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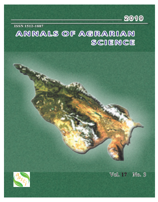

Typical departure-arrival cycle emissions in international airports of Georgia

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A B S T R A C T

The role of air traffic, the number and geography of flight worldwide is rapidly growing. Situation in Georgia is not exception of this pattern. Along with positive effect of air traffic such as development of global business, tourism, etc, the negative impacts are worth to mention. Increase of the number and frequency of flights leads to increase of the load on environment both at the local and the global level. Of the local impacts noise and emissions are noteworthy. The objective of this study was to assess emissions of landing – take off (LTO) cycle for international airports of Georgia and suggest mitigation measures for emission reduction. Daily distribution of flights in Tbilisi and Kutaisi international airports has been analysed. Emissions at various stages of the mentioned cycle have been calculated using the International Civil Aviation Organization (ICAO) database and airport specific information. Effect of continuous arrival-departure on reduction of fuel consumption and related emission of main pollutants have been looked into. Additional impact reduction achieved in case of e-taxiing have been considered.

Keywords: LTO cycle, E taxiing, Air emissions, Airport, Continuous descent, Continuous departure

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Introduction

In conditions of global economy the role of air transport – the fastest way of cargo and passengers transportation is growing. Number of flights, frequency and geography of the travel gradually increases. Aviation contributes the global market by increasing access to international markets, is essential for global business and tourism as well as ensures rapid delivery of humanitarian and first aid to any location in the world.

In 2018, on daily basis, aviation served 12 million passengers, 120,000 flights and transported 18.8 billion USD worth cargo. Direct jobs in the industry accounted for 10.2 millions. The share of aviation in global GDP reached 794.4 billion USD [1].

According to the International Air Transport Association (IATA) this trend will persist. 1.9 time increase in passenger number worldwide in 2015-2035 is forecasted [2]. Situation in Georgia does not differ from the mentioned pattern. According to the Georgian Civil Aviation Agency, number of flights via airports of Georgia, including cargo increases. In 2018, compared to the previous year, almost 17% increase in the number of flights was registered [3]. The number of passengers travelling to/via Georgia reached 5,024,883 – showing around 23.5% growth against the previous year.

Results and Analysis

There are three international, two local (Mestia and Ambrolauri) and two private (Natakhtari and Telavi) airports in Georgia. General information on international airports is given in Table 1.

Table 1. *International airport in Georgia – general information*

Tbilisi Shota Rustaveli International Airport	Coordinates: N41°40.15' / E44°57.29' Runway - 3000mX45m Pavement – asphalt-concrete Distance from runway to nearest residential area - 860m
Kutaisi David Aghmashenebeli International Airport	Coordinates: N42°10.61' / E42°28.96' Runway - 2,500x45m; Pavement – asphalt-concrete Number of terminals – 4, number of gates - 3 Distance from runway to nearest residential area - 2.3-2.4 km.
Batumi Alexande Kartveli International Airport	Coordinates: N41°36.61' / E41°35.97' Runway - 2500მX45მ Pavement – asphalt-concrete Distance from runway to nearest residential area - 240-260m

The main passenger flow is via Tbilisi, however, the role of the Kutaisi airport is also growing. These airports serve in average 50-55 (Tbilisi) and 5-10 (Kutaisi) flights daily. Compared to 2017, the number of passengers travelling though Kutaisi in 2018 increased by 52.5%.

However, along with benefits of air traffic such as simplicity, speed and positive impact on economy, air traffic, airports and related infrastructure have certain negative impact on environment on local and global scale. The main impact factors being noise and emissions.

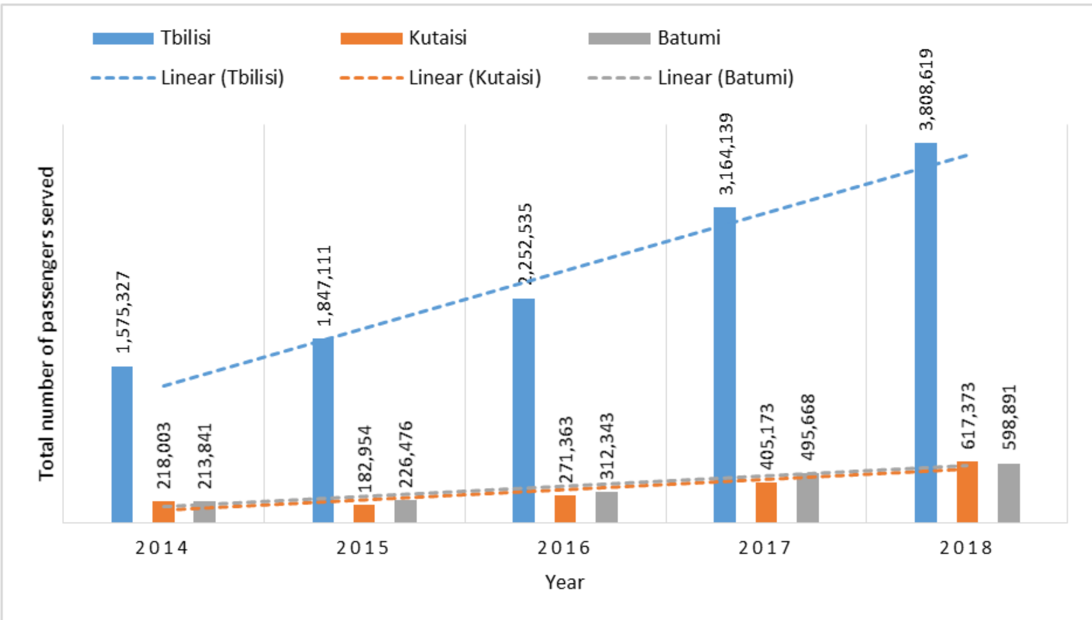

Fig. 1. *Dynamics of passengers served*

The purpose of the study was calculation of departure-arrival cycle emissions for international airports of Georgia. This article provides information on air emissions with consideration of maximum number of flights per time interval followed by recommendations for impact reduction and effect of suggested mitigation measures on total emission values.

Assessment is based on of the flight statistics via international airports of Georgia. In the course of assessment data on distribution of flights within 24 hours timeframe through the busiest hubs - Tbilisi and Kutaisi airports were collected and analysed. The results show that the main load is registered in day (08:00-19:00) and night (23:00-08:00) time interval, whereas the evening flights account for 10-12% of total daily flights only (Fig.2).

Impact of landing – take off (LTO) cycle emissions on local air quality has been assessed based on information on the main type of aircrafts [4], engine type and characteristics and duration of LTO stages for selected airports. Using ICAO data bases [5] mass of the fuel burnt per stage of the cycle and related emissions have been estimated. Considered LTO stages are shown in Fig.3.

It should be mentioned that at each stage of the cycle the engines of the aircraft are operating in different regime (power settings), respectively the fuel usage differs. Amount of the burnt fuel also depends on 'duration' of the stage.

Description of the main characteristics of the LTO stages considered in assessment is described below:

Departure

- A. *Engine start* - the main engines start immediately prior to taxi.
- B. *Taxi to runway* - all or fewer engines are on. Taxi-out is normally carried out at the idle/taxi

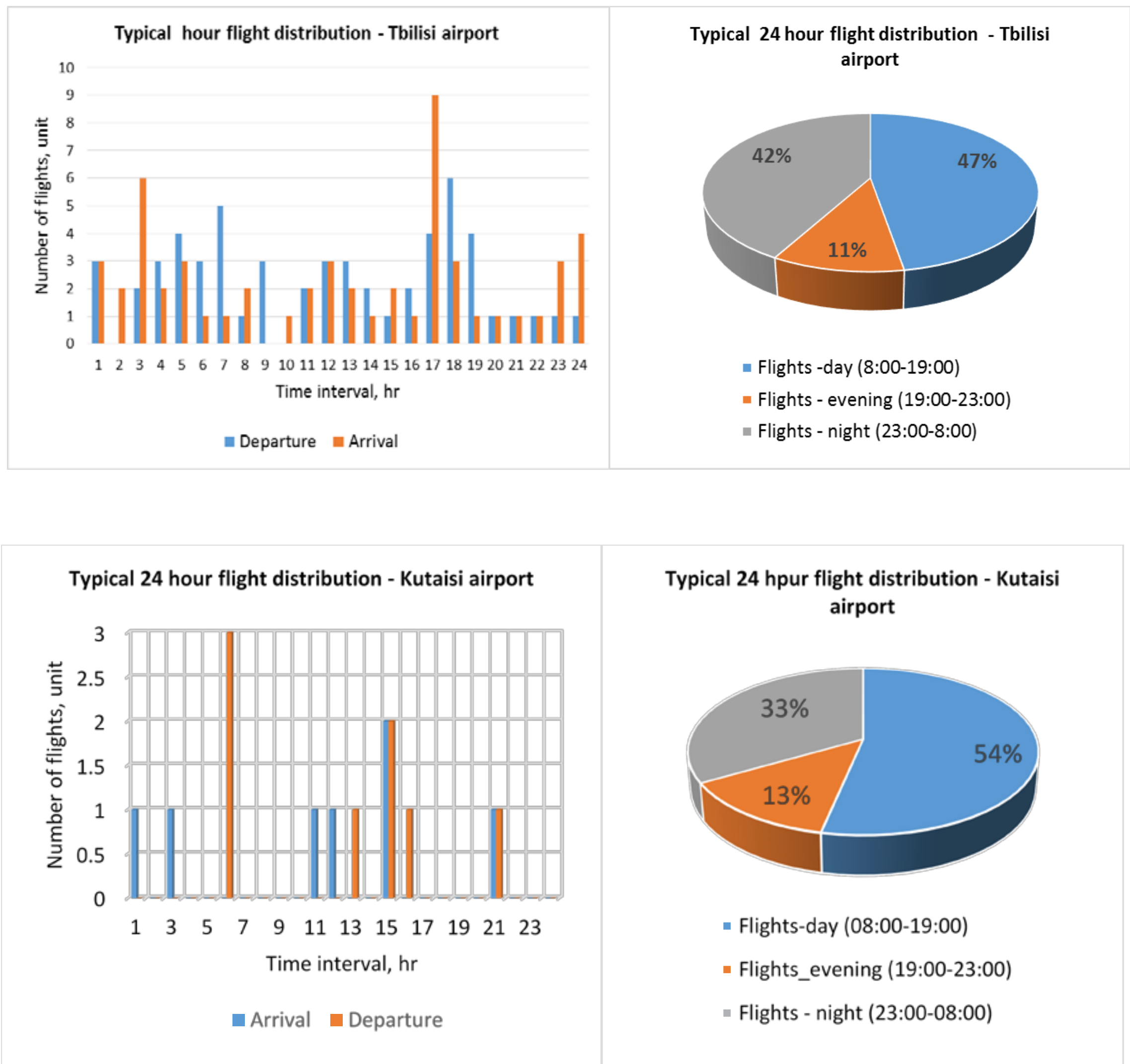

Fig. 2. *Typical distribution of flights (Tbilisi and Kutaisi airports)*

power setting, apart from brief bursts of power to overcome the initial inertia at the start of taxiing or, if necessary, to negotiate sharp turns.

- C. *Holding on ground* - main engines are set to idle thrust with brief bursts of power to move into position.
- D. *Take-off roll to lift-off* - the aircraft is accelerated along the runway to the predetermined rotation speed at the end of the take-off run with the main engines set to take-off power. Full power for take off is rarely used; a predetermined thrust setting is set at the beginning of the take-off roll. Either derated take-off thrusts or, reduced thrust settings, which are determined by the aircraft's actual take-off weight, runway length and prevailing meteorological factors are used.
- E. *Initial climb to power cutback* – the wheels of the aircraft are raised, the aircraft climbs at constant speed with the initial take-off power setting until the aircraft reaches the power cutback height (i.e. between 244-457m above ground level) where the throttles are retarded.
- F. *Acceleration, clean-up and en-route climb* - the aircraft climbs at a thrust setting less than that used for take-off with flap/slat retraction following as the aircraft accelerates and reaches cruising altitude.

Arrival

- G. *Final approach and flap extension* - thrust settings are increased to counteract the additional drag as flaps and the undercarriage are lowered, while speed decreases towards the flare.
- H. *Flare, touchdown and landing roll* - throttles are normally retarded to idle during the flare and landing roll. This is followed by application of wheel brakes and, where appropriate, reverse thrust to slow down the aircraft on the runway.
- Taxi from runway to parking stand/gate – similar to taxi-out described above; however, one or more engines can be shut down, as appropriate, during the taxi-in if the opportunity arises.
- J. Engine shutdown - remaining engines are shut down after the aircraft has stopped taxiing and power is available for onboard aircraft services.

While moving from terminal to runway the airplane uses 7% of engine capacity, from entering the runway until departure 100% capacity is used, while the climb required 85% of the capacity. On the descent stage 30% capacity is used, after landing and taxiing to the terminal 7% of capacity is required.

At local level assessment of impact on air quality of one LTO cycle during the standard stepwise departure-arrival with consideration of the time per each stage of the cycle and engine load, fuel consumption data and ICAO data bases was done. Fuel consumption and emissions for three international airports for typical aircrafts Airbus A320 (type and number of engine: Turbofan/turbojet, 2; engine code and model: 1CM008 (CFM56-5-A1)) and Boeing 737 (type and number of engine: Turbofan/turbojet, 2; engine code and model: 3CM030 (CFM56-7B20)) has been evaluated. Results of calculation for Airbus A320 are given below.

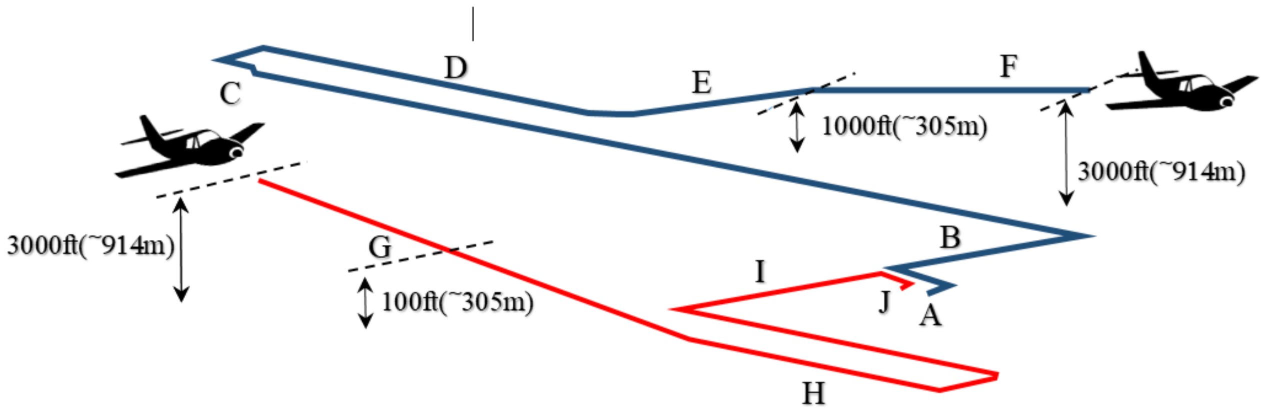

Fig. 3. *LTO flight cycle [3]*

Table 2. *LTO cycle emissions calculated for International airports (Airbus A320)*

	Departure phase	Arrival phase	Total departure+ arrival
Tbilisi airport			
Taxi out time (sec):			706
Taxi in time (sec):			453
Fuel burnt (kg)	458.792	231.296	690.089
CO emitted (kg)	2.8	1.961	4.761
HC emitted (kg)	0.273	0.184	0.457
NOX emitted (kg)	7.205	1.484	8.689
CO2 emitted (kg)	1445.196	728.583	2173.779
Kutaisi airport			
Taxi out time (sec):			640
Taxi in time (sec):			459
Fuel burnt (kg)	445.17	231.296	676.466
CO emitted (kg)	2.56	1.9613	4.521
HC emitted (kg)	0.254	0.1841	0.438
NOX emitted (kg)	7.15	1.4839	8.634
CO2 emitted (kg)	1402.287	728.583	2130.869
Batumi airport			
Taxi out time (sec):			310
Taxi in time (sec):			284
Fuel burnt (kg)	378.588	231.296	609.884
CO emitted (kg)	1.387	1.9613	3.349
HC emitted (kg)	0.16	0.1841	0.344
NOX emitted (kg)	6.883	1.4839	8.367
CO2 emitted (kg)	1192.555	728.583	1921.138

At the local level impact on air quality depends on the number of flights per time unit (1 hour). With consideration of the airport load, this number is maximum in Tbilisi. According to the typical flight schedule, the maximum number of flights served per hour totals 9-10 flights (Fig.1). Respectively, total emission within this time frame is 10 times higher.

Taxiing time in Georgian airports is less than ICAO default taxi-out time (=1140 sec) and average taxi-out time for the busiest airports (=816 sec). Thus, fuel consumption and LTO cycle emissions are lower [6]

Emission can be reduced by substitution of standard stepwise departure-arrival procedure with continuous departure-arrival method. Calculation revealed significant reduction of emissions through this change [7.8]

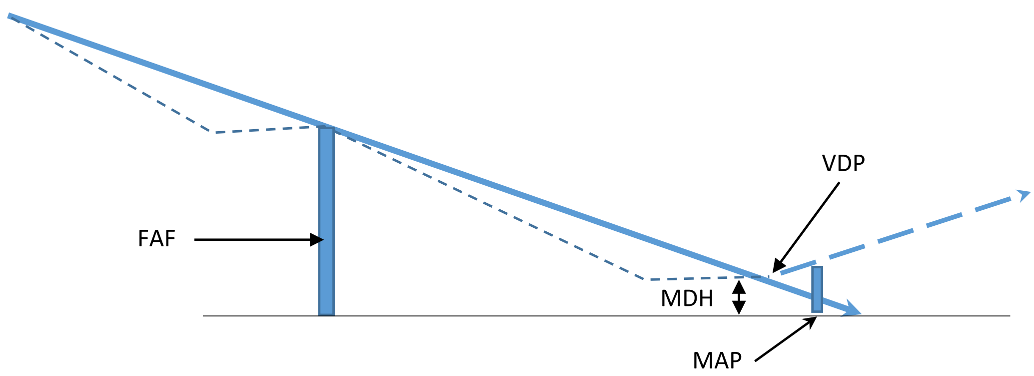

Fig. 4. *Stepwise and continuous arrival scheme*

VDP – Visual Descend Point; MDH – Minimum Descend Height; FAF – Final Approach Fix;
MAP – Missed Approach Point

The method enables reduction of emissions through decrease of 'amount' of the fuel consumed. Calculation showed that substitution of stepwise with continuous departure and arrival scheme reduces fuel consumption by 48% and 40-45% respectively. The change based on example of the Tbilisi airport is given in Table 3.

Addition reduction of emission can be achieved by using e taxiing instead of conventional method. The e taxiing system allows fully autonomous aircraft movement on ground, almost fully avoiding main engine emissions during taxing in and out [9-16]

Continuous departure-arrival and e taxiing allows to reduce emissions sharply. Mass of the fuel burnt and emission reduction while using both mitigation measures – by the example of Tbilisi airport is shown in Table 4.

Conclusion

Results of calculation show that compared to the standard (stepwise) departure-arrival scheme, continuous departure-arrival coupled with the e taxiing enables to reduce the mass of the burnt fuel by 63%. Emission reduction achieved as a result of this change is: CO emissions – by 92%; HC – by 84%, NOX – by 52% and CO2 – by 63%.

It is worth to mention that, along with reduction of emissions, continuous departure-arrival and e taxiing reduces noise related local impact that can

Table 3. *Comparison of stepwise and continuous departure-arrival (Tbilisi airport, Airbus A-320)*

Description	Departure (total)		Arrival (total)		Total departure + arrival	
	Stepwise	Continuous	Stepwise	Continuous	Stepwise	Continuous
Fuel burnt (kg)	458.792	238.572	231.296	138.778	690.089	377.350
CO emitted (kg)	2.800	1.456	1.961	1.177	4.760	2.632
HC emitted (kg)	0.273	0.142	0.184	0.110	0.457	0.252
NOX emitted (kg)	7.205	3.746	1.484	0.890	8.689	4.637
CO2 emitted (kg)	1445.196	751.502	728.583	437.150	2173.779	1188.652

Table 4. *Fuel burnt and emissions - continuous arrival-departure and e taxing – example of Tbilisi airport*

Description	Departure phase		Arrival phase		Arrival-departure	
	Departure (total)	Total – continuous departure with e taxiing	Arrival (total)	Total – continuous arrival with e taxiing	Total departur e-arrival	Total – continuous departure – arrival with e taxiing
Fuel burnt (kg)	458.792	164.243	231.296	83.808	690.089	248.051
CO emitted (kg)	2.800	0.148	1.961	0.210	4.760	0.357
HC emitted (kg)	0.273	0.038	0.184	0.034	0.457	0.071
NOX emitted (kg)	7.205	3.449	1.484	0.670	8.689	4.119
CO2 emitted (kg)	1445.196	517.366	728.583	263.995	2173.77 9	781.361

be also considered as significant positive effect and additional evidence of efficiency of the proposed mitigation approach [17].

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Scientific experimental research on plants stem vibro-cutting in dense environment

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A B S T R A C T

The article discusses the objective of testing the results of theoretical researches on cutting the water plants stem (cane) in the dense medium and in water medium in particular by means of empiric methods. A plant for cane vibro-cutting in the water environment has been developed, which enables to determine the cutting resistance force factors by means of resistance strain gage both in case of vibration and vibrationless cutting. Data obtained upon the results of the experiments from the theoretical research have been factually proved.

Keywords: Water plants, Vibro-cutting, Resistance forces, Energy consumption, Experimental results, Theoretical research.

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Introduction

The exploitation practice of different mowers/harvesters and the results of numerous research works [1-4] indicate that the segmental and rotary apparatus available for the plants stem cutting in the dense medium (water, soil) are not applicable. The segmental cutting apparatus aren't relevant for cleaning the reservoirs and channels from the water plants due to transmitters with complex structure and insufficient relief copy. They aren't applicable in the soil medium at all since the contacting surfaces get covered with soil, which inevitably leads to the breakdown and destruction of the machine parts.

The mentioned shortcomings are lacking in the rotary apparatus. Anyhow, their application in the dense environment is still related to other types of difficulties, which are caused due to the resistance forces of that very dense environment. The available cutting apparatus implement cutting of the plants stems without any support in usual conditions in case of 30÷50m/s circumferential velocity of the blade tip [2, 5].

Such a speed rate in the blades of the rotary apparatus generates forces in the dense environment, which exceed the stem cutting forces in several times. Due to those forces the rotation numbers of the rotor sharply fall down, as a result of which the overwhelming part of the stems is left uncut, the technological processes of harvesting is disrupted and the exploitative indices of the cutting apparatus deteriorate. In order to realize flawless cutting in the dense medium it is necessary to increase the rotation numbers in the rotor and therefore the consumed power.

The exploitation practice of the cutting apparatus and numerous research experiments testify that in order to implement proper cutting with the rotary cutting apparatus in the dense medium it is necessary to increase their power in 5÷6 times [1, 2, 4].

It is obvious that the wide-scale application of such cutting apparatus isn't economically viable; so upgrading of rotary cutting apparatus or the design of the new ones is an urgent issue.

The practice has shown that the first method is not prospective, since the attempts aimed at the improvement of the working process of the existing apparatus in the dense environment have doomed to failure [1, 5].

Thus, it is necessary to follow the second method, i.e. to develop a fundamentally new cutting machine.

The long-year experience gained from the activities implemented in the mentioned direction indicates, that the most efficient way of stem cutting in the dense medium is vibrational cutting in case when the blade performs vibrational movement with low amplitude (2÷8mm) and high frequency (50÷100 s^{-1}), while the rotor is provided with relatively small rotation numbers 0.1÷0.25s^{-1} [2, 3, 6].

The small rotation numbers and consequently the small circumferential (moving) speeds hardly cause any resistance forces in the dense environment, while the vibration movement of the blades rapidly reduces the cutting resistance forces in the stems [1, 2, 4].

As a result of investigations of the research works and analyses related to the mentioned issues we haven't managed to find one where the significance of the vibration cutting effect could be theoretically interpreted. That is why we have conducted some theoretical investigations with the aim of disclosing the main point of the mentioned phenomenon [6, 7].

During the theoretical research a calculation pattern has been selected, which enables to determine the resistance forces of the blade movement in the rotary cutting apparatus in water medium with great precision in case of blade vibration and without it. In the result of the theoretical investigations it has been proved that in case of vibration of the blade in the cutting apparatus, the resistance forces of the water medium decrease from 10 to 35 times [1, 7] depending on the rate of critical speed in the cutting process.

It is worth mentioning that due to the application of the selected original calculation scheme and the patterns of hydrodynamics it becomes possible to evaluate the phenomenon of resistance force reduction caused by the blade vibration in the water environment.

Materials and methods

It is obvious that the results of theoretical investigation can be accepted as a base only if they have been proved through the experiments. To this end we have developed and designed a laboratory plant, which enables to determine the dynamic parameters of the cane stem vibro-cutting in water medium.

The general layout and view of the mentioned laboratory plant are introduced in figures 1,2 respectively, while the working principle is as follows: the container filled with water, where the stems of the experimented plant, particularly those of canes are attached, rotates with the help of transmission shaft connected to the engine, while the rotary equipment consisting of the electromagnetic vibrator stays fixed/immobile. So, through rotation of the container the cane stems in the water medium is transferred to the vibration blade edge and their cutting is implemented.

The scientific experiments were conducted with two types of blades with toothed and flat edges. Besides, it has been proved through both theoretical [2, 4] and experimental methods, that the critical cutting force in case of the blade with toothed edge is much lower, than that of in case of the flat-edge blade.

Determination of some parameters in the process of vibration cutting will enable to conduct accurate analyses and to find optimal cutting regime for the stems. During vibro-cutting the oscillation amplitude (1÷5mm) and frequency (50÷100s^{-1}) of the vibro-blade, as well as the blade supplying speed (0.1÷0.5m/s) or the rotation number (0.1÷0.25s^{-1}) of the rotor are the most significant factors.

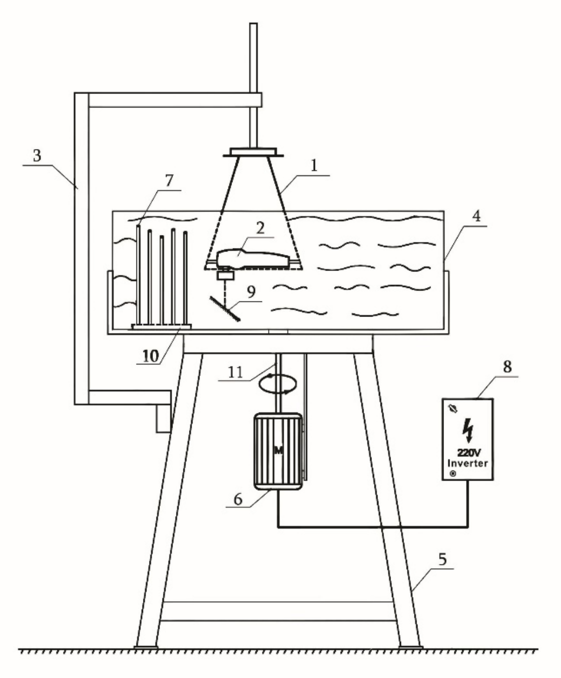

Fig. 1. *The general layout of the experimental plant for the stems vibration cutting in the water medium: 1 - framework, 2 - electromagnetic vibrator, 3 – metal bar, 4 – container filled with water, 5 -trapezium, 6 - engine, 7 – cane stem, 8 - converter, 9 – vibration blade edge, 10 – metal disk, 11 – transmission shaft.*

To determine the cutting force of the plants stem and to register the resulted data, resistance force gages were attached to the vertical bar of the blade and then dehydrated, moreover one of the resistance strain gages is installed at 45˚ angle towards the longitudinal axis of the vertical cylindrical sector, which enables to gain reliable data on the torque moment. Hinging schemes consisting of the strain gages (resistance elements) were connected with the ends of the resistance strain gages, which exclude any deformations and thermal effects. The obtained data were recorded and processed through the measuring and recording computer software ZetLab.

Fig. 2. *The general view of the experimental plant for the plants vibration cutting in the water medium.*

Results and discussions

Upon the conducted theoretical investigations [6, 7] some expressions have been derived, which enable to identify the blade of the apparatus cutting the resistance forces in the dense environment:

- vibrationless

tangent force: $\boldsymbol{T_x = \frac{8}{15}\rho\omega^3 \cdot \sqrt{\frac{\upsilon b}{\omega}} \cdot \ell^2 \cdot \sqrt{\ell}}$,

resistance moments: $\boldsymbol{M_1 = \frac{c\lambda\omega^2\rho\ell^4}{8} + 4b\sqrt{\mu\rho\omega^3} \cdot \ell^3}$, $\boldsymbol{M_2 = \frac{4}{9}\omega^3\rho\sqrt{\frac{\upsilon b}{\omega}} \cdot \ell^4 \cdot \sqrt{\ell}}$.

- in case of vibration

$\boldsymbol{T_x = 0}$, $\boldsymbol{M_2 = 0}$, and $\boldsymbol{M_1}$ is determined by the same formula,

where $\boldsymbol{\rho = 1000\mathrm{kg/m^3}}$ is the concentration of water medium, $\boldsymbol{\omega}$ is the rotation frequency of the rotor shaft ($\boldsymbol{0 \div 100s^{-1}}$), $\boldsymbol{\upsilon = 0.01cm^2/s}$ is the water kinematic viscosity, $\boldsymbol{b = 0.03m}$ is the width of the blade sheet, $\boldsymbol{l = 0.3m}$ is the length of the blade cutting edge, $\boldsymbol{\mu = 0.1kg/m \cdot s}$ is the coefficient of water viscosity, $\boldsymbol{\lambda = 0.001m}$ is the thickness of the blade sheet, $\boldsymbol{c = 1.45}$ is a coefficient, the value of which depends on the ratio of $\boldsymbol{b/\ell}$.

Placing the numerical values we'll have the following:

- Without vibration of the blade - $\boldsymbol{M_1 = 47.1N \cdot \mathrm{m}}$
- In case of vibration $\boldsymbol{M_1 = 1.3N \cdot \mathrm{m}}$.

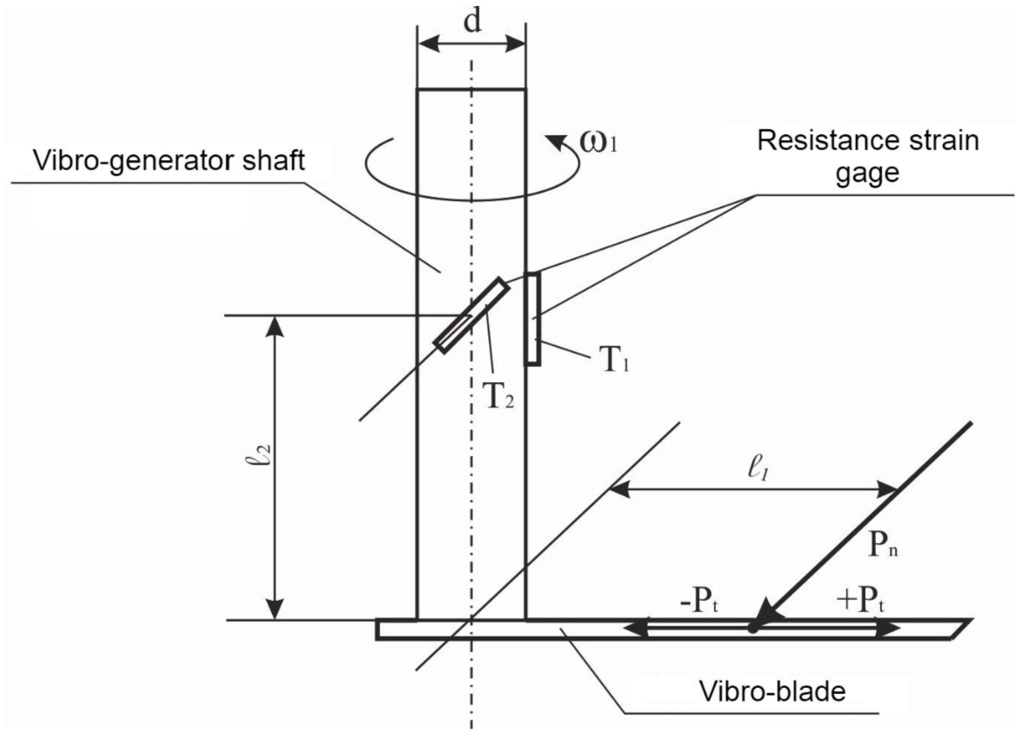

Fig. 3. *The scheme of experimentally identified force factors of vibro-cutting and system calibration.*

The calibration of the force factors in the experimental plant has been conducted in line with the methodology [8] developed by our research group according to the scheme depicted in figure 3. The relation of the measured force factors between the recorded deformations (strains) of the resistance strain gages is apparent. T_1 strain gage records the tangent force factors at the blade cutting edge, the maximum regular strain in the sticking sector of transmitter:

$$\sigma_{max} = \frac{M_z}{W_z},$$

where $M_z = (T_x \pm P_t) \cdot l_2$, is the bending moment in the mentioned sector, while $W_z = \frac{\pi d^3}{32}$ is the resistance moment of the vibro-generator shaft.

T_2 resistance strain gage records the deformation of the regular component of the cutting power (P_n) and the twisting of the shaft in the vibro-generator affected by the resistance forces of the environment. The resistance strain gage is stuck at the angle of 45°, hence $\sigma_{max} = \tau_{max}$, besides:

$\tau_{max} = \frac{M_t}{W_\rho}$, where $M_t = \left(P_{n(c)} + P_r\right) \cdot l_1$, $W_\rho = \frac{\pi d^3}{16}$ is the polar resistance moment of the shaft sector.

In the result of conducted scientific investigations the most significant force factors have been determined: M_1 **and** P_t.

Figure 4 depicts the cutting oscillograms (for M_1 moment) received from the T_2 resistance strain gage in the air medium for two individual cane stems in case of vibro-blades with toothed cutting edge and flat edge and in case of oscillating amplitude along the cutting edge with the value of $a_x = 2.0mm$ and with the frequency equal to $\omega = 60s^{-1}$.

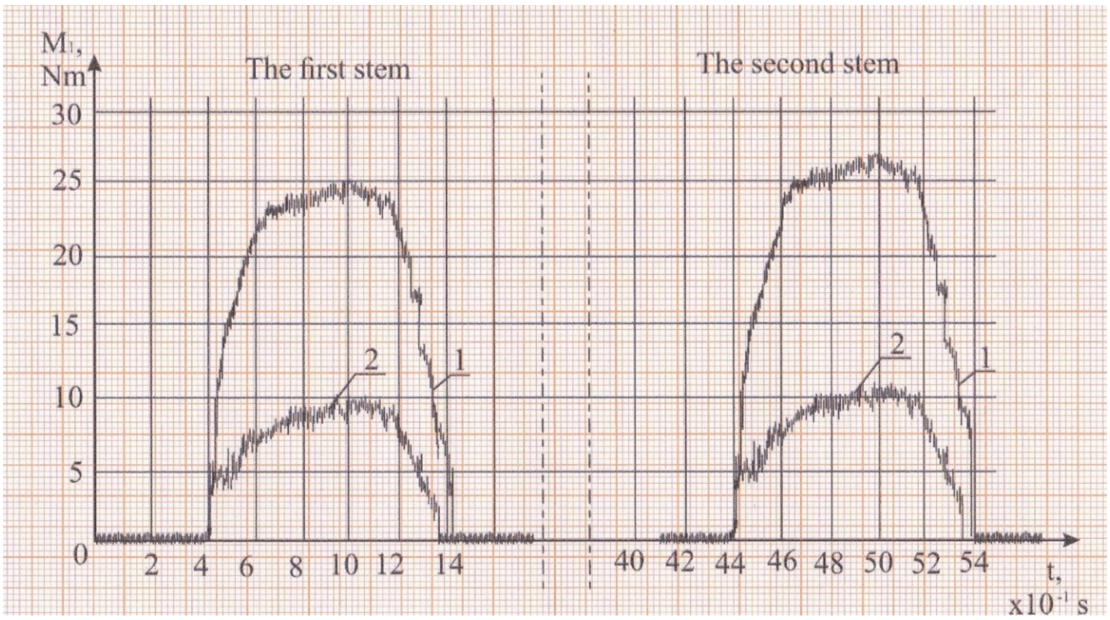

Fig.4. *The osscilloram sample of the resistance* M_1 *moment caused by the regular component (P_n) of vibro-cutting (* $a_x = 2.0mm$ *and* $\omega = 60s^{-1}$ *) power in the air medium for one cane stem.*
1- Blade with flat cutting edge, 2- Blade with toothed cutting edge.

Figure 5 depicts the changing oscillogram of the tangent component in the cutting force of one cane stem (apart from each other, also the second stem) in air medium in case of parameters of $a_x = 2.0mm$ and $\omega = 60s^{-1}$.

It is noteworthy that the tangent component of the cutting force in case of flat cutting edge is smaller than that of recorded in case of toothed cutting edge.

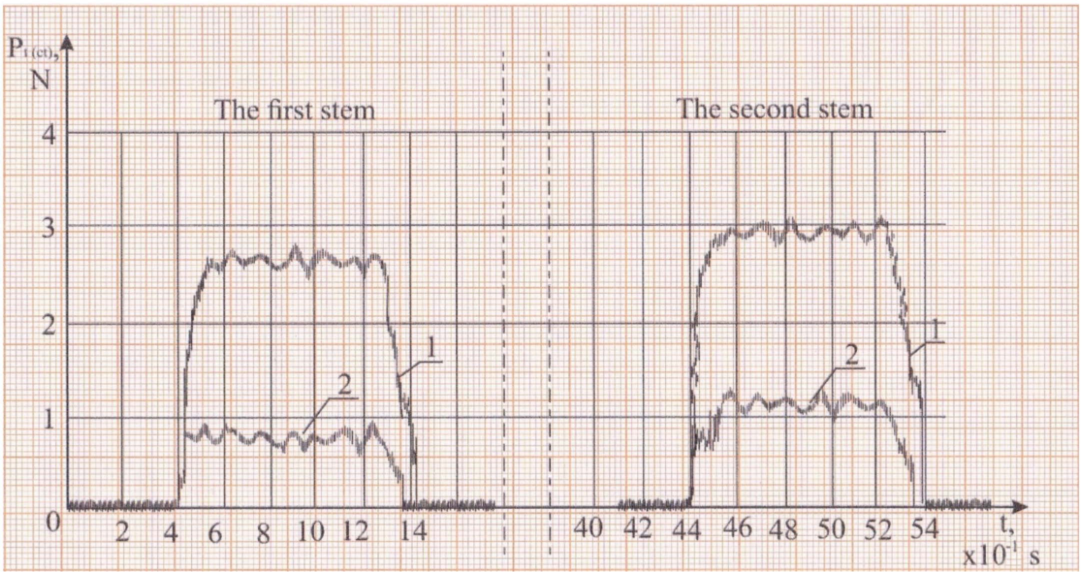

Fig.5. *The sample of changing oscillogram in the tangent component (P_t) of the vibro-cutting ($a_x = 2.0mm$ and $\omega = 60s^{-1}$)force for one cane stem in air medium.*
1- Blade with toothed edge, 2- blade with flat cutting edge.

Figure 6 illustrates the most important oscillogram in view of the discussed issue, that is the change of resistance M_1 moment in the water medium without blade vibration (curve 1) and with its administration (curve 2).

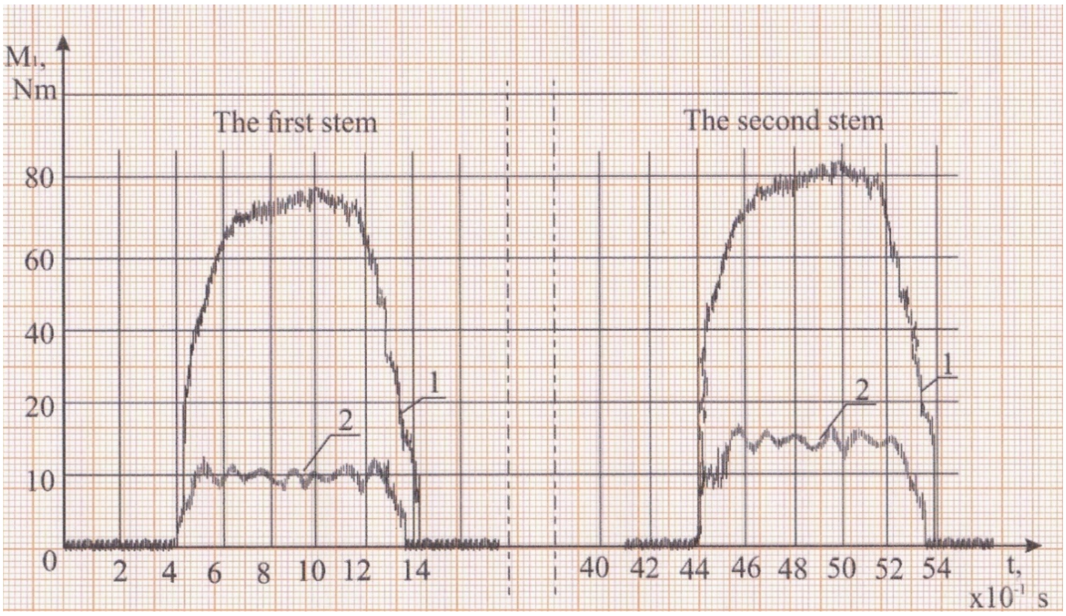

Fig.6. *The sample of the changing oscillogram of the resistance moment M_1 affected by the environmental resistance forces and the regular component of the cutting resistance force for one cane stem in water medium.*

1-Without blade vibration (vibrationless) in the water medium, 2- with blade vibration in the water medium ($a_x = 2.0mm$ and $\omega = 60s^{-1}$).

As we can see from the last oscillogram, the resistance moment in water medium is about 10 times less in case of blade vibration as compared to that of observed in case of vibrationless cutting, besides, in case of oscillation frequency increase this difference becomes even larger. Thus, by increasing the oscillation frequency from $60s^{-1}$ to $90s^{-1}$, the mentioned difference amounts from 10 to 23 times.

As to the tangent component of the resistance forces in case of vibro-cutting, they hardly undergo any significant changes in water medium as compared to that of observed in air medium. The main point in the tangent component of the cutting forces is that it is about three times higher in case of the toothed blade in comparison with the index recorded in case of flat blade (Fig. 5), this being quite expected.

It is also quite clear that irrespective of the above mentioned, the cutting efficiency in case of the toothed blade grows up, as a result of which the regular cutting component, which determines the general resistance $\boldsymbol{M_1}$ moment, falls down in 2.5÷3.0 times.

Conclusion

Thus, in the result of the laboratory research experiments the most significant outcomes received through the theoretical researches have been mostly verified. Particularly, this is related to the fact that the cutting resistance forces in case of vibro-cutting in water medium, and hence the energy costs fall down in about 20 times. In case of vibro-cutting the toothed blades are effective, the application of which reduces the cutting resistance force factors in about 3 times, as compared to those observed in case of applying flat cutting edge blades.

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Laboratory studies of the physicomechanical properties in the cane stem

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A B S T R A C T

The article considers the research results of the physicomechanical properties in the wild plants, particularly in cane. The experiments have been conducted through special testing devices, as a result of which it has been disclosed that per the height of the stem the proportional and strength (fatigue) limits, as well as the modulus of elasticity fall down, while the relative deformations rise up. The experimental results have been introduced through a table and diagrams.

Keywords: Wild plants, Physicomechanical properties, Stem pull-out, Elasticity, Deformation, Special testing.

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Introduction

There are multiple factors affecting the cutting process of the plants stems and they are mainly related to the physicomechanical properties of the stem in the cutting plant, which are factually taken into account when designing the cutting apparatus. The values of the stem height, its thickness, resistance during the cutting process, the threshold pressure and strain in the cutting plant, as well as the knowledge and analyses of other properties are necessary to estimate the strength of individual units in the cutting apparatus and the main geometric parameters in the blade. As a result of the force exerted by the blade, considerable pressure appears between the blade and the cutting material, which results in the destruction of the connections between individual parts of the material.

The phenomenon related to the changes of physicomechanical properties in the stem is based on the restrictions of the strains and the size of deformation variation depending on the effect of the blade speed, humidity of the environment, on the thickness of the stem in the cutting plant, etc. [1, 2].

In the accomplished works [3, 4], the investigations of the physicomechanical properties of the plants have shown that throughout the process of stems' pull-out only elastic deformation (there is no plastic deformation) takes place before their cutting; the directly proportional relationship between the drag force and deformations holds up, while the limits of strength and proportion overlap. Nevertheless, the diagrams designed as a result of the investigations conducted by the academician A.P. Tarverdyan [5, 6] have enabled to clearly enhance the differences between the limits of strength and proportion. As a result of pulling out the samples, plastic deformation together with the elastic one is generated and the directly proportional relationship between the cutting force and deformation fails to keep up until the cutting moment. Also it has been shown [5, 6] that from the lower stem part of the cutting plant upwards the proportional and strength (fatigue)limits, as well as the elasticity modulus are reduced, while the deformation increases.

Materials and Methods

In order to describe the mechanical properties four parameters have beed identified: proportional limit (σ_r), elastic deformation (ε_r), endurance (fatigue) limit (σ_e), plastic deformation (ε_e) and modulus of elasticity (E).

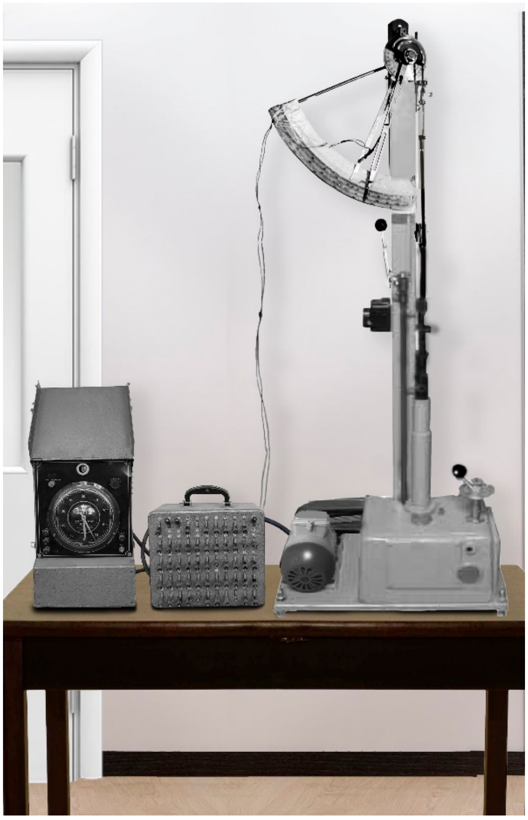

Fig. 1. *The general view of the device for testing the samples made from the cane stem*

The stem properties of the thick-stemmed crops and wild plants are subjected to huge changes parallel to the plants height, which apparently causes some problems during the cutting process.

The experiments on pulling out the stems of the plants, particularly those of the canes have been conducted on the machine of PTM-3 series (Fig. 1). It should be mentioned that the mentioned machine has been subjected to some structural changes by the academician A.P. Tarverdyan in order to eliminate the existing shortcomings (damage of the stem samples in the handles and slipping out of the stems through them), which enable to gain verified measurement data [5, 6]. Taking into account that our observations concern the cane stem cutting process in the water medium with vibro-cutting principle, it is relevant to implement the experiments in the 3rd inter-node from the lower part of the cane stem. Strata/samples with 150 mm length and 2-3 mm width have been prepared which have been experimented through the methodology and machine developed and recommended by A.P. Tarverdyan. Metallic rings have been adhered to both ends of the stem with special glue (würth), which are intended for fastening the samples in the handles (Fg.2). The choice of the width in the samples (2-3 mm) depends on the need to reduce the cutting force down to the value in case of which the sticking connection by glue and the obtainment of verified measurement data are simultaneously ensured for the determination of the mechanical properties of the sample and for the design of the deformation diagrams.

Fig. 2. *Experimented samples of the cane*

Results and Analysis

The average values for the changes of physicomechanical properties of the stem material in the plant studied by our research group are introduced in the table below, while the diagrams of the stem pullout are introduced in Figures 3,4.

Table. *Indicators describing the physicomechanical properties of the cane stem*

Indicators describing the mechanical properties / The height of the sample location from the root node (cm)	Proportional limit, σ_r [MPa]	Elastic deformation, ε_r	Modulus of elasticity, E [MPa]	Strength (Fatigue) limit, σ_e [MPa]	Plastic deformation, ε_e
10	21.6	0.083	260	25.9	0.0061
40	20.4	0.09	226	24.5	0.0068
70	19.6	0.095	206	23.5	0.0074
100	18.8	0.1	188	22.6	0.0078
130	18.2	0.104	175	21.8	0.0083

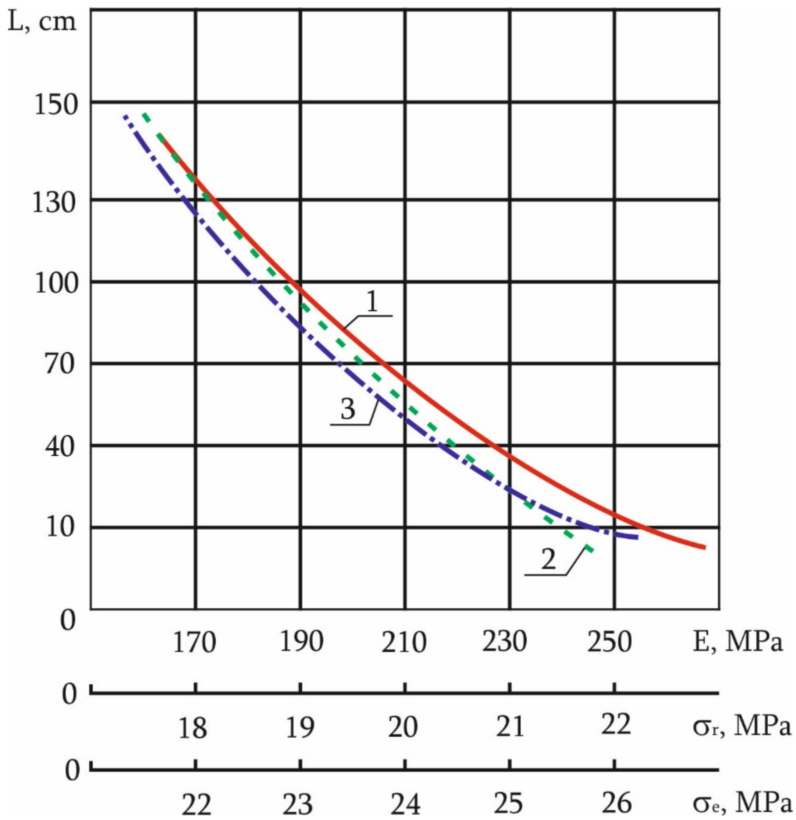

Fig. 3. *Diagrams of the changes of mechanical properties in the cane stem per its height.*
1- Modulus of elsaticity (E), 2- Proportional limit (σ_r), 3- Strength/Fatigue limit (σ_e)

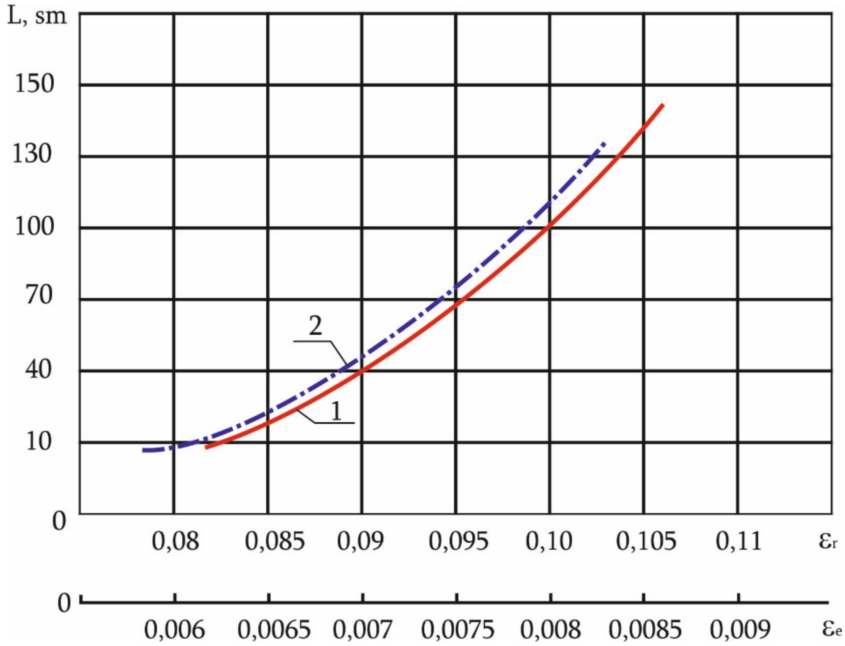

Fig. 4. *Diagrams of the deformation changes in the cane stem per its height.*
1- Elastic deformation (ε_r), 2- Plastic deformation (ε_e).

The laboratory experiments of the studies on physicomechanical properties of the cane have testified that the updated device and developed methodology enabled to adjust the indices of the physicomechanical properties in the cane substance. The data received by our research group differ from those commonly found in literature [7] in 1.5-2 times, which surely will give an opportunity to adjust the geometric and kinematic parameters in the blades of cutting apparatus.

Conclusion

1.The methodology and updated devices applied during the laboratory studies of physicomechanical properties in the cane stem have enabled to significantly adjust (in 1.5-2 times) the indicators of the physicomechanical properties.

2.As a result of investigations it has been found out that the indices of the strength in the stem material fall down per the plant height, while the deformation indices grow up.

3.Based on the concise analyses of the laboratory trials on the cane stem it can be inferred that the acquired results enable to adjust the kinematic and geometric parameters of the operating parts in the cutting apparatus.

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