THEORETICAL AND EXPERIMENTAL RESEARCH CONCERNING THE INFLUENCE OF VERTICAL OSCILLATIONS OF THE PRECISION SEEDER UNITS ON THE DRILLING PARAMETERS

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Abstract. In the first part of the paper the equivalent oscillatory dynamic model of the precision seeder unit is presented in order to study the vertical forced oscillations produced by the soil profile upon the compaction wheel of the seeder unit. The established mathematical models, which describe the dynamic behavior of the oscillatory systems, are simulated on computer for different parameters and work conditions of the seeders. In the second part of the paper the construction of a stand for the experimental research of the vertical forced oscillations of the seeder unit is presented and it is compared with the results obtained from the theoretical research (simulation on the computer) and from the experimental research obtained from the stand and in the field conditions.

Keywords: precision seeder, dynamic model, oscillating model, mathematical model, computer simulation, laboratory stand, experimental research.

Introduction

The diagram of external forces acting upon a working unit of a precision seeder is shown in Figure 1. The seeding unit is made up of an oscillating arm 2, fixed on articulated basis at point O_2 to the framework 1 of the seeder. The following component parts of the section are fixed on the framework: a seed box 5 (at the basis of which the seed hopper is mounted), the share to open slide 3 and a compression wheel 4 [1, 2].

The section is kept pressed on the soil under the action of its own weight (including the weight of the wheel assembly G_r, of the share G_b and of the seed box G_s), to which extra pressing force is added given by the elastic force in the (adjustable) spring in tension 6, fixed with one end to the framework 1 of the seed drill (through articulation O_1) and with the other end to the oscillating arm 2 (through articulation O_3). The seed hopper is generally driven from the compression wheel 4 through chain transmission. The connection between the share 3 and the arm 2 is made through the chain 8 coupled at articulations O_4 and O_5; the chain also adjusts the working depth of the share [3].

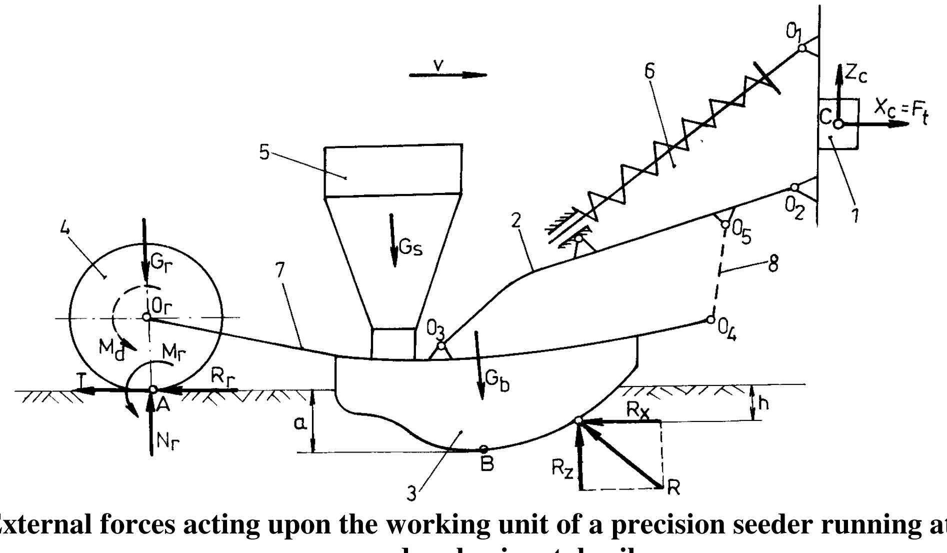

Fig.1. **External forces acting upon the working unit of a precision seeder running at constant speed on horizontal soil**

Beside the wheel weight G_r, share weight G_b and seed box weight G_s, Figure 1 shows the following external forces [1, 2]: N_r – normal reaction of soil upon the compression wheel; T – tangential force upon the compression wheel (to reach the torsion moment M_d, to actuate the distribution device); R_r – rolling resistance of the compression wheel; M_r – moment of rolling resistance of the compression wheel; R – working resistance of the share (horizontal component R_x and vertical component R_z); Z_c – pressing force of the section upon the seed drill frame; $F_t = X_c$ –tractive force of the seeder unit (given by the forces balance equation to traction: $F_t = R_r + T_d + R_x$)

Materials and methods

1. Dynamic and mathematical modeling of the seeder unit

The equivalent oscillatory dynamic model of the seeder unit for study of forced oscillations produced by the soil profile upon the compaction wheel is shown in Figure 1 [2]. Taking into account the oscillatory mass of a sowing unit, its dynamic model for the study of forced oscillations the following notations were made:

- m_O – oscillatory mass of the sowing unit;
- m_C – mass of the frame participating on a sowing unit;
- c_e – equivalent viscous damping constant of the sowing unit damper;
- k_e – equivalent elastic constant of the unit pressing spring;
- k_{rs} – elastic rigidity of the contact between the compaction wheel and the soil;
- c_{rs} – viscous rigidity of the contact between the compaction wheel and the soil.

In the process of the seeder unit movement during the work, the following forces act upon the compaction wheel:

- $F_{s,arc} = K_e z_{st}$ – static force in the spring (where Z_{st} represents static pre-stressing of the spring system);
- $F_d = h_o\left(k_e \sin \omega_p t + \omega_p c_e \cos \omega_p t\right)$ – dynamic force of the springs and dampers which act upon the compaction wheel during the work (in the case of the unit equipped only with springs without dampers) the second term disappears;
- $F_p = -F_o \sin \omega_p t$ – perturbation force of the soil that impresses the unit vertical oscillations.

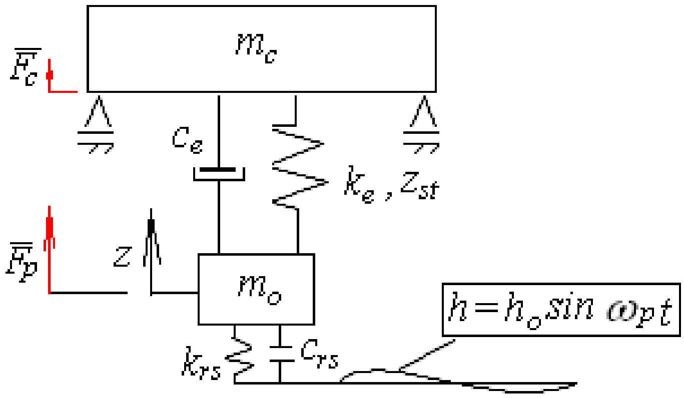

Fig. 2. **Equivalent oscillatory dynamic model of the seeder unit for study of forced oscillations produced by the soil profile upon the compaction wheel**

By summing up these forces, the normal reaction of the soil results upon the compaction wheel during the work *Nr* (which is not represented on the scheme in Fig.1):

$$N_r = m_o g + k_e z_{st} + h_o\left(k_e \sin \omega_p t + \omega_p c_e \cos \omega_p t\right) - F_o \sin \omega_p t \,. \tag{1}$$

For the purpose of compaction wheel stability during the work, it is necessary for the soil reaction N_r to be permanently positive, that is: $N_r \geq 0$ [1, 2].

2. Experimental research under conditions of stand simulation

In order to reproduce as accurately as possible the oscillations of the seeder units and the dependence between the parameters of these oscillations as well as the seeding precision, a stand was built to study them under laboratory conditions (Fig. 3) [2].

The settlement wheel 1 is supported by the driving wheel *10* fixed at the end of the reciprocating lever *8* (articulated in O_6) on the stand frame, being activated by the electrical motor M_2, by means of a V-shaped belt *9*. In order to produce the harmonic oscillations of the settlement wheel 1 we created an eccentric mechanism, consisting of an electrical motor M_1, which transmits motion to an oscillating lever 14 using the V-shaped belt 13. This mechanism provides vertical oscillations to the settlement wheel, equivalent to the random oscillations in the field, based on a previous established program, and its amplitude is adjustable due to the eccentric mechanism.

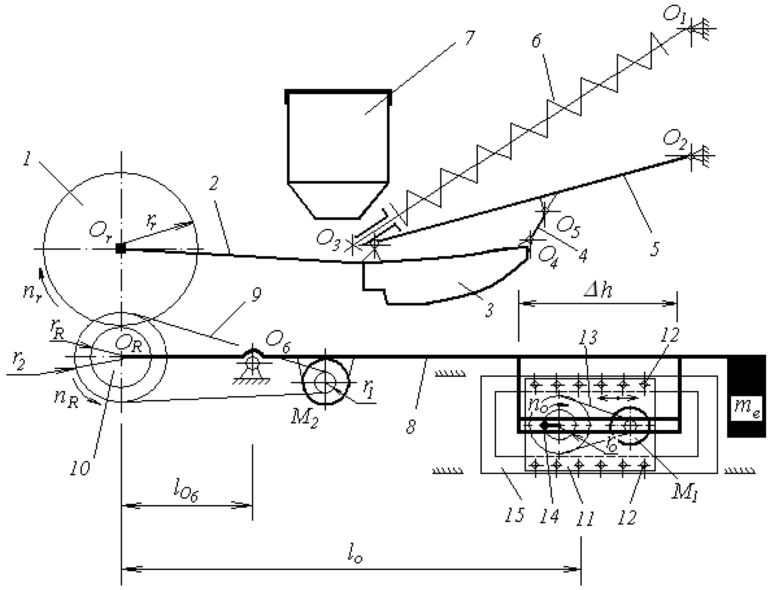

Fig.3. **Diagram of the stand for experimental testing of the seeder unit:**
1 – settling wheel; 2 – fork; 3 – share; 4 – chain; 5-oscillatory arms; 6 – spring system (or springs + viscous dampers); 7 – seed box; 8 – oscillatory lever; 9 – trapezoidal belt for operating the rolling system; 10 – roll (rolling system); 11 – oscillatory mechanism plate (adjustable); 12 – fixing screws by contact pressure of the oscillatory mechanism; 13 – trapezoidal belt for acting the oscillatory finger; 14 – oscillatory finger; 15 – fixed frame of oscillatory mechanism; M_1 – electric motor of the oscillatory mechanism; M_2 – electric motor of the rolling system; m_e – balance mass of the oscillatory lever; O_6 – oscillatory lever joint to the mass; O_r, O_R – rotation axes of the settling wheel and of the roll to the rotation axis of the oscillatory lever (l_{o6} = 150 mm); l_0 – distance between the rotation axes of the settling wheel and of the roll at the acting point of the oscillatory finger (l_o = 600 mm – adjustable); Δh = adjustment range of the oscillations amplitude (Δh = 200 mm)

The stand was designed by taking into account the following conditions:

- it could generate oscillations of frequencies that suit a large range of working speeds;
- it could simulate oscillations upon the settling wheels for a range of amplitudes specific to all types of soils processed in a proper way for seeding hoeing plants;
- the support base of the settling wheel should comply with the properties of the soil;
- the original attachments of the unit must be respected, in order not to modify its kinematics;
- the measuring and registration devices of the data must not be affected by the oscillations, in order not to distort the measured data.

Results and discussion

1. Computer simulation of the oscillatory system

In order to study the influence of the units upon the frame of the SPC precise seeder (made in Romania), the dynamic model in Figure 2 is used, where besides the action of the units upon the frame by the forces F_{ci} where $i = 1…n$ (n – being the number of the units) and the dynamic action upon the uneven soil upon the compaction wheels through the mediation of the contact of support wheel – soil, defined by elastic rigidity of the contact between the support wheels and the soil k_{ps}. The established mathematical model (1), which describes the dynamic behavior of the oscillatory systems, is simulated on computer for different parameters and work conditions of the seeders. Finally the mathematical conditions are established, which have to be fulfilled of the dynamic system in order to stabilize the evolution of the seeder unit on the support wheels.

Table 1

Input data for the modeling of the normal reaction upon the compaction wheel for the seeder unit of SPC precision seeder with metallic rim, equipped with original springs

Input data	
Travel speed	v_a =2.78 m s^{-1}
Unevenness height	h_o =0.00417 m
Oscillatory mass of the unit	m_o =36.476 kg
Unevenness length	L =0.243 m
Gravitational acceleration	G =9.81 ms^{-2}
Equivalent static deformation	Z_{st} =0.07 m
Equivalent spring constant	k_e =1.797·10^3 N m^{-1}
Disturbing throb: $\omega_p = \dfrac{2 \cdot \pi \cdot v_a}{L} = 71{,}88\ \ \mathrm{s}^{-1}$	

Normal reaction of the soil upon the compaction wheel N_r applied for the concrete analyzed system is given by the following equation:

$$N_r = k_e \cdot z_{st} + m_o \cdot g + k_e \cdot h_o \cdot \sin\left(2 \cdot 3.1415927 \cdot v_a \cdot \frac{t}{L}\right) - F_o \cdot \sin\left(2 \cdot 3{,}1415927 \cdot v_a \cdot \frac{t}{L}\right). \qquad (2)$$

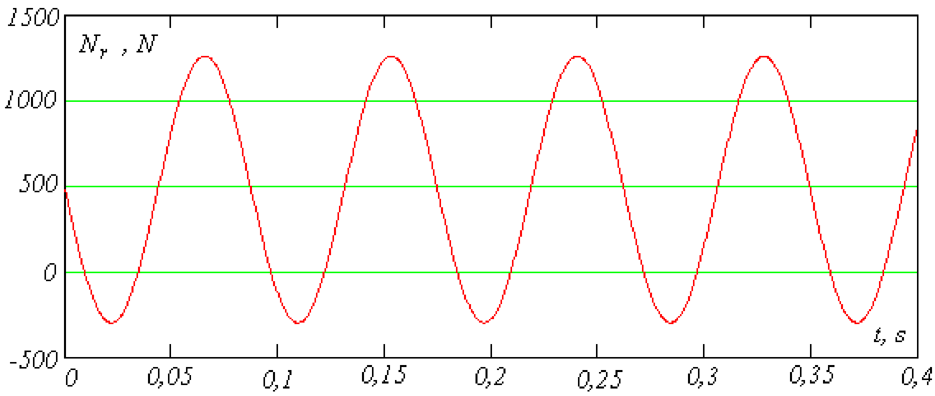

Fig. 2. **Variation of the normal reaction of the soil upon the compaction wheel at the moving speed of the unit with v_a = 2.78 m s^{-1} (≈10 km h^{-1})**

Introducing in the relation (2) the known values for the parameters of the system with the unit of SPC seeder (given in Tab. 1) and modelling this relation by *MATHCAD* Programme [2], the speeds were graphically determined at which the compaction wheel interrupts the contact with the soil. In Figure 2 the graph of the moving speed of the machine of 10 km h^{-1} (2.78 m s^{-1}) is shown.

2. Experimental research on the laboratory stand

Under these circumstances, a series of trials were made among which we compared the results of the trials on the stand of the unit with original springs with the same trials, but at the unit equipped with a system of viscous damper springs, especially conceived by the authors. The trials at the unit with original springs had the following aims:

- establishing the limit working speed of the unit, under similar conditions with those on the field, so that the settling wheels should have a continuous contact with the rolling system;
- comparing the determined limit speed with that in the book of directions.

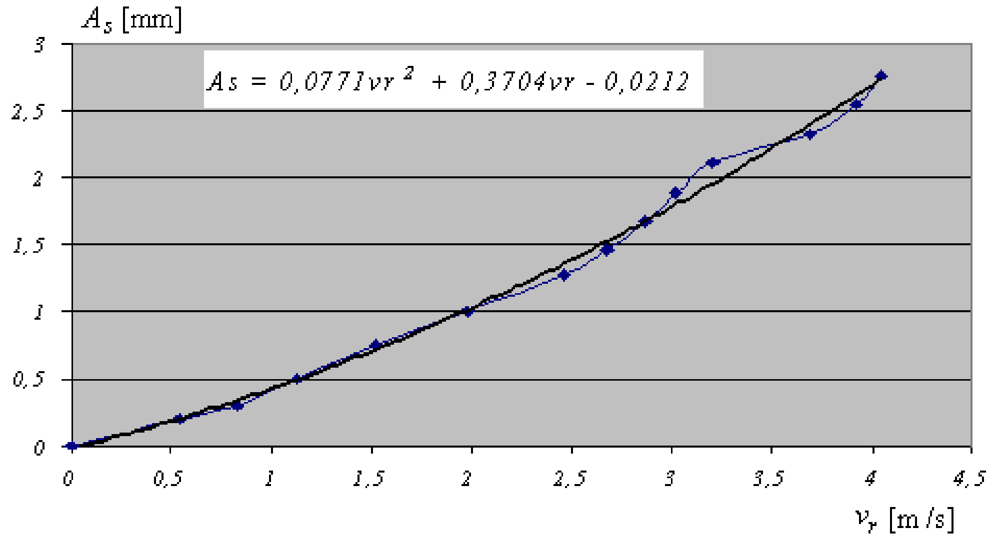

Fig. 4. **The dependence of the amplitude of the settling wheel leaps on the running speed at the unit with springs which is subject to oscillations**

On the basis of the experimental results, the dependence of the amplitude of the settling wheel leaps on the running speed is shown graphically, as presented in Figure 4. The maximum running speed the seeder can reach, without interrupting the contact with the rolling system is maximum 2 m s^{-1} (7.2 km h^{-1}).

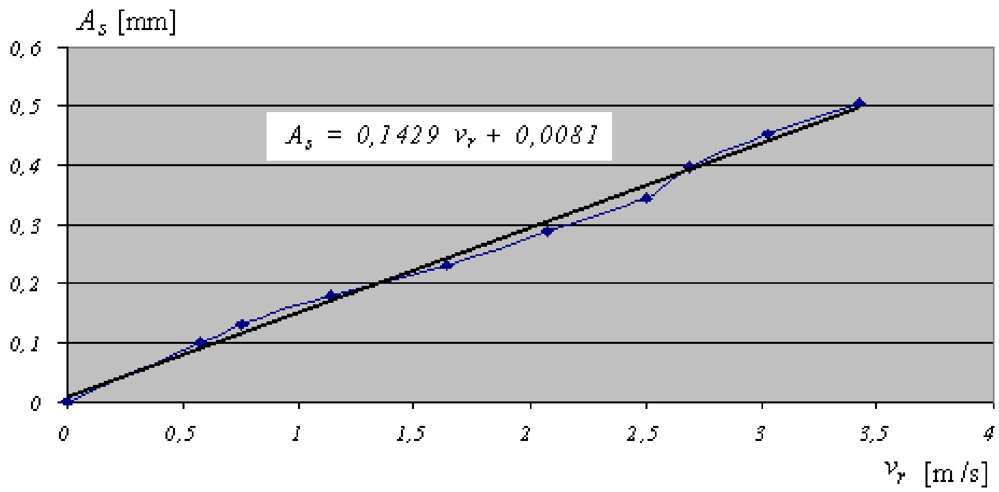

Fig. 5. **The dependence of the leap amplitude on the settling wheel speed**

The testing on the stand at the seeder unit equipped with springs and dampers, the special system conceived by the authors had the following purposes: improvement of the system, in order to reduce the vertical oscillations of the settling wheel, as well as the determination on the stand the performances obtained by this new seeding unit. The dependence between the leap amplitude and the working speed is shown in Figure 5, obtained on the basis of processing the experimental data.

Conclusions

1. The dynamic model of the hoeing plants section mechanism, SPC type (made in Romania) is an elasto-plastic pushed in the soil wheel (rolling track). Also, the soil, being a deformable rolling track represents an elasto-plastic support.
2. During the working process the soil normal reaction upon the settlement wheel depends on the displacement velocity of the unit. Thus, the unit velocity influences the section stability upon the soil and finally the work quality.
3. In order to research the working velocity without the perturbing pulsations leading to the loss of contact between the settlement wheel and the soil, it is necessary to introduce a viscous damping

of these oscillations, providing a phase-shifted hydraulic resistance (at 0.25π) with respect to the own oscillation of the spring systems.

4. The experimental research performed in lab conditions on a stand revealed the way how the sowing section equipped with an elasto-viscous system, specially conceived for the ground irregularities, achieves a good stability during operations, even for velocities exceeding the actual limits of the tractors displacement.
5. By using the system with springs and dampers, it is possible to considerably reduce the oscillations of the unit and to increase the stability of the settling-acting wheel on the rolling system, at higher working speeds than the maximum speeds used at present.

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