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CONTENTS

IMPLEMENTATION OF THE IMPROVED METHODOLOGY IN PRACTICE AND ASSESSMENT OF ITS ECONOMIC EFFICIENCY	8
Eshniyazova Yulduz Yuldashbayevna	
EXPERIMENTAL OPTIMIZATION OF DESIGN AND ENERGY PARAMETERS OF A GARLAND-TURBINE MOBILE MICRO HYDROPOWER PLANT FOR FREE-FLOWING WATER	13
Sultonov Sanjarbe, Zokirov Islomjon, Nurillaev Ahadullo, Abdullaev Shavkat	
METHODOLOGY FOR INCREASING THE EFFICIENCY OF CREDIT OPERATIONS IN COMMERCIAL BANKS	19
Djumaniyazov Ikram Karimbaevich	
COMPARATIVE ANALYSIS OF A COMPACT RESIDUAL CONVOLUTIONAL MODEL AND LINEAR REGRESSION FOR IMAGE SUPER-RESOLUTION	27
Husan Arziqulov Normurod o'g'li	
COMPARATIVE EVALUATION OF MACHINE LEARNING ALGORITHMS AND CLASS IMBALANCE HANDLING STRATEGIES FOR CREDIT CARD FRAUD DETECTION	33
Mahmudova Dilnoza Avaz qizi	
DIGITAL TRANSFORMATION OF FINANCIAL RESOURCE MANAGEMENT IN PUBLIC SOCIAL SECTOR INSTITUTIONS	39
Khasanov Tulkin Axmatovich	
WAYS TO ENSURE THE STABILITY OF THE CAPITAL BASE OF COMMERCIAL BANKS	45
Isakov Isobek Janabay's son	
CROSS-DAY EXPERIMENTAL EVIDENCE OF THERMAL-LOAD SHIFTING IN A SOLAR-DRIVEN HYDRONIC RADIANT FLOOR WITH MACROENCAPSULATED RT52 PHASE CHANGE MATERIAL	50
Jurabek Kamolov, Sokhib Temirov, Marjona Makhmudova	
STUDY OF THE TRACTION DYNAMICS OF AN AGGREGATE CONSISTING OF A FRUIT-HARVESTING MACHINE AND ITS TWO-AXLE CONTAINER-CARRYING TRAILER PLATFORM	59
Norchayev Davron, Sardor Nigmatjonov, Norchayev Jaloliddin, Norchayev Rustam	

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STUDY OF THE TRACTION DYNAMICS OF AN AGGREGATE CONSISTING OF A FRUIT-HARVESTING MACHINE AND ITS TWO-AXLE CONTAINER-CARRYING TRAILER PLATFORM

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Abstract. The paper presents a theoretical study of the traction dynamics of an aggregate consisting of a self-propelled fruit-harvesting machine proposed for intensive orchards and its two-axle container-carrying trailer platform. Based on the force diagram for the machine and trailer platform moving on a slope, equilibrium and motion equations are derived to determine the normal wheel reactions, the total traction force of the machine, and the drawbar force, together with expressions for the machine power balance. A worked numerical example shows that, with a fully loaded trailer, increasing the slope from 0 to 5° raises the drawbar force from 2.35 to 4.40 kN, the machine traction force from 4.91 to 9.16 kN, and the required motor power at 10 km/h from 17.2 to 37.3 kW, while the front-axle load decreases from 11.21 to 9.79 kN. The results can be used to calculate the drawbar force and power of the fruit-harvesting machine, select an appropriate electric motor, and design similar machines.

Keywords: intensive orchard; mechanization; fruit-harvesting machine; trailer platform; container; traction dynamics; drawbar force; power balance.

Annotatsiya. Maqolada intensiv bog'lar uchun taklif etilayotgan o'ziyurar meva teradigan mashina va uning konteyner tashiydigan ikki o'qli tirkama platformasidan iborat agregatning tortish dinamikasi nazariy jihatdan tadqiq etilgan. Qiyalikda harakatlanayotgan mashina va tirkama platformaga ta'sir etuvchi kuchlar sxemasi asosida g'ildiraklarning normal reaksiyalari, mashinaning umumiy tortish kuchi va ilmoq kuchini aniqlovchi muvozanat va harakat tenglamalari hamda mashinaning quvvat balansini ifodalari keltirib chiqarilgan. Olingan bog'liqliklar bo'yicha hisobiy misol bajarilgan: to'la yuklangan tirkama bilan qiyalik 0 dan 5° gacha ortganda ilmoq kuchi 2,35 dan 4,40 kN gacha, mashinaning tortish kuchi 4,91 dan 9,16 kN gacha, 10 km/soat tezlikda talab etiladigan dvigatel quvvati esa 17,2 dan 37,3 kW gacha ortadi; bunda oldingi o'q yuklamasi 11,21 dan 9,79 kN gacha kamayadi. Natijalar meva teradigan mashina ilmog'idagi kuch va quvvatni hisoblash, maqbul elektr dvigatelni tanlash hamda shunga o'xshash mashinalar konstruksiyasini yaratishda qo'llanilishi mumkin.

Kalit so'zlar: intensiv bog'; mexanizatsiya; meva teradigan mashina; tirkama platforma; konteyner; tortish dinamikasi; ilmoq kuchi; quvvat balansini.

Аннотация. В статье теоретически исследована тяговая динамика агрегата, состоящего из предлагаемой для интенсивных садов самоходной плодуборочной машины и её двухосной прицепной платформы для перевозки контейнеров. На основе схемы сил, действующих на машину и прицепную платформу при движении на уклоне, получены уравнения равновесия и движения, определяющие нормальные реакции колёс, суммарную силу тяги машины и силу на крюке, а также выражения баланса мощности машины. По полученным зависимостям

выполнен расчётный пример: с полностью загруженным прицепом при увеличении уклона от 0 до 5° сила на крюке возрастает с 2,35 до 4,40 кН, сила тяги машины — с 4,91 до 9,16 кН, потребляемая мощность двигателя при скорости 10 км/ч — с 17,2 до 37,3 кВт; при этом нагрузка на переднюю ось снижается с 11,21 до 9,79 кН. Результаты могут использоваться для расчёта силы и мощности на крюке плодуборочной машины, выбора электродвигателя и создания конструкций аналогичных машин.

Ключевые слова: интенсивный сад; механизация; плодуборочная машина; прицепная платформа; контейнер; тяговая динамика; сила на крюке; баланс мощности.

INTRODUCTION

At present, alongside meeting the population's demand for food products, measures are being implemented in the republic to increase export volumes through the intensive cultivation of agricultural products. In particular, the area of intensive orchards in the republic is planned to reach 110 thousand hectares by 2030 [1]. In fruit cultivation, harvesting is one of the most labour-intensive processes, and its costs may account for up to 60 per cent of total production costs [2]. Therefore, further expanding the use of specialized harvesting machinery and increasing the level of mechanization are important factors in improving labour productivity and optimizing harvesting costs.

Accordingly, the development of an energy- and resource-saving machine capable of mechanized harvesting of apples, peaches, sour cherries, plums, sweet cherries, apricots, and other fruits grown in intensive orchards, while taking into account the geometric dimensions, habit, architectonics, and physical and mechanical properties of the trees, is an important scientific and practical task. In cooperation between scientists from the Research Institute of Agricultural Mechanization and the Scientific and Practical Centre for Agricultural Mechanization of the National Academy of Sciences of Belarus, the design of a self-propelled fruit-harvesting machine adapted to the soil and climatic conditions of the republic has been proposed [3], and its turning characteristics have been studied [4].

The machine collects the harvested fruit into containers, while the filled containers are transported on a two-axle trailer platform. The aggregate consisting of the machine and the trailer forms a mechanical system that is continuously subjected to static and dynamic forces. The forces required for its translational motion are transmitted to the wheels by the supporting surface in the form of friction forces, while forces acting parallel to the supporting plane (traction forces) and perpendicular to it are transmitted through the machine hitch. The general theory of traction dynamics and the power balance of wheeled machines and machine-tractor aggregates is presented in [5–8]. Building on these theoretical foundations, the traction characteristics of an aggregate consisting of an electrically driven fruit-harvesting machine and a two-axle container-carrying trailer platform are considered in this study.

The **aim** of the study is to investigate the traction dynamics of an aggregate consisting of a fruit-harvesting machine and its two-axle container-carrying trailer platform, namely, to derive expressions for determining the normal wheel reactions, the traction force of the machine, the drawbar force, and the power balance, and, on this basis, to determine the design parameters required for selecting the electric motor.

LITERATURE REVIEW

The theoretical foundations of traction dynamics, power balance, wheel–soil interaction, and the operating stability of wheeled agricultural machines have been widely considered in classical tractor theory and in studies devoted to machine–tractor aggregates [5, 8]. These works provide the basic relationships for determining traction forces, rolling resistance, wheel reactions, power requirements, and the influence of slope and operating conditions on machine performance.

In the studies of M. Toshbol'tayev and co-authors, the theoretical and methodological aspects of improving the efficiency of machine–tractor aggregates under agricultural conditions were investigated, including the influence of slope, traction conditions, and trailer parameters on the operational characteristics of tractor trains [6, 7]. These findings form an important methodological basis for analysing the traction characteristics of agricultural transport aggregates.

Recent studies by D. R. Norchayev and co-authors have focused on the mechanization of fruit harvesting in intensive orchards, the theoretical justification of the main parameters of fruit-harvesting machines, and the study of the turning characteristics of self-propelled harvesting equipment [2–4]. These studies provide a foundation for the further analysis of the traction dynamics of a fruit-harvesting machine operating with a two-axle container-carrying trailer platform.

Based on these theoretical and applied studies, the present research further develops the analysis of the interaction between the fruit-harvesting machine and the trailer platform by considering wheel reactions,

drawbar force, traction force, and power balance under different slope and loading conditions.

RESEARCH METHODOLOGY

2.1. Object of the study

The machine for harvesting stone fruits in intensive orchards consists of a chassis 1, a main base frame mounted on it 2, a central conveyor 3, auxiliary fruit-feeding conveyor arms 4, a control panel 5, two side guards mounted on the main frame 6, two folding side steps located beneath the frame 7, a container rack 8, and a container base 9 (Fig. 1). The rear wheels of the chassis are the main driving wheels and are driven by an electric motor. A hybrid engine mounted beneath the frame drives the conveyors and continuously charges the batteries. During operation, the fruit pickers place the fruit on the conveyor arms, which deliver it to the central conveyor; the central conveyor, in turn, delivers the fruit to the containers.

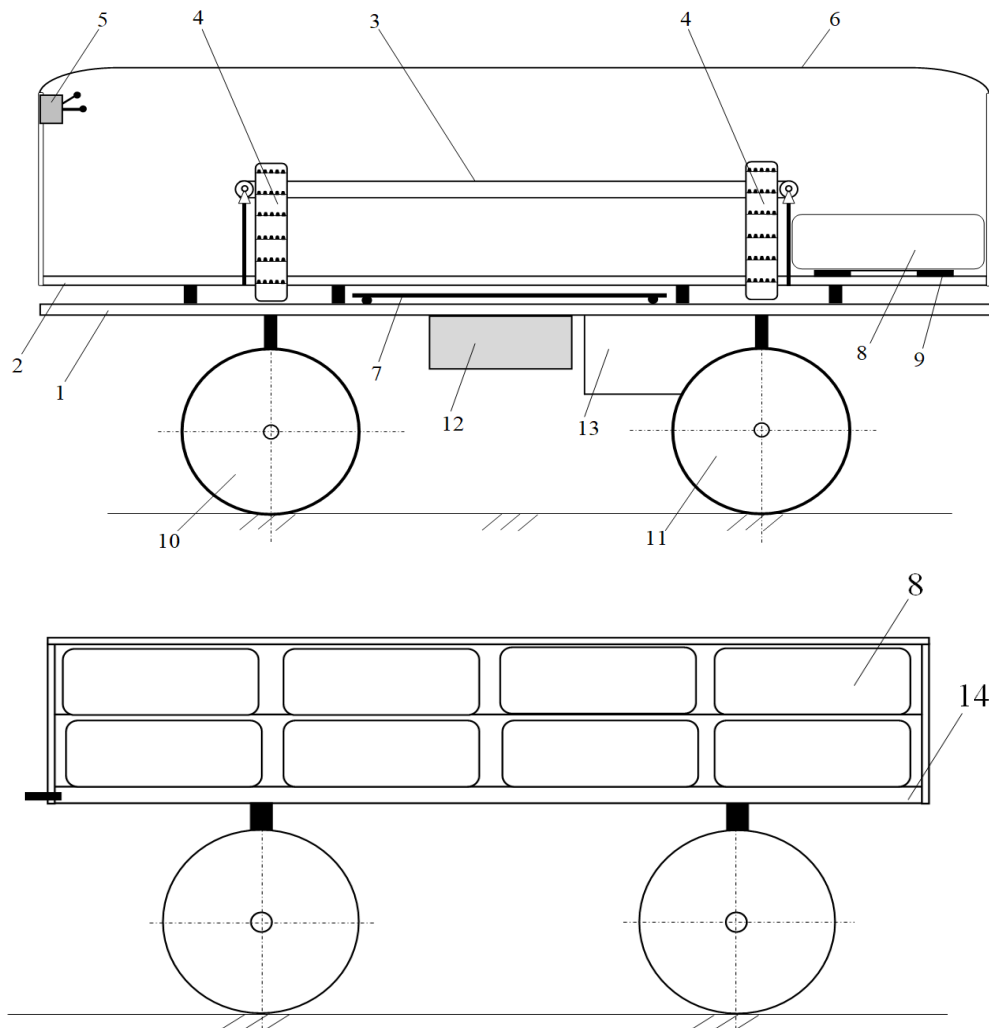


Figure 1. Structural diagram of the self-propelled fruit-harvesting machine and its two-axle container-carrying trailer platform

Source: developed by the authors.

2.2. Forces acting on the aggregate

The study was carried out using the methods of theoretical mechanics and tractor theory [5]. On a supporting plane inclined at an angle α to the horizontal, a moving fruit-harvesting machine with an operating mass m is subjected to the following forces (Fig. 2): the weight $G_m = mmg$, whose projections along the direction of travel and normal to the plane are $G_m \sin \alpha$ and $G_m \cos \alpha$, respectively; the inertia force mmW ; the air resistance force Ph ; the vertical Z_{il} and longitudinal P_{il} forces acting on the hitch; the torques M_1 and M_2 transmitted to the front and rear axle shafts, which generate the tangential traction forces P_{1m} and P_{2m} ; the normal reactions Z_{1m} and Z_{2m} , shifted forward from the wheel axes by the distances c_{1m} and c_{2m} owing to the deformation of the soil and tyres; and the rolling resistance forces X_{1m} and X_{2m} .

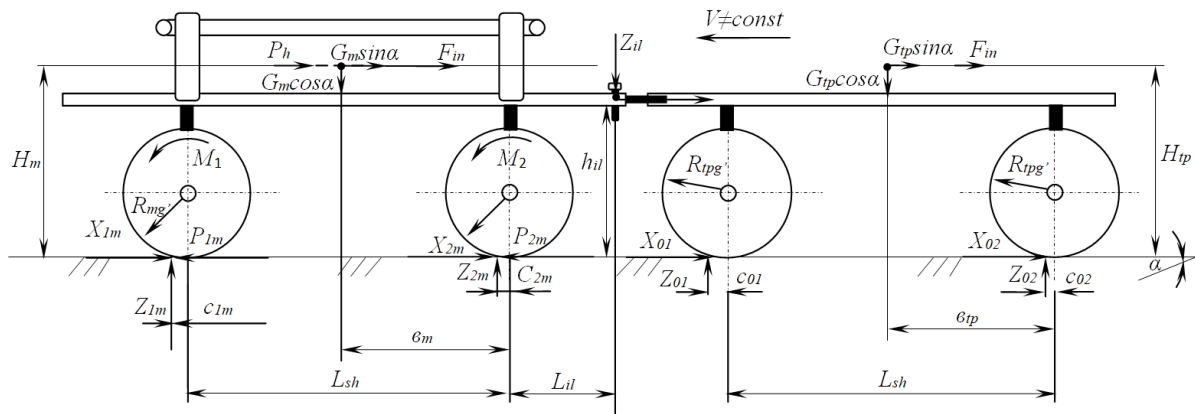


Figure 2. Scheme for determining the traction dynamics of the aggregate consisting of the fruit-harvesting machine and its two-axle container-carrying trailer platform

Source: developed by the authors.

In practical calculations, the air resistance force is determined using the following empirical formula [6, 7]:

$$P_h = (1 + 0.25n)K_h F_{yuz} V^2 \quad (1)$$

where n is the number of trailers coupled to the machine; K_h is the streamlining (drag) coefficient, kg/m^3 ; $F_{yuz} = B_m H_m$ is the frontal area of the machine, m^2 ; and V is the travel speed, m/s . Taking $K_h = 0.7 \text{ kg/m}^3$ and $F_{yuz} = 3 \text{ m}^2$ gives $P_h = 3.5(1 + 0.25n)V^2$.

The trailer platform, with a gross mass m_{tp} (the sum of its structural mass and payload mass), is subjected to the weight G_{tp} , the inertia force $m_{tp}W$, the normal reactions at the wheels Z_{01} and Z_{02} , and the rolling resistance forces X_{01} and X_{02} . In the diagram, L_m and L_{tp} are the wheelbases of the machine and the trailer, respectively; b_m , h_m , b_{tp} , and h_{tp} are the coordinates of the centres of gravity; and h_{il} and l_{il} are the height of the hitch above the supporting plane and its overhang behind the rear axle, respectively.

2.3. Equilibrium equations of the forces acting on the machine

Taking moments of the forces about the point of application of Z_{2m} gives the normal reaction of the front wheels of the machine:

$$Z_{1m} = \frac{m_m g [(b_m - c_{2m}) \cos \alpha - h_m \sin \alpha] - (m_m W + P_h) h_m - Z_{il} (l_{il} + c_{2m}) - P_{il} h_{il}}{L_m + c_{1m} - c_{2m}} \quad (2)$$

From the equilibrium equation of the forces in the vertical direction, the normal reaction of the rear wheels is determined as follows:

$$Z_{2m} = m_m g \cos \alpha + Z_{il} - Z_{1m} \quad (3)$$

The equilibrium equation for the projections of the forces along the direction of travel is:

$$P_{1m} + P_{2m} = X_{1m} + X_{2m} + m_m g \sin \alpha + m_m W + P_h + P_{il} \quad (4)$$

where the tangential traction forces and the rolling resistance forces are:

$$P_{1m} = \frac{M_1}{R_1} = \frac{M_d i_{1m} \eta_{1m}}{R_1}, \quad P_{2m} = \frac{M_2}{R_2} = \frac{M_d i_{2m} \eta_{2m}}{R_2}, \quad X_{1m} = f Z_{1m}, \quad X_{2m} = f Z_{2m} \quad (5)$$

M_d is the torque developed by the electric motor; i_{1m} and η_{1m} are the gear ratio and efficiency of the transmission to the front axle shaft, respectively; i_{2m} and η_{2m} are the gear ratio and efficiency of the transmission to the rear axle shaft, respectively; R_1 and R_2 are the wheel radii; and f is the rolling resistance coefficient. $P_m = P_{1m} + P_{2m}$ represents the total traction force of the machine (for the 4K2 configuration, $P_{1m} = 0$). Substituting equations (3) and (5) into equation (4), we obtain:

$$P_m = f(m_m g \cos \alpha + Z_{il}) + m_m g \sin \alpha + m_m W + P_h + P_{il} \quad (6)$$

Hence the force that can be developed at the hitch of the machine is:

$$P_{il} = P_m - f(m_m g \cos \alpha + Z_{il}) - m_m g \sin \alpha - m_m W - P_h \quad (7)$$

For an approximate estimate of the nominal drawbar force, it is assumed that $P_{il} = (0.37 \dots 0.39)G_m$ for machines with a 4K2 wheel arrangement and $P_{il} = (0.40 \dots 0.45)G_m$ for machines with a 4K4 wheel arrangement [5].

2.4. Equilibrium equations of the forces acting on the trailer platform

Since the front and rear wheels and tyres of the trailer platform are identical and the load is distributed almost equally between them, it may be assumed that $c_{01} = c_{02} = c_0$ and $X_{01} + X_{02} = X_0$. From the equation of moments about the point of application of Z_{02} and the equilibrium equation for the vertical projections, we obtain:

$$Z_{01} = \frac{m_{tp} g [(b_{tp} - c_0) \cos \alpha - h_{tp} \sin \alpha] - h_{tp} m_{tp} W + P_{il} h_{il}}{L_{tp}}, \quad Z_{02} = m_{tp} g \cos \alpha - Z_{01} \quad (8)$$

From the equilibrium equation in the direction of travel, the coupling force required to pull the trailer is:

$$P_{il} = m_{tp} (g \sin \alpha + W) + X_0 = m_{tp} g (f \cos \alpha + \sin \alpha) + m_{tp} W \quad (9)$$

2.5. Power balance

Part of the effective power N_e delivered by the electric motor is used to overcome various resistances. For an aggregate moving at a constant speed on a slope of angle α , the following power expenditures are considered [5–7]: N_m — power loss due to mechanical resistance in the transmission; N_δ — power loss due to driving-wheel slip; N_f — power required to overcome the rolling resistance of the machine; N_α — power required to overcome the slope resistance; and N_h — power required to overcome air resistance. The remaining power constitutes the useful power at the hitch, N_{il} :

$$N_{il} = N_e - (N_m + N_\delta + N_f + N_\alpha + N_h) \quad (10)$$

The power components are [8]:

$$N_e = M_d \omega_d, \quad N_m = N_e (1 - \eta_m), \quad N_\delta = N_e \eta_m \delta \quad (11)$$

$$N_f = m_m g f V \cos \alpha, \quad N_\alpha = m_m g V \sin \alpha, \quad N_h = 3.5(1 + 0.25n)V^3, \quad N_{il} = P_{il} V \quad (12)$$

where ω_d is the angular velocity of the motor shaft, rad/s; η_m is the efficiency of the transmission; δ is the slip coefficient. From (10)–(12), the power required from the motor for a given regime is:

$$N_e = \frac{N_f + N_\alpha + N_h + N_{il}}{\eta_m (1 - \delta)} \quad (13)$$

The slip coefficient was estimated as a function of the traction coefficient $\varphi_k = P_m / Z_{2m}$ by the approximation $\delta = -\ln(1 - \varphi_k / \varphi_{\max}) / k_\delta$ ($\varphi_{\max} = 0.65$; $k_\delta = 12$).

2.6. Parameters of the worked example

To demonstrate the application of the expressions obtained, a calculation was performed with the design parameters given in Table 1 (assuming $W = 0$, $Z_{il} \approx 0$, $c_{1m} = c_{2m} = c_0 = 0$).

Table 1. Parameters of the worked example

Parameter	Value
Machine mass m_m	2600 kg
Machine wheelbase $L_m / b_m / h_m$	2.50 / 1.15 / 1.05 m
Hitch height h_{il}	0.55 m
Gross mass of the trailer platform m_{tp}	2400 kg (with 8 containers)
Trailer $L_{tp} / b_{tp} / h_{tp}$	2.60 / 1.30 / 1.20 m
Rolling resistance coefficient f	0.10
Transmission efficiency η_m	0.85
Number of trailers n	1

Source: design (approximate) values adopted by the authors on the basis of the structural diagram of the machine and trailer platform given in [3, 4].

ANALYSIS AND RESULTS

3.1. Forces and normal reactions

The forces calculated by expressions (2), (3), (6), (8), (9) are given in Table 2.

Table 2. Forces acting on the aggregate as a function of slope, kN ($V = \text{const}$)

α , deg	P_{il}	P_m	Z_{1m}	Z_{2m}	Z_{01}	Z_{02}	ϕ_k
0	2.35	4.91	11.21	14.29	12.27	11.27	0.34
3	3.58	7.47	10.37	15.10	11.95	11.57	0.49
5	4.40	9.16	9.79	15.62	11.71	11.74	0.59
8	5.61	11.68	8.89	16.36	11.33	11.98	0.71

Source: authors' calculations based on expressions (2), (3), (6), (8), (9) and the parameters in Table 1.

As the slope increases from 0 to 8°, the drawbar force required to pull the trailer increases by a factor of 2.4, while the total traction force of the machine rises from 4.91 to 11.68 kN. Under the action of the drawbar force and the longitudinal component of the machine weight, the load on the front axle decreases from 11.21 to 8.89 kN, whereas the load on the driving rear axle increases from 14.29 to 16.36 kN. On the trailer platform, the front axle carries a higher load on level ground owing to the moment generated by the drawbar force; as the slope increases, the load is progressively redistributed toward the rear axle. On level ground, an acceleration of 0.5 m/s² increases the drawbar force from 2.35 to 3.55 kN and the total traction force to 7.41 kN.

The dependence of the drawbar force on trailer mass and slope is shown in Fig. 3 together with the nominal drawbar force, $(0.37...0.39)G_m = 9.4...9.9$ kN. For a fully loaded trailer, the required drawbar force is 4.1 times lower than the nominal value on level ground and 2.2 times lower on a 5° slope. At the same time, the traction coefficient of the rear driving wheels, ϕ_k , reaches 0.71 on an 8° slope. With an adhesion coefficient of approximately 0.6 on the orchard surface, the practical climbing capability of the aggregate is therefore governed primarily by the wheel–surface adhesion condition, corresponding to a slope of approximately 5°.

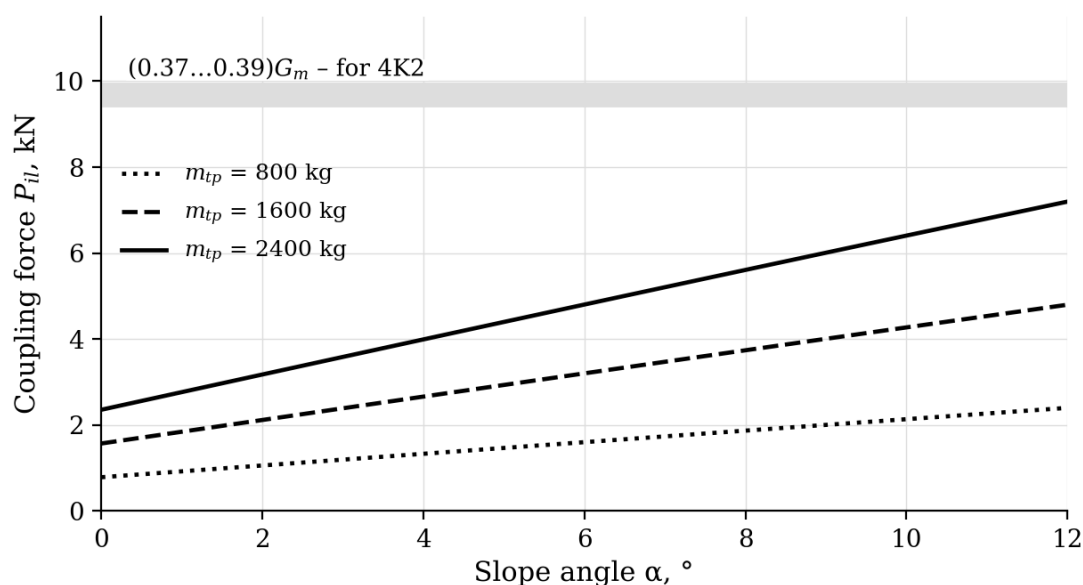


Figure 3. Dependence of the drawbar force required to pull the trailer on the slope angle and trailer mass
Source: developed by the authors.

3.2. Power balance

The power balance calculated using expressions (10)–(13) is presented in Table 3, while the dependence of the required power on travel speed is shown in Fig. 4.

Table 3. Power balance of the aggregate, kW

α , deg	V , km/h	N_s	N_m	N_o	N_f	N_a	N_k	N_{tr}	δ , %
0	5	8.56	1.28	0.46	3.54	0	0.01	3.27	6.3
0	10	17.22	2.58	0.92	7.09	0	0.09	6.54	6.3
3	5	13.86	2.08	1.40	3.54	1.85	0.01	4.98	11.9
3	10	27.82	4.17	2.82	7.08	3.71	0.09	9.95	11.9

α , deg	V, km/h	N_e	N_m	N_s	N_f	N_a	N_h	N_{II}	δ , %
5	5	18.58	2.79	3.06	3.53	3.09	0.01	6.11	19.4
5	10	37.27	5.59	6.14	7.06	6.17	0.09	12.22	19.4

Source: authors' calculations based on expressions (10)–(13) and the data in Tables 1 and 2.

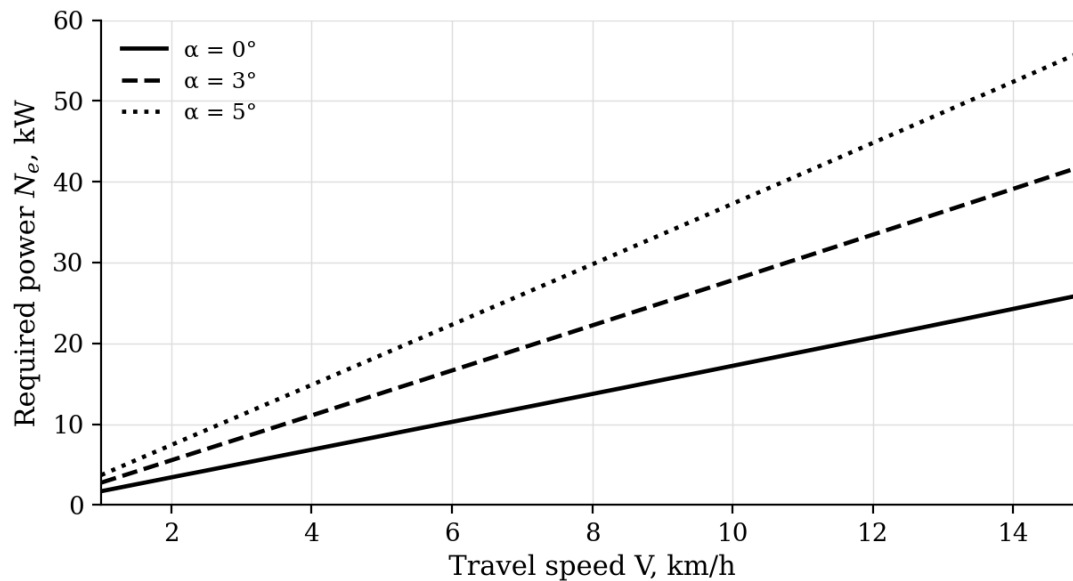


Figure 4. Dependence of the motor power requirement on the travel speed of the aggregate and the slope angle (fully loaded trailer)

Source: developed by the authors.

On a horizontal surface, at a speed of 10 km/h, the required motor power is 17.2 kW, of which 38% corresponds to useful power at the hitch, 41% to overcoming the rolling resistance of the machine, 15% to transmission losses, and 5% to slip losses. On a 5° slope, the required power increases to 37.3 kW, while the share of slip losses reaches 16%. The power required to overcome air resistance does not exceed 0.1 kW within the considered speed range and may therefore be neglected in practical calculations.

The expressions (2)–(9) obtained in this study describe the relationships between the design parameters of the machine and the trailer platform, including the wheelbases, coordinates of the centres of gravity, and hitch height, as well as the travel conditions, including slope, acceleration, and rolling resistance, and the drawbar force. These expressions are consistent with the general relationships adopted in tractor theory [5] and take into account the specific features of the fruit-harvesting aggregate, namely the electric drive, rear driving axle, and two-axle trailer platform. Expression (9) determines the force required to pull the trailer, whereas expression (7) determines the traction force that the machine is capable of developing; their equality represents the condition under which the aggregate can move.

The worked example shows that an important operating condition for selecting the motor is travel at transport speed on a slope with a fully loaded trailer. On a 5° slope, at least 37 kW is required at a speed of 10 km/h and 19 kW at 5 km/h. In the working regime during fruit harvesting, the travel speed is very low; therefore, the power demand is mainly determined by the conveyor drive. On a slope, a reduction in the front-axle load may decrease steerability, while wheel slip exceeding 15% may increase energy consumption and influence the soil structure. These results are consistent with the regularities reported for machine-tractor aggregates and tractor trains in the works of M. Tosholtayev [6, 7].

The parameters used in the worked example were adopted as approximate design values. Therefore, further refinement of the obtained results based on the actual mass and geometric characteristics of the prototype, together with field-test data, will improve the accuracy of the calculated parameters.

CONCLUSION AND SUGGESTIONS

For the aggregate consisting of a fruit-harvesting machine and a two-axle container-carrying trailer platform, equilibrium and motion equations determining the normal wheel reactions (2), (3), and (8), the total traction force of the machine (6), and the drawbar force (7) and (9), as well as the power balance expressions (10)–(13), have been derived.

With the adopted design parameters and a fully loaded trailer, as the slope increases from 0 to 5°, the drawbar force increases from 2.35 to 4.40 kN and the traction force of the machine from 4.91 to 9.16 kN, while the front-axle load decreases from 11.21 to 9.79 kN.

At a speed of 10 km/h, the required motor power is 17.2 kW on a horizontal surface and 37.3 kW on a 5° slope, while the share of useful power at the hitch is 33–38%.

The derived expressions can be used to calculate the drawbar force and power of the fruit-harvesting machine and to select an appropriate electric motor. They can also serve as a theoretical basis for deriving equations describing the stable travel and turning of the machine and trailer platform in an intensive orchard, as well as their movement in the transport position.

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REFERENCES

1. O'zbekiston Respublikasi Prezidentining 2024-yil 16-fevraldagi PF-36-son “Respublikada oziq-ovqat xavfsizligini ta'minlashning qo'shimcha chora-tadbirlari to'g'risida”gi Farmoni. — Qonunchilik ma'lumotlari milliy bazasi. — LexUZ. — [Official source](#).
2. Norchayev D. R. va boshq. Respublikamiz intensiv bog'larida yetishtirilayotgan mevalarni yig'ishtirishning mexanizatsiyalashgan yechimlari // *Resurstejamkor qishloq va suv xo'jalik mashinalarini yaratish va ulardan foydalanish samaradorligini oshirish*: Respublika ilmiy-amaliy anjumani materiallari. — Buxoro, 2025. — B. 133–138. — [Conference proceedings](#).
3. Norchayev D. R., Kambarov B. A., Kholikov B. A., Norchayev J. R., Khamarakulov T. T. Intensiv bog'lardagi mevalarni yig'ishtiradigan mashina parametrlarini nazariy asoslash // *Qurilish va ta'lim ilmiy jurnali*. — Namangan, 2026. — B. 428–432. — [Indexed record](#).
4. Norchayev R., Norchayev D. R., Rustamova N. R., Kambarov B. A., G'aybullaev B. Sh., Kholikov B. A. Intensiv bog'lar uchun mo'ljallangan o'ziyurar meva yig'ishtirish mashinasining burilish xususiyatlarini tadqiq etish // *Agro ilm — O'zbekiston qishloq va suv xo'jaligi*. — 2026. — № 2 (122). — B. 158–159. — [Journal issue](#).
5. Тракторы: теория: учебник для студентов вузов по спец. «Автомобили и тракторы» / В. В. Гуськов, Н. Н. Велев, Ю. Е. Атаманов и др.; под общ. ред. В. В. Гуськова. — М.: Машиностроение, 1988. — 376 с. — ISBN 5-217-00100-3. — [Library catalogue](#).
6. Toshboltayev M. *O'zbekiston qishloq xo'jaligida mashina-traktor agregatlaridan foydalanish darajasini oshirishning nazariy-metodologik asoslari*: monografiya. — Toshkent: Fan va texnologiya, 2016. — 604 b. — ISBN 978-9943-11-321-3. — [Bibliographic record](#).
7. Toshboltayev M., Xoliqov B. Traktor poyezdi yengib o'tadigan eng katta qiyalik burchagini aniqlash // *Mexanika muammolari*. — Toshkent, 2019. — № 1. — B. 38–42.
8. Зангиев А. А., Шпилько А. В., Левшин А. Г. *Эксплуатация машинно-тракторного парка*: учебник. — М.: КолосС, 2004. — 320 с. — ISBN 5-9532-0051-X. — [Library catalogue](#).

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