DOI: 10.23968/2500-0055-2019-4-2-53-60

Surface Transportation Engineering Technology

ACTUALIZATION OF THE QUANTOMOBILE FORCE BALANCE IN THE PITCH PLANE

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Abstract

Introduction: As we approach introduction of quantum engines (QE) into the transportation industry, it will be useful to analyze properties of a hypothetical automobile with a QE (quantomobile). The purpose of the study is to conduct a calculation analysis of the quantomobile force balance and options of its motion in the pitch plane. **Methods**: Assuming that it is possible for a quantum engine to generate the vertical component of the thrust vector (of anti-gravity orientation), a two-dimensional approach to analyze the quantomobile force balance is used. A generalized force balance equation for all quantomobile motion modes in the longitudinal pitch plane is derived. Five typical motion modes are identified. The graphic images provided represent a part of the combination of analytical actions intended to record and comprehend the distinctive end points and curves. **Results**: The numerical examples based on the mentioned force balance equation allowed us to construe the quantomobile motion modes in the pitch plane, as well as obtain a picture of uniform course motion of the quantomobile. **Discussion**. The analysis revealed that it was possible to minimize the thrust for maintaining constant speed under the middle degree of vehicle suspension. The derived force balance equation that matches the 2D option of quantomobile motion in the pitch plane can be expanded to the 3D option of vehicle motion. This will make it possible to assess the dynamics and energetics of quantomobile motion in a three-dimensional space in more detail, as well as compare such vehicles with other vehicles operating in this space, e.g. planes, helicopters, etc.

Keywords

Automobile, quantum engine, quantum thrust, quantomobile, pitch plane, force balance.

Introduction

Fundamental discoveries of the quantized space-time (QSP) with its structural particle — the quanton — in combination with the theory of Superunification can radically change the principles of power generation and conversion (Leonov, 2002, 2010, 2018). One of the conclusions of the theory of Superunification is the possibility of direct extraction of energy from the physical vacuum.

A new generation of vehicles with quantum engines (QE) — quantomobiles — will replace automobiles. The main difference of the QE from the ICE is that the QE directly generates thrust, which can be applied to the vehicle body to create motion (Brandenburg, 2017; Fetta, 2014; Frolov, 2017; Shawyer, 2006; Tajmar et al., 2007).

Changing the thrust vector position from horizontal to inclined (almost to the vertical plane) will allow creating a vertical component of traction that can be used to overcome gravitation and get the quantomobile above the bearing surface to establish the quantum flying car mode (Kotikov, 2018a).

In earlier papers (Kotikov, 2018a, 2018b, 2018c, 2019a, 2019b), the author described individual aspects of the topic. In future, quantum energetics will be mastered and used in mass consumption. In this regard, now it would be useful to study theoretical aspects and specifics of future quantomobiles.

In the papers mentioned above, the author described basic differences between quantomobiles and modern automobiles in terms of design and loading pattern, as well as functional differences in forming and managing traction and speed properties of automobiles and quantomobiles — with regard to motion along the bearing surface (without suspension of a vehicle above the surface). Examples of calculating traction and power consumption are given, and a relevant quantitative analysis has been conducted.

Purpose and tasks of the study

Purpose of the study: deepen the knowledge of the force balance and options of its use in the longitudinal pitch plane, including with breakoff from the bearing surface and suspension above it.

For achievement of this purpose we plan the decision of following tasks:

1. Develop a generalized force balance equation for all quantomobile motion modes, including breakoff from the bearing surface.
2. Provide graphic images as a part of the combination of analytical actions intended to record and comprehend the distinctive end points and curves.
3. Provide numerical and graphic examples.
4. Discuss the results and define the prospect of topic elaboration.

Methods

Thrust generation by a quantum engine and decomposition of the thrust vector

The basic principle of QE operation is that the vacuum environment is deformed in the body of the QE operating unit that actively interacts with the vacuum environment of the QE. The internal thrust appears in the body of the operating unit (thrust $\boldsymbol{F_T}$). This thrust rests upon an elastic fragment of the continuous vacuum environment (field) and, when applied to the QE structure, it can make it move relative to the field (Brandenburg, 2017; Fetta, 2014; Frolov, 2017; Leonov, 2002, 2010, 2018; Shawyer, 2006; Tajmar, 2007).

Let us decompose the three-dimensional thrust vector into unit vectors (Leonov, 2018):

$$\mathbf{F_T} = \mathbf{F_{Tx}} + \mathbf{F_{Ty}} + \mathbf{F_{Tz}} \qquad (1)$$

The scalar form of this equation is as follows:

$$F_T = \sqrt{F_{Tx}^2 + F_{Ty}^2 + F_{Tz}^2} \qquad (2)$$

Equations (1) and (2) are general initial equations for calculation of quantomobile motion both along the bearing surface and at vehicle breakoff from the surface (in the quantum flying car option), as well as in the mode of lateral motion correction.

Within the tasks of the study, i.e. only longitudinal pitch motion of the vehicle, α, equations (1) and (2) take the following form:

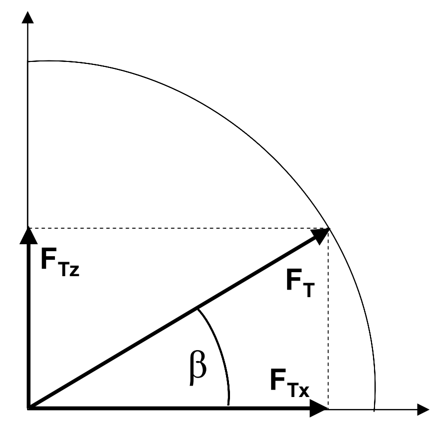

Figure 1. $\boldsymbol{F_T}$ thrust decomposition into the horizontal ($\boldsymbol{F_{Tx}}$) and vertical ($\boldsymbol{F_{Tz}}$) components: β — thrust angle $\boldsymbol{F_{Tz}}$ relative to the horizon.

$$\mathbf{F_T} = \mathbf{F_{Tx}} + \mathbf{F_{Tz}} \qquad (3)$$

The scalar form of this equation is as follows:

$$F_T = \sqrt{F_{Tx}^2 + F_{Tz}^2} \qquad (4)$$

Graphically, it is given in Figure 1.

It can be seen that representing the F_T thrust value by the arithmetic sum of scalar values of the F_{Tx} horizontal thrust and F_{Tz} vertical carrying capacity (i.e. $F_T = F_{Tx} + F_{Tz}$) will be deeply incorrect (since there is geometric addition of the vectors). The quantomobile force balance analysis will therefore differ from that of the common automobile force balance, which will be described below.

Developing a generalized quantomobile force balance equation

Let us start deriving a generalized quantomobile force balance equation from the known equation of automobile motion along the horizontal bearing surface (Jacobson, 2016; Jante, 1958; Kotikov, 2006; Selifonov, 2007) (it corresponds to motion of a quantomobile with only driven wheels, without any vertical suspension of the vehicle):

$$F_{Tx} = P_T = P_f + P_w + P_j = G_q f_{wh.0}(1 + f_{wh.v} V_x^2) + k_{w.x} S_{front} V_w^2 + \frac{G_q}{g} a_x \cdot (1 + \delta_{wh}), \qquad (5)$$

where P_T is the thrust, N;

P_f is the force of resistance to the rolling of driven wheels, N;

P_w is the wind resistance, N;

P_j is the vehicle inertia force, N;

G_q is the quantomobile weight, N;

$f_{wh.0}$ is the coefficient of resistance to the rolling of driven wheels at a speed close to zero, and $F_{Tz} = 0$ (if there is no suspension or pressing-down of the vehicle);

$f_{wh.v}$ is the velocity coefficient of resistance to the rolling of driven wheels 3–4 s^2/m^2 (Jacobson, 2016; Jante, 1958; Selifonov, 2007);

V_x is the current speed of longitudinal (course) motion of the vehicle, m/s;

$k_{w.x}$ is the horizontal (longitudinal) wind shape coefficient, $N \cdot s^2/m^4$;

S_{front} is the frontage area of the vehicle, m^2;

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

g is the gravitational acceleration, m/s^2;

a_x is the longitudinal acceleration of the vehicle, m/s^2;

δ_{wh} is the rotational inertia coefficient of driven carrying wheels.

At actualization of the vertical component of the thrust F_{Tz}, modernization of equation (4), taking into account (5), generally results in the following expression:

$$F_T^2 = F_{Tx}^2 + F_{Tz}^2 = (f_{wh.0}(1+f_{wh.v}\cdot V_x^2)\cdot (G_q - F_{Tz})\big|_{F_{Tz}\le G_q} + k_{w.x}\cdot S_{front}\cdot V_w^2 + \frac{G_q}{g}a_x\cdot(1+\delta_{wh}))^2 + \left((k_{w.z}\cdot S_{plan}\cdot V_z^2 + \frac{G_q}{g}a_z)\big|_{F_{Tz}>G_q} + \min(F_{Tz},G_q)\right)^2, \quad (6)$$

where $k_{w.z}$ – vertical wind shape coefficient, N·s²/m⁴;

S_{plan} is the vehicle area in plan view, m²;

V_z is the vertical motion speed of the vehicle, m/s;

a_z is the vertical acceleration of the vehicle, m/s²;

$\big|F_{Tz} \le G_q$ is the range of allowable values of F_{Tz} in the pressing-down mode (downwards – to improve stability) or partial suspension of the vehicle (without breakoff from the bearing surface);

$\big|F_{Tz} > G_q$ is the range of allowable values of F_{Tz} in the mode of full suspension of the vehicle above the bearing surface (with possible breakoff from the surface).

Equation (6) represents a generalized expression of the quantomobile force balance that comprises all typical cases of quantomobile motion:

1. only longitudinal motion – in the vehicle pressing-down mode, with the vertical component of the thrust $F_{Tz} < 0$, i.e. at downward motion;
2. only longitudinal motion – in the mode of a conventional automobile with no vertical component of the thrust, $F_{Tz} = 0$;
3. longitudinal motion – in the mode of partial suspension of the vehicle, without wheels' breakoff from the bearing surface, when $0 < F_{Tz} < G_q$;
4. longitudinal boundary motion – with the wheels touching the bearing surface (without connecting to it, but without vehicle breakoff upwards), when $F_{Tz} = G_q$;
5. longitudinal and vertical (with vehicle breakoff from the bearing surface) – when $F_{Tz} > G_q$.

There are some peculiarities of using equation (6):

- for cases 1-3, the coefficient of resistance to the rolling of driven wheels at a speed close to zero $f_{w.0}$, as well as the rotational inertia coefficient of wheels δ_{wh} are relevant (e.g. $f_{w.0} = 0.3$; $\delta_{wh} = 0.04$);
- for cases 5) and 6), these coefficients become zero (which is, however, backed up in equation (6) by determinative ranges of values of F_{Tz}: $\big|F_{Tz} \le G_q$ and $\big|F_{Tz} > G_q$;
- the term of equation "min(F_{Tz}, G_q)" represents a force to overcome gravity created by the vehicle mass: partially – when at $F_{Tz} \le G_q$, it is not physically possible for the vehicle to go upwards, or at $F_{Tz} > G_q$, when gravity is overcome completely, it is possible for the vehicle to break off due to the remaining force $R_{FTz} = F_{Tz} – G_q$;
- Equation (6) does not take into account vertical movement of the vehicle when the value F_{Tz} changes in cases of motion 1-3, which (though insignificant) will occur because of deformation of tires and soil flexibility. Vertically oriented speed and acceleration actualized in this case will be massively smaller than the speed V_z and acceleration az at vehicle breakoff with $F_{Tz} > G_q$ – therefore, we neglect those values in this study.

Results: special cases and their numerical examples

For the quantitative analysis, we choose a hypothetical quantomobile with the specifications of a similar automobile (KamAZ-4326) with a QE (instead of the ICE), used in the previous analysis (see in detail in (Kotikov, 2018c, 2019a)), under extremely severe conditions of motion (sand, silt, swamps (Pauwelussen, 2007; Popov, 2003)):

G_q = 88,000 N; Sfront = 7 m²; $f_{w.0}$ = 0.3; $f_{wh.v}$ = = 4·10⁻⁴ s²/m²; $k_{w.x}$ = 0.5 N·s²/m⁴.

We will also use the following values of variables determining the force balance of the quantomobile under consideration for vertical components of its motion:

$k_{w.z}$ = 0.8 N·s²/m⁴; S_{plan} = 7·2.5 = 17.5 m².

Let us agree that the maximum value of the QE thrust, with this value maintained in the pitch plane in the range of directions β = 0–90º, equals F_T = 90 kN (with a small margin relative to the quantomobile weight $R_T = F_T – G_q$ = 90–88 = 2 kN). The remaining thrust force R_T = 2 kN is provided for the quantum flying car to be able to move horizontally in a suspended condition or break off from the bearing surface.

Let us provide calculations of two values of F_{Tz} for the automobile mode (without any suspension of the quantomobile, i.e. for case 2 when F_{Tz} = 0) at the steady uniform motion (a_x = 0), performed according to equation (6):

0 km/h: F_{Tx} = 88,000 · 0.3 =26,400 N;

67.2 m/s (242 km/h): F_{Tx} = 88,000·0.3 (1 + 4·10⁻⁴ · · 67.2²) + 0.5·7·67.22 = 88,000·0.3 (1 + 1.8063) + 15,805 = 74,086 + 15,805 = 89,892 N.

The quantomobile force balance at steady motion for the whole range of speeds is given as yellow *CD* curve in Figure 2. If the maximum value of the thrust is limited to, for example, 90,000 N, then the point of intersection of the curve with the limiting red line F_T = 90 kN will determine the maximum speed of quantomobile motion (here, 242 km/h = 67.2 m/s) at strictly horizontal direction of the thrust vector (no suspension of the vehicle).

At speeds V < 67.2 m/s, the available thrust resource can be used for vehicle acceleration. For instance, for the quantomobile under consideration, equation (6) can be converted as follows:

$$89892 - F_{Tx} = \frac{G_q}{g}a_x\cdot(1+\delta_{wh}), \quad (7)$$

where δ_{wh} = 0.04 is taken.

Then, the following working equation can be derived for horizontal acceleration:

a_x = (89,892 – F_{Tx}) 9.81 / (88,000·1.04) = = (89,892 – F_{Tx}) / 9,329.

Initial acceleration at V = 0 km/h will be (89,892 – – 26,400) / 9,329 = 63,492 / 9,329 = 6.8 m/s².

The whole acceleration curve *AB* is given in Figure 2 in green. The field of conditions when acceleration of a non-suspended quantomobile is possible is colored in light green.

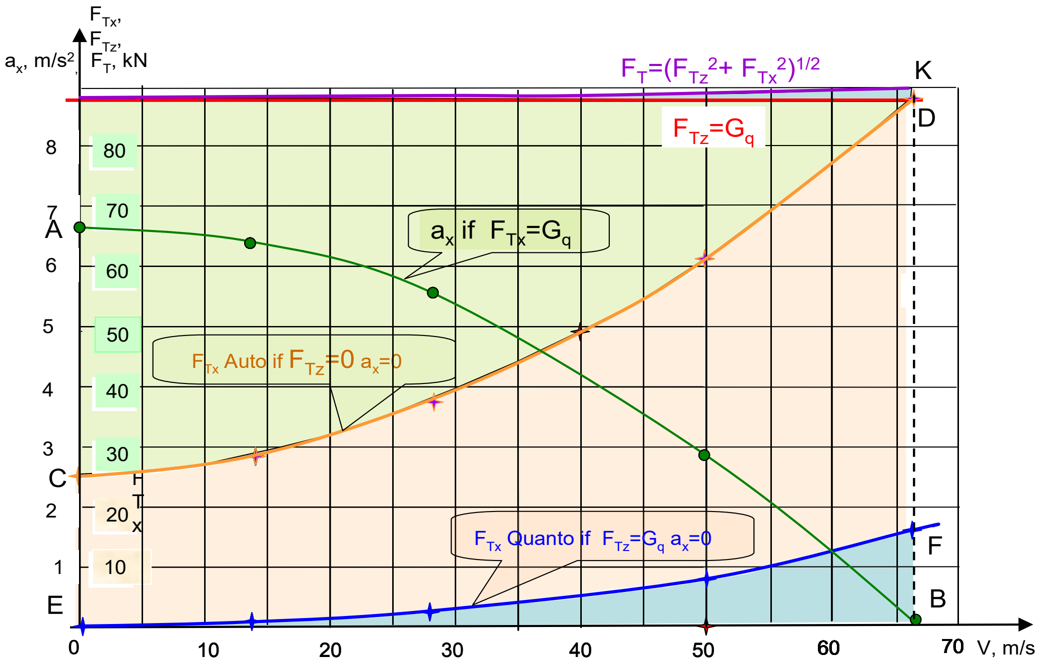

Figure 2. Force balance at steady motion of the quantomobile along the bearing surface with $f_{wh.0}$ = 0.3.

Let us review the use of equation (6) in the analysis of the moment of quantomobile breakoff (without fly-off) from the bearing surface (case 4 of the motion modes listed above, when $F_{Tz} = G_q$). In this case, $\delta_{wh} = 0$, $V_z = 0$, $a_z = 0$, and equation (6) can be simplified as follows:

$$F_T^2 = F_{Tx}^2 + F_{Tz}^2 = \left(k_{w.x} \cdot S_{front} \cdot V_w^2 + \frac{G_q}{g} a_x\right)^2 + (G_q)^2 \quad (8)$$

Taking into account that $F_{Tz} = G_q$, the balance of horizontal forces can be simplified as follows:

$$F_{Tx} = k_{w.x} \cdot S_{front} \cdot V_w^2 + \frac{G_q}{g} a_x. \quad (9)$$

At $a_x = 0$, the F_{Tx} value necessary to maintain uniform longitudinal (horizontal) motion (hovering, at the moment of wheels' breakoff from the bearing surface) (see the *EF* blue curve in Figure 2) is as follows:

at V = 0 km/h: F_{Tx} = 0.5·7·0² = 0 N;

at V = 67.2 m/s (242 km/h): F_{Tx} = 0.5·7·67.2² = 15,805 N (see point *F* in Figure 2).

Then, the required value of the QE thrust F_T will be:

$F_T = (F_{Tz}^2 + F_{Tx}^2)^{1/2}$ = (88,000² + 15,805²)^½ = = (7,744,000,000 + 249,798,025)^½ = (7,993,800,000)^½ = = 89,408 N (see point *K* in Figure 2).

The thrust angle can be found through the following equation:

β = arctan (F_{Tz} / F_{Tx}) = arctan (88 / 15,805) = 79.82°.

Please note that there is practical coincidence of the thrust values for steady motion at the speed of 67.2 m/s in the automobile mode (case 2: $F_T = F_{Tx}$ = 89.9 kN) and in a fully suspended condition of the vehicle (case 4: $F_T = (F_{Tz}^2 + F_{Tx}^2)^{1/2}$ = (882 + 15.82)^{1/2} = 89.4 kN). In other words, the course speed of 67.2 m/s can be achieved through actualization of the same thrust value ~ 90 kN, but by different methods: case 2 – horizontal thrust; case 4 – thrust angle β = 79.8° relative to the horizon. Such special combination will allow simplifying conceptual studying of numerous options when searching for the value and direction of the thrust for various degrees of vehicle suspension, but for the same speed (which will be shown below).

The orange field in Figure 2 (between the blue *EF* and yellow *CD* boundary curves) represents a set of all possible options of the force balance for various speeds at the change of the vertical component of the thrust F_{Tz} from 0 to G_q (please note that for the initial coefficient of wheel rolling resistance $f_{wh.0}$ = 0.3).

It should be noted that if the balance conditions in equation (9) are maintained, the following can be written for the longitudinal acceleration of a suspended vehicle (at $F_{Tz} = G_q$):

$$a_x = \frac{g}{G_q}(F_{Tx} - k_{w.x} \cdot S_{front} \cdot V_w^2) \quad (10)$$

The maximum speed can be determined by setting a_x = 0:

$$V_{x.\max} = \sqrt{F_{Tx} / k_{w.x} \cdot S_{front}} \quad (11)$$

The longitudinal acceleration at the initial moment of longitudinal motion of a suspended vehicle can be determined by setting V_x = 0:

$$a_x = \frac{F_{Tx} \cdot g}{G_q} \quad (12)$$

The use of generalized equation (6) and its special cases (8–12) allows calculating the components of the thrust for options of quantomobile motion along the bearing surface at different degrees of suspension, up to the breakoff from the surface (see Table 1), as well as making a graphic presentation of the calculation results as a graph of spatial use of the thrust in the longitudinal pitch plane (Figure 3).

The objective was to identify the type of relationship between the thrust value, necessary for uniform motion at the set speed, and the degree of vehicle suspension.

Let us introduce some terms:

"degree of suspension" of the vehicle – ratio $\gamma = F_{Tz}/G_q$;

"maximum thrust" – thrust F_T of the maximum value and any direction in the pitch plane, ensured by the QE installation (here, F_T = 90 kN);

"sufficient thrust" – thrust $F_{T.st}$ of the value sufficient to maintain the set speed of horizontal **st**eady motion that, as a rule, does not coincide with the maximum thrust (in terms of direction) that ensures the same degree of vehicle suspension.

The following designations are taken for the new values in Table 1 and in Figure 3:

$F_{Tx.ac}$ – the horizontal component of the maximum thrust that ensures the set degree of vehicle suspension, maintaining the set speed (here, 67.2 m/s) and the possibility of further **ac**celeration;

$F_{Tx.st}$ – the horizontal component of the sufficient thrust necessary and sufficient to maintain the set steady speed of the vehicle of 67.2 m/s;

R_{FTx} – the difference between the values ($F_{Tx.ac} - F_{Tx.st}$) that ensures further horizontal acceleration a_x when the set speed of the vehicle of 67.2 m/s is achieved;

$F_{T.st}$ – the sufficient thrust to maintain the **st**eady set speed of 67.2 m/s;

R_{FT} – the difference between the values ($F_T - F_{T.st}$) that can ensure acceleration of the vehicle (a_x and/or a_z) when the set horizontal speed of the vehicle of 67.2 m/s is achieved;

β_{ac} – the maximum thrust angle F_T relative to the horizon;

β_{st} — the sufficient thrust angle $F_{T.st}$ relative to the horizon.

The algorithm of calculating the mentioned values is as follows:

1) $F_{Tz} = \gamma \cdot G_q$;
2) $\beta_{ac} = \arcsin (F_{Tz} / F_T)$;
3) $F_{Tx.ac} = \cos \beta_{ac} \cdot F_T$;
4) $F_{Tx.st} = P_f + P_w = f_{wh.0}(1 + f_{wh.v}V_x^2)(G_q - F_{Tz}) + k_{w.x}S_{front}V_w^2$;
5) $R_{FTx} = F_{Tx.ac} - F_{Tx.st}$;
6) $\beta_{st} = \arctan (F_{Tz} / F_{Tx.st})$;
7) $F_{T.st} = F_{Tz} / \sin \beta_{st}$;
8) $R_{FT} = \beta_{ac} \cdot F_T - F_{T.st}$.

Discussion

The target dependence of the horizontal component of the thrust vector, sufficient to maintain uniform motion of the quantomobile with a constant speed, on the degree of suspension turned out to be linear. This is understandable since the dependence determined by equation (13) is essentially linear, type $y = kx+c$, where y is $F_{Tx.st}$, $k = f_{wh.0}(1 + f_{wh.v}V_x^2)$, the argument x is the force of interaction between the vehicle wheels and the bearing surface ($G_q - F_{Tz}$), and the free term is $c = k_{w.x}S_{front}V_w^2$.

That peculiarity determines availability of the force reserve when the thrust is used in the medium zone of vehicle suspension, as shown in Figure 3, e.g. in point 4. The excess horizontal component of the thrust force R_{FTx} can be used to increase the course speed. Also, it is possible to increase the degree of vehicle suspension, which is beneficial in terms of reduced resistance to traction.

The linear nature of dependences (5), (6) and (13) (at constant speed) matches the simplest approach to vehicle motion modeling. It allowed solving the task of obtaining the picture of the thrust use in the pitch plane, as well as the task of developing the method of respective analysis. However, in reality, the functions are, of course, non-linear. This fact will undoubtedly affect the type of the target dependences (like the red line in Figure 3). The analysis will also become more complex when numerous speeds, roads and other attributes are used.

Table 1. Calculation of thrust components for options of quantomobile motion along the bearing surface with the coefficient $f_{wh.0}$ = 0.3.

Point No.	Degree of suspension γ	Thrust components, kN						Thrust angle relative to the horizon, *degrees*	
		F_{Tz}	$F_{Tx.ac}$	$F_{Tx.st}$	R_{FTx}	$F_{T.st}$	R_{FT}	β_{ac}	β_{st}
1	0	0	90	89.89	0.11	89.89	0.11	0	0
2	1/8	11	89.32	80.63	8.69	81.36	8.64	7.03	7.77
3	1/4	22	87.27	71.37	15.90	74.68	15.32	14.15	17.13
4	1/2	44	78.52	52.85	25.67	68.77	21.23	29.26	39.78
5	3/4	66	61.18	34.33	26.85	74.37	15.67	47.17	62.56
6	7/8	77	46.60	25.07	21.53	80.97	9.03	58.82	71.99
7	15/16	82.5	37.09	20.43	16.66	85	5	65.66	76.09
8	1	88	18.87	15.80	3.07	89.41	0.59	77.90	79.82
9	1.022	90	–	–	–	90	2	90	90

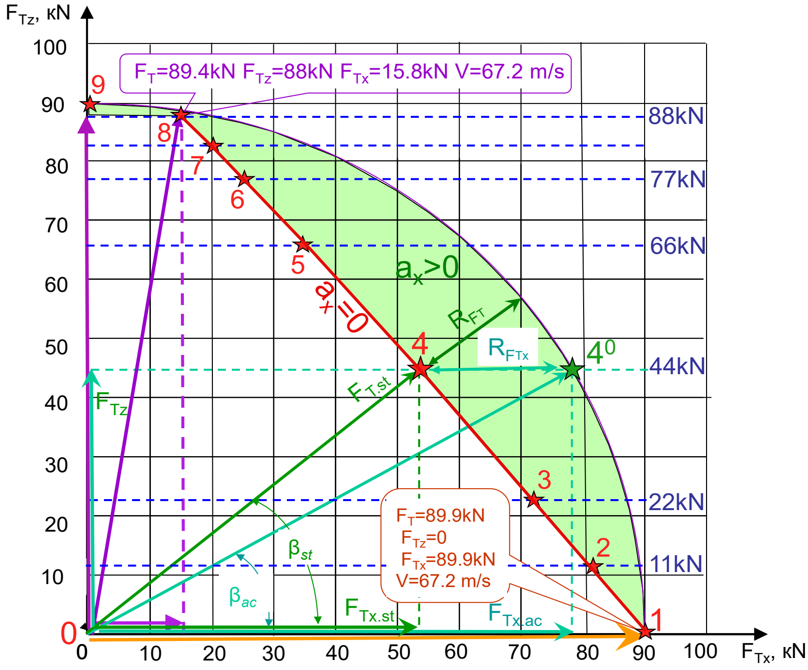

Figure 3. Graph of spatial use of the thrust in the longitudinal pitch plane.

The derived force balance equation that matches the 2D option of quantomobile motion in the pitch plane can be extended to the 3D option of vehicle motion (this independent task was not included in the list of the objectives).

Naturally, the 3D model should include lateral forces actualized in the transversal direction, as well as the moments of rotational motion forces of the vehicle, relative to all three axes of the coordinate system. This will make it possible to assess the dynamics and energetics of quantomobile motion in a three-dimensional space in more detail, as well as compare such vehicles with other vehicles operating in this space, e.g. planes, helicopters, etc.

Conclusion

Based on the assumption of forthcoming introduction of quantum engines (QE) in the transportation industry, for the purposes of conceptual and theoretical training, the generalized force balance equation for a hypothetical quantomobile with five cases of its motion in the pitch plane was derived.

The vector approach to the force balance of a quantomobile distinguishes the derived dependences and their use from traditional force balance diagrams obtained in the classic automobile theory. The analysis revealed that it was possible to minimize the thrust for maintaining constant speed under the middle degree of vehicle suspension.

The authors believes that the derived generalized equation and brief calculations for a limited number of cases of uniform quantomobile motion can serve as an impetus for further studies in this area: analysis of other cases of quantomobile motion (pressing-down, breakoff from the bearing surface, optimization of the thrust vector use in variable motion modes, use of the lateral component of the thrust F_{Ty}, etc.). Naturally, the author's scheme may seem elusive since there are no technical (much less, statistical) data on quantomobile designs, but anything is possible.

DOI: 10.23968/2500-0055-2019-4-2-53-60

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РЕАЛИЗАЦИЯ СИЛОВОГО БАЛАНСА КВАНТОМОБИЛЯ В ПЛОСКОСТИ ТАНГАЖА

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Аннотация

Введение: В преддверии внедрения квантовых двигателей (КвД) в транспортную отрасль небесполезно экспертное исследование свойств гипотетического автомобиля с КвД – квантомобиля. **Цель**: Осуществить расчетное исследование силового баланса квантомобиля и вариантов его движения в плоскости тангажа. **Методы**: Исходя из возможности генерации квантовым двигателем вертикальной составляющей вектора тяги (антигравитационной направленности) привлечен двухмерный подход к рассмотрению силового баланса квантомобиля. Сформировано обобщенное уравнение силового баланса для совокупности режимов движения квантомобиля в продольной плоскости тангажа. Выделено 5 характерных режимов движения. Выстраиваемые графические отображения являются частью совокупности аналитических действий, направленных на фиксацию и осмысление характерных граничных точек и кривых. **Результаты**: Реализованные численные примеры на базе названного уравнения силового баланса позволили интерпретировать режимы движения квантомобиля в плоскости тангажа, а также сформировать общую картину равномерного курсового движения квантомобиля. **Обсуждение**: Анализ выявил возможность минимизации величины траста для поддержания постоянной скорости в состоянии средней степени вывешивания экипажа. Сформированное уравнение силового баланса, отвечающее 2D-варианту движения квантомобиля в плоскости тангажа, может быть расширено до 3D-варианта движения этого экипажа. Это позволит более точно оценивать динамику и энергетику движения квантомобиля в трёхмерном пространстве, а также проводить сравнения с другими транспортными средствами, оперирующими в этом пространстве: самолетом, вертолётом и прочими.

Ключевые слова
Автомобиль, квантовый двигатель, квантовая тяга, квантомобиль, плоскость тангажа, силовой баланс.