Surface Transportation Engineering Technology

QUANTUM QUARRYING LIFT-AND-TRANSPORT MACHINERY (QQLTM)

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Abstract

Introduction: Mastering of the methods of energy extraction from the physical vacuum and their implementation in engineering will change the motion mechanics and the pattern of using lift-and-transport machinery if those are equipped with quantum engines (QEs). **Purpose of the study:** The study is aimed to develop a conceptual foundation and a working hypothesis for the operation of quantum quarrying lift-and-transport machinery (QQLTM). **Problem statement:** The paper addresses challenges of rock transportation from the pit bottom to the upper levels. **Methods:** The thrust vector is decomposed into orthogonal components. A QQLTM force balance and motion equation is derived. Typical modes of QQLTM operation are determined. Calculations as well as graphical-and-analytical studies are performed. **Results:** The paper presents the results of calculations regarding time and energy consumption required for rock transportation, describing the motion of loaded QQLTM during rock transportation from the pit bottom to the transfer station and the upper level of a quarry. **Discussion:** The existing groups of motor and railway vehicles as well as lift-and-transport machinery can be substituted by groups of transport machines with QEs — QQLTM. This will allow for the significant improvement of quarrying technology, implementation of continuous cargo transportation without transshipment, reduction of energy consumption as well as material expenditures and labor efforts.

Keywords

Quantum engine, quantum thrust, quantomobile, quantum quarrying lift-and-transport machinery, force balance, quarrying.

Introduction

In a number of papers (Kotikov, 2018a, 2018b, 2018c, 2018d, 2019a, 2019b, 2019c, 2019d), the author addressed the prospects of using the methods of energy extraction from the physical vacuum in the transport industry. The introduction of quantum thrust in automobiles will result in the appearance of a new type of transport — quantomobiles.

The author also considered the possibility of replacing lift-and-transport machinery at terminals and warehouses with universal quantum lift-and-transport machinery (QLTM) by introducing quantum thrust (Kotikov, 2019e). The possibility of energy extraction from the physical vacuum, uncovered in case of potential mastering of the foundations of the theory of Superunification (Leonov, 2002, 2010, 2018), will change the motion mechanics and the pattern of using lift-and-transport machinery if those are equipped with quantum engines (QEs).

Unlike ICEs and electric motors, QEs directly generate thrust, which can be applied to the vehicle/machine/wagon body (Brandenburg, 2017, Fetta, 2014, Frolov, 2017, Tajmar et al., 2007). This creates prerequisites for the appearance of quantum lift-and-transport machinery (QLTM) able to lift off the bearing surface (overcoming gravity) and transport cargo hovered over such surface horizontally or at an angle (Kotikov, 2019e).

Acknowledging that the addressed ideas are hypothetical and the proposed design solutions are quite distant in time, we will consider the possibility and prospects of using QLTM in quarrying technology.

Purpose and tasks of the study

The purpose of the study is to develop a conceptual foundation and a working hypothesis for the operation of lift-and-transport machinery with quantum thrust used for quarrying (Quantum Quarrying Lift-and-Transport

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Machinery (QQLTM)) as an idea-driven basis for the modernization of quarrying technology.

To achieve the purpose, it is required to solve the following tasks:

- to describe challenges of rock transportation from the pit bottom to the upper levels;
- to assess specific features and capabilities of QE thrust to ensure lift-and-transport operations related to quarrying;
- to build a mathematical model of QQLTM force balance and motion;
- to analyze numerical examples describing rock transportation with the use of QQLTM;
- to summarize the results of the study and offer recommendations for further studies in this area.

Challenges of rock transportation from the pit bottom to the upper levels

Let us describe general aspects of mining technology and corresponding issues using data on the Lebedinsky Mining and Processing Plant (Lebedinsky GOK) located in the area of the Kursk Magnetic Anomaly (Alekseev, 2012, Vasiliev, 2016, Yandex Zen, 2018a, 2018b). A general view of the Lebedinsky GOK quarry is given in Figure 1.

Figure 1. Lebedinsky GOK quarry (https://cont.ws/uploads/pic/2018/10/a65.jpg).

The amount of ferruginous quartzites annually mined at the Lebedinsky GOK is more than 50 mln t. The open pit has a length of 5 km, a width of 3 km, and a depth of 350 m (Vasiliev, 2016).

After blasting operations and destruction of a rock mass, excavators, front loaders, and bulldozers load ore-bearing rock into dump trucks, which transport and unload it at transfer stations at higher quarry levels. Then, excavators load ore on trains. A mining and processing plant and stockpiles are the final destinations of minerals.

The distance between the levels at the Lebedinsky GOK quarry is 15 m. The number of quarry benches is about 20.

Figure 2 shows a scheme of operations in quarries of such a type. The yellow (Euclidean) line reflects the relationship between the truck loading area at the pit bottom (AB level) and the truck unloading area at the transfer station level (CD level). Trucks move along the expanding spiral of temporary roads (berms) on the lower slope. The route length may be as high as 5 km. The speed of trucks is 10–15 km/h.

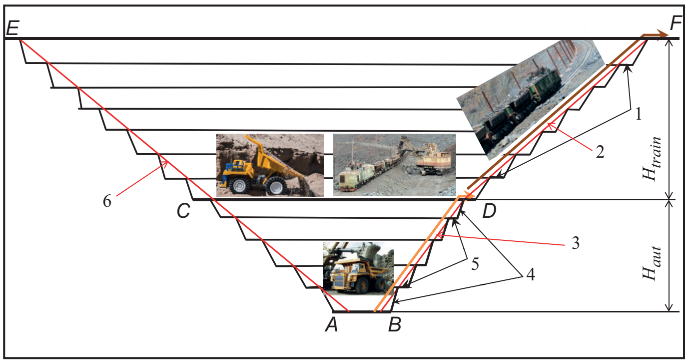

Figure 2. Quarry components and organization of work in quarries: 1 — berms of the upper levels; 2 — slope of the upper highwall; 3 — slope of the lower highwall; 4 – bench faces; 5 — berms of the lower levels; 6 — slope of the spoil bank; H_{aut} — height of the lower slope (road-served); H_{train} — height of the upper slope (rail-served); AB, CD, EF — lower (bottom), intermediate (transfer), and upper (output) levels, respectively.

On the upper slope (in the CEFD space), the rock is transported by railway: traction units including electric locomotives, motor-coach trains, and non-motorized wagons (dumpcarts). Power is supplied from a grid expanding with the railway tracks into the depth of the quarry. Traction units are loaded at the CD level transfer station by excavators. Obviously, such a transfer slows down rock transportation.

The brown (Euclidean) line reflects the relationship between the traction unit loading area at the transfer station (CD level) and the traction unit unloading area at the upper EF level (mining and processing plants for ore-bearing rock or stockpiles for waste rock). Traction units move along the railway network on the upper slope and in adjacent areas. The route length in the CEFD space on the upper slope can be as high as 20 km. The speed of trains moving along the berms of the upper slope is around 15 km/h.

As we can see, the technology of rock transportation from the lower (bottom) to the upper level is quite energy-consuming. Even if we consider only the process described, we should take into account truck loading, movement of trucks on uphill winding roads (berms) for 1–5 km (although, along a Euclidean line, the distance is just 80–100 m), unloading at the CD level storage area, and their movement back. We also should factor in train loading, movement of trains along the temporary low-quality railway network for 5–20 km (although, along a Euclidean line, the distance is just 200–300 m), their movement back, and maneuvering. Material and energy consumption aimed to ensure transportation is rather significant since it is required to lay and maintain roads on the lower slope, ensure the continuous expansion of the railway network and its power supply on the upper slope.

The production of the machinery mentioned is also material- and energy-consuming since the process of design development requires significant expenditures.

As for the quarry operations with the use of automobiles, the main transportation workload falls on 25 large BelAZ-75131 dump trucks (Trucks Review 2019, Vasiliev, 2016). Electric excavators load the dump trucks with rock. The bucket capacity of EKG-8Sh, EKG-10, EKG-11i and EKG-12.5 excavators is 8, 10, 11 and 12.5 m^3, respectively. A dump truck can be filled in 6–10 cycles.

The trucks haul away 40,000 tons of ore and 5000–6000 m^3 of overburden rocks per shift. 120,000 tons of rock mass can be transported per day. For instance, the average monthly excavation volume per BelAZ-75131 can reach 147,000 tons, the average monthly distance covered by a loaded truck — 18,000 km, and the average monthly cargo turnover — 1,720,000 t·km (Vasiliev, 2016).

Based on the foregoing, we can distinguish the following challenges related to rock transportation from the pit bottom to the upper levels (both for the Lebedinsky GOK quarry and other quarries worldwide): 1) low speed of rock transportation; 2) high energy consumption in terms of individual components and the rock transportation process in general; 3) high material intensity in terms of transportation facilities and maintenance of their operation.

These issues can be addressed with the introduction of QQLTM considered in this paper.

Methods

Mathematical model of QQLTM force balance and motion

Thrust vector decomposition

The three-dimensional thrust vector can be decomposed into unit vectors (Leonov, 2018, Kotikov, 2019c, 2019d):

$$\boldsymbol{F_T} = \boldsymbol{F_{Tx}} + \boldsymbol{F_{Ty}} + \boldsymbol{F_{Tz}} \tag{1}$$

Within the framework of the task considered, which is to describe the longitudinal (course) motion of QQLTM in the plane of pitch angle β, equation (1) takes the following form:

$$\boldsymbol{F_T} = \boldsymbol{F_{Tx}} + \boldsymbol{F_{Tz}} \tag{2}$$

The scalar form of this equation is as follows:

$$\sqrt{F_{Tx}{}^2 + F_{Tz}{}^2} \tag{3}$$

Graphically, it is given in Figure 3.

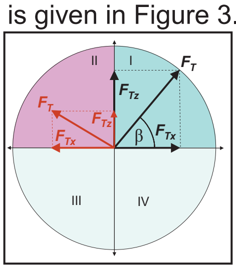

Figure 3. $\boldsymbol{F_T}$ thrust decomposition into the horizontal ($\boldsymbol{F_{Tx}}$) and vertical ($\boldsymbol{F_{Tz}}$) components: β — $\boldsymbol{F_T}$ thrust angle relative to the horizon

Equations (2) and (3) are general initial equations for the calculation of QQLTM motion both in vertical (with the takeoff of cargo from the bottom surface and its lifting) and horizontal direction (transportation of cargo within the level), as well as in case of combined motion along inclined trajectories.

Vectors located on the vertical axis correspond to the true vertical motion of QQLTM (Figure 3). The first (blue) quadrant of the circle formed by the thrust vector tip corresponds to the uniformly accelerating longitudinal motion of QQLTM (with the realization of direct thrust). The second (pink) quadrant corresponds to the longitudinal braking and reverse modes.

QQLTM and ground LTM force balance analyses differ. This is due to the fact that the force balance and motion equation involves new entities and physical quantities, which manifest when vertical forces (gravity, hovering, wind resistance to vertical motion, vertical accelerations) are taken into account.

QQLTM force balance equation and motion equations based on it

Let us modify the force balance equation for a vehicle with a QE, derived by the author earlier (Kotikov, 2019c, 2019d, 2019e), and use it as a working equation:

$$F_T{}^2 = F_{Tx}{}^2 + F_{Tz}{}^2 = \left(P_{w.x} + P_{j.x}\right)^2 + \left(P_{w.z} + P_{j.z} + P_g\right)^2 = \left(k_{w.x} \cdot S_{front} \cdot V_x^2 + \frac{G_{QQLTM}}{g} a_x\right)^2 + \left(\left(k_{w.z} \cdot S_{plan} \cdot V_z^2 + \frac{G_{QQLTM}}{g} a_z\right)\Big|_{F_{Tz} > G_{QQLTM}} + \min(F_{Tz}, G_{QQLTM})\right)^2, \tag{4}$$

where:

F_T, F_{Tx}, F_{Tz} — thrust and its coordinate components, respectively, N;

$P_{w.x}$ — wind resistance to the horizontal motion, N;

$P_{j.x}$ — a force of resistance to horizontal acceleration, N;

$P_{w.z}$ — wind resistance to the vertical motion, N;

$P_{j.z}$ — a force of resistance to vertical acceleration, N;

$P_g = G_{QQLTM}$ — a part of the vertical component of thrust used to neutralize the gravity of loaded QQLTM being transported, N;

V_x — the current velocity of QQLTM longitudinal (course) motion, m/s;

G_{QQLTM} — weight of QQLTM (loaded or unloaded as the case may be), N;

$k_{w.x}$ — QQLTM horizontal (longitudinal) wind shape coefficient, N · s^2/m^4;

S_{front} — the frontage area of QQLTM, m^2;

V_w — the longitudinal velocity of QQLTM relative to the wind (in the present study, $V_w = V_x$), m/s;

g — gravitational acceleration, m/s^2;

a_x — longitudinal acceleration of loaded QQLTM, m/s^2;

$k_{w.z}$ — QQLTM vertical wind shape coefficient, N · s^2/m^4;

S_{plan} — the area of QQLTM in plan view, m^2;

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V_z — vertical motion velocity of QQLTM, m/s;
a_z — vertical acceleration of QQLTM, m/s².

It should be noted that $G_{QQLTM} = G_{QQLTM.0} + G_c$, where $G_{QQLTM.0}$ is the weight of unloaded QQLTM and G_c is the weight of transported cargo with the package.

Equation (4) represents a generalized expression of QQLTM force balance that comprises the following typical cases of QQLTM operation:

1) initial state of QQLTM with cargo (at the pit bottom), $F_{Tz} = 0$;
2) transition mode of partial hovering of loaded QQLTM, when $0 < F_{Tz} < G_{QQLTM}$;
3) boundary mode — with zero contact between cargo and the bearing surface (without QQLTM takeoff), when $F_{Tz} = G_{QQLTM}$;
4) vertical takeoff of QQLTM with acceleration (at $F_{Tz} > G_{QQLTM}$);
5) vertical takeoff of QQLTM with deceleration (at $F_{Tz} < G_{QQLTM}$);
6) vertical landing with downward-directed acceleration ($F_{Tz} < G_{QQLTM}$);
7) vertical landing with downward-directed deceleration ($F_{Tz} > G_{QQLTM}$);
8) mode of final fixation of QQLTM (or rock unloading).

Equation (4) has the following distinctive feature: the "min(F_{Tz}, G_{QQLTM})" equation term represents a force to overcome gravity created by the mass of loaded QQLTM: partially — when at $F_{Tz} \le G_{QQLTM}$ it is not physically possible for QQLTM to take off, or at $F_{Tz} > G_{QQLTM}$ — when gravity is overcome completely, it is possible for QQLTM to take off the bearing surface due to the remaining force $R_{FTz} = F_{Tz} - G_{QQLTM}$.

In one of his papers (Kotikov, 2019e), the author generated several equations for individual cases and QLTM motion modes. Some of them can be of use here:

The velocity of steady motion in a horizontal plane V_x:

$$V_x = \sqrt{\frac{F_{Tx}}{k_{w.x} \cdot S_{front}}} \tag{5}$$

The longitudinal acceleration of QQLTM in the mode of full hovering (at $F_{Tz} = G_{QQLTM}$):

$$a_x = \frac{g}{G_{QQLTM}} (F_{Tx} - k_{w.x} \cdot S_{front} \cdot V_x^2) \tag{6}$$

The maximum possible longitudinal velocity of hovering QQLTM can be determined by setting $a_x = 0$:

$$V_{x.\max} = \sqrt{F_{Tx} / k_{w.x} \cdot S_{front}} \tag{7}$$

The longitudinal acceleration at the initial moment of longitudinal motion of hovering QQLTM can be determined by setting $V_x = 0$:

$$a_x = \frac{F_{Tx} \cdot g}{G_{QQLTM}} \tag{8}$$

The vertical acceleration of QQLTM (at $F_{Tz} > G_{QQLTM}$):

$$a_z = \frac{g}{G_{QQLTM}} (F_{Tz} - G_{QQLTM} - k_{w.z} \cdot S_{plan} \cdot V_z^2) \tag{9}$$

Setting $V_z = 0$, it is possible to calculate the vertical acceleration at the initial moment of QQLTM ascent:

$$a_z = \frac{g}{G_{QQLTM}} (F_{Tz} - G_{QQLTM}) \tag{10}$$

The analysis based on equations (3)...(10) can be complemented with corresponding graphical models. We used Maple software to program the mentioned equations with different graphical representations (Kotikov, 2019d).

Comparative analysis of rock transportation time

We will evaluate the transportation time (and later — energy consumption) with regard to the batch of rock with a mass of 130 t, starting from the moment when a loaded vehicle started moving (at first, BelAZ-75131, and then QQLTM). Let us record the time when the cargo is delivered to the CD level transfer station.

Then we will calculate the transportation time (and later — energy consumption) with regard to the batch of rock with a mass of 130 t to the upper EF level, starting from the moment when a loaded vehicle started moving at the pit bottom and ending with unloading at the EF level. In this case, the cargo with a mass of 130 t is transported with standard vehicles in three stages: transportation with a BelAZ-75131 with unloading at the CD level, loading with an EKG-8i excavator on a train, rail delivery to the EF level. If the cargo is transported with QQLTM, the delivery will not be interrupted.

Transportation from the pit bottom to the transfer station with a dump truck

Let us consider the option with the use of standard technologies. Even if the loaded BelAZ-75131 moves along the berms of the lower slope at a maximum allowable speed of 15 km/h (with no regard for deceleration on turns and when avoiding obstacles), in the case of the statistically average route length of 2 km, the transportation time will be 8 min.

Transportation from the pit bottom to the upper level with two types of standard vehicles

After the delivery by road (8 min mentioned), the cargo is unloaded (2 min) and held at the transfer station to be consolidated with cargo from other trucks and then loaded on a traction train (30 min). The time of transportation by train is 42 min (Allbest, 2019). Therefore, the total transportation time is 82 min.

Since the train capacity is 1040 t (Allbest, 2019, Vasiliev, 2016), then eight rock batches with a mass of 130 t each can be loaded on a train. If we reduce the rail transportation time (30 + 42 = 72 min) to one batch with a mass of 130 t, we will obtain 72/8 = 9 min. Then the reduced time for the transportation of 130 t of rock from the pit bottom to the upper level is 8 + 2 + 9 = 19 min.

Transportation from the pit bottom to the transfer station with QQLTM

Let us consider the option when automobiles are replaced by quantum lift-and-transport machinery

(QQLTM) used at the lower levels of a quarry. Instead of rock transportation with dump trucks along the winding berms of the lower levels (see item 5 in Figure 2), we will consider rock delivery to the transfer station with QQLTM along rectangular trajectory 8 (Figure 4).

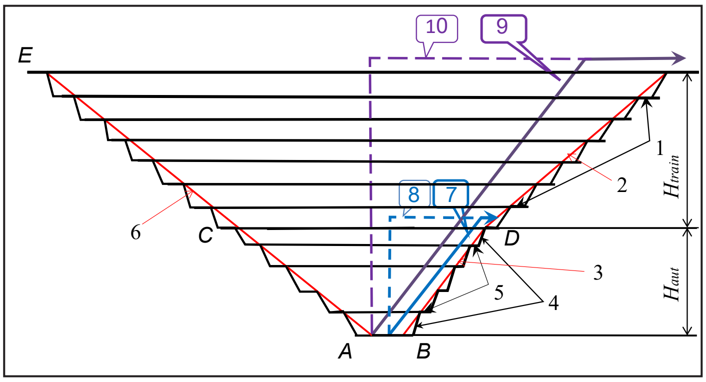

Figure 4. Quarry components and organization of QQLTM motion in quarries: 1 — berms of the upper levels; 2 — slope of the upper highwall; 3 — slope of the lower highwall; 4 — bench faces; 5 — berms of the lower levels; 6 — slope of the spoil bank; 7 — inclined trajectory of QQLTM motion to the transfer station; 8 — rectangular trajectory of QQLTM motion to the transfer station; 9 — inclined trajectory of QQLTM motion to the upper level; 10 — rectangular trajectory of QQLTM motion to the upper level; H_{aut} — height of the lower slope; H_{train} — height of the upper slope.

To substitute BelAZ-75131 for one-time transportation of the batch of rock with a mass of 130 t, we use QQLTM with an own mass of 40 t (30 t — the mass of the load-bearing body (Sibdepo, 2010) + 10 t — the mass of the QE, bearing, fixing, joining and other structural elements (this value is determined by expert estimation)). Then the mass of the loaded machine is 170 t (weight of ≈1700 kN).

It is easy to imagine that QQLTM used for rock transportation can be quickly assembled from two parts: a load-bearing body and a spreader with a QE.

The load-bearing body is designed to accommodate rock. The top of the body is open so that it would be possible for excavators to load the machine with rock at the pit bottom. When the body is filled with rock, the spreader approaches it from above, and the QQLTM structure locks (obviously, it has the required fixing and joining elements). The loaded QQLTM sets off, being lifted with the vertical pulling force of thrust F_{Tz} generated in the QE and applied to the load-bearing body. In the unloading area at the CD level, the QQLTM cargo can be unloaded on the ground or a train wagon. For that purpose, the QQLTM design shall include a dump unloading system (with the tipping axle on one of the body sides). During unloading, the thrust vector shall decrease according to changes in the QQLTM mass. The load-bearing body can be placed on the ground or a train wagon, unlocked from the spreader, and then locked again to return to the pit bottom for another batch of rock.

Let us assume that the upper part of the QQLTM structure is represented by a spreader (like a container spreader (Alfa Group, 2019, Container Spreaders. Com, 2019) but with a larger size and mass) equipped with a QE. We will set other characteristics of loaded QQLTM, required for modeling as per equation (4), by expert estimation: $k_{w.x}$ = 0.8 N×s²/m⁴; S_{front} = 10 m²; $k_{w.z}$ = 0.9 N×s²/m⁴; S_{plan} = 20 m².

By analogy with the substantiation of a case with container transportation (Kotikov, 2019e), we will take the value of maximum thrust as exceeding the total weight of a lift-and-transport machine by 5–6%, i.e. 1800 kN.

Figure 5 shows representations of the QQLTM thrust characteristics: maximum vertical thrust $F_{Tz.acc}$ enabling QQLTM ascent with acceleration along the verticals of rectangular trajectories 8 and 10 (Figure 4), as well as maximum but inclined thrusts $F_{T.acc}$ and $F_{T.dec}$ enabling motion of the hovering QQLTM along the horizontals of rectangular trajectories 8 and 10 (Figure 4). Angles β_{acc} and β_{dec} are equal to 70.8°. $F_{Tz.acc}$ = 1800 kN, $F_{Tz'dec}$ = 1600 kN. $F_{Tz.hov} = G_{QQLTM}$ = 1700 kN, $F_{Tx.acc} = -F_{Tx.dec}$ = 592 kN.

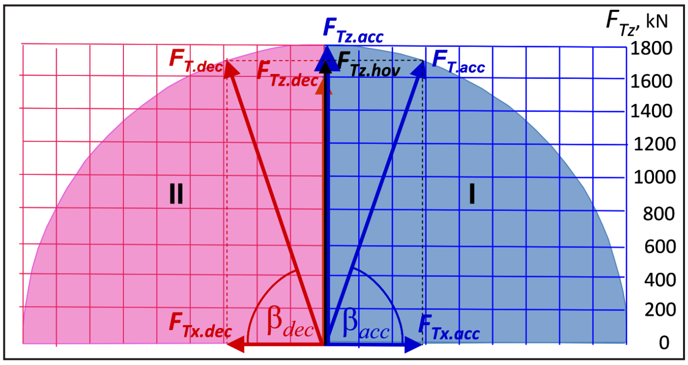

Figure 5. QQLTM thrust characteristics and the correspondence between the thrust representations and motion modes: $F_{Tz.acc}$ — vertical ascent with acceleration (or vertical descent with deceleration); $F_{Tz.hov}$ — hovering; $F_{Tz.dec}$ — vertical ascent with deceleration (or vertical descent with acceleration); $F_{T.acc}$ — horizontal acceleration; $F_{T.dec}$ — horizontal deceleration; $F_{Tx.acc}$ — a horizontal component of accelerating thrust; $F_{Tx.dec}$ — a horizontal component of decelerating thrust; β_{acc} and β_{dec} — inclination angles of accelerating and decelerating thrusts, respectively.

Let us assume that rectangular trajectory 8 for the motion of loaded QQLTM is determined as follows (Figure 4):

1) vertical ascent to a height of 78 m (3 m higher than the CD level): with acceleration and then with deceleration to V_z = 0; 2) horizontal motion for 90 m: uniformly accelerated and uniformly decelerated to V_x = 0; 3) bin unloading.

1. Vertical acceleration is conditioned by the fact that the value of vertical thrust exceeds the QQLTM weight (i.e. 1800 – 1700 = 100 kN, see Figure 5):

$$a_z = \frac{g}{G_{QQLTM}}(F_{Tz.acc} - G_{QQLTM}) =$$

$$9.8 * (1800 - 1700)/1700 = 0.576 \text{ m/s}^2$$

(which can be accepted).

Then the ascent time to a height of 78/2 = 39 m: t = sqrt(2h/a_z) = sqrt(2*39/0.576) = 11.6 s.

Vertical velocity (at the moment when a height of 39 m is reached) V_z = sqrt(2a_z*h) = sqrt(2*0.576*39) = 6.7 m/s (which also can be accepted).

Let us calculate the value of wind resistance at this speed:

$P_{w.z}=k_{wz} \cdot S_{PLAN} \cdot V_z^2 =$ 0.9 N×s²/m⁴ * 20 m² * 6.72 m²/s² = 808 N = 0.808 kN. Thus, we obtain a rather small value (0.8%) (when compared with the excess vertical thrust). Therefore, we can neglect wind resistance at such QQLTM speeds.

Let us assume that QQLTM decelerates in a mirror-like manner with respect to acceleration, now with an acceleration of –0.576 m/s². This is possible due to the fact that the value of vertical thrust falls short of the QQLTM weight (i.e. 1600 – 1700 = –100 kN, see Figure 5):

$$a_z = \frac{g}{G_{QQLTM}}(F_{Tz.dec} - G_{QQLTM}) =$$

$$9.8 * (1600 - 1700)/1700 = -0.576 \text{ m/s}^2.$$

Then the total time of ascent to a height of 78 m: t = 11.6 * 2 = 23.2 s.

2. The horizontal motion at the section of 90 m similarly comprises such stages as acceleration and deceleration.

Acceleration:

$$a_x = \frac{F_{Tx.acc} \cdot g}{G_{QQLTM}} =$$

$$592 \text{ kN} * 9.8 \text{ m/s}^2 / 1700 \text{ kN} = 3.41 \text{ m/s}^2.$$

The acceleration time at the section of 45 m:
t = sqrt($2l/a_x$) = sqrt(2*45/3.41) = 5.14 s.

Let us assume that QQLTM decelerates in a mirror-like manner with respect to acceleration, now with an acceleration of –3.41 m/s². Then the total time of horizontal motion at the section of 90 m: t = 5.14 * 2 ≈ 10.3 s.

The total time of rock transportation from the pit bottom to the transfer station at the CD level: t = 23.2 + 10.3 = 33.5 s.

Let us compare this result with the time of transportation with a BelAZ-75131 truck. When it moves along the berms of the lower slope at a speed of 15 km/h and the statistically average route length is 2 km, the transportation time will be 8 min. Therefore, the time of transportation with QQLTM is 480 s / 33.5 s =14 times lower than the time of transportation with a truck.

Transportation from the pit bottom to the upper EF level with QQLTM

Let us assume that rectangular trajectory 10 for the motion of loaded QQLTM is determined as follows (Figure 4):

1) vertical ascent to a height of 350 m: with acceleration and then with deceleration to V_z = 0;

2) horizontal motion for 500 m: uniformly accelerated and uniformly decelerated to V_x = 0; 3) bin unloading.

1. Vertical acceleration is conditioned by the fact that the value of vertical thrust exceeds the QQLTM weight (i.e. 1800 – 1700 = 100 kN):

$$a_z = \frac{g}{G_{QQLTM}}(F_{Tz.acc} - G_{QQLTM}) =$$

$$9.8\ (1800 - 1700)/1700 = 0.576 \text{ m/s}^2$$

(which can be accepted).

Then the ascent time to a height of 350/2 = 175 m: t = sqrt($2h/a_z$) = sqrt(2*175/0.576) = 24.65 s.

Vertical velocity (at the moment when a height of 175 m is reached) V_z = sqrt($2a_z*h$) = sqrt(2*0.576*175) = 14.2 m/s (which also can be accepted).

Let us calculate the value of wind resistance at this speed:

$$P_{w.z} = k_{w.z} \cdot S_{plan} \cdot V_z^2 = 0.9 \text{ N·s}^2/\text{m}^4 * 20 \text{ m}^2 *$$

$$* 14.2^2 \text{ m}^2/\text{s}^2 = 3629 \text{ N} = 3.629 \text{ kN}.$$

Thus, we obtain a rather small value (3.6%) (when compared with the excess vertical thrust). Therefore, we can neglect wind resistance at such QQLTM speed.

Let us assume that QQLTM decelerates in a mirror-like manner with respect to acceleration, now with an acceleration of –0.576 m/s². Then the total time of ascent to a height of 350 m: t = 24.65 * 2 = 49.3 s.

2. The horizontal motion at the section of 500 m similarly comprises such stages as acceleration and deceleration.

Acceleration (quadrant I, Figure 5):

$$a_x = \frac{F_{Tx.acc} \cdot g}{G_{QQLTM}} =$$

$$592 \text{ kN} * 9.8 \text{ m/s}^2 / 1700 \text{ kN} = 3.41 \text{ m/s}^2.$$

The acceleration time at the section of 250 m: t = sqrt($2l/a_x$) = sqrt(2*250/3.41) = 12.1 s.

Let us assume that QQLTM decelerates (quadrant II) in a mirror-like manner with respect to acceleration, now with an acceleration of –3.41 m/s². Then the total time of horizontal motion at the section of 500 m: t = 12.1 * 2 = 24.2 s.

The total time of rock transportation from the pit bottom to the upper EF level:

t = 49.3 + 24.2 = 73.5 s ≈ 1.3 min.

Let us compare this result with the total time required to transport 130 t of rock with two types of standard vehicles, involving transshipment (the reduced time was 19 min). We can state that cargo can be transported with QQLTM 19/1.3 ≈ 14 times faster.

Comparative analysis of energy consumption for rock transportation

Transportation from the pit bottom to the transfer station with a BelAZ dump truck

Just to be on the safe side, let us determine energy consumption for rock transportation with a BelAZ-75131 dump truck in two ways: 1) considering standard pre-determined fuel consumption for transportation (in g/(t-km)); 2) considering statistical fuel consumption required to lift 1 t of rock to a height of 1 m.

Method 1. According to Lel’ et al. (2017), standard values of fuel consumption by dump trucks can be presented in the form of a nomogram in Figure 6.

In our case, N_a = ƒ (L, м) =ƒ (2.0; 3.0) ≈ 100 g/t-km. If 130 t of rock are transported for 2 km, then diesel fuel consumption will be 100 g/t-km * 130 t * 2 km = 26 kg.

Method 2. According to Voroshilov and Lel’ (2009), the relationship between the specific fuel consumption by BelAZ-7519 (similar to BelAZ-55131 in terms of specifications) when hill-climbing (P) and inclination (i) and rolling resistance (ω_0) can be presented in the form of a nomogram in Figure 7.

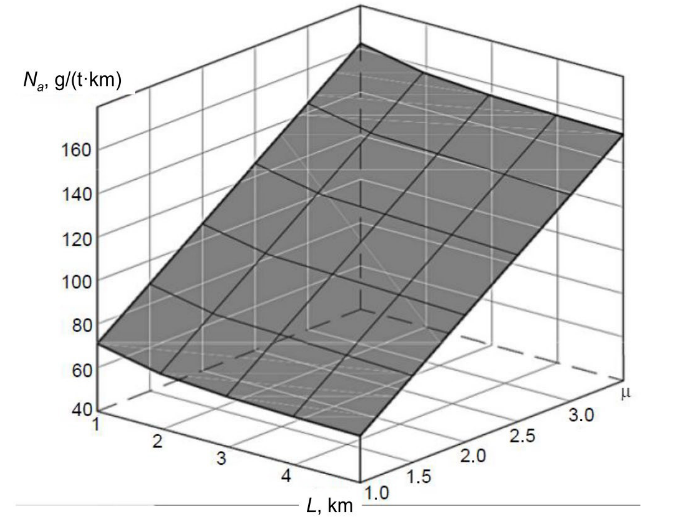

Figure 6. Standard values of fuel consumption by a dump truck N_a, g/(t·km) vs. transportation distance *L* and route complexity factor μ.

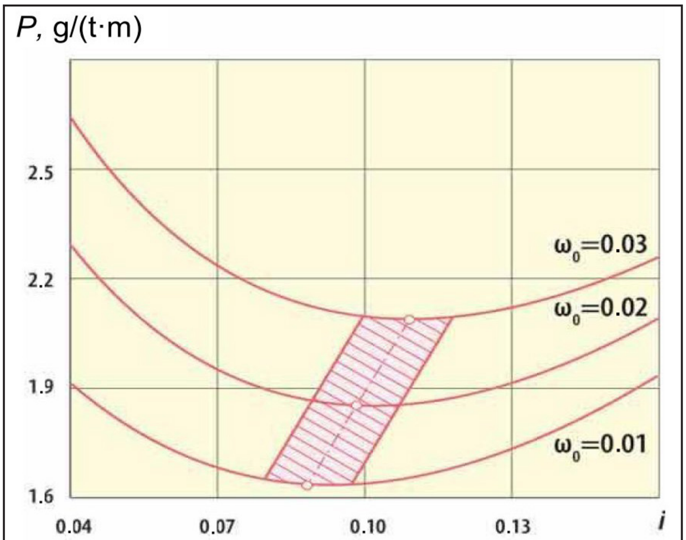

Figure 7. Specific fuel consumption by BelAZ-7519 when hill-climbing (P) vs. inclination (i) and rolling resistance (ω_0).

In our case, inclination *i* = 80 m/2000 m = 0.04. Then, for ω_0 = 0.03, P = 2.7 g/t-m. To transport 130 t of rock to a height of 80 m, diesel fuel in the amount of 2.7 g/t-m * 130t * 80 m = 26.325 kg will be required.

The calculation results are quite similar. Let us settle on the value of 26 kg and convert that to MJ: E_{Aut} = 26 kg * 42.7 MJ/kg =1110 MJ.

Transportation from the pit bottom to the upper level with two types of standard vehicles

On the CD level, rock is loaded on train wagons by EKG-8i excavators with a standard specific consumption of 1.11 kWh/m³ (Vunivere.ru, 2019).

At the iron ore bulk density of 2 t/m³ (Engineering reference book. DPVA.ru tables, 2019), rock with a mass of 130 t occupies a volume of 65 m³. Therefore, during the loading of 130 t of ore on a train using EKG-8i excavators, energy consumption amounts to 65 m³ * 1.11 kWh/m³ = 72.15 kWh = 259,740 kJ ≈ 260 MJ.

Let us determine energy consumption for rail transportation based on data (Voroshilov and Lel', 2009) on energy consumption required to lift 1 t of rock to a height of 1 m.

Specific energy consumption of railway transport required to transport rock mass from quarries is 0.009–0.012 kWh/t·m (Voroshilov and Lel', 2009). Let us take this value equal to 0.01 kWh/t·m. Then, to deliver 130 t of ore to a height of 270 m, energy in the amount of 0.01 * 130 * 270 = 351 kWh ≈ 1264 MJ will be required.

Total energy consumption for rock transportation from the pit bottom to the upper level with two types of standard vehicles, involving transshipment, will amount to 1110 + 260 + 1264 = 2634 MJ.

Transportation from the pit bottom to the transfer station with QQLTM

When rock is transported with QQLTM, the energy of the physical vacuum is used to generate the bearing thrust vector.

The route consists of vertical and horizontal components: *L* = 78 + 90 = 168 m. The value of the thrust vector at the section of ascent with acceleration (39 m) $F_{Tz.\ acc}$ = 1800 kN, at the section of ascent with deceleration (39 m) — $F_{Tz.dec}$ = 1600 kN, at horizontal sections — F_T = 1800 kN (only its direction changes when switching from acceleration to deceleration). The work done is as follows: A = 1800 kN * 39 m + 1600 kN * 39 m + 1800 kN * 90 m = 294,600 kJ.

It shall be particularly noted that despite the fact that horizontal motion is initiated by the horizontal component of thrust F_T, i.e. force F_{Tx} = 592 kN, the corresponding work done at the horizontal section of 90 m is determined by force F_T = 1800 kN, since energy of motion here is associated with the simultaneous gravity overcoming (accompanied by energy consumption) and QQLTM support at a height within the entire section of horizontal motion.

Since 10% of power flow (for the purposes of discussion and with account for the results of studies (Leonov, 2010)) are spent for QE operation related to the extraction of energy from the physical vacuum and thrust generation, energy consumption will amount to the following: E_{QQLTM} = *A* * 1.1 = 324,060 kJ ≈ 324 MJ.

Let us compare the values of energy consumption: E_{Aut} / E_{QQLTM} = 1110 MJ / 324 MJ = 3.43. In other words, during transportation with QQLTM, energy consumption is 3.43 times less.

Transportation from the pit bottom to the upper level with QQLTM

The route consists of vertical and horizontal components: *L* = 350 + 500 = 850 m. The value of the thrust vector at the section of ascent with acceleration (175 m) $F_{Tz.acc}$ = 1800 kN, at the section of ascent with

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deceleration (175m) — $F_{Tz.dec}$ = 1600 kN, at horizontal sections — F_T = 1800 kN (only its direction changes when switching from acceleration to deceleration). The work done is as follows: A = 1800 kN * 175 m + 1600 kN * 175 m + 1800 kN * 500 m = 1,495,000 kJ = 1495 MJ.

Since 10% of power flow are spent for QE operation, energy consumption will amount to the following: $E_{QQLTM} = A * 1.1$ = 1,644,500 kJ ≈ 1645 MJ.

Let us compare the values of energy consumption: $E_{Aut+Train} / E_{QQLTM}$ = 2634 MJ / 1645 MJ = 1.6. In other words, during transportation with QQLTM, energy consumption is 1.6 times less.

Discussion

The calculation results are summarized in Table 1.

Table 1. Results of the comparative analysis for two methods of rock transportation.

Transportation area	Transportation time, min		Vehicle substitution effect multiplicity, times	Energy consumption, MJ		Vehicle substitution effect multiplicity, times
	Standard transport	QQLTM		Standard transport	QQLTM	
Lower slopes	8	0.56	14	1110	324	3.43
All slopes (total)	19	1.3	14	2634	1645	1.6

It can be seen that, with the use of QQLTM, the time required to deliver rock from the pit bottom can be decreased by an order and energy consumption can be reduced by 1.5–3 times.

Despite the fact that the example of QQLTM motion along the rectangular trajectory with sudden changes in the nature of motion (switching from vertical motion to horizontal, rough thrust vector switching, and, as a consequence, rough changes in QQLTM accelerations) is rather simple, we have managed to get an overview of QQLTM motion.

Sure enough, QQLTM motion can be more complex and elegant, with inclined ascents and descents, maneuvering over the facilities of a quarry, consideration of the difference between ascent and descent stages as well as their specifics (in contrast with their “mirror-like” nature).

Transportation operations at a mining and processing plant require at least a half of total economic expenditures and energy consumption. Besides, since the quarry space intended for transportation is tight and challenging, rock excavation is carried out rather slowly. The continuous process of preparing road and railway vehicles for rock transportation is also time- and material-consuming. QQLTM can reduce all the mentioned expenditures significantly: first, due to the possibility of using the air space of a quarry for transportation; second, due to the elimination of labor-consuming road works; and third, due to the substitution of material-consuming road-building machinery, transport equipment, and power supply facilities.

In case of mass use of QQLTM, dispatching can be performed with the distribution of trajectories in a 3D space, where all QQLTM units are unified by a single purpose — prompt delivery of rock to destination points.

QQLTM can be introduced by stages: at first, trucks (ABCD in Figures 2 and 4), and then railway transport (CDEF) will be substituted. It is possible that in the long run rock transportation from the pit bottom directly to mining and processing plants as wells as stockpiles will be carried out by joint groups of unified QQLTM controlled by automatic control systems.

With no trucks and trains on the slopes of a quarry, it will be possible to perform mining development not only in the pit bottom but on the slopes as well. This will speed up quarrying in general. It is likely that the new methods of extracting energy from the physical vacuum will result in the modernization of equipment and technologies used for mining development.

The aspects discussed will be elaborated in detail with the development of quantum machinery.

Conclusion

The study shows that given the actual realization of the idea and implementation of the principles of non-fuel energy production based on the extraction of energy from the physical vacuum, the presented QQLTM concept and its use in quarrying technology are rather sounded. However, the actual realization of the QQLTM concept will require significant research and implementation efforts of the scientific and technical community in the area of non-fuel energy production, which is currently in its infancy. In the course of its development, materials, equipment, and technologies will improve as well, which will determine the difference of future QQLTM from the hypothetical machine and its use described in this paper.

As for future global exploration and implementation efforts in the extraction of energy from the physical vacuum, if we limit the range of problems by the transport industry, then the solution of the QE development problem will play a key role in a breakthrough to new technologies. In the short term, it will be necessary to accelerate efforts in searching for required QE designs and the technological capabilities of their manufacturing.

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КВАНТОВАЯ КАРЬЕРНАЯ ПОДЪЕМНО-ТРАНСПОРТНАЯ МАШИНА

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Аннотация

Освоение способов извлечения энергии из физического вакуума и внедрение их в инженерную деятельность изменит механику движения и характер использования подъемно-транспортных средств, при установке на них квантовых двигателей (КвД). **Цель.** Формирование концепции и рабочей гипотезы функционирования квантовой карьерной подъемно-транспортной машины (QQLTM). **Проблемы**. Рассматриваются проблемы доставки горной породы со дна карьера на верхние уровни. **Методы.** Разложение вектора траста на ортогональные компоненты. Формирование уравнения силового баланса и движения QQLTM. Определение характерных режимов QQLTM. Расчетные и графоаналитические исследования. **Результаты.** Представлены результаты вычислений времени перемещения и энергозатрат по переносу горной породы на конкретных примерах движения груженого QQLTM со дна карьера на перегрузочную площадку и верхний горизонт карьера. **Обсуждение.** Существующие комплексы автомобильных, железнодорожных транспортных средств и погрузочно-разгрузочной техники могут быть заменены группами транспортирующих машин с КвД в их конструкциях – QQLTM. Это позволит существенно совершенствовать технологию разработки карьеров (quarrying), внедрить непрерывное перемещение груза без перегрузки с одного вида транспорта на другой и значительно снизить энергозатраты, уровень материальных и трудозатрат.

Ключевые слова

Квантовый двигатель, квантовая тяга, квантомобиль, квантовая карьерная подъемно-транспортная машина, силовой баланс, разработка карьера.