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NEW VIEWPOINTS IN OPTIMIZING THE ENERGETICS OF WORKING PROCESSES OF THE AGRICULTURAL AGGREGATES

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ABSTRACT: The article presents the insertion manner - naturally from the physical point of view - of some nonlinear components that generates optimal points, into the optimal calculation of the energetic field of agricultural aggregates. Possible optimal models are exposed into the energetic space of working processes and their outcomes. It is shown that the different optimal patterns relative to the objective function for example, generally, lead to different optimal points. Is offered and an alternative of objective function constructed from several elementary objective functions. Also in the article is made and a review of the development directions of the problem optimal of the energetic space of working processes of agricultural aggregates.
KEYWORDS: energetics of agricultural aggregates, optimal models, optimization

INTRODUCTION

According to [12], the energetic balance is a balance relating to the sources and energy consumption, including losses into a system or energetic plant. The balance of power after [12] is an equilibrium relation developed to the engine shaft of a motor vehicle, tractor, etc. and the sum of powers consumed for moving, performing the useful mechanical work and covering losses. Another important balance is the balance of traction that according to [12] is a relation of balance of the external forces operating on the tractor or of another traction vehicle. In [16] it is shown that the balance of traction allows the determination of working conditions of the tractor for the different areas and conditions of use. Also in [16], it is shown that the analysis of balance traction presents, both practically and theoretically, a particular importance for optimizing the exploitation of agricultural tractors. In [10] it is shown that the energy consumption in agricultural works is in directly dependency of the working capacity of aggregates. For this reason, the working capacity enters in the optimization models of working processes of agricultural aggregates. In fact [10] is totally dedicated to the optimization of the energetic consumption, but this can not be really optimized without considering a number of problems strictly related to the needs of agricultural holdings: the rational use of traction parameters of agricultural tractors, the rational formation of agricultural aggregates, optimization of displacement methods of agricultural aggregates, correlation of the mechanization technologies with the requirements of reducing the energy consumption, the introduction of automation in the driving of the agricultural aggregates, optimization the parameters for construction of machines and agricultural aggregates, etc.

Following research, revealed that the most accessible and natural source that allows obtaining of some optimal points in the energetic space (space of traction force functions, consumed power, consumed energy, fuel consumption, working capacity), este neliniaritate funcțiilor frecare şi rezistența la deformare a solului. These functions take the place of the conventional friction coefficients and resistance to soil deformation. La baza acestei schimbări de optică, stau fapte experimentale descrise în literatura On the basis of this change in optical, stay experimental facts described in the specialized literature, for example, [6], [8], [7]. We exploited such some aspects neglected by the cited authors, and we could obtain the optimal points of an working process carried out by an agricultural aggregate, in a natural manner physically speaking. A similar technique of introducing of some nonlinearities in the behavior of the same sizes have used some authors to get optimal points in the energetic space of working processes of the agricultural aggregates, but the introduction of nonlinearities was done without a physical motivation, thus causing the emergence of *some physical quantities unused until then and too little physically significant, [5], [10], [11]. Moreover, the vision presented here leaves room and for further investigations, relating to the dependency on other parameters of the friction coefficients and of resistance to the soil deformation. The optimal models elaborated are of four types, depending on the chosen objective function: the energy consumed specific to the unit of surface, working capacity, fuel consumption, a mixed objective function consisting of the previous three. All the four optimal models use as main optimization parameters, the movement speeds of the aggregate during the three main stages of the working process: the effective work, the turning at the ends of plots and the displacement in no load. Outside these four models, it is shown that exist also optimal models using the power or the traction force like objective functions can estimate the possible optimal points, but only separately by working stages. Only the energy and the mixed objective function enable the formulation of a global vision. These are, within the optimal models expressed as objective functions of three variables: the speed in working, the speed in turnings and the speed in no load.*

MATERIAL AND METHOD

The list and significance of the parameters used in the mathematical modeling of the problem appear in Table 1.

Table 1. List of parameters of mathematical models used to optimize the energetics of aggregates for the seedbed preparation

No.	Parameter	Notation	M.U.
1	Working speed (under load)	v	m/s
2	Coefficient of friction at the tractor wheels running on the ground	f	-
3	Coefficient of sliding friction of the machine with the ground	μ	-
4	Coefficient characterizing the specific resistance at deformation of soil	k	N/m^2
5	Coefficient depending on the shape of the active surface of working	ε	-
6	Working depth	a	m
7	Working width	b	m
8	Mass density of the soil	ρ	Kg/m^3
9	Machine weight	G_m	N
10	Tractor weight	G_t	N
11	The tensile strength force opposed by the machine	F_t	N
12	The width of the plot	C	m
13	The length of the plot	L	m
14	Power required for overcoming the rolling resistance	P_f	W
15	Power required for the movement of the aggregate	P_d	W
16	Working capacity	W	m^2/s
17	Minimum loading coefficient of the tractor	c	-
18	Coefficient value of rolling friction on ground for zero speed	f_0	-
19	The minimum value of the coefficient of rolling friction on the ground	f_1	-
20	The speed at which the wheels friction with the ground is minimal	v_f	m/s
21	Coefficient value of sliding friction between parts of the machine and the soil at zero speed	μ_0	-
22	The minimum value of the coefficient of sliding friction between parts of the machine and the ground	μ_1	-
23	Speed at which the sliding friction between parts of the machine and ground is minimal	v_μ	m/s
24	Coefficient value of resistance at deformation of soil at travel speed zero	k_0	-
25	The minimum value of the coefficient of resistance at deformation of the soil	k_1	-
26	The speed at which the coefficient of resistance at deformation of the soil takes the minimum value	v_k	m/s
27	Working Speed (at harvesting or under load)	v_r ,v	m/s
28	Speed in no load	v_g	m/s
29	Speed at u turns	v_i	m/s
30	The string of lengths of traveled routes to repair the errors	L_{si}	m
31	The energy consumption of the aggregate per surface unit	E_S	j/m^2
32	Total time in working	t_T	s
33	Total time of u turns	t_i	s
34	Total time of running in no load	t_g	s
35	Fuel consumption for the agricultural machine, specific to the surface unit	C_s	l/m^2
36	Multiobjective equation for the calculation of an optimal point in the working process	Ψ	-
37	Power available for the movement of aggregate and performing of useful work, [15]	P_{disp}	w
38	Power necessary to carry out of stage in working	P_T	w
39	Power consumed in u turns	P_i	w
40	Power consumed for traveling in no load	P_g	w

BASIC IDEA

As shown in the introduction, the basic idea of the whole development is the transformation of rolling friction coefficients and of contact between the parts of aggregates in contact with the soil or the vegetation and of the coefficient of resistance at deformation of soil in equations that depend on the movement speed of the aggregate, and perhaps of other parameters.

For the three parameters specified above, were used formulas of the type:

$$f(v)=f_0+2\frac{f_1-f_0}{v_f}v+\frac{f_0-f_1}{v_f^2}v^2,\ \mu(v)=\mu_0+2\frac{\mu_1-\mu_0}{v_\mu}v+\frac{\mu_0-\mu_1}{v_\mu^2}v^2,\ k(v)=k_0+2\frac{k_1-k_0}{v_k}v+\frac{k_0-k_1}{v_k^2}v^2 \quad (1)$$

IMMEDIATE EFFECTS ON MINIMIZING OF TOTAL TRACTION FORCE FOR AN AGGREGATE INTENDED FOR SEEDBED PREPARATION

An immediate use for a working process of an aggregate is obtained considering only the stage of actual work not and the u turns and / or travels. no load Consider the following expression is the total force required for the movement of the aggregate intended for the seed bed preparation (easy deducted by [7], for example):

$$F_T(v)=f_0G_t+\mu_0G_m+k_0ab+2\left(\frac{f_1-f_0}{v_f}G_t+\frac{\mu_1-\mu_0}{v_\mu}G_m+\frac{k_1-k_0}{v_k}ab\right)v+ \\ +\left(\frac{f_0-f_1}{v_f^2}G_t+\frac{\mu_0-\mu_1}{v_\mu^2}G_m+\frac{k_0-k_1}{v_k^2}ab+\varepsilon\rho ab\right)v^2 \quad (2)$$

By cancellation of the derivative in relation to the speed, v, is obtained the optimal point of coordinates:

$$v_{\min}=-\frac{\frac{f_1-f_0}{v_f}G_t+\frac{\mu_1-\mu_0}{v_\mu}G_m+\frac{k_1-k_0}{v_k}ab}{\frac{f_0-f_1}{v_f^2}G_t+\frac{\mu_0-\mu_1}{v_\mu^2}G_m+\frac{k_0-k_1}{v_k^2}ab+\varepsilon\rho ab},$$
$$F_{T\min}=\left[\left(\frac{f_0-f_1}{v_f^2}G_t+\frac{\mu_0-\mu_1}{v_\mu^2}G_m+\frac{k_0-k_1}{v_k^2}ab+\varepsilon\rho ab\right)\left(f_0G_t+\mu_0G_m+k_0ab\right)- \\ -\left(\frac{f_1-f_0}{v_f}G_t+\frac{\mu_1-\mu_0}{v_\mu}G_m+\frac{k_1-k_0}{v_k}ab\right)^2\right]\left(\frac{f_0-f_1}{v_f^2}G_t+\frac{\mu_0-\mu_1}{v_\mu^2}G_m+\frac{k_0-k_1}{v_k^2}ab+\varepsilon\rho ab\right)^{-1} \quad (3)$$

In a similar way it can obtain optimal points in the stages of u turn and of displacement in no load, separately.

RESULTS - Formulating the problem in energetics terms

For energy calculation using classical way of separation process in three phases (actual work, back and shift the goal, according to [10], for example), is estimated the traction force for each, is multiplied at each stage of the traction force with the speed that the final energy is calculated for each phase by multiplying the total power required by step. To complete the calculation of power balance can be used the power balance from [15], then summing up, we obtain all the energy consumed. For independence processed surface area can be divided by the total energy consumption resulting specific area of the surface per unit area, E_s. On this way we obtain the following expression for the energy consumption of an aggregate work for seedbed preparation:

$$E(v,v_i,v_g)=\left[f(v)G_t+k(v)ab+\mu(v)G_m+\varepsilon\rho abv^2\right]L\left(\left[\frac{C}{b}\right]+1\right)+f(v_i)(G_t+G_m)l_i\left(\left[\frac{C}{b}\right]+1\right)+f(v_g)(G_t+G_m)L_s \quad (4)$$

which has an optimal point (a minimum) of coordinates:

$$v_{opt}=\frac{G_t\frac{f_0-f_1}{v_f}+ab\frac{k_0-k_1}{v_k}+G_m\frac{\mu_0-\mu_1}{v_\mu}}{G_t\frac{f_0-f_1}{v_f^2}+ab\frac{k_0-k_1}{v_k^2}+G_m\frac{\mu_0-\mu_1}{v_\mu^2}+\varepsilon\rho ab},\ v_{iopt}=v_f,\ v_{gopt}=v_f. \quad (5)$$

The minimum energy specific to the unit of surface consumed for carrying out the work will be:

$$E_{s\min}=\frac{E(v_{opt},v_{iopt},v_{gopt})}{Lb\left(\left[\frac{C}{b}\right]+1\right)}. \quad (6)$$

For example, in the case of tractor the aggregate A-1800 - Combinator BIPLAN 700, it is solved an optimal problem of type (8 in Table 2)

$$v>0, v_i>0, v_g>0,\ cP_{disp}\le\max(P_T(v),P_i(v),P_g(v))\le P_{disp},\ E_s(v,v_i,v_g)\to\min, \quad (7)$$

is found the optimal point of coordinates: v_{opt}= 1.018 m/s (3.666km/h), v_{iopt}= 1.78 m/s (6.408 km/h), v_{gopt}= 1.78m/s (6.408 km/h) using the formula for calculating the working capacity:

$$W(v,v_i,v_g)=\frac{LC}{t_T(v)+t_i(v_i)+t_g(v_g)}, \quad (8)$$

where:

$$t_T(v)=\frac{L}{v}\left(\left[\frac{C}{b}\right]+1\right),\ t_i(v_i)=\frac{l_i}{v_i}\left(\left[\frac{C}{b}\right]+1\right),\ t_g(v_g)=\frac{L_s}{v_g}, \quad (9)$$

are: time spent for the working stage, where [•] is the function the whole part, the time spent for returns stages, respectively, the time spent for stages of no load traveling. In this case the results W=

1.956 ha/hour. The variation in specific energy consumed in the case with the operating speed and the turning speed is represented graphically in Fig. 1. If for the same aggregate, the objective function is the fuel consumption, then the optimal coordinate point moves slightly, moving to operating speed of the minimum consumption: v= 0.706 m/s (2.54 km/h), v_i=1.78 m/s (6.408 km/h), v_g= 1.78 m/s (6.408 km/h). It is observed that only the optimum working speed changed because the machine acts only at the working stage of the process. The variation of fuel consumption for the combinator BIPLAN 700 towed by the tractor A-1800, depending on the working speed and the turning speed is graphically represented as a surface in three-dimensional space in Fig. 2.

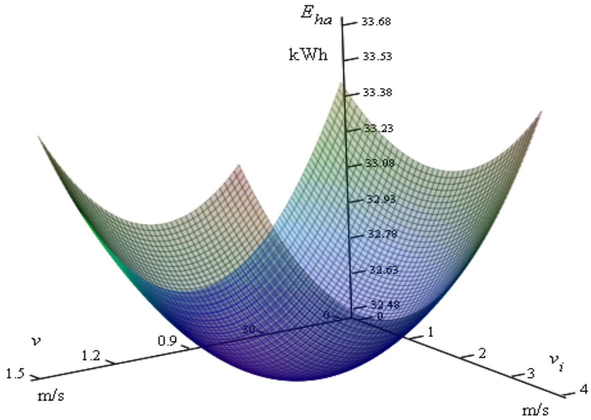

Figure 1 - Variation specific energy consumed per hectare for the aggregate tractor A1800-combinator BIPLAN 700, in the subspace of the working speeds and of turning around the point of minimum

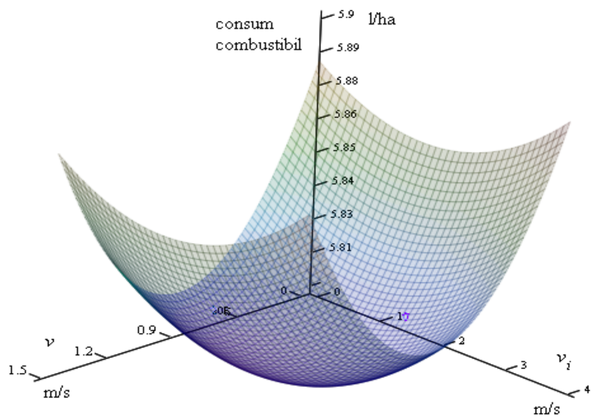

Figure 2 - Variation of fuel consumption per hectare for the combinator BIPLAN 700, in the working speeds and of turning subspace, around the point of minimum, traction with tractor A - 1800

The data used in the calculation for the aggregate tractor A-1800 - Combinator BIPLAN 700 are: δ=0.1193, k_0=31500 Pa, k_1=30500, v_k= 1.5 m/s, ρ=1000 kg/m^3, f_0=0.2, f_1=0.17, v_f=1.78, μ_0=0.5, μ_1= 0.4, v_μ=1.7 m/s, ε=2, m_m=3950 kg, m_t=10200 kg, η_{tr}=0.98, c=0.85, a=0.18 m, b=7.0 m, P_e=147.2 kW.

OPTIMAL MODELS

It can now formulate several types of optimal problems, [9], [3], [2], [5], [14], [4], [13]. These problems differ by the type and number of functions objective, the number of optimization variables and the number and type of restrictions imposed to involved variables. Among the objective functions of optimal models, the most commonly considered are: the tractive forces, consumed powers, the energy consumed working, working capacity, fuel consumption. As functions objective can be considered and the charging capacity of the tractor, functions of an economic nature related to financial resources, functions objective with a topological character which take into account the geometry of surfaces of some farms and choice of a best route to working, combinations of them, etc.

Table 2. Optimal energetic issues (models) for agricultural machines of seedbed preparing

Crt. No.	The objective function	Variables optimization	Restrictions	Enunciation
1	$F_t(v)$	v	facultative	Annulment the first derivative with change of sign
2	$F_T(v)$	v	facultative	Annulment the first derivative with change of sign
3	$F_t(v,v_i,v_g)$	v,v_i,v_g	facultative: v_i<v	Annulment of first order partial derivatives
4	$F_T(v,v_i,v_g)$	v,v_i,v_g	facultative: v_i<v	Annulment of first order partial derivatives
5	W(v)	v	$cP_d<P_f<P_d$	Mathematical programming
6	$W(v,v_i,v_g)$	v,v_i,v_g	$cP_d<P_f<P_d$	Mathematical programming
7	$E(v,v_i,v_g)$	v,v_i,v_g	-	Annulment of first order partial derivatives
8	$E(v,v_i,v_g)$	v,v_i,v_g	$cP_d<P_f<P_d$	Mathematical programming
9	$C_s(v,v_i,v_g)$	v,v_i,v_g	-	Annulment of first order partial derivatives
10	$C_s(v,v_i,v_g)$	v,v_i,v_g	$cP_d<P_f<P_d$	Mathematical programming
11	Combinations of objective functions, Ψ	v,v_i,v_g	facultative	Mathematical programming
12	Combinations of objective functions, Ψ	v,v_i,v_g	$P_f<P_d$, for the working stage and turning	Mathematical programming

As variables of optimization can be used all the variables arguments of functions that appear in Table 1. Of these, the most used are: the working speed, the working width (if this can vary).

The restrictions are of the type of inequalities, typically by limiting the range of speeds or by ordering the working speeds (on the three different stages, if any). It is also possible put the condition of fuel consumption limitation but also of the working capacity in a positive or negative sense. In some cases, the quality of the work is measured by a formula linking the quality to the *optimization variables, this function can be used for expressing a restriction or as objective function. The positively of speeds is a natural requirement that no longer need to be specified.*

Issues or models with which will work in this material is the most common. Some of the most important issues that can be formulated are given in Table 2. For simplicity, it will be assumed that the three types of speed (in working, in no-load and in turnings) have the same value in time, being therefore constant. Comparative results obtained using various objective functions for the aggregate U-650 tractor + universal drill carried SUP-29 are given in Table 3.

Table 3. Optimal regimes obtained using different objective functions for the aggregate U-650 tractor + universal drill carried SUP-29

Objective function	Optimal values					
	v, m/s	v_i, m/s	v_g, m/s	E_s, kWh/ha	W, ha/h	C_s, l/ha
E_s	0.578	1.780	1.360	33.837	0.540	3.298
W	1.181	4.258	1.834	36.753	1.100	4.158
C_s	0.365	1.780	1.360	34.151	0.350	3.236
ψ	0.937	3.686	1.834	34.971	0.881	3.692

The functional multiobjective used for the simultaneous attainment of optimal conditions for three objective functions has the structure:

$$\Psi(v,v_i,v_g)=\sqrt{p_W\left(1-\frac{W(v,v_i,v_g)}{w_{\max}}\right)^2+p_e\left(1-\frac{e_{\min}}{E_s(v,v_i,v_g)}\right)^2+p_c\left(1-\frac{c_{\min}}{C_s(v,v_i,v_g)}\right)^2}\,, \quad (12)$$

e_{min}, c_{min} and w_{max} being optimal values obtained for single objective functionals energy, consumption and working capacity, and the shares of each term corresponding to one of the three objective functions being set by the author of the optimization, on condition:

$$p_W+p_e+p_c=1\,. \quad (13)$$

CONCLUSIONS

The investigations optimal of the energetic field of aggregates intended for seedbed preparation, bring as main novelty an acceptable physical point of view on the main factors involved in the existence and positioning of the points defining their optimal working processes. If our predecessors considered nonlinear laws to get optimal points only in order to obtain some equations providing points of extremum in the strict sense, in this attempt is proposed the alternative that the formulation of nonlinear laws to start from a transparent reality in the scientific literature starting with the the first half of the twentieth century and continuing with the latest research. In this specialized literature we found the reasons to extend the friction coefficients and resistance to advance coefficients of agricultural machines and aggregates to nonlinear functions of the travel speed, that make that the parameters previously called coefficients to become functions.

Another note of originality in the results presented was to emphasize the importance of point of view which makes optimization (choice of objective function). For each choice, the results dieferă, even if often only little quantitative and without reversing the order generated on a specific collection of variants. It was built as a joint objective function capable of simultaneously consider three objective functions, the user can choose a lower consumption or an increased working capacity, or a reasonable balance between them for example.

The optimal calculation is very voluminous, contains a large number of parameters defining the energetic framework of the problem. For this reason, each of the specific cases of the calculation is very specific, depending on the configuration parameter values from a large number of such combinations. In the chosen combination, a calculation is made to determine the optimal speed for an triplet (in the working in turnings and empty) that the tractor will try to achieve or approach them as much as each of the three step. It also shows and how important it is the partial farness of optimal points through the effects that it has.

In general, the optimal calculation described in this chapter, gives results in good agreement with the experimental results [1]. The differences are coming from the fact that the consumptions and the calculated working capacity is an optimal one, whereas in experiments there are instances of working various. Also, there is no experimentally determined values for all the constants defining the optimal models, in fact some of them never longer being experimentally determined (non-existing therefore any standardized methodology for determining).

For all simulation algorithms, for all processes, it must that the analysis of turnings to be detailed and from the dynamic point of view [1], to decide whether the optimal speed indicated by the optimal model solution is accessible or not. Study of aggregates dynamics into curves, in turnings is a

[1] A general formulation of the optimal problem into the energetic space of the agricultural aggregates is a complex problem that we do not see currently realizing than using a basic framework of functional analysis, doubled with the theory of systems with command, both interwoven by the base model of the dynamics of aggregates given by the classical mechanics. It is a future formulation for this problem, aiming to determine the optimal path into the energetic space of working processes of the agricultural aggregates.

separate study who must decide the speed limit within which the stability (especially the lateral one) of the aggregate is satisfactory, taking into account also the slope of the land.

Second-degree polynomial coefficients defining coefficients of friction and the resistances to advance as functions of the travel speed, can be identified from experimental data by the method of least squares, for example.

In the second degree polynomial coefficients defining the coefficients of friction and soil resistance to deformation as functions of the travel speed, can be introduced and other soil parameters such as moisture content, the percentages of sand, clay, etc.. These new parameters may have the role of deciding the existence of a minimum point of these laws, condition necessary for the realization of some optimal points in the strict sense, and in this case, they decide the movement of optimal points in one direction or another.

One of the parameters that in the future optimal models will become function and must be based on the travel speed (laterand of the soil moisture) is the slipping, which is introduced into computational models presented only as a coefficient, constant which is a characteristic of process.

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