U-bars 13 are set.

Pneumatic cushions 14 are installed between U-bars and the mine face front.

After the air had injected from the backbone network into the space of the pneumatic cushions, it expands and fills the space between U-bars and the mine face front, and as a consequence, provides the holding of the mine face front.

The solids' working off during subsequent phases (II-IV phase) is made in a similar way. The total breaks are shipped by load-haul-dump machines. A tubbing tunnel framing (Yungmeyster, *et al.*, 2016b) is made installed after excavation, fastening and solid shipment.

RESULTS AND DISCUSSION

In We conducted experimental studies for determining the constructive parameters of duplex impact operating member in the tunneling system.

It should be noted that the power exposure efficiency of the rock destruction tools to the solid mass depends on several factors, including the method of transmitting the impact energy and characteristics of

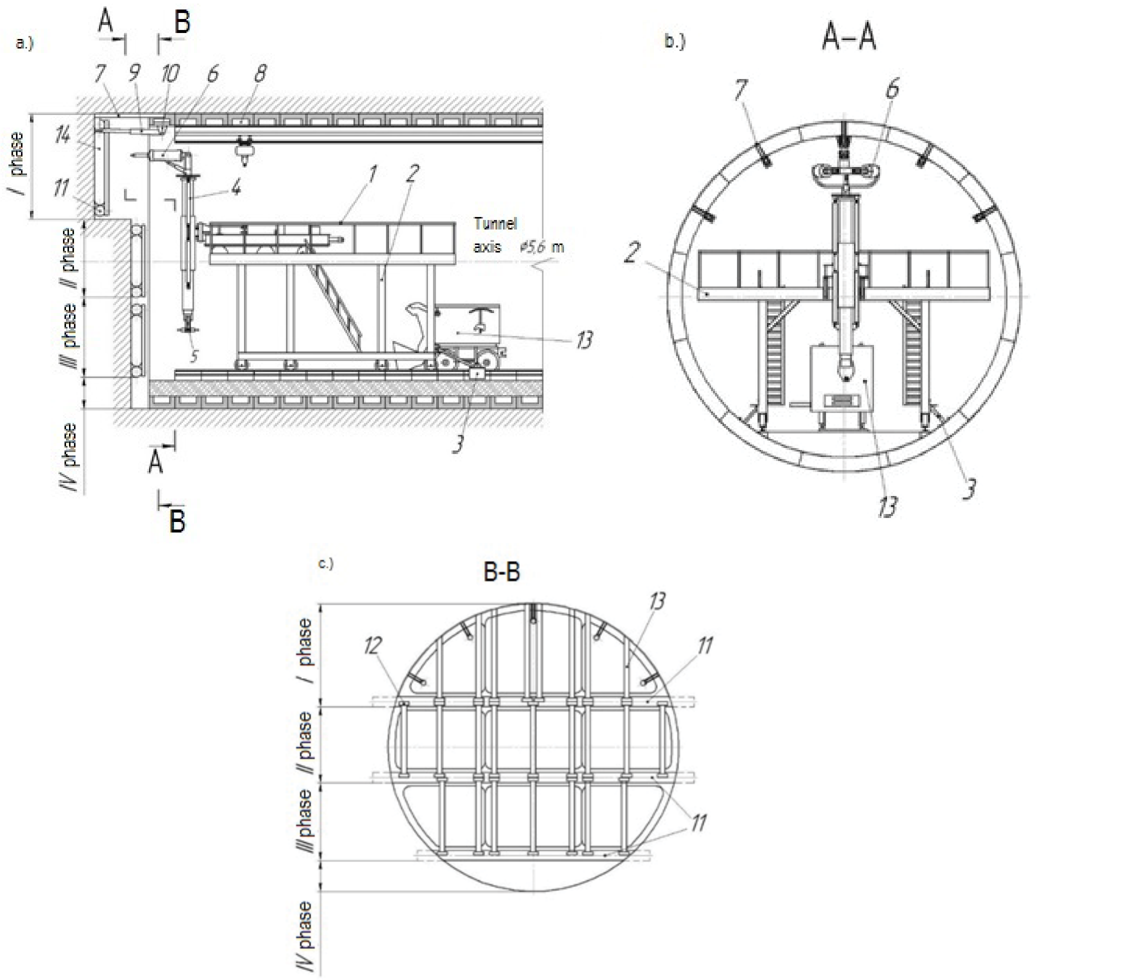

Fig. 2 The tunneling system for the relieving tunnel driving with tubbing lining: a) general view of the system; b) Sectional drawing A-A (mine face view); c-Sectional drawing B-B (tunneling system view).

change the solid tightness. Studying the mechanism of the stressed field formation in material under the current drain, it is important to select the parameters of the impact-shear operating member (Yungmeyster, *et al.*, 2014a; Yungmeyster, *et al.*, 2016b; Parton and Boriskovsky, 1988). Determination of the impact waves propagation in the Cambrian clay at its destruction by impact operating members, was carried out on the stand shown in Fig. 3.

Shown experimental setting is made on the basis of the electric perforator Auer, mounted on a frame made of two U-bars. Cambrian clay samples were used as a test of rock materials. Impact pulses are registered piezoelectric transducer installed on the test sample rocks. The signal of the strain meter produced by Textronic company arrived at the oscilloscope connected to a PC with the relevant software to make the necessary measurements, both in graphics and in an analytical form. Oscilloscope synchronization was carried out by a signal of strain meter, mounted on the bar.

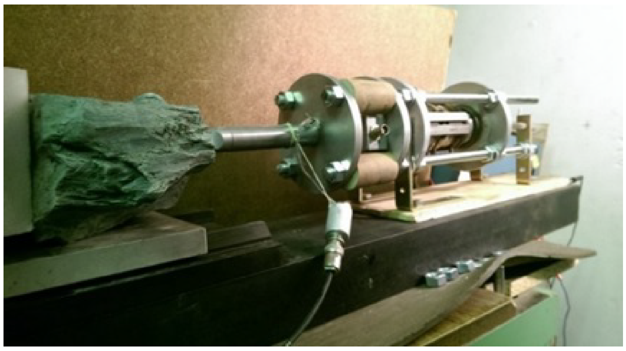

Fig. 3 Installation for studying the propagation of shock waves in the clay.

Measurements for the dissemination of the shock wave in the Cambrian clay test sample were carried out as a result of the experiments. Measurements were carried out after every single impact entering into a series of impacts. The peaks with different angles of sharpening α=30°; 60°; 70°; 80° were used at destruction of clays. Charts dependencies shown in Fig. 4, were built on the basis of the Origin Lab

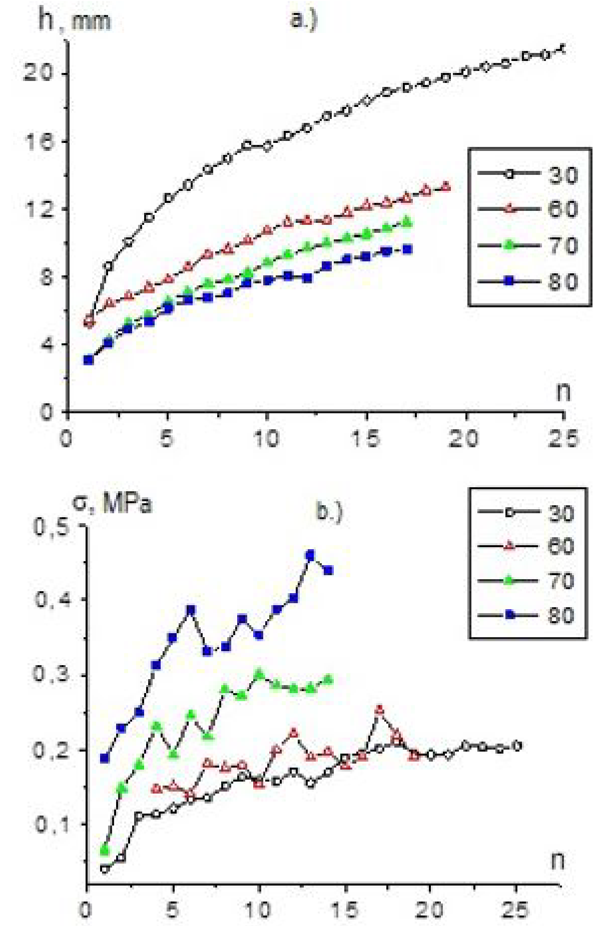

Fig. 4 Diagrams of penetration (a) and amplitude values (b) dependence on the number of strokes for different angles of the peaks sharpening.

program using data obtained during the experiment.

The obtained data allow us to conclude that the change in the implementation of the peaks in the samples of Cambrian clay occurs by the power law; this circumstance is connected with the fact that the front of the tool forms an ellipsoidal seal in the rock fracture zone. In the process of applying the impacts, their zone develops down into the sample, increasing its size. After reaching an ultimate intense condition at the interface of greater zone there occurs the separation crack that grows through the loading axis and joins the second zone, destroying the test sample. Thus, the impact energy is spent not for the implementation of the instrument (peaks) in the rock sample, but for the formation of cracks and chips. It follows from this that upon reduction of the peak cutting-point angle, the energy imparted to the tool impact is implemented into peaks of Cambrian clay samples; and upon increasing of the peak cutting-point angle the value of reduction is reduced, but at the same time increases the intensity of bulb pressure and splintering. For more accurate calculation of duplex impact operating member performance, there had been implemented a number of experiments to determine the shock-wave attenuation in the destroyed Cambrian clay (Fig. 5), which allowed to determine the constructive value of the distance between the impactor sat which there is mutual influence of shock waves generated by embedded peaks of each drummer, set on a single manipulator (Fig. 6).

Fig. 6 shows the proposed impact operating member, which consists of a body 1 with a movable platform located on it 2. Inside the body 1 there is a ball screw, which consists of a screw 3 and locknut moving on it 4. By rotating the screw 3, the motor-reducer 5 there comes the translational movement of the nut 4, which is rigidly fixed to the mobile platform. Platform 2, moved by the nut 4, with its guides 6 glides the gutters 7, located in body of operating member, thereby effecting the filing of the operating member for mine face (Fig. 6d-6g).

On the mobile platform, there are two rotation axis,

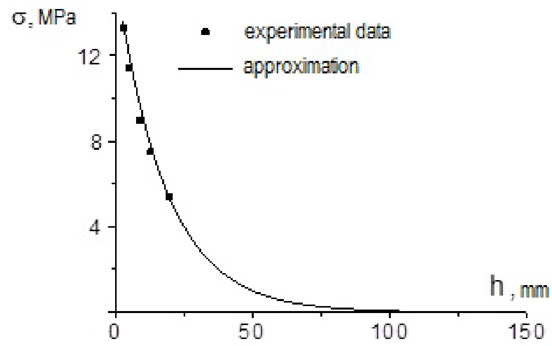

Fig. 5 The attenuation of a plane wave in the clay.

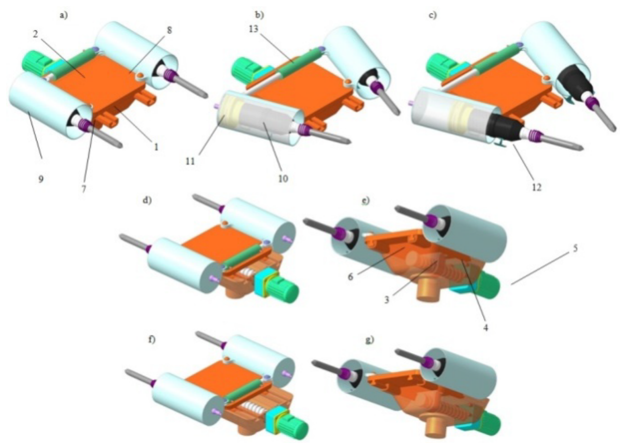

Fig. 6 Duplex impact operating member: a) the initial position; b) drawing apart of gad pickers; c) filing the gad pickers for mine face; d), e), f), g) filing of the operating member for the mine face.

where via the bearings 8 mounted two air cylinders 9, which pistons are the modified gad pickers MO-2B (item 10); at the same time the distance between the pneumatic cylinders is in the range, where guaranteed the interference on each other, distributed in Cambrian clay, ground blasts produced to the solid by rock destruction tools.

Modification of chipping hammers consists in replacing the handle on the piston head 11 and installation guides 12 for centering the hammers in the pneumatic cylinder 9 (Isaev, 2015). For the calculation of productivity drummers were defined volumes of a single cleaving, both individually used impactors (each on it sarrow), and for the dual. Volumes fitted into geometric shapes, whose form is shown in Fig. 7.

Fig. 8 shows a nomogram, determining LHD types depending on the performance of the tunnel complex and the performance of the dual impact device, defined by the formula

$$Q_{prod} = \frac{\sqrt{3}}{2} \cdot \left(\sqrt{\frac{A_{com}}{d \cdot \sigma_c \cdot (tg \, \alpha/2 + \mu) \cdot K}} \right)^3 n^{(3\beta-1)} \cdot n_{com}$$

where A_{com}-impact energy, Joule; d-peak diameter, м; σ_c-ultimate compression strength of soil, mPa; α-peak angle.; μ-coefficient of friction the tool upon the solid; K-coefficient of peak edge bluntness; n-number of impacts; n_{com}-impact frequency of a gad picker, c^{-1}; β-per-law index of the peak penetration changes.

Analysis of the curves in Fig. 8 shows that during the destruction by duplex impactors of the mine faces of a various fortress, there occurs the increased productivity in 1.31 times in comparison with the processing mine face by two individual gad pickers. In some cases, there could be used punchers (Yungmeyster, *et al.*, 2014b), the construction of which may provide a shock-rotary drilling and pure hammer destruction when disconnecting the mechanism of the rotary.

Monograph of depending types of LHD, on the

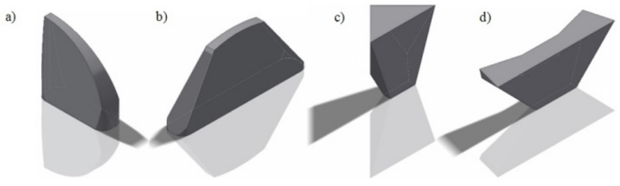

Fig. 7 The amount of gouged rocks during breaking of clay: a) during longwall face and work by a single impact operating member; b) during longwall face and work by duplex impact operating member; c) during stepped face using a single impact operating member; d) during stepped face using duplex impact operating member.

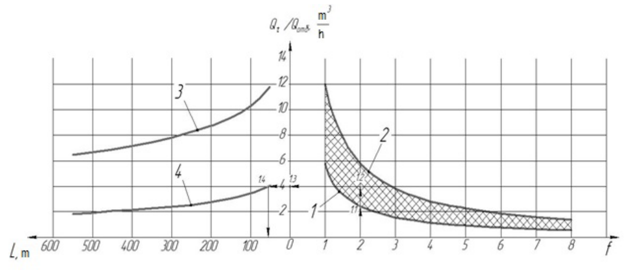

Fig. 8 Nomograph of LHD types depending on the performance of tunnel boring machine: 1-the graph of theoretical performance for dry clay of a small fracturing; the graph of theoretical performance for dry clay of an intense fracturing, blockiness and cleavage; 3-graph of productivity LHDSandvik LH203ot long transportation; 4-Performance curve LHDSandvik LH201ot long transportation.

performance of tunnel boring machine, allows in accordance with a predetermined strength of clay to determine the type and parameters of the delivery machine.

For example, for the strength 2, according to the scale of prof. Protodeacon, the theoretical performance is equal to 2.18 m^3/h (point 1.1) in Fig. 8, with the presence of cracks, displaying the blockings of mine face, the performance is specified and is 4 m^3/h (1.2-1.3 point in Fig. 8).

At a known productivity, there selected the appropriate model of LHD (point 1.4) in Fig. 8, which length of the transportation is determined by the nomogram.

In that case, LHD Sandvik LH201 had been selected. In the necessity of the greater length of transportation, there should be selected the model of LHD machine with a large bucket capacity (Yungmeyster, *et al.*, 2012).

CONCLUSION

The performed research reveals to establish that theoretical output of the tunneling systems with the impact operating member during the destruction of the solids of Cambrian clays depends on the depth of penetration of the rock destruction tool; it is described by a power-law dependence of the number of applied impacts with the exponent which varies in the range of the value of 0.37-0.56 depending on the sharpening angle of the peak, with multiplication factor of the function equal to the initial penetration (Yungmeyster, *et al.*, 2016a).

It is also worth mentioning that during the joint operation of two impactors, installed on the operating member of a tunneling system and oriented in a plane under the convergent angle of 40 degrees with the distance between the sharp peak points embedded into the Cambrian clay located in the range of 200 mm to 300 mm, in comparison with the parallel arrangement of impactors leads for increasing the productivity of peaking clay to 15% to 20%, due to the weakening of the solid, concluded between the peaks of the impactors.

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