The 3rd International Conference on "Computational Mechanics and Virtual Engineering"
COMEC 2009
29 – 30 OCTOBER 2009, Brasov, Romania

THE FRONTAL AND REAR PLOUGHS EFFECTS ON 4WD TRACTORS

Carol Csatlos
Transilvania University, Brasov, ROMANIA, e-mail (csk@unitbv.ro)

Abstract : *The paper proposes a study on the possibility of achieving agricultural aggregates consisting of 4 WD tractors endowed with plugs positioned both at their front and rear.*
Due to the tendency of relieving the front axles of the tractor under the influence of rear - coupled agricultural machines, this axle has to be loaded with additional weights else the maneuverability of the system will be affected. The disadvantage off these weights consists in the fact that they load the front axle without generating a useful mechanical work. The present study aims at bringing arguments to underpin the improvement of 4WD tractors dynamic qualities, when aggregated with frontal and rear ploughs.
Keywords : *frontal ploughs, rear ploughs, tractors, agriculture, agriculture engineering*

1. INTRODUCTION

The work capacity of agricultural units displays a continuous rising tendency, which led to the necessity of creating some tractors endowed with better traction qualities. One of the most frequent means of productivity enhancement is the enlargement of the working the breadth accompanied, within limits imposed by the working technologies, by an enhancement of the moving spud. These determined the appearance of more powerful engines. At the same time the tendency to assume the four motives wheels formula amplified.

Nowadays, more than 60 % of the tractor production is made in this variant, and 98 % of the products have power of over 80 kW. The development of this technical issue is explained by the multiple advantages of which the most important are:

- the whole exploitation weigh is adherent, which leads to an increase in the engine power;
- the adherent weigh of the 4WD tractors can be increase from 500 – 600 N/kW to 950 N/kW, using the loading of both axles;
- their work capacity is 15…30 % greater on compressed soils, and up to 50 % greater to on loosened soils as compared to those in the 4x2 formula;
- the drive efficiency is greater, and fuel consumption when related to the traction power is smaller;
- allowing the formation of complex aggregates, it diminishes the destruction of soil structure by reducing the number crossings.

2. GEOMETRICAL AND KINEMATIC ELEMENTS OF THE COUPLING MECHANISM

An accurate modeling starts from analyzing the geometry of the suspension mechanism. For this purpose the whole assembly was comprised in a system of Cartesian coordinates, presented in figure 1 in a vertical longitudinal view.

The study of the coordinates of the main linkage points, of the instantaneous rotation centers and of the bar lengths of the two mechanisms was achieved by the method of vector contours of the bars presented in figure 1 a and b.

By imposing the working depth at the coordinates of the inferior linkage points will result for the rear mechanism:

$$x_{22} = x_{21} - a_2 \cdot \sin\varphi_{23};$$
$$z_{22} = h_{p2} - a, \qquad (1)$$

and for the plough, respectively:

$$x_{12} = x_{11} + a_1 \cdot \sin\varphi_{13};$$
$$z_{12} = h_{p1} - a. \qquad (2)$$

Subsequently to the analysis of the rear suspension mechanism it can be noticed, that the instantaneous rotation center, π_2 (x_{26}, z_{26}), is placed at the intersection of the supporting straight lines of bars S_3S_4 and S_1S_2. By solving the system of equations described by them, the following coordinates result:

$$x_{26} = \frac{m_2 \cdot x_{24} - m_2` \cdot x_{21} + z_{21} - z_{24}}{m_2 - m_2`};$$
$$z_{26} = z_{24} + m_2 \cdot (x_{26} - x_{24}), \qquad (3)$$

wherein m_2,$m_2^{`}$ represent the inclinations of the supporting straight lines S_3S_4 and S_1S_2. The front suspension mechanism is carried out in a variant with a telescope superior bar, the instantaneous rotation center being placed exactly in the linkage point $F_1(x_{12}, z_{12})$. Knowing the rotation points F_1 and π_2, by writing the equations of static equilibrium with respect to them, the reactions of the soil on the supporting wheels of the two semi - lifted ploughs care be determined:

$$Z_{s1} = \frac{G_{p1} \cdot (x_{17} - x_{12}) + R_{z1} \cdot (x_{15} - x_{12}) + R_{x1} \cdot (z_{12} + |z_{15}|)}{x_{18} - x_{12} - z_{12} \cdot f_p};$$
$$Z_{s2} = \frac{G_{p2} \cdot (|x_{27}| + x_{26}) + R_{z2} \cdot (|x_{25}| + x_{26}) - R_{x2} \cdot (z_{26} + |z_{25}|)}{x_{26} + |x_{28}| - z_{26} \cdot f_p}. \qquad (4)$$

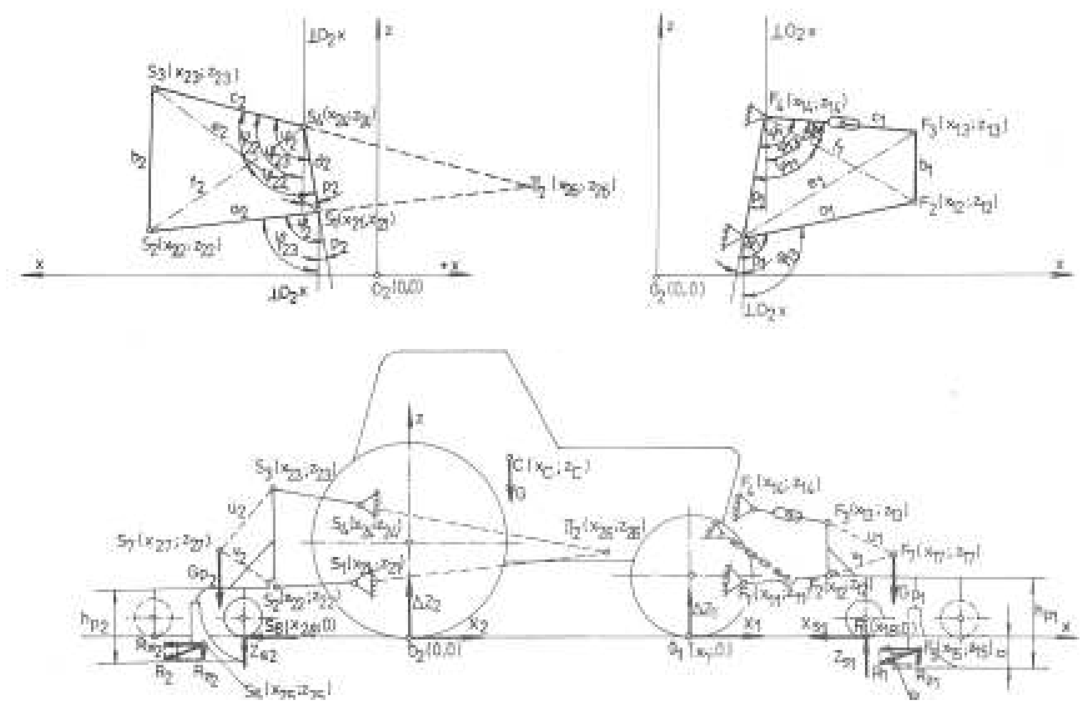

Figure 1: Scheme of the 4 WD tractor with frontal and rear ploughs

It can be noticed, that from the dynamic point of view, their values depend on the components of the forces which act on the plough:

$$R_{x1,2} = k_0 \cdot a \cdot b \cdot n_{1,2};$$
$$R_{z1,2} = R_{x1,2} \cdot tg\beta_{1,2}. \qquad (5)$$

In order to determine the variation of the loads on the tractor front axles, first the case of its being equipped only with a front plough is analyzed. After writing the equilibrium equations with respect to the tangency point of the front wheel with the soil, there follows:

$$\Delta Z_1^{`} = \frac{G_{p1} \cdot x_{17} - Z_{s1} \cdot x_{18} + R_{z1} \cdot x_{15} + R_{x1} \cdot (x_{15} - x_1)}{x_1};$$
$$\Delta Z_2^{`} = \frac{Z_{s1} \cdot (x_{18} - x_1) - G_{p1}(x_{17} - x_1) - R_{x1} \cdot |z_{15}| - R_{z1} \cdot (x_{15} - x_1)}{x_1}. \quad (6)$$

The procedure is similar for the rear plough, with variations of the loads on the two axles:

$$\Delta Z_1^{''} = \frac{Z_{s2} \cdot |x_{28}| - R_{z2} \cdot |x_{25}| + R_{x2} \cdot |z_{25}| - G_{p2} \cdot |x_{27}|}{x_1};$$
$$\Delta Z_2^{''} = \frac{G_{p2} \cdot (x_1 + |x_{27}|) + R_{z2} \cdot (x_1 + |x_{25}|) - Z_{s2} \cdot (x_1 + |x_{28}|) - R_{x2} \cdot |x_{25}|}{x_1} \quad (7)$$

By applying to the ploughs the method of effects overlapping, the analytical expressions of the dynamic loads on the two tractor axles are obtained:

Table 1: Technical data of the tractor and ploughs

TECHNICAL DATA OF THE TRACTOR			
PARAMETER	Symbol	Unit of measure	Value
Tractor weight	G	N	41595
Static load on the front axle	Z_{01}	N	14458
Static load on the rear axle	Z_{02}	N	27137
Distance from the mass center to the rear axis	x_c	m	0,886
Axle base	x_1	m	2,549
Static radii of wheels	r_{s1}	m	0,575
	r_{s2}	m	0,752
Transmission ratios	i_1	-	24,444
	i_2	-	33
Coordinates used in the suspension mechanism	x_{11}	m	2,9
	x_{21}	m	-0,2
	x_{24}	m	-0,6
	z_{11}	m	0,5
	z_{21}	m	0,5
	z_{24}	m	0,935
Lengths of the suspension mechanism bars	a_1	m	0,860
	a_2	m	0,75
	b_2	m	0,530
	c_2	m	0,5

TECHNICAL DATA OF PLOUGHS						
PARAMETER	**Front plough**			**Rear plough**		
	Symbol	Unit of measure	Value	Symbol	Unit of measure	Value
Weight	G_{p1}	N	3000	G_{p2}	N	5000
Number of plough - bodies	n_1	-	2	n_2	-	3
Working depth	a_1	m	0,15….0,3	a_2	m	0,15….0,3
Width of a furrow	b_1	m	0,3	b_2	m	0,3
Angle of the resultant of the breast with the soil	β_1	o	15	β_2	o	15
Height of frame	h_{p1}	m	0,8	h_{p2}	m	0,8
Coordinates	F_5	m	4,4; -a/3	S_5	m	-2,5; -a/3
	F_7	m	4,5;0,45	S_7	m	-2,1;-0,45
	F_8	m	6;0	S_8	m	-3,5;0

$$Z_{1,2} = Z_{01,2} + \Delta Z_{1,2}^{'} + \Delta Z_{1,2}^{'''}, \quad (8)$$

where Z_{01} and Z_{02} are the static loads on the tractor axles, determined experimentally or computed by annulling the torque with respect to the center of gravity.

In order to determine the tangential forces X_1,and X_2, the interaction of wheels and soil has to be analyzed. These forces have the general expressions:

$$X_1 = \varphi_{m1,2} \cdot Z_{1,2}, \tag{9}$$

where φ_{m1} and φ_{m2} represent the adherence coefficients for the two axles. Their general expressions is known from literature [4]:

$$\varphi_m = \frac{A+\delta-\sqrt{(A+\delta)^2-4\cdot B\cdot C\cdot\delta}}{2\cdot B}, \tag{10}$$

where δ is the slippage coefficient and A,B,C described by relations:

$$A = \frac{3\cdot m\cdot\varphi}{4},\ B = \frac{m}{2},\ C = \varphi + \frac{m\cdot\varphi^2}{4} \tag{11}$$

The elements of which are given in table 1.In the case of the studied 62 kW tractor, k>1, in which case $\delta_2 \in [1-k,1]$, [4] and δ_1 has the expression:

$$\delta_1 = \frac{k+\delta_2-1}{k} \tag{12}$$

The slippages of the two axles can be written in dependence on the kinematical non-concordance [4], [5]:

$$k = \frac{i_2}{i_1}\cdot\frac{r_{s1}}{r_{s2}} \tag{13}$$

with the components given in table 1, which comprises all data required for running a computer program was devised and run in MATHCAD , the results being presented in the diagram of figure 2. The values of the employed coefficients are:

- the road resistance of the tractor f_{tr} = 0,2;
- the road resistance of the plough wheel f_p = 0,12;
- the specific soil resistance k_0 = 0,6. 10^4;
- the inclination of the slippage curves m =0,3;
- the slippage δ_2= 0,15.

3. THE OBJECT AND PURPOSE OF THE EXPERIMENTAL ATTEMPTS

The object of the experimental research was a system made of the U 833 – DT tractor having a 62 kW nominal power. As to the transmission, this tractor has a complex speed -changer box, with a planetary reducer placed at the back.

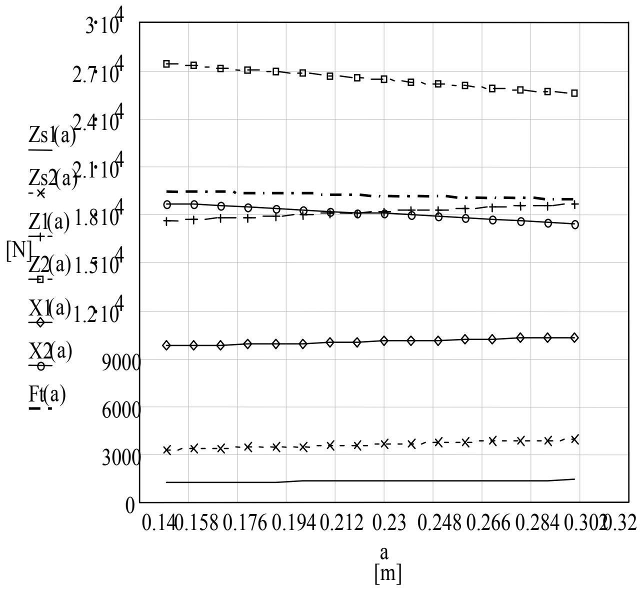

Figure 2: Load variations in dependence on the working depth.

It has four levels of speed for forward movement and one for backward movement, developing four ranges (fast, average, slow, and very slow), for each and every level.

In order to accomplish the coupling of some agricultural machines at the front, the tractor was equipped with a frontal suspension device and a frontal powerful axle.

Experimental research was a conducted under the usual circumstances of ploughing works combined with those typical of the ploughing with a frontal plough. It is equipped with two plough bodies, a device for the control of the working depth and the control of position of the supporting wheel on the frame of the plough (figure 3).

The main objectives viewed were:

– the emphasis of the main charges over the tractor axles and over the supporting wheel of the frontal plough;

- establishing a correlation between the number of plough bodies of the frontal plough and the back plough, with a view to an optimum charge of the tractor axles;
- establishing a correlation between, the main parameters of the working process (depth, breadth, working speed), and the loading of the tractor up to the slipping limit.

As the phenomenon the physical dimensions viewed within the experimental research is mechanical in nature, their conversion to electrical signals was necessary with the help of some adequate transducers.

Figure 3: The system working

Their construction depends on the mechanical measurement methods and on the nature of the dimension, which is being measured.

We saw to it that the intensity and polarity of the electric signal at the terminals of the transducers be proportional to the level and direction of the measured physical dimension. To this purpose, the electrical signal is sent to an amplifying system for that it to be further transmitted to the recording device (main board), and computer. This latter block allows the operator's access to the information in order to make possible its viewed processing (numerical, flowchart, tabular etc.)

4. THE METOD AND PROGRAMME OF THE TESTS, AND EXPERIMENTALLY DETERMINED DIMENSIONS

The method and program of the tests were chosen in such a manner that they may reach the objectives and the purpose of the experimental research.

A single parameter was changed for each and every experiment within the experimental determinations made, in order to obtain conclusive results, which would emphasize the influence of every parameter upon the behavior of the system.

Experimental attempts on the tractor system U 833 – DT equipped with frontal and back plough were made under the following circumstances:

- with the tractor moving on a horizontal stubblefield, with both ploughs up in a transportation position;
- at work with the back plough only, the front plough playing the part of a load and having a transportation position;
- at work with the front plough only, equipped with two plough bodies (functional model);
- at work with both ploughs;

In all the above cases measurements were made for different levels and ranges of specific speeds of the ploughing works at different working depths and breadths.

The recording of the data within the very framework of the testing was made on a stubble field with the help of the acquisition techniques mentioned above.

Eight different dimensions were recorded for the reaching of the desired objectives, as it follows:

- the moments of rotation transmitted to the back motor- wheels;
- the moments of rotation transmitted to the front axle;
- the theoretical and real moving speeds of the assembly;
- the pressing force of the supporting wheel of the front plough at the bottom of the furrow;
- working time.

The experimental determination of the moments of rotation was accomplished with the use of tensometric electro resistive method, and that of the rotation with the help of some inductive transducers.

A correct positioning of the electrical resistive transducers doesn't notice the unitary efforts introduced by the moment of deflection and / or by the axial force. In order to accomplish the correlation between the value of the force and the level of the signal on the screen of the measuring device (to make possible the further interpretation of the results) the calibration of the tensometric transducers conceived was made.

An end collector of the SK 12 type produced by the German company HOTTINGER BALDWIN was used the signal given by the electrical resistive transducers.

Such a collector was placed on each posterior planetary shaft in the console at the ends next to the back motor wheels. Such a fitting could be made by the installing of a central longitudinal channel which allowed the bringing of the connecting conductors to the collector, as well as that of a central thread hole within a board fixed with screws coaxial on the stud bolt flange of the planetary shafts.

5. CONCLUSIONS

The disposition of the ploughs at the front and back of the tractor allows a rational distribution of the plough bodies a method switch leads to a diminution of the effect of load lessening of the front axle under the action of the back plough, an effect which amplified with the growth of number of plough bodies and of the working depth.

The main favorable outcomes of the research are:

a. the degree of participation of the front axle increases with the accomplishment of the traction force of the tractor;
b. the time requested by the ploughing of a hectare reduced by approximately 34 % and the fuel consumption by about 26,5 %;
c. an appropriate charge on the front axle is ensured; the dynamic charge on the front axle increases by about 16…18 % in the complex variant with both ploughs, as compared to the disposition of the three bodies at the back of the tractor;
d. the breath of the turning area of the aggregate at the ends of the lot diminishes, because the length at the track necessary for the introduction and removal out of the ploughs into the clod is considerably reduced.

6. REFERENCES

[1] Bánházi I.: A szántóföldi munkagépek müködésének elméleti alapjai, Mezőgazdasági Kiadó, Budapest, 1984.

[2] Borsa, B.: Prüfung der Zugkraftverteilung beim Pflügen auf Normalitat. Grundl., Landtechnik Nr.5,1988.

[3] Guskov, V.V.: Ksenevici, I.P. Vaprosî kacenia tiagovogo i moşcinosnogo balansa kolesa, Traktorî i selhozmaşinî, nr. 8,1986.

[4] Năstăsoiu, St.: Tractoare, Editura didactică şi pedagogică, Bucureşti, 1983.

[5] Popescu, S.: Contributions a l’etude de l’etude de la dynamique des tracteurs avec machines agricoles couplees a l’avant. Lucrările celei de a V - a Conferințe de motoare, automobile, tractoare şi maşini agricole, vol. II, Universitatatea din Braşov, 1985.