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# The analysis of the distribution of unitary stresses for the universal plowshare in tiller seeder combos (UPTSC)

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**Abstract:** The sustainable development of agriculture is an important component of economic and social progress of the mankind aiming especially at promoting environmentally friendly systems and technologies. Thus, the implementation of sustainable agriculture also requires some high performance farming aggregates such as tiller seeder combos. Their most stressed active working part is the plowshare which has an important part in cutting the soil. For this reason, we consider that theoretical and experimental research is needed for the tear to which this working part is subjected to. This paper analyses the behavior of the universal plowshare, component part of UPTSC, using the Finite Element Method (FEM) and the Ansys software program. With the help of FEM, we analyzed the universal plowshare in the material structure during the soil cutting process, highlighting the deformation degree and the stress field in the working part. In the first stage, we identified a representative set of problems concerning the soil cutting process, for which we designed the solutions through numerical simulations. In the processing stage, we designed a 3D model which respects entirely the geometric shape of the active element in Cartesian coordinates. In order to simulate the soil cutting process in accordance with the real conditions, the compilations are done for various refinement degrees of the discretization network in finite elements. In the same stage we introduced the constraints represented by: the fixation of the plowshare support, direction, as well as the action of the cohesion and shear strength. Using the Explicit Dynamics module of the Ansys software, which allows studying the plowshare behavior, we analyzed in real conditions, the normal and the shear stresses as well as the deformation, for various soil types and various soil states. Considering the data on the existent stresses, following the FEM analysis of the working part, we determined the wear and suggested the safety coefficients for this case.

## Introduction

For humankind on the whole, agriculture has a major contribution to the sustainable development of the economy, by providing food to people, thus ensuring their life on the planet.

The increase in productivity and economic efficiency in agriculture has been made possible by the continuous development of the mechanized agriculture technologies, specifically the use of ever bigger and heavier tractors and machines, leading to the intensification and expansion of some physical degradation processes, as well as to the anthropogenic destructuring and compaction of the soil [1].

The Earth population has tripled in the last century, making it necessary for the world economy to grow over 20 times, the industrial production increasing over 50 times, leading to a 30 times higher fuel consumption.

According to the latest reports an area of 1ha of productive land is lost every six seconds due to various forms of degradation, so the future expansion of agriculture on a “horizontal” plane is no longer possible [1].

Considering all these aspects, there is a growing interest worldwide in the conservative agriculture system which allows the rational management of natural resources with direct implications in preventing and/or minimizing soil degradation and restoring its productive capability. Thus, now more than ever, there is necessary to adopt measures on a global level in order to stop environmental degradation and allow a rational and safe future development of society [1].

Using the Finite Element Method (FEM) for analysis is one of the most recent and advantageous calculus and simulation methods, being a must in engineering, manufacturing and high performance research.

The Finite Element Method FEM analyses the behavior of the working part (the universal plowshare), ensuring the validaty and the accuracy of the used finite element program, its results being comparable to the experimental ones, as well as highlighting the main changes taking place in the material structure during deformation: the thinning degree of the material, the stress field, the orientation, the sense and the velocity of the deformations.

Simulating the working process of the universal plowshare, as well as its behavior when altering the soil, we can predict the deformation and the wear of the working part, we can analyze the stress and determine the working strength and study the possible cracks that may occur. FEM has a wide range of uses, solving a multitude of problems that may occur in engineering.

**Material and Method**

In order to study the behavior of the universal plowshare 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. We imported the drawing representing the universal plowshare into the Explicit Dynamics module.

The ANSYS software package has a materials library in which their main properties are predefined. In this case there are the physical-mechanical properties of the material used for the plowshare, OLC 45 according to the Romanian STAS 880 – 80 and European standard SR EN 10083-2:1995 with the symbol 1C45 (Table 1).

Table 1 Mechanical and physical characteristics of the 1C45 steel

| **Steel brand** | **Tensile yield strength $Rp_{0,2}$ [MPa]** | **Ultimate tensile strength $R_m$ [MPa]** | **Poisson Coefficient $n_{med}$** | **A [%]** |
|---|---|---|---|---|
| **1C45** | 410 | 800 | 0.3 | 14 |

To study the behavior of the universal plowshare, we chose size 8 with the following constructive dimensions presented in table 2, where B is the plowshare width and g its thickness.

Table 2 Main dimensions of the universal plowshare

| | |
|---|---|
| B [mm] | 220 |
| g [mm] | 6 |

Since the simulation of the soil displacement process done by the universal plowshare fitted 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 Ox axis.

The motion of the plowshare takes place on the Ox alignment, the motion sense being opposite to the axes system, as showed (Figure 1). The Oz orientation refers to the angle of the working part in relation to the field surface.

We are making a tridimensional study on the unitary and tangential stresses according to the direction of the plowshare motion during the soil displacement process Ox.

After introducing the mechanical characteristics of the material, to design the simulations set we need to choose the optimum discretization for the working part (the plowshare) and the soil constraints from the whole system, according to the importance it has in the working process [2]. Thus, for the universal plowshare we choose the 1 mm discretization.

We are doing the simulation for three types cernoziom non -carbonated soil textures: sandy, sandy - loam, sandy - clay, according to the soil state, taking into consideration soil cohesion, the internal coefficient of friction between the soil particles and the external coefficient of friction between the soil and the working part [3].

Following simulation we notice that the area of maximum deformation, and dangerous as regard the wear and tear, is located in the centre of the plowshare as shown (Figure 2).

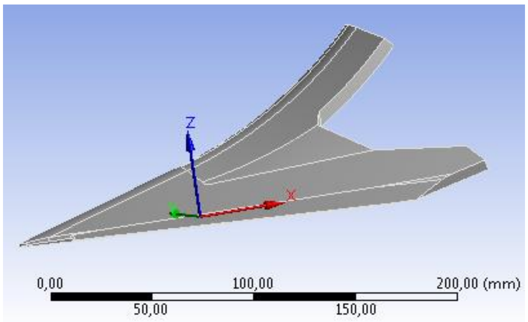



Figure 1 The axes system and the direction of the plowshare motion

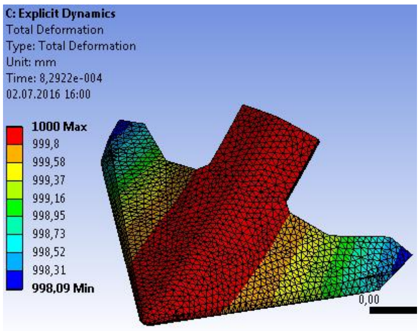



Figure 2 Total deformation for the plowshare

A representative set of trials with finite elements was done on the solid model during simulation in accordance with the type of soil, in Cartesian coordinates and same conditions [4, 5].

We notice that for a sandy clay soil the working part that is 120 mm deep at an angle of $3^0$, the maximum normal stress is 615.91 MPa (Figure 3) and the shear stress is 320.36 MPa (Figure 4), observing a dangerous area of the red color, possibly leading to cracks occurring in the plowshare.

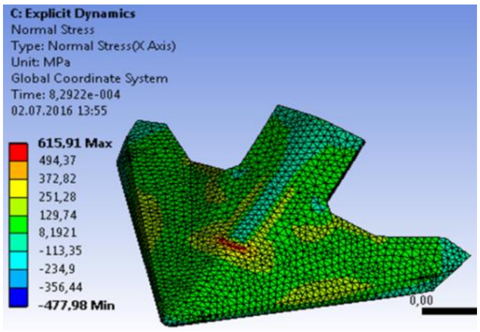



Figure 3 The normal stress on the motion direction OX for the sandy clay texture

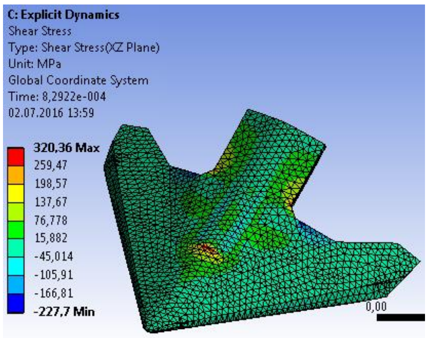



Figure 4 The shear for the sandy clay texture (XZ)

The loading of the plowshare was done using directly the pressure corresponding to the working depth, according to the type of texture: $P_{max}$ = 1.00 MPa, $P_{min}$= 0.5 MPa for the sandy clay texture; $P_{max}$ = 0.50 MPa, $P_{min}$ = 0.30 MPa for the sandy loam texture; $P_{max}$ = 0.25 MPa, $P_{min}$ = 0.10 MPa for the sandy texture.

It can be observed that for a sandy loam soil in the same working conditions as for the previous trial, the maximum normal stress is 305.52 MPa (Figure 5) and the shear stress is 158.91 MPa (Figure 6).

For the sandy soil texture, in which the plowshare is at a depth of 120 mm and $3^0$ angle as in the previous cases, the maximum normal stress has the value of 158.55 MPa (Figure 7), while the maximum shear stress is 82.469 MPa (Figure 8).

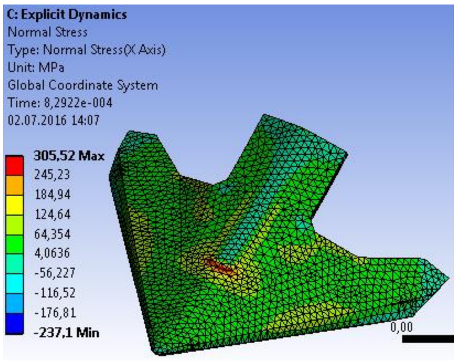



Figure 5 The normal stress on the motion direction OX for the sandy loam texture

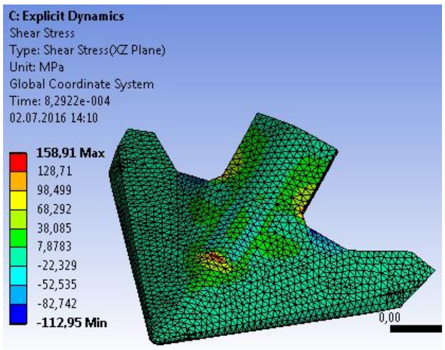



Figure 6 The shear for the sandy loam texture (XZ)

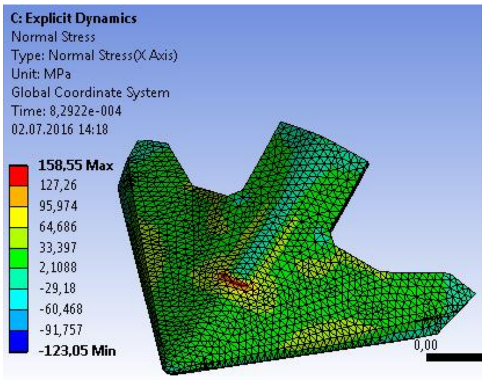



Figure 7 The normal stress on the motion direction OX for the sandy texture

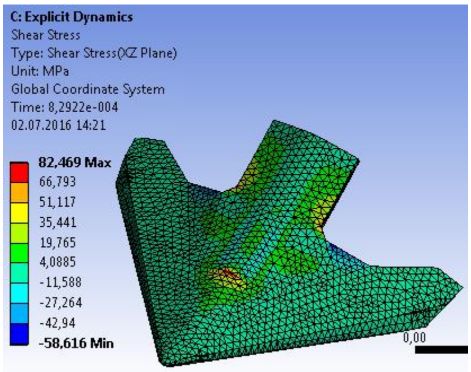
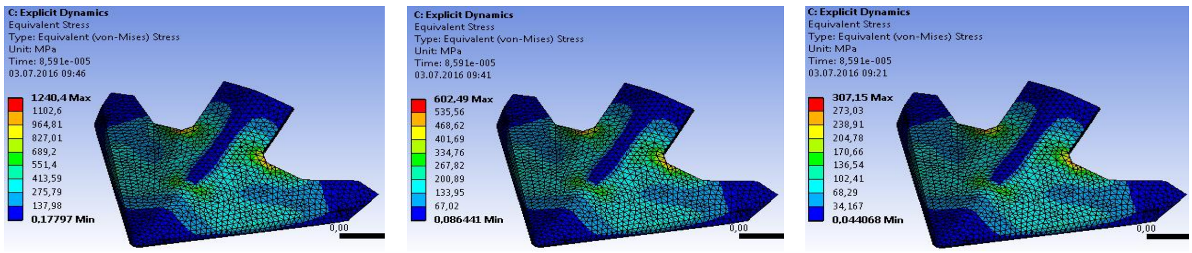



Figure 8 The shear for the sandy texture (XZ)

The distribution of the equivalent Von Mises stresses on the model subjected to the pressure according to the textures type is depicted (Figure 9).




Sandy clay texture Sandy loam texture Sandy texture

Figure 9 The distribution of the equivalent Von Mises stresses for the universal plowshare

We can conclude after the simulation that the soils of the sandy-clay texture can take over high yield or shear stresses due to the binding strengths between the particles or between the particles and the aggregates, thus leading to small deformations in these types of texture. In the case of the sandy texture, big deformations occur under the action of small value stresses. For the sandy-loam texture, one can notice after the simulation that the stresses taken over have average values.

Table 3. The maximum and minimum values of the normal unitary and shear stresses for the minimum pressure

| Texture type | $P_{min}$ [MPa] | Maximum normal stress [MPa] | Minimum normal stress [MPa] | Maximum shear stress [MPa] | Minimum shear stress [MPa] |
|---|---|---|---|---|---|
| Sandy | 0.1 | 64.761 | -49.27 | 33.182 | -21.927 |
| Sandy loam | 0.3 | 189.16 | -148.52 | 97.592 | -68.149 |
| Sandy clay | 0.5 | 305.52 | -237.1 | 158.91 | -112,95 |

Table 4. The maximum and minimum values of the normal unitary and shear stresses for the maximum pressure

| Texture type | $P_{max}$ [MPa] | Maximum normal stress [MPa] | Minimum normal stress [MPa] | Maximum shear stress [MPa] | Minimum shear stress [MPa] |
|---|---|---|---|---|---|
| Sandy | 0.25 | 158.55 | -123.05 | 82.469 | -58.616 |
| Sandy loam | 0.5 | 305.52 | -237.1 | 158.91 | -112,95 |
| Sandy clay | 1 | 615.91 | -477.98 | 320.36 | -227.7 |

In relation to the maximum stress $\sigma_{max}$ and the minimum one $\sigma_{min}$ determined by using the plowshare model with the finite elements (Table 3) and (Table 4), we calculated the wear and tear determining the wear safety coefficients for different types of textures [6]. We determine the average value of the stresses $\sigma_m$ and the stress range $\sigma_a$ as follows:

$$\sigma_m = \frac{\sigma_{max}+\sigma_{min}}{2}; \ \sigma_a = \frac{\sigma_{max}-\sigma_{min}}{2} \quad (1)$$

The asymmetry coefficient of the cycle is given by the ratio between $\sigma_{min}$ and $\sigma_{max}$:

$$R = \frac{\sigma_{min}}{\sigma_{max}} \quad (2)$$

The wear and tear determination starts from the wear limit for the alternating symmetric cycle which is calculated using the formula [7]:

$$\sigma_{-1}=0.25(\sigma_R+\sigma_C)+50 \text{ [MPa]} \quad (3)$$

The maximum range of the cycle after Soderberg is determined according to the yield limit $\sigma_c$, while after Goodman it is in relation to the shear strength:

$$\sigma_{aS} = \sigma_{-1}\left(1-\frac{\sigma_m}{\sigma_c}\right); \quad \sigma_{aG} = \sigma_{-1}\left(1-\frac{\sigma_m}{\sigma_R}\right) \quad (4)$$

The safety coefficient for variable stresses after the Soderberg criterion and after the Goodman criterion is determined using the following formulae:

$$C = \frac{1}{\frac{\sigma_a}{\sigma_{-1}}+\frac{\sigma_m}{\sigma_c}}; \quad C = \frac{1}{\frac{\sigma_a}{\sigma_{-1}}+\frac{\sigma_m}{\sigma_R}} \quad (5)$$

Following the determinations, the following safety coefficients dependent on the texture type were reached (Table 5):

Table 5. The safety coefficients after Soderberg and Goodman criteria

| Texture type | The safety coefficient after Soderberg | | The safety coefficient after Goodman | |
|---|---|---|---|---|
| | $P_{min}$ | $P_{max}$ | $P_{min}$ | $P_{max}$ |
| Sandy | 0.89 | 0.92 | 0.88 | 0.90 |
| Sandy loam | 0.92 | 0.95 | 0.90 | 0.92 |
| Sandy clay | 0.95 | 1.05 | 0.92 | 0.96 |

## Conclusions

A representative set of six problems regarding the process of soil displacement using the universal plowshare, was elaborated, differentiated by the value of minimum and maximum pressure.

All six problems concerning the soil displacement process were solved through numerical simulations, using the Ansys software package, employing the same refinement degree of the discretization network into finite elements in Cartesian coordinates.

The maximum deformation is also defined as being dangerous and is observed in the central area of the universal plowshare where its wear occurs during the working process.

The experiments were realised around the Western Romanian Steppes where the soil is non – carbonated cernoziom in which the predominant textures are : sandy, sandy loam and sandy clay.

Moreover the improvement of the productivity is made by the implementation of new hydroameliorative methods and their protection.

For the analyzed texture types of non-carbonated cernoziom, the wear value of the working part is higher in the middle of the plowshare where the angle of inclination changes.

It transpires from determinations that, although the universal plowshare is resistant to static stresses, it does not cope well with the wear stresses at the oscillating loading cycle to which it is subjected in the soil.

The safety coefficient according to Goodman criterion is subunitary for all three types of analyzed textures (sandy C=0.90; sandy loam C=0.92; sandy clay C=0.96), meaning that the plowshare is resistant to stresses.

According to the Soderberg criterion, the coefficient is subunitary for the sandy texture (C=0.92) and the sandy loam texture (C=0.95). For the sandy clay texture, the coefficient is over one unit (C=1.05) which means that there is the possibility of cracks occurring, which, due to variable stresses, can lead to irreversible deformations or the breaking of the working part if the maximum pressure reaches values over 1 MPa. This phenomenon is caused by the stresses inside the working part that are over the yield limit or the shear limit of the material of which is made, fact confirmed by finite element simulations.

For this reason, specific actions are required such as increasing the durability of these plowshares through various methods. Based on the conclusions achieved, we are planning to continue the research in order to compare the experimental results with the simulated ones.

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