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THEORETICAL MODEL FOR DYNAMIC ANALYSIS OF THE ACTIVE ELEMENTS FOR DEEP SOIL PREPARETED

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Abstract: *The last decades have been characterized by a continuous increase in studying methods of modeling works that uses formal methods to write differential equations of motion for multibody systems. Analysis of such problems leads to a mixed set of second order differential equations and linear relationships whose outcome is achieved through evolution of the independent coordinates that define the movement system and unknown the liaison, forces internal and external, which occurs. Unknowns such a mixed system differential and algebraic (DAE) can be obtained first by eliminating unknowns, force liaison linear equations involved, after that remains to solve a system of second order differential equations. A natural way to eliminate the connection forces will be used to write equations of motion of all tractor-agricultural machinery.*
Keywords*: dynamic; soil; aggregates no-tillage;*

1. INTRODUCTION

Disposal method of the connection forces is based in many applications, where the reactions are not required or are not interesting. The method can be applied as multibody rigid systems and multibody elastic systems and can be applied in parallel computing methods of finite element, and could thus obtain the equations of motion in very complex cases. The method, which is rooted in the methods of Routh's reduction and the Hamel`s method of quasi-coordinates and other results was developed by many researchers (in an effort to economic use as description equations of motion for the purposes Mach`s). The main method is based on the orthogonally that exists for ideal links between generalized forces and generalized displacements.
In classical mechanics, methods of obtaining the equations of motion are:

a) the fundamental theorems of mechanics;
b) The form of the principle of Lagrange d' Alembert;
c) Lagrange's equations;
d) Method of Lagrange multipliers;
e) Hamilton's equations,

They are used in various forms. If it seeks only solve the equations of motion, that determine the evolution in time it can be used independent coordinates methods “b”, “c” and “d” as not responding as unknown. But if it is necessary to calculate the forces connecting (if is a necessary to calculate the resistance of the various elements of the multibody system) will be using the methods ”a” and “d”. In following will be using the method “the fundamental theorems of mechanics”.

2. THE DYNAMICS SYSTEM OF THE AGRICULTURAL MACHINE WITH WHEEL SUPPORT

In the following, we intend to study the dynamics of the system of complex aggregates that are working in the "No-tillage" system.
The tractor unit will pair with bars (suspensions) linkage and working bodies can be active (they are driven through PTO) or passive (using the available thrust of tractor).

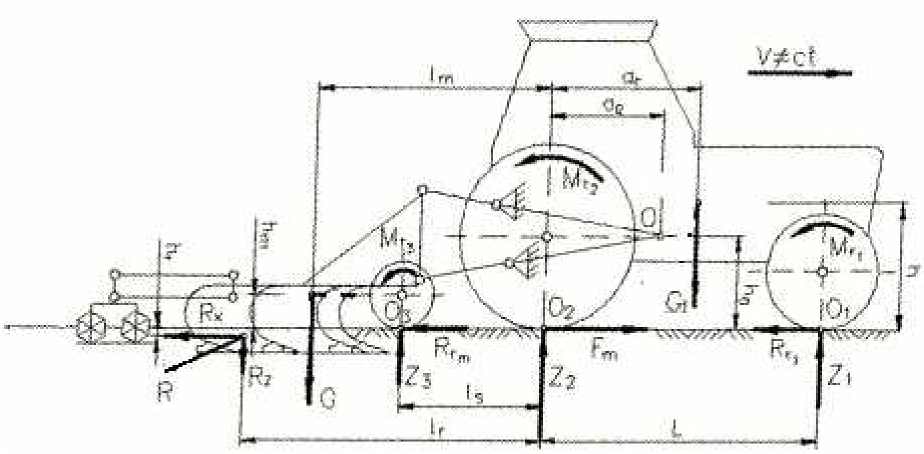

Figure 1. External forces acting on the tractor

For the case that are analyzing in Figure 1 linkage work on floating point (O) which is instantaneous center of rotation, wheel will provide back support (tracking) of land surface and thus maintain a constant working depth is required for seedbed preparation.
In this study, we will consider the tractor up in a slope angle α and moving fast. If working in constant speed operating mode, will be a special case of the problem studied.

External forces acting on the tractor:
In the process of working, there are the following forces:
- Tractor weight G, which will decompose into a tangential component which opposes the tractor on the slope and climb the normal component to load the tractor tires with a contribution of normal forces Y1 and Y2;
- FRT rolling resistance forces that will occur when the front wheels, rear wheels and wheel support;
- Rolling resistance moments at the front axle wheels and rear MR1 Mr2;
- The driving force (tangential traction force) at the wheels of the tractor which is a result of action Fm torque to both driving wheels:
- The reactions of normal soil Y1 and Y2 at the front axle and wheels, respectively, back.

$$F_m = \frac{M_m}{R_2} \tag{1}$$

Tractor weight without considering the wheels are deemed applicable G its center of weight, determined by the coordinated action in relation to the longitudinal axis of the rear axle of the tractor and coordinated in relation to the surface h (height of center of weight). For dynamic power calculation G decomposes into a normal component $\cos\alpha \cdot G_n = G$ and a component parallel to the running surface $GTG = G \cdot \sin\alpha$, weight rear wheels, front and support let G_2, G_1 and G_3 respectively. They will have inertial effects on moving the tractor and the tractor axle load will help. Note with: R_2, R_1 and R_3 the rays of the three wheels. Total weight of the tractor will be:

$$G_t = G + G_1 + G_2 \tag{2}$$

For smaller angle of the way, we can admitting that: *sin* $\alpha \approx$ *tg* $\alpha = 0{,}01i$ and the relationship be:

$$G_{tg} = \pm 0{,}01 G_t \cdot i \tag{3}$$

Determination of soil on the reactions of normal tractor axle Y1 and Y2 is based on balance equations of all tractor-agricultural machines under the action of external loads. Thus, from the equation of the moments to: A2, resulting normal reaction Y1 to the front axle of the tractor. The relationship is:

$$\begin{aligned} Y_1 L = {} & G_t(a_c \cdot \cos\alpha - h \cdot \sin\alpha) - G_m(l_m \cdot \cos\alpha + h_m \cdot \sin\alpha) + R_x \cdot h_r - R_z \cdot l_r + Y_3 \cdot l_s - \\ & -(R_{it} \cdot h + R_{im} \cdot h_m + M_{r1} + M_{r2} + M_{r3}) - G_3(h_m \sin\alpha + l_s \cos\alpha) + \\ & + G_1(L\cos\alpha - R_1 \sin\alpha) - G_2 R_2 \sin\alpha \end{aligned} \tag{4}$$

During the tractor wheels roll without slipping on the work surface, rolling resistance moments are given by relations:

$$M_{r1} = sY_1; \quad M_{r2} = sY_2 \quad ; \quad M_{r3} = sY_3 \tag{5}$$

The inertial forces are:

$$R_{it} = m_t a; \quad R_{im} = m_m a \tag{6}$$

The torque relation is:

$$Y_1 L = G_t\left(a_c \cdot \cos\alpha - h \cdot \sin\alpha\right) - G_m\left(l_m \cdot \cos\alpha + h_m \cdot \sin\alpha\right) + R_x \cdot h_r - R_z \cdot l_r + Y_3 \cdot l_s -$$
$$- m_t a \cdot h - m_m a \cdot h_m - sY_1 - sY_2 - sY_3 - G_3(h_m \sin\alpha + l_s \cos\alpha) +$$
$$+ G_1(L\cos\alpha - R_1 \sin\alpha) - G_2 R_2 \sin\alpha \qquad (7)$$

and :

$$Y_1(L+s) + sY_2 + (s - l_s)\cdot Y_3 = G_t\left(a_c \cdot \cos\alpha - h \cdot \sin\alpha\right) - G_m\left(l_m \cdot \cos\alpha + h_m \cdot \sin\alpha\right) +$$
$$+ R_x \cdot h_r - R_z \cdot l_r + Y_{O3} \cdot l_s - m_t a \cdot h - m_m a \cdot h_m - G_3(h_m \sin\alpha + l_s \cos\alpha) +$$
$$+ G_1(L\cos\alpha - R_1 \sin\alpha) - G_2 R_2 \sin\alpha \qquad (8)$$

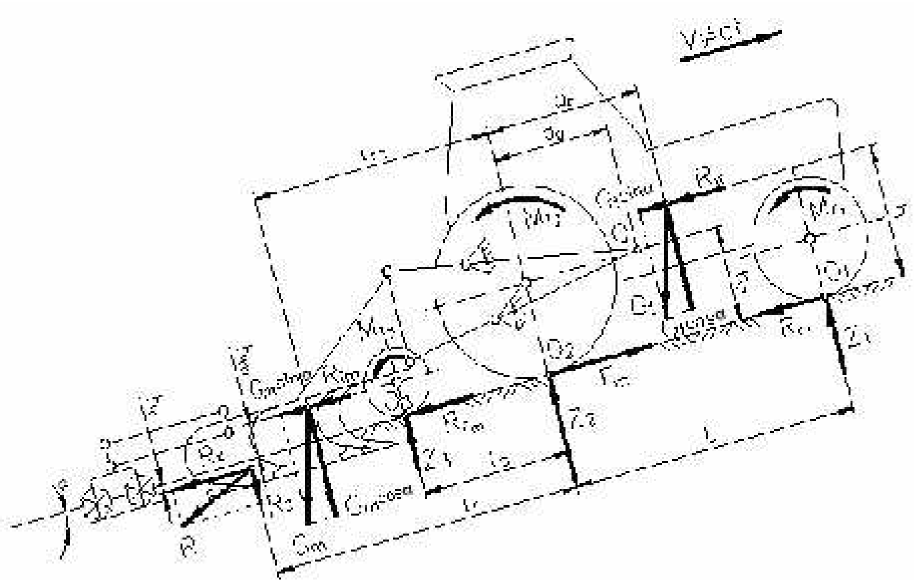

Figure 2. External forces acting on the tractor and agricultural machinery to climb the slope

From the equation of moments relative to the fulcrum of the front axle wheel normal reaction resulting A1 rear axle which is expressed Y2.

$$Y_2 L = G_t\left(L - a_c\right)\cos\alpha + \left(G_t \cdot \sin\alpha + R_{it}\right)h + G_m\left(l_m + L\right)\cos\alpha + \left(G_m \cdot \sin\alpha + R_{im}\right)h_m +$$
$$+ G_2 L\cos\alpha + G_2 R_2 \sin\alpha + G_3(L + l_s)\cos\alpha + G_3 R_3 \sin\alpha + R_z\left(l_r + L\right) - R_x \cdot h_r - Z_3\left(l_s + L\right) +$$
$$+ M_{r1} + M_{r2} + M_{r3} \qquad (9)$$

If you enter the moments rolling resistance and inertia forces is obtained:

$$Y_2 L = G_t\left(L - a_c\right)\cos\alpha + \left(G_t \cdot \sin\alpha + m_t a\right)h + G_m\left(l_m + L\right)\cos\alpha + \left(G_m \cdot \sin\alpha + m_m a\right)h_m +$$
$$+ G_2 L\cos\alpha + G_2 R_2 \sin\alpha + G_3(L + l_s)\cos\alpha + G_3 R_3 \sin\alpha + R_z\left(l_r + L\right) - R_x \cdot h_r$$
$$- Y_{O3}\left(l_s + L\right) + sY_1 + sY_2 + sY_3 \ . \qquad (10)$$

and:

$$- sY_1 + Y_2(L - s) - (s + l_s + L)\cdot Y_3 = G_t\left(L - a_c\right)\cos\alpha + \left(G_t \cdot \sin\alpha + m_t a\right)h + G_m\left(l_m + L\right)\cos\alpha +$$
$$+ \left(G_m \cdot \sin\alpha + m_m a\right)h_m + G_2 L\cos\alpha + G_2 R_2 \sin\alpha + G_3(L + l_s)\cos\alpha +$$
$$+ G_3 R_3 \sin\alpha + R_z\left(l_r + L\right) - R_x \cdot h_r \ . \qquad (11)$$

Total normal reaction on the axle tractor Yt is determined by the relation:

$Y_t = Y_1 + Y_2 = (G_t + G_m + G_3)\cos\alpha + R_z - Y_3$ (12)

Normal reaction wheel support on the machine Y3 is determined taking into account that this car follows the ground by wheel support linkage being floating position. Therefore all machine ranges in relation to instant rotation center O. We have noted with a_0 and h_0 instantaneous coordinates of the rotation center (Figure 3).

Equation of moments relative to point O (CIR) be:

$$Y_3(l_s + a_0 - s) = G_m\left(l_m + a_0\right)\cos\alpha - \left(G_m \sin\alpha + R_{im}\right)\left(h_0 - h_m\right) - R_x\left(h_0 + h_r\right) + R_z\left(l_r + a_0\right) - F_{r3} \qquad (13)$$

and solving the Y_3:

$$Y_3 = \frac{G_m\left(l_m + a_0\right)\cos\alpha - \left(G_m \sin\alpha + R_{im}\right)\left(h_0 - h_m\right) - R_x\left(h_0 + h_r\right) + R_z\left(l_r + a_0\right) - F_{r3}}{l_s + a_0 - s} \qquad (14)$$

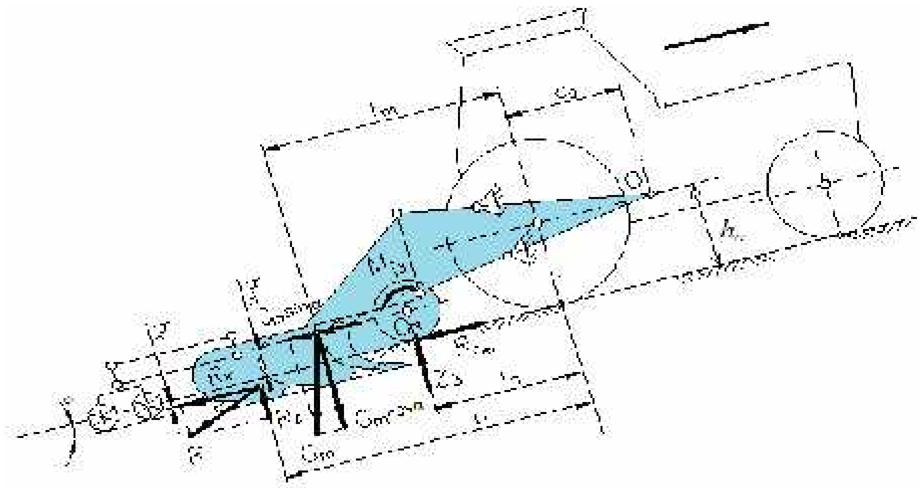

Figure 3. Instantaneous coordinates of the rotation center

If the value Y_3 is known, then the equation of reaction be:

$$Y_1(L+s)+sY_2=A \tag{15}$$

$$-sY_1+Y_2(L-s)=B \tag{16}$$

solve:

$$\begin{aligned} A &= G_t(a_c\cdot\cos\alpha-h\cdot\sin\alpha)-G_m(l_m\cdot\cos\alpha+h_m\cdot\sin\alpha)+ \\ &+R_x\cdot h_r-R_z\cdot l_r+Y_{O3}\cdot l_s-m_t a\cdot h-m_m a\cdot h_m-G_3(h_m\sin\alpha+l_s\cos\alpha)+ \\ &+G_1(L\cos\alpha-R_1\sin\alpha)-G_2R_2\sin\alpha-(s-l_s)\cdot Y_3 \end{aligned} \tag{17}$$

$$\begin{aligned} B &= G_t(L-a_c)\cos\alpha+(G_t\cdot\sin\alpha+m_t a)h+G_m(l_m+L)\cos\alpha+ \\ &+(G_m\cdot\sin\alpha+m_m a)h_m+G_2L\cos\alpha+G_2R_2\sin\alpha+G_3(L+l_s)\cos\alpha+ \\ &+G_3R_3\sin\alpha+R_z(l_r+L)-R_x\cdot h_r+(s+l_s+L)\cdot Y_3 \end{aligned} \tag{18}$$

If the Y_3 in known:

$$\begin{bmatrix} L+s & s \\ -s & L-s \end{bmatrix}\begin{Bmatrix} Y_1 \\ Y_2 \end{Bmatrix}=\begin{Bmatrix} A \\ B \end{Bmatrix} \tag{19}$$

and:

$$\begin{Bmatrix} Y_1 \\ Y_2 \end{Bmatrix}=\frac{1}{L^2}\begin{bmatrix} L-s & -s \\ s & L+s \end{bmatrix}\begin{Bmatrix} A \\ B \end{Bmatrix} \tag{20}$$

3. CONCLUSIONS

Apparently they give Reaction Y_1, Y_2 and Y_3 as shown in the works. In reality they are related to the equations of motion, once the inertia forces which are introduced in these equations of dynamic equilibrium and the second time by rolling FR3 force density that occurs in the third equation of equilibrium which is obtained also from complete resolution of the equations of motion. We believe that the tractor is moving in a first phase under constant speed, so all the forces of inertia that appear are zero. Also rolling resistance of the wheel support can be neglected in a first phase. Under these assumptions we obtain the three axes in response to the deck and the tractor. With these values we solve the equations of motion and strength where accelerations get rolling resistance. These values in formulas to introduce the reactions and continue the process until the difference between the solutions obtained after two successive iterations becomes very small. The process of determining the reactions of the tractor and acceleration becomes part of an iterative process.

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