DYNAMIC MODELING OF WORKING SECTIONS OF GRASSLAND OVERSOWING MACHINE MSPD-2.5

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Abstract. The paper presents the dynamic modelling using an analyzing and optimization software of working sections, which is equipped with an oversowing machine MSPD-2.5. The oversowing machine for degraded grasslands MSPD-2.5 is a farming equipment carried on rear 3 point hitch of I/II category of the tractors and is composed of 17 independent sowing sections, situated on two rows (8 sections in the front and 9 sections in the back) articulately tied of the machine body through some deformable parallelogram type mechanisms. The dynamic modelling method and simulation of the sowing section, using the Inventor 2010 software, supposes going through three main stages: pre-processing (virtual modelling of the sowing section); processing (rolling the dynamic analysis); post processing (working the results). The dynamic model developed was realized using the following elements: 3D models sowing section components, the cinematic couplings between the components, the mass components characteristics, and the external forces system which acts on the sections. As a consequence of the process there were graphically represented variations of joint forces and of torques, the force variation and the length of the elastic element (coiled spring), and on their basis using the analysis of finite element there were represented the tensions which occur in the elements of the sowing sections.

Keywords: sowing section, oversowing machine, dynamic model, dynamic simulation.

Introduction

The oversowing machine for degraded grasslands MSPD-2.5 is a farming equipment carried on rear 3 point hitch of I/II category of the tractors and is composed of 17 independent sowing sections, situated on two rows (8 sections in the front and 9 sections in the back) articulately tied to the machine body through some deformable parallelogram type mechanisms [1; 2]. The parallelogram mechanism 7 of the sowing sections (Fig. 1) allows constant maintaining, during work, of the furrow attack angle, and on the other side allows copying the soil unevenness by the wheel rigid rim 2, that ensures this way the constant maintaining of the depth the seeds are introduced in the soil. The helical pretensioned spring 5 (with adjustable tension) realizes the press force on the soil of the disc wheel with the rim 2 and of the furrow 3. The disc set on the rim wheel circumference 2 allows cutting (splitting) in a longitudinal - vertical plan, of the soil (fallowed), making it easier for opening and realizing the drain by furrow 3, in order to introduce the seeds in the soil. After introducing the seeds in the soil, these are covered by the press wheel 6 [1].

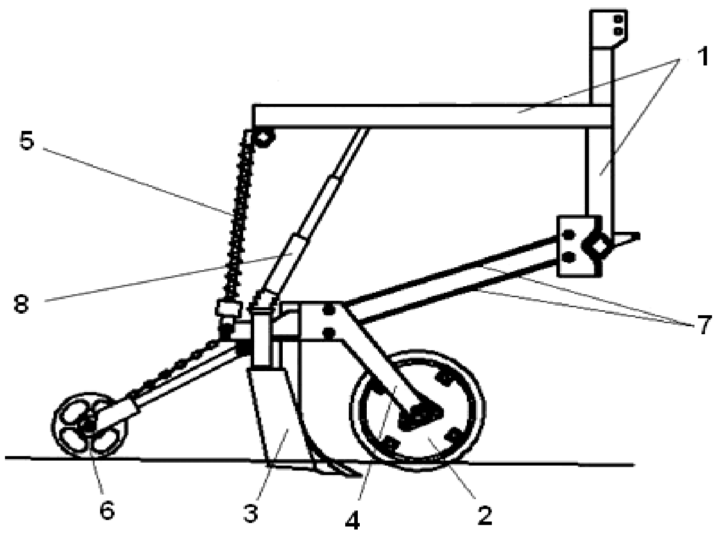

Fig. 1. **Constructive scheme of working section of grassland oversowing machine [3]:**
1 – body of the machine; 2 – wheel support with rigid rim and disc by splitting; 3 – furrower opening gutters; 4 – body of sowing section; 5 – helical spring pressing; 6 – compaction wheel; 7 – parallelogram mechanism coupling to the body; 8 – seeds conducting tube

The functional constructive optimization of the sowing section can be done based on a dynamic analysis, which consists in studying the real motion of the system under the action of the forces introduced in the system by the soil micro profile. The input data are: the assembled configuration of the section, the mass and inertial characteristics of the parts and sub ensembles in the section component, the external-internal force characteristic and the initial conditions over the component positions. The output data are: the real motion parameters of the components and the joints reactions [3; 4].

To accomplish the dynamic analysis, optimizing and view of the virtual model motion of the sowing section the *Dynamic Simulation* mode of the *Inventor* software was used, which allowed performing a dynamic analysis of the sowing section, based on the elastic-geometric model and the restrictions in motion existing in the system.

Materials and methods

The dynamic modeling method and simulation of the sowing section, using the Inventor 2010 software, supposes going through three main stages: preprocessing (virtual modeling of the sowing section); processing (rolling the dynamic analysis); postprocessing (working the results).

The preprocessing stage assumed the following work stages:

- developing the virtual model at real dimensions, defining the kinematic components that involved in transmitting motion (position, orientation, mass-inertial characteristics), defining the relations, the restrictions regarding motion and introducing motion to the conducting element, defining the generating elements of the internal forces (elastic elements), defining the external forces and the application points;
- specification of the information regarding the following aspects: the type of analysis that must be done, the measure unit system used, the coordinates system used for modeling the system, the gravitational accelerating vector, the time interval in which the analysis is made, the entrance measures (motion, force, etc.).

The virtual model of the section was elaborated in 3 distinct stages.

The first stage of the dynamic model elaboration consisted in representing in 3D form all the pieces and subassemblies composing the work section, after which the restrictions were imposed regarding the assembly mode, restrictions by which the correct positioning of all the composing elements of the section was accomplished. Following the application of these restrictions resulted the structural model of the section, which from a kinematic point of view is composed by two kinematic chains, characterized by six degrees of mobility. The structural model is composed by 8 mobile elements, a fixed element (the soil) and 8 cylindrical joints.

The second stage of the dynamic model elaboration consisted in realizing the kinematic model, by applying the kinematic restrictions and introducing the entrance motion. The kinematic restrictions represent constraints that generate the motion of the section elements, thus canceling degrees of mobility. To ensure a correct functioning, from a kinematic point of view, of the section, in the system were introduced 3 kinematic restrictions. The first restriction refers to the fact that the disc wheel with rim must copy the unevenness of the ground and at the same time, to maintain the depth of the introduction of the seeds in the soil. Thus, it was necessary introducing a Rolling Joints [5] type of restriction between the wheel rim and the soil microprofile. The second kinematic restriction refers to the fact that the compaction wheel rolls on the soil, to ensure this a Rolling Joints type of restriction was introduced between the compaction wheel and the soil microprofile. The third kinematic restriction was introduced between the guiding rod of the helical spring (pretensioned) and the body of the oversowing machine, by using a Contact 3D restriction [5], that allows the spring rod to have a single mobility degree in relation with the machine body, this way allowing only the compression of the helical spring. To simulate the kinematic model the entrance motion was introduced, which consists in electing a displacement movement of the machine frame in relation to the soil of 2.7 $m \cdot s^{-1}$ [3]. The kinematic model of the sowing section of the grassland oversowing machine MSPD-2.5, analyzed in this paper, is presented in Figure 2. The kinematic model contains 8 mobile elements, one fixed element, 4 kinematic chains and 2 degrees of mobility.

The third stage of the dynamic model elaboration consists in defining the elements generators of internal forces (elastic elements), defining the external forces and the application points [3]. For this, the helical spring was generated for press the section on the soil, having the following characteristics: The spring stiffness (experimentally determined) 16.6 N·mm^{-1}, the initial length of the spring (pretensioned) 387 mm, the winding diameter of the whirl 20 mm and the whirl diameter 3 mm. In continuance the soil reaction over the furrow was introduced R_b, considered a concentrated force whose value, point of application and direction, were experimentally determined (the value of this force is of aprox. 200 N and the angle formed with the horizontal is of about 30 degrees). Reaction R_d, of the soil over the disc wheel with rim was considered a concentrated force applied in the contact point between the disc and the surface of the soil microprofile, its value, experimentally determined, is about 100 N.

For the elaborated dynamic model to be as close to the physical real model, in the system were introduced also the friction coefficients between the soil and the disc wheel with rim, the compaction wheel of the section. Also, for simplifying, it was considered that the frictions of the two wheel joints (mounted on the shaft through ball bearings) are negligible. In which regards the mass-inertial characteristics of the bodies: mass, the position of the mass center and the inertia moments, it is mentioned that these are automatically calculated by the used application, by introducing the characteristics of the materials of which the pieces are made. Introducing inside the model the force of gravity was accomplished by establishing the direction of the gravitational acceleration according to the arrow on the dynamic model of the sowing section presented in Figure 2. To analyze the influence of the microprofile of the soil on the dynamic of the sowing section it was considered that the section moves on two soils with different surfaces: a soil with a perfectly smooth surface, with linear microprofile (Fig. 2, a) and a soil with unevenness, whose deviation from straightness is of maximum ±50 mm (Fig. 2, b).

After elaborating the dynamic model, the functional parameters are introduced which characterize exclusively each functioning mode which follows to be simulated: the analysis type (dynamic); the displacement speed of the sowing machine's frame (2.7 m·s^{-1}); the initial position of the work station; the duration of the simulation (2.5 s); the number of values registered per second (100 frame·s^{-1}).

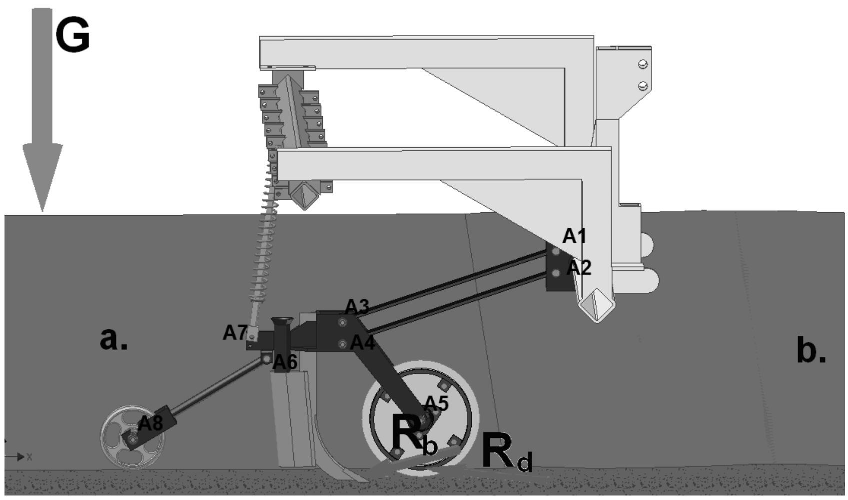

Fig. 2. **Dynamic model of working section of grassland oversowing machine:**
a – soil with smooth surface (linear microprofile); b – soil with surface with unevenness

Based on the model previously described, the processing stage (model running) is automatically realized by the application and consists in the following stages:

- assembling the system according to the restrictions introduced in the composing bodies motion;
- identifying and eliminating the redundant relations (over constraints) in the system.

After performing the analysis (processing the model) the ***postprocessing stage*** was performed, which consisted in the following: processing results obtained from the temporal variation diagrams of the interest measures (forces and moments in joints, speeds and acceleration, forces of the spring and variation of the spring length), graphic simulation (animation) of the model in different projections (representations plans) and the tabular representation of the interest measures, later processed in the specific tabular calculation application Excel. For exemplification, in Figures 3 and 4 are represented the time variation graphics of the forces in the parallelogram mechanism's joints for the two microprofiles of the soil: uneven soil (Fig. 3) and straight soil (Fig. 4).

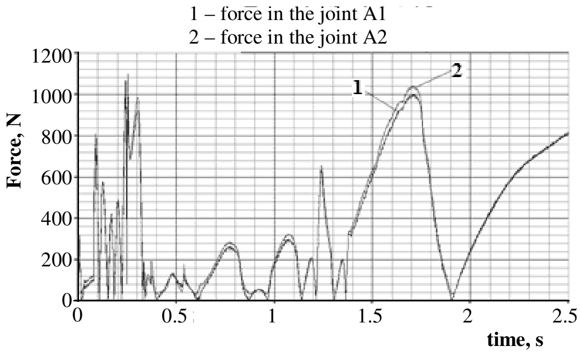

Fig. 3. **Diagram of variation in time of forces from A1 and A2 joints of parallelogram mechanism (s. Fig. 2), for soil with unevenness**

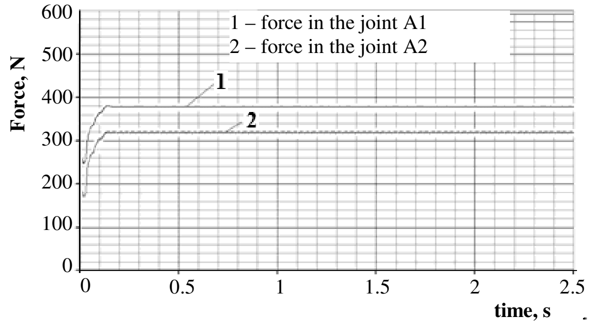

Fig. 4. **Diagram of variation in time of forces from A1 and A2 joints of parallelogram mechanism (s. Fig. 2), for soil with smooth surface**

The variations in time of the force inside the press spring of the sowing section as well as of the length of the spring are graphically represented in Figure 5, having as a result the fact that during the section displacing on the microunevenness of the soil, the spring compresses with about 21.5 mm at a maximum force of compression of 372 N and extends with about 20 mm, when the force of the spring diminishes at 325 N.

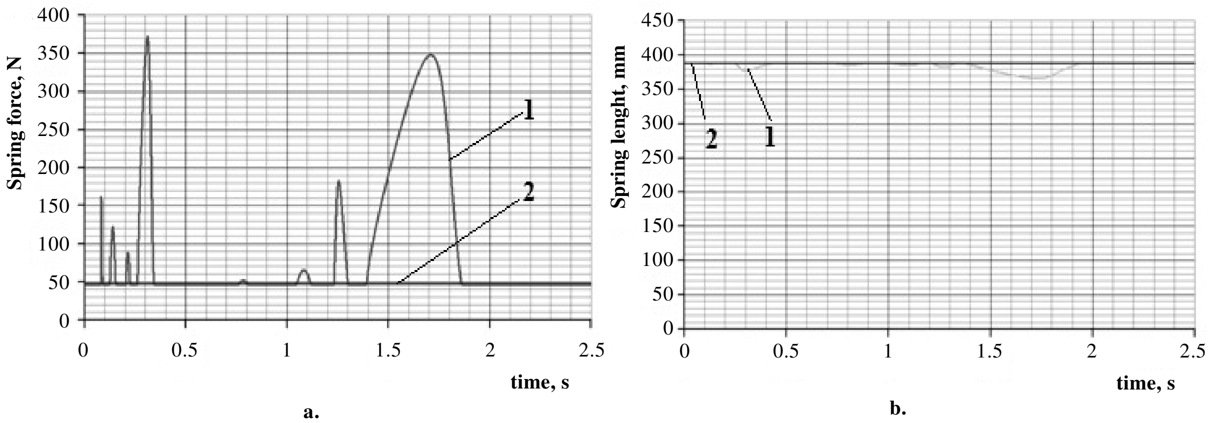

Fig. 5. **Diagram of variation in time of force from spring (a) and spring length (b), for two profiles of soil surface:** 1 – soil with smooth surface; 2 – soil with unevenness

Inventor soft 2010 has implemented a new technology for the analyzing module with finite element analysis (FEA), with which it can make calculations of resistance components and assemblies in order to verify their behavior in actual operating conditions without building physical prototypes.

The analyzing method with finite elements consisted of the following steps:

- the first stage consist in realizing the analysis model. This stage assumed the export of the section model and of loads from the dynamic module and their import in the Stress Analysis module. In order to highlight how the tensions varies in section components depending on soil microprofile, the simulation duration was reduced to a second, and divided into 10 time steps, for each step was necessary to repeat the analysis with finite elements;

- the second stage is to choose the type of analysis, of analysis component and of time step;
- choosing the materials for each component of the section, the software enables also the use of materials that were used in developing the dynamic model and also the choice of other materials from the library or even the definition of some new materials by introducing the basic properties. In the present case the materials were used adopted in the dynamic model, only for soil was defined again the material;
- generating the contacts between pieces. Stress Analysis module allows performing both manual and automatic generation of this operation by selecting the contact surfaces between pieces. In this case we used the automatic generation of contacts, on the grounds that the finite element analysis was repeated for each component and each time step;
- meshing finite element components. The module allows both coarse mesh applied to the entire model to be analyzed and fine mesh done manually in areas where high accuracy of results is desired;
- verifying the finite element model and running the analysis.

Results and discussion

At the beginning the processing stage of results is carried out by software, this generates a report for each analysis performed completely in doc format. After studying the reports the maximum values of stress and strain components were extracted, which appear in the section for each time step. These values have been processed using Excel application under the shape of graphics which give the maximum stress and deformation variation depending on soil microprofile.

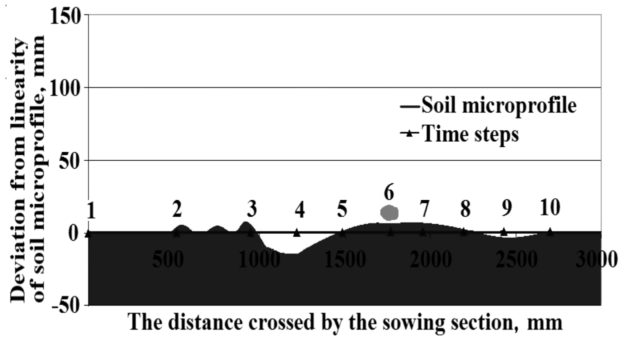

Fig. 6. **Arrangement mode of time steps on surface covered by sowing section**

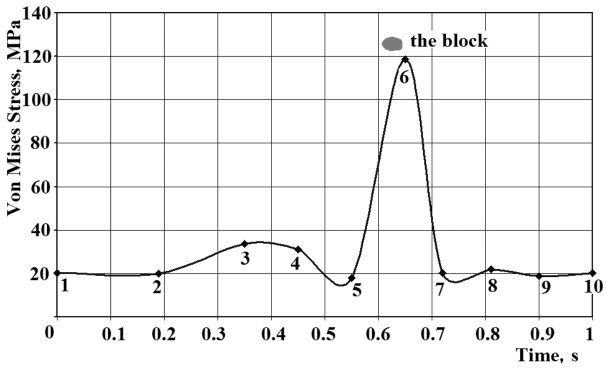

Fig. 7. **Curve of maximum stress in top bar of parallelogram mechanism**

Based upon these graphics there are changes to components done in order to minimize the section mass, while keeping at the same time the stress and strain values within admissible limits. For example, in Figure 6 the arrangement of measurement points (time steps) on the soil surface and the deviation from linearity of soil microprofile are shown and in Figure 7 the way of how the maximum stress varies from the top bar of the parallelogram mechanism for the 10 time steps is shown.

Analyzing the two charts we find out that when the sowing section displaces on an uneven soil without the maximum value of stresses which occur in the top bar of the parallelogram mechanism are about 20 MPa. When it goes on an uneven soil the microprofile of which presents a deviation of ± 20 mm, the maximum tensions in the bar reach about 34 MPa.

In Figure 8 the distribution of the stress state of the top bar of the parallelogram mechanism for a time step located in the linear surface soil is shown.

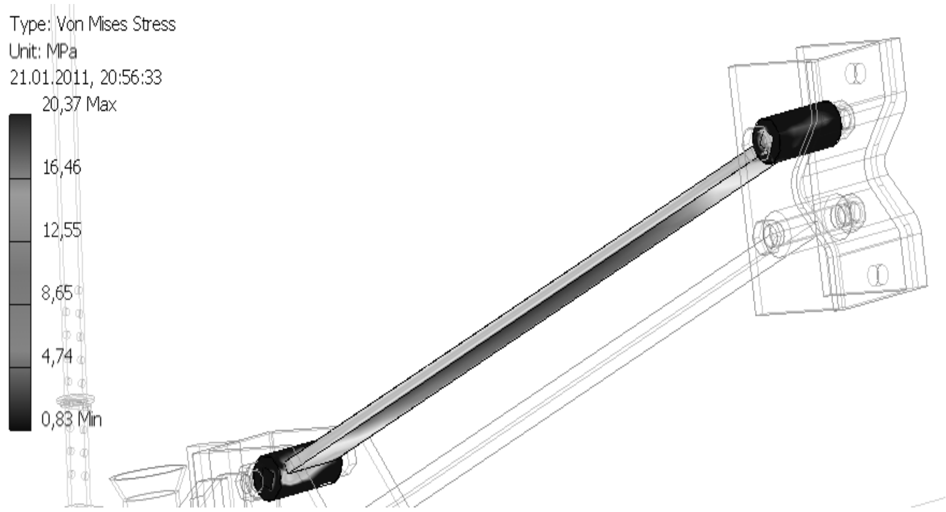

Fig. 8. **Distribution of Von Mises Stress in top bar of parallelogram mechanism**

Conclusions

The theoretical modeling by virtual prototyping of the sowing section allows its functionality assessment and offers the possibility of a functional optimization of the section, by obtaining a correlation between the total mass of the section, the dimensions of the parallelogram mechanism elements, the characteristics of the section press spring, the type of furrow used, the work resistances of the furrow and the rim wheel and disc, the microprofile of the soil on which it displaces etc.

Analyzing the diagrams of Figures 3 and 4 regarding the forces in the parallelogram mechanism joints it can be seen that for the linear microprofile of the soil (even soil) the forces from the joints of the mechanism are of about 380 N for the A1 joint and 320 N for the A2 joint. For the microprofile with unevenness the forces in the joints of the mechanism reach to the value of 1100 N for joint A1 and 1050 N for joint A2 and for uneven microprofile an increase of about 3 times of the forces in the joints, in comparison to the ideal case in which the soil profile is linear

The data and conclusions resulted from this study mode constitute a very useful instrument for projecting and accomplishing new constructive solutions, as well as for comparing the performances of these solutions with those of the ones already existing in order to constructively functional perfect them.

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