THEORETICAL MODELING THROUGH VIRTUAL PROTOTYPING OF TRANSMISSION OF SOWING MACHINES

Fl. Loghin and Fl. Rus

Abstract: *This paper presents the dynamic modelling using an analysing and optimisation software of transmission of sowing machines. The dynamic model developed was realised using the following elements: 3D models transmission components, the cinematic couplings between the components, the mass components characteristics, the external forces system which acts on the transmission components and on soil microprofile. As a consequence of the dynamic simulation process there were graphically represented: the variations cinematic parameters of transmission depending on soil microprofile and radius of wheel drive, the variation of force and the length of the elastic element of the pressing wheel drive.*
Key words: *Sowing Machine; Transmission, Dynamic Model, Simulation.*

INTRODUCTION

The agro-technical conditions required by working process run by the universal sowing machines is about ensuring a uniform spread of seeds on land surface, fact which requires that the speed metering devices to be proportional to the speed of the sowing machine.

The transmission of the universal sowing machine must ensure the correlation between the motion velocity and the metering speed equipment, their involvement being from the "active wheel" of sowing machine, which is possible due to relatively low power required for driving the rotary motion.

The functional constructive optimization of the transmission 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's microprofile. The input data are: the assembled configuration of the transmission, the mass and inertial characteristics of the parts and subensembles in the transmission's component, the external-internal force characteristic and the initial conditions over the component's positions. The output data are: the real motion parameters of the components and the joints reactions [1, 2].

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

MATERIAL AND METHODS

The dynamic modeling method and simulation of the transmission, using the Inventor 2010 soft, supposes going through three main stages: preprocessing (virtual modeling of the transmission); 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 transmission was elaborated in 3 distinct stages.

The first stage of the dynamic model elaboration consisted in representing in 3D form all the pieces and subassembles composing the transmission, after which the restrictions were imposed regarding the assembly mode, restrictions by which the correct positioning of all the composing elements of the transmission was accomplished. Following the application of these restrictions resulted the structural model of the transmission. The structural model is composed by 11 mobile elements, a fixed element (the soil) and 10 cylindrical joints (the rotation couplers A1, A2,...A8 in figure 1).

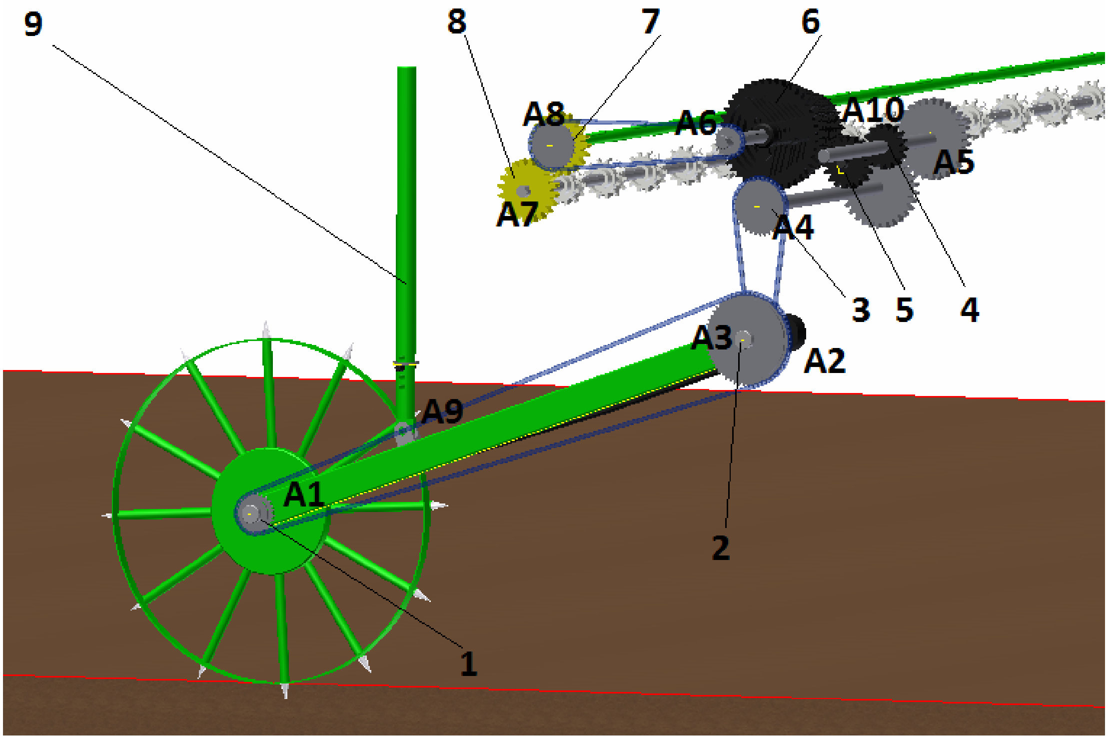

Fig. 1. The kinematic model of transmission:
1 – chain sprocket; 2 – chain wheel; 3 –Northon input shaft; 4 – Northon intermediate shaft; 5 – gear wheel; 6 – Northon driven shaft; 7 – seeds stirrer; 8 – driving shaft of the dosage devices; A1, A2,…A10 - the rotation couplers;

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 transmission's elements, thus canceling degrees of mobility. To ensure a correct functioning, from a kinematic point of view, of the transmission, in the system were introduced 9 kinematic restrictions.

The first restriction refers to the fact that the wheel with rim and spurs must copy the unevenness of the ground. Thus it was necessary introducing a Rolling Joints [3] type of restriction between the wheel's rim and the soil's microprofile.

The following four restrictions refer to the three spur gears gearbox Northon B1, B2, B3 and B4 gear (s. fig. 4). The INVENTOR Soft by the module Design Accelerator, allows rapid design of gears using as input data: the gear ratio, the distance between wheel centers, the number of teeth, module of teeth, the pressure angle and the initial width of the wheels. Also the Design Accelerator module allows the stress calculation that are necessary for the design of the gear by introducing some specific parameters (power, speed, torque, etc.). By generating the four gears there were automatically introduced restrictions type Rolling Joints in the kinematic model between the diameters division of the wheels spin.

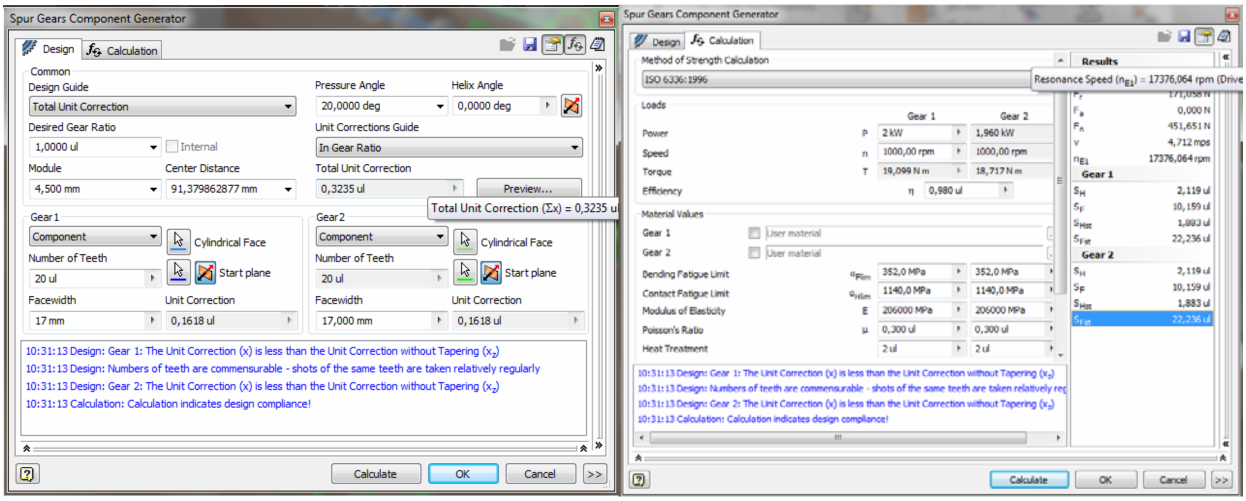

Fig. 2. Rapid design of a spur gear
a – the 3D generation model; b – stress calculation.

Regarding the chain gears, they are automatically generated by Design Accelerator module. This module allows the design calculus and as a consequent of the generation of chain gear, restrictions are introduced in the kinematic model type Belt [3].

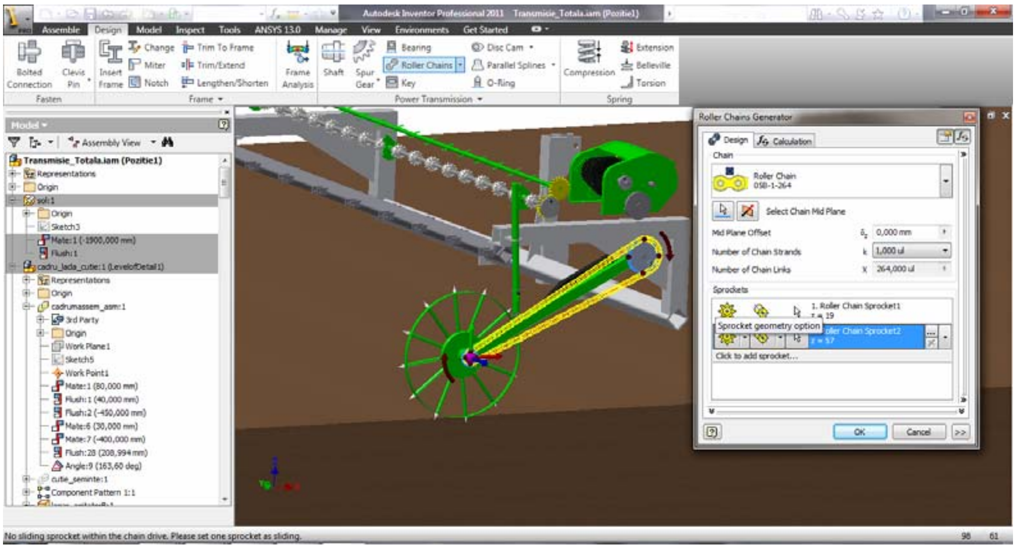

Fig. 3. The generation of a chain gear

The ninth kinematic restriction was introduced between the guiding rod of the coil spring (pretensioned) and the body of the sowing machine, by using a Contact 3D restriction [3], that allows the spring's rod to have a single mobility degree in relation with the machine's body, this way allowing only the compression of the coil spring. To simulate the kinematic model the entrance motion was introduced, which consists in electing a displacement movement of the machine's frame in relation to the soil of 2.7 m/s.

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 coil spring was generated for press the copying wheel on the soil, having the following characteristics: The spring's stiffness *15 N/mm*, the initial length of the spring (pretensioned) 270 *mm*, the winding diameter of the whirl *18 mm* and the whirl's diameter *3 mm*.

For the elaborated dynamic model to be as close to the physical real model, in the system were introduced also the friction coefficient between the soil and the wheel with rim (copying wheel).

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.

To analyze the influence of the microprofile of the soil on the dynamic of the transmission it was considered that the section moves on two soils with different surfaces: a soil with a perfectly smooth surface, with linear microprofile and a soil with unevenness, whose deviation from straightness is of maximum ± 50 mm.

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); the initial position of the sowing machine; the duration of the simulation (10 s); the number of values registered per second (100 frame/s).

Based on the model previously described, the processing stage (model running) is automatically realised 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.

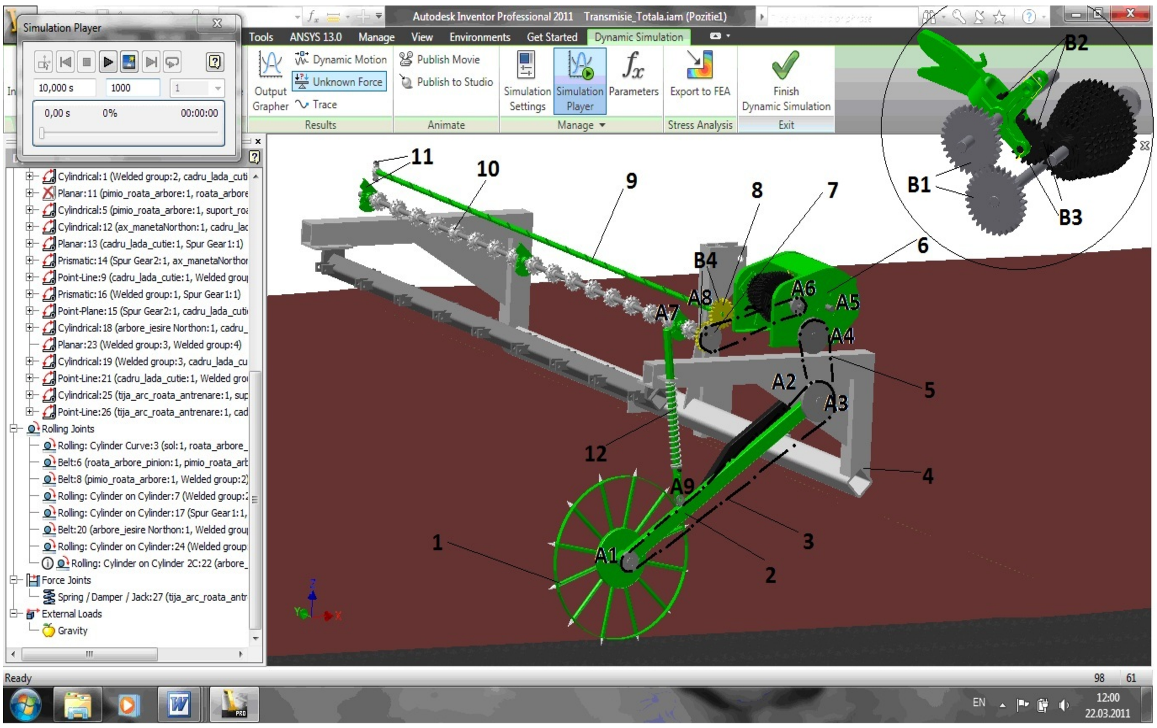

Fig. 4. The dynamic model of the transmission:
1 – copying wheel; 2 – copying wheel support; 3 – chain gear; 4 – body of machine; 5 - chain gear; 6 – Northon gear box; 7 - chain gear; 8 – spur gear; 9 – seeds stirrer; 10 – driving shaft of the dosage devices; 11 – bearing boxes; 12 – elastic element (coil spring) to press the copying wheel; A1, A2,...A9 – rotation couples; B1, B2,…B4 – spur gears.

RESULTS AND DISCUSSION

After the analysis (the model processing) it was performed post-processing stage, which consisted of the following: the processing of the results obtained from the variation diagrams in time: the motion laws (speed and acceleration), the forces of the arc and arc length, graphical simulation (animation) of the model in various projections (flat representation) and tabular representation of the quantities of interest, and then processed in specific application Excel spreadsheet.

For example, in Figures 5 and 6 there are presented the motion laws (speed and acceleration) for the driven shaft of the dosage devices respectively for the seeds stirrer.

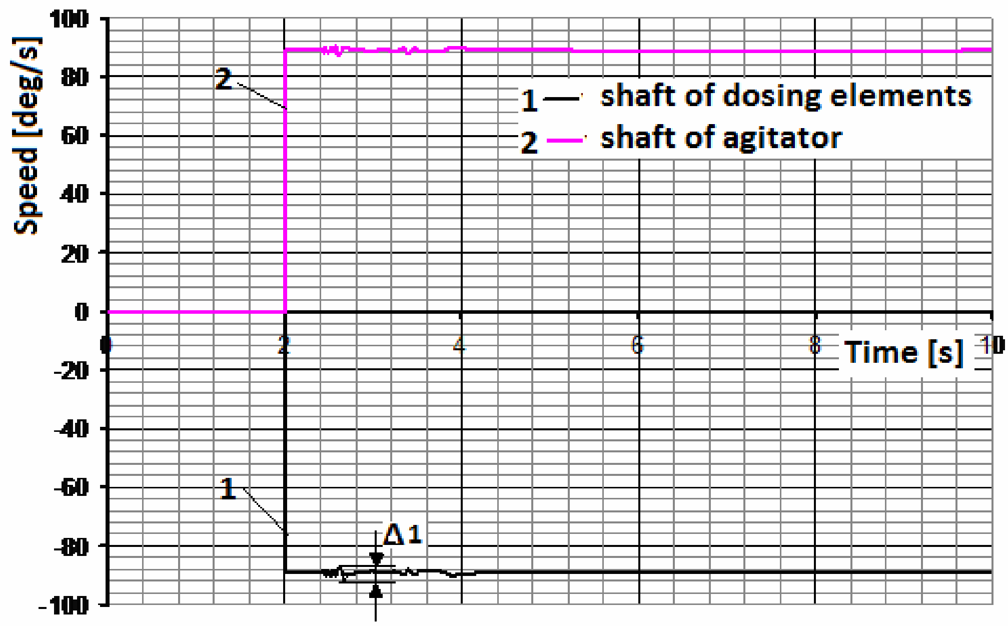

Fig. 5. The variation in time of the speed of the driven shaft of the dosage devices, respectively of the stirrer speed

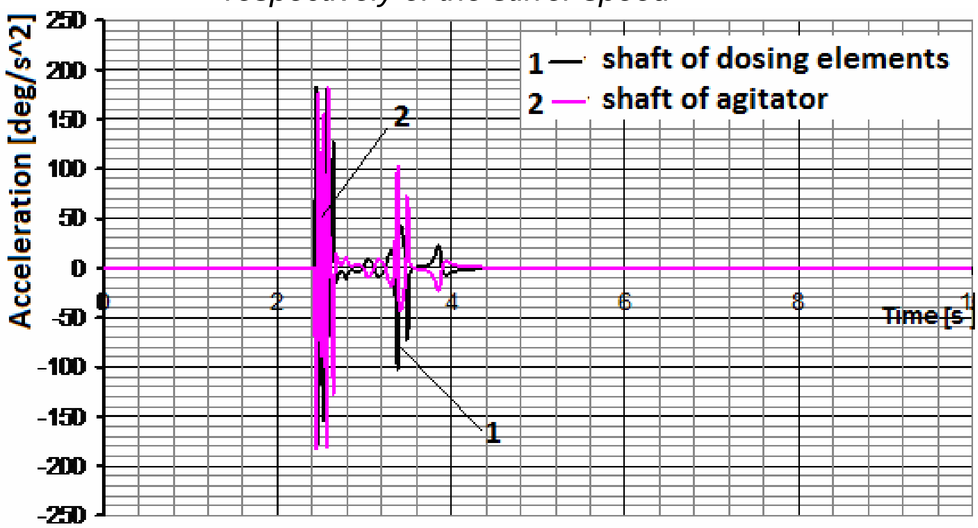

Fig. 6. The variation in time of the acceleration of the driven shaft of the dosage devices, respectively of the stirrer acceleration

In figure 7 it can be observed how there are propagated the irregularities of the soil surface, in the flow of the of movement from the ”active wheel” to the driven shaft of the metering devices. This chart shows the speed variation for all the elements involved in the motion transmission (moving parts 1, 2…8 of the kinematic model).

From the diagrams analysis we can observe that the influence, of the surface with uneven soil on the motion flow transmission, is reduced gradually. It is noted that the deviation from linearity of the copying wheel speed is of ± 50 degrees / s and the speed of the driven shaft of the dosing devices is almost linear, the deviation is between the range of ± 2 degrees / s.

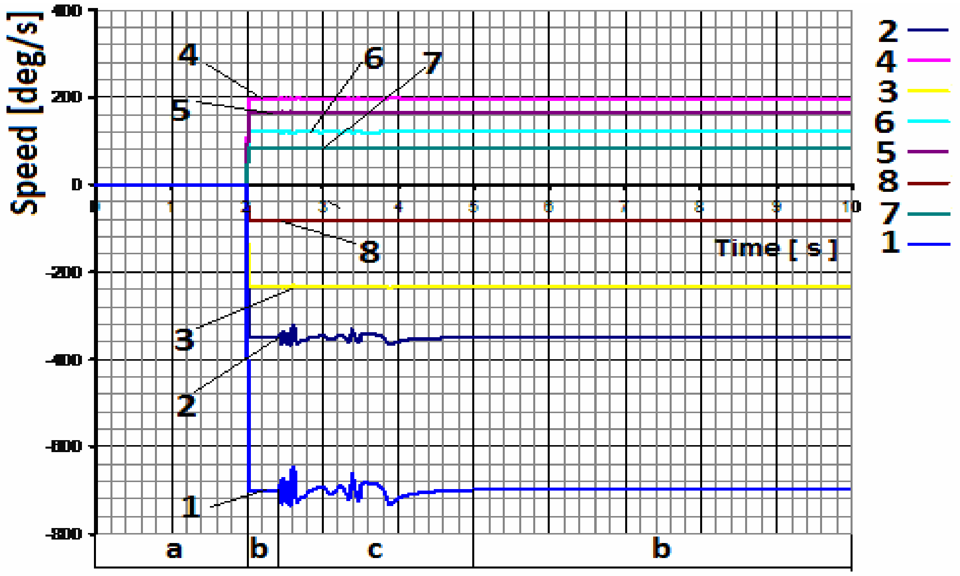

Fig. 7. The propagation way irregularities of soil surface irregularity in the motion flow: 1,2, …8 – mobile elements of the transmission (see fig. 2); a – area where the car is stationary; b –area where the surface soil is linear; c – area where the surface soil presents oscillations level.

CONCLUSIONS AND FUTURE WORK

The theoretical modelling by virtual prototyping of the transmission allows it's functionality assessment and offers the possibility of a functional optimization of the transmission, by obtaining a correlation between the total mass of the transmission, the dimensions of the transmission's component, range of gear ratios, the characteristics of the press spring and the diameter of driving wheel.

The data and conclusions resulted from this study mode constitutes 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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