THE DISTRIBUTION OF STRESS WHICH APPEARS IN THE WORKING ORGAN OF THE CULTIVATOR IN CONTACT WITH SOIL

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Abstract: *The cultivators are agricultural machinery used for: loosening the soil before plantation, elimination of weeds or soil aeration after the crops started growing. In this present paper, because of the complexity of the system soil – agricultural machine, we will use an analytical model which respects the geometry of the active element, realising a prediction of the forces which result at the dislocation of the soil. In the pre-processing stage, the objective was to design a three dimensional model in CATIA V5, in keeping with the geometry of the active element, represented by the Cartesian coordinates, together with a portion of the soil rendered as a parallelepiped shape. The second stage followed the introduction of conditions both for the working part, through the fastening of the working organ frame, the moving direction and velocity, and for the soil, through the action of the cohesion and internal friction forces. In the third stage, called the processing stage, there is the simulation of the process of soil displacement done in real conditions, for various degrees of refinement of the discretization network in finite elements. Using the Explicit Dynamics module of the Ansys software, which allows the study of the working organ behaviour and in real conditions the normal stress, deformation at different speeds and working depths are analysed.*

Key words: *cultivator, working organ, normal stress, deformation*

INTRODUCTION

National Rural In general for the romanian society, classic agriculture as well as the durable one adopted recently, represents an activity with a major contribution to economic evolution assuring getting the necessary goods for people's food.

At the evolution of agriculture, soil works represented agrotechnical measures of the biggest importance for the plant crops. Among the many technologic processes for the application of different soil works, superficial loosening, is representative because it changes the constitution of the backed layer (JITĂREANU G, TENU I, ET.AL., 2007).

During the processing process, especially while ploughing, the soil is subjected to great stress because of the agricultural machines.

The specific resistance is established by reporting the traction resistance force of the work part to the transversal section of the furrow that resulted after processing.

Experimentally it was noticed that aerated soils are characterized by lower apparent density and the specific resistance force to ploughing is lower compared to compressed soil. At the same time, once the soil humidity is lower the soil ploughing resistance is higher.Knowing the value of the specific resistance force to ploughing and the specific resistance to soil work in general is highly important because they influence fuel consumption.

Studies have shown that the higher the apparent density of the soil and its resistance to penetration is the higher the consumption is too. Consequently, fuel consumption increases with the work depth of the active part.

The research done in the present focused on the interaction between the soil and the type of work; the study of physical and mechanical caracteristics for different types of soils; the examination of the shape and form, of the angle of inclination and the number of the working organs situated on the soil working machinery; as well as the main working conditions among which we mention the depth of work, the cutting width and travel speed.

Because of the complexity of the soil-machine system, analytical models are used, limiting the study to the geometry of the active organ, making a prediction of the forces resulting from engaging the soil (CHIORESCU E, PREPELITA D, ET.AL.,2009).

The continuous development of computers combined with the improvement of the mathematical techniques and methods have lead to the occurrence of new generations of very efficient software which have succeeded in simulating various agricultural operations. The determination model of the soil-tool system to be submitted to the finite element analysis consists in passing from a continuous structure having an infinite number of points to a discrete model with finite number of points called knots, covering the model in a discretization network (BERNACKI H., HAMAN J, ET.AL.,1972).

The drawing of the working organ of the cultivator is realised with one of the most used integrated systems CAD/CAM/CAE on a worldwide plan, CATIA V5, with applications in different areas, from the car construction industry to aeronauctics. This program favors the realisation of a virtual prototype composed of an assembly of computer data which permit the handling of the virtual object created on the computer in the same way as a real object.The choice of this integrated system CATIA was realised because it has a modular structure, which assures a wide versatility, moving from one module to another is made rapidly with continous editing posibilities of the entity in the works, without information loss.

The interaction study between the soil and the working organ is very complex due to the variation of the factors which influence the soil (BERTICI ET AL, 2013BENTAHER H., IBRAHMI A.,ET AL, 2013).

MATERIAL AND METODS

This study analyses the behaviour of the working tool, part of the soil processing machine, using the Finite Element Method (FEM), being determined by the maximum values of the normal stress, respectively of the total deformation produced following the action of the soil. In order to study the behavior of the working organ using the finite element method, we designed a tridimensional model which respects entirely the geometry of the active element, using the drawing software CATIA and saving the file with the .igs extension so that it could be imported.

Importing the entire scarificator-soil knife system is done in the Ansys software package, the Explicit Dynamic module.The analysis is made in three different stages.

In the pre-processing stage, the objective was to design a three dimensional model in CATIA V5, in keeping with the geometry of the active element, represented by the Cartesian coordinates, together with a portion of the soil rendered as a parallelepiped shape.

The second stage followed the introduction of conditions both for the working part, through the fastening ofthe working organ frame, the moving direction and velocity, and for the soil, through the action of the cohesion and internal friction forces. In the third stage, called the processing stage, there is the simulation of the process of soil displacement done in real conditions, for various degrees of refinement of the discretization network in finite elements.

RESULTS AND DISCUSSIONS

The case study was done on a type of soil of cambic chernozem with clay-loam predominant texture.

The physical – mechanical properties of the material of the working organ OLC 45 under the Romanian standard STAS 880-80 and the European standard SR EN 10083-2:1995 symbolized as 1C45 in table 1, are introduced in the pre-processing stage.

Table 1

Mechanical and physical characteristics of the 1C45 steel

Steel brand	Tensile yield strength Rp 0,2 [MPa]	Ultimate tensile strength Rm [MPa]	Poisson Coefficient nmed	A [%]
1C45	410	880	0.3	14

The three-dimensional drawing of the plowshare created using the CATIA program is made respecting the real dimensions according to STAS 7247/1973.

Since the simulation of the soil displacement process done by the scarificing knifefitted on a tiller seeder combo (UPTSC) is tridimensional, a system of coordinates made of three axes (Ox, Oy and Oz) is introduced, the direction of the motion being represented by the Oy axis.

The motion of the scarificing knife takes place on the Oy alignment, the motion sense being in the same sense of the axis system , as showed (Figure 1).

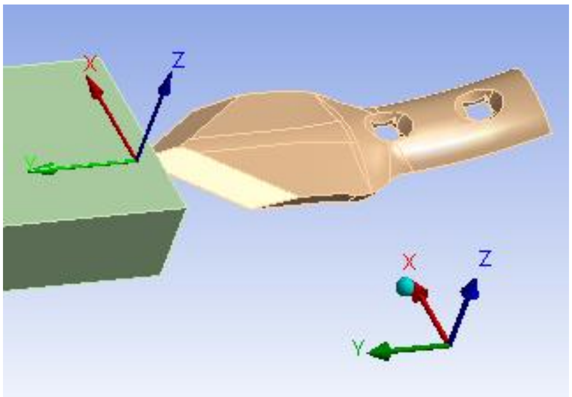

Figure 1 The axes system and the directionof the scarificing knife motion

Considering the nonlinear plastic behavior of the DruckerPrager type of the clay-sandy soil, its characteristics are shown in table 2.

Table 2

Soil properties

Soil Properties	Corresponding Values
Soil Type	Clay - loam
Young's modulus of elasticity (Es)	19000 kPa
Posson's ratio (η)	0.3
Cohesion (C)	23kPa
Internal friction angle (Ø)	32

We will conduct a three-dimensional study on the unitary stress according to the direction of the scarificing knifeduring the aeration process on the OX direction, for three different speeds (0.50, 1.00, 1.50 m/s), at different depths. The stress resistance force was established experimentally using pin transducers. It was used a VISHAY - HS 100 MG7128 type force cell of 1000 kN, invertor number FO21633 – USA, calibrated on 20.09.2015. For the measurements it was used a data system consisting of a laptop and the master unit – Traveller 1, model MUT – 1, 1016-S type with 8 SG-2 type tensometric amplifying channels with a transmission band of 1kHz.The results were obtained on a clay-loam soil at different depths, synthetized in table 3.

After introducing the mechanical characteristics of the scarificing knife material as well as the soil properties, we need, for the simulations set, to choose the optimum discretization for the working part as well as the constraints within the system, according to the importance during the working process. Thus, for the scarificing knife we choose a discretization of 1 mm and for the soil 3 mm, to shorten the time needed for cycles rolling.

Table 3

Maximum and minimum normal stress at different velocities and depths

No.	Velocity v [m/s]	Depth a [m]	Traction resistance R_{tr} [N]	Maximum normal stress [MPa]	Minimum normal stress [MPa]
1	0.50	0.18	5290	105.61	-632.04
2		0.25	7464	108.14	-651.35
3		0.36	8827	112.87	-678.63
4		0.38	9834	118.12	-686.30
5	1.00	0.18	6500	111.76	-684.26
6		0.25	8259	120.85	-685.71
7		0.36	8756	121.76	-724.28
8		0.38	9865	124.71	-752.80
9	1.50	0.18	7869	138.57	-814.84
10		0.25	8264	140.71	-812.27
11		0.36	11428	145.85	-810.66
12		0.38	13684	153.36	-819.20

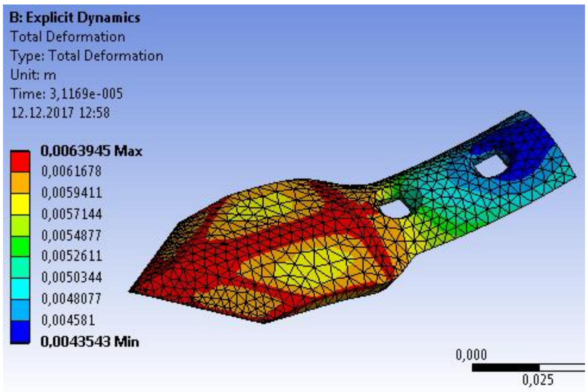

Figure 2 Total deformation for the scarificing knife

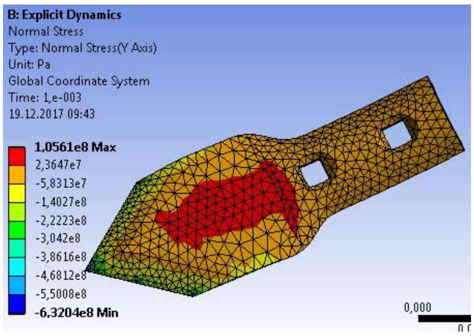

Figure 3 Normal stress on movement direction y, at v=0.5m/s, a=0.18m, for clay-loam soil

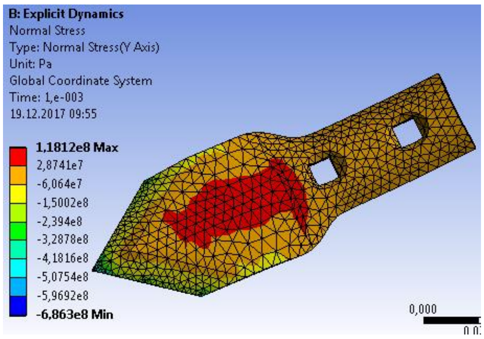

Figure 4 Normal stress on movement direction y, at v=0.5m/s, a=0.38m, clay-loam soil

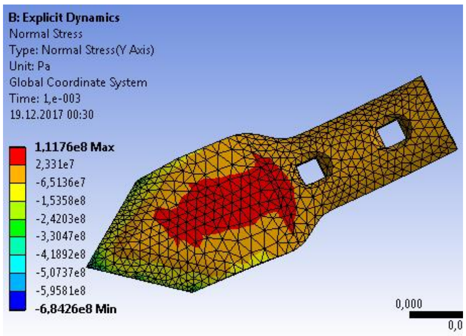

Figure 5 Normal stress on movement direction y, at v=1.0 m/s, a=0.18m, for clay-loam soil

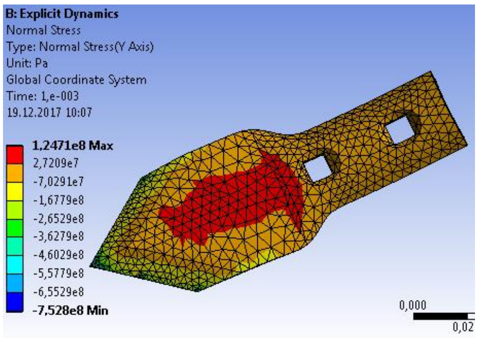

Figure 6 Normal stress on movement direction y, at v=1.0 m/s, a=0.38m, for clay-loam soil

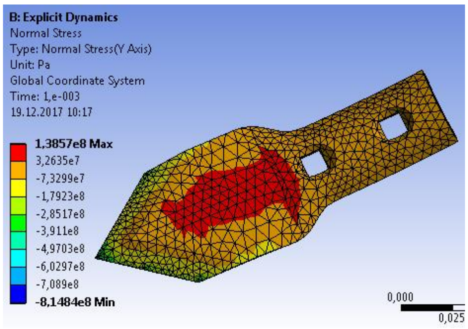

Figure 7 Normal stress on movement direction y, at v=1.5 m/s, a=0.18m, for clay-loam soil

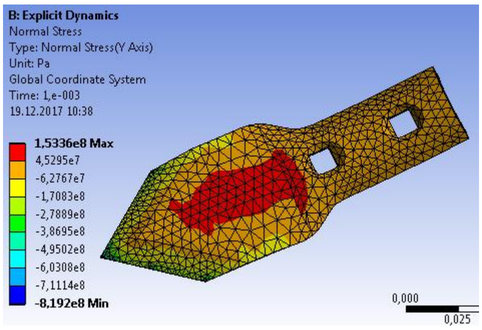

Figure 8 Normal stress on movement direction y, at v=1.5 m/s, a=0.38m, for clay-loam soil

CONCLUSIONS

A representative set of 12 problems was made on the soil dislocation process using the plowshare being differentiated by the different speed values and depth.

All the 12 problems on the soil aeration process were solved using numerical simulations and the Ansys software package, applying the same refinement degree of the same discretization network into finite elements in Cartesian coordinates.

It is noted from the analysis with finite element of the total deformation, at the joining of attack surfaces, changes of angles, red zones, which shows stress with values close to the breaking limit.

The cause of this phenomenon is due to the stress the work part is subjected to as it is higher than the yield limit of the material it is made of, fact confirmed also by the finite element simulations.

Consequently, special actions are required to increase the durability of the active parts used in working the soil in different methods as covering the surface with titanium based ceramic materials, or changing of the joining angles of the surface.

From the analysis of normal stress, the appearance of a stress is noted, at the interaction with the soil , powerful friction on the superior surface (red zone) of the active organ, which can lead to the cracking of the knife.

So the necessity of creating of new organs with optimal geometry, resulted from joining angles of the surface different from the actual ones.

Bases on the resulting conclusions it can be considered continuing the research process with other parts, at different speed values and depths to compare the results of the finite element simulation with those obtained experimentally.

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