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USING MODERN CAD-CAE DESIGN METHODS TO DESIGN A SEEDER FOR DIRECT SOWING INTO MEADOW FIELD

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Abstract: *The present work presents the constructive description of a technical equipment, which carries out the sowing directly in the stubble of creeping plants (maize, sunflower, etc.), whose execution project used modern CAD-CAE design methods. The reasons that imposed the approach of some modern CAD-CAE methods are the following: - reducing design time and eliminating specialized capabilities by: creating files for CNC machines (stamping, bending, laser cutting, vertical and horizontal machining centers, etc.) or obtaining injection molds for plastic parts; - the ability to design parts in an assembly context; - granting view, search, modification and annotation for project related files; - checking for interference between parts of assemblies, detecting collisions between moving parts, quickly changing a dimension in three dimensions, checking for static load resistance through finite element analysis (FEA) and submitting these changes to the execution drawings. The direct-in-stubble weed planter, which was designed using CAD-CAE design, is intended for the establishment of weed crops on fields with unploughed grass cereal stubble for the second crop or after harvesting other plants (sunflower, soybeans, etc.) on soils not plowed or insufficiently prepared for spring sowing.*

Keywords: *CAD-CAE, direct sown, hoeing plants*

1. Introduction

Continuing to practice conventional agriculture will lead to negative effects on the environment by degrading the main component, the soil, affecting the development of a healthy society [1].
By practicing sustainable agriculture, the aim is to produce agricultural products with positive effects on the environment, while ensuring, at the same time, food for future generations [2].
In the countries of the European Union there is a requirement for the promotion of conservative agriculture, in this sense, the European ecological agreement aims in particular to achieve a fair, healthy and environmentally friendly food system [3].
Conservative systems, which are based on less intensive agricultural land work, represent a viable solution to promote environmental protection, because by storing organic carbon, they lead to a more productive and resistant soil [4].
The evaluation of a tillage system in the conservative category is done by determining the degree of surface coverage with plant residues or protective crops [5].
Direct seeding helps maintain good soil structure by leaving earthworms and plant roots undisturbed, which creates durable drainage channels and pore spaces that remain even after the crop has been harvested [6].
Depending on the degree of coverage of the soil surface with plant residues, the intensity and the method of tillage, the most conservative system is sowing directly in the stubble [7].
Under these conditions, at INMA Bucharest, for the establishment of spring crops by direct sowing in stubble or on land prepared with minimal work, a seeder of creeping plants for direct sowing in stubble was designed as part of a research project financed by the ADER sector program of MADR, whose patent application with the title ”*Tillage equipment and seeding weeds directly into the meadow field*” was registered at OSIM with no. A00562/20.09.2024.
The software SOLIDWORKS® was used for the design [8].

The shift from two-dimensional to three-dimensional design was a very important step in computer-aided design, as designed objects begin to have a shape and thus can be seen from any direction [9].
The reasons that imposed the way of embarking on the execution projects of the performance of technical equipment of direct seeding in stubble and on ridges for leek crops using modern CAD methods through 3D modeling with the parametric design program, were the reduction of design time, the increase of the capacity of designing parts in an assembly context and checking for interference between parts of assemblies, detecting collisions between moving parts, quickly changing a dimension in three dimensions and passing these changes to production drawings [10].

2. Materials and methods

The seeder of creeping plants for sowing directly in stubble (fig. 1) performs the following operations in a single pass:

- uncovering stubble or topsoil by creating a strip 20 centimeters wide and 2 cm deep cleared of plant debris by the two notched discs mounted inclined;
- cutting weeds, plant debris and notching the soil in a vertical plane along the axis of the row to be sown, to a depth of 4...15 cm by the notched straight disc;
- penetrating the soil to a depth of 2...20 cm to create a channel filled with loose soil by breaking and partially driving the soil with the chisel knife;
- the mobilization and loosening of the soil in strips with a width of 20 cm and a depth of 2...8 cm by the pair of spherical discs;
- the sown hoeing plants.

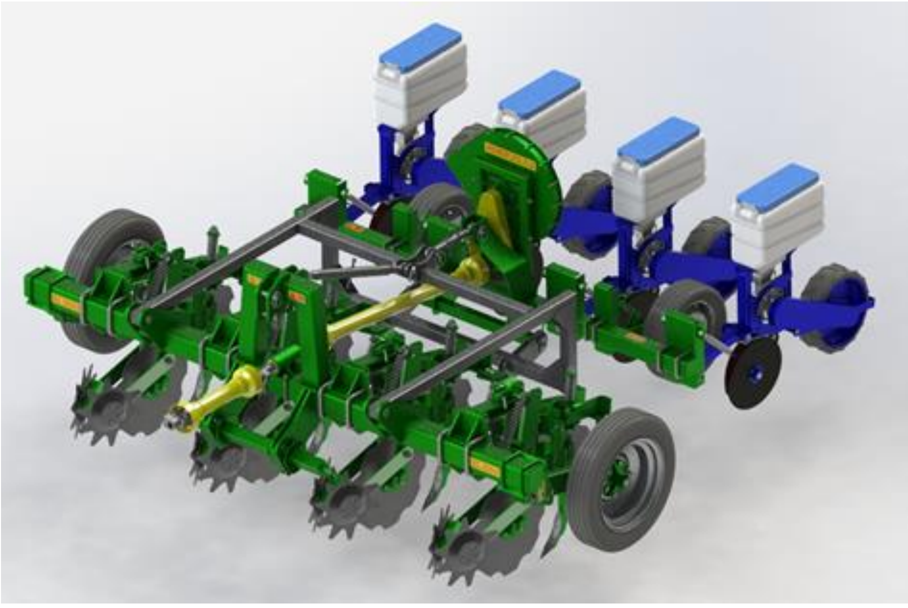
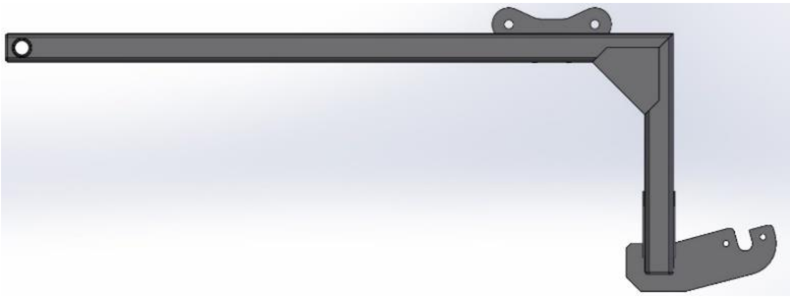


Fig. 1. Cultivator seeder for sowing directly into stubble

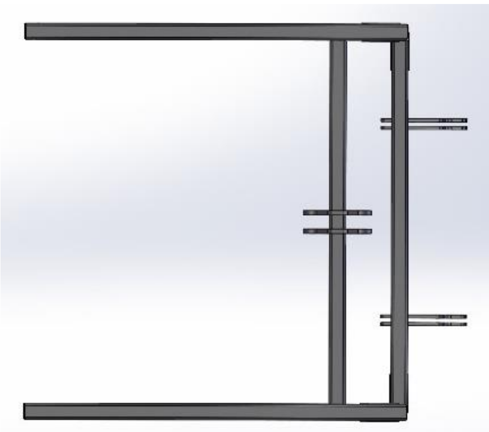
A constructive optimization method of a subassembly was used in the work ”Seeder support” from the structure ”Tillage equipment and seeding weeds directly into the meadow field”, by using static analysis with finite elements.
In the first stage of this study, the three-dimensional geometric model of the subassembly was made ”Seeder support” (fig. 2). For this purpose was used a Workstation 22H2, Intel(R) Xeon(R) W-2123 CPU @ 3.60GHz. The 3D modeling was done with the parameterized design program SOLIDWORKS® Premium 2018.

Three-dimensional modeling of the subassembly ”Seeder support” was made in the module „Parts” from the design program, in figure 3 two different views of the obtained model are presented, as well as the program interface SOLIDWORKS® Premium 2018.
After completing this step, the next step was to enter the 3D geometric model of the subassembly ”Seeder support”, in the module „Simulation” of the design program.
In the construction of welded metal constructions, different metal materials are used, which mitigate the negative influence of disturbing factors that occur directly during work, such as: shocks, vibrations, uneven terrain, the appearance of rigid obstacles, etc. [11].

Fig. 2. The three-dimensional geometric model of the subassembly ”Seeder support”- isometric view



a.



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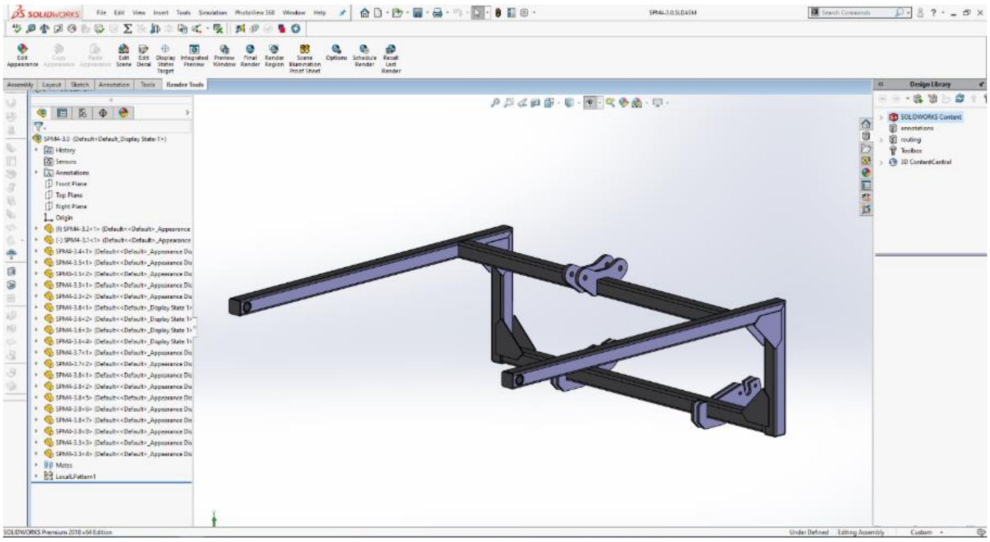

c.

Fig. 3. Subassembly views ” Seeder support”
a. side view, b. top view, c. the interface of the software used

Table 1 shows the characteristics of the materials used in the design of the subassembly ”Seeder support”.

Table 1: Characteristics of the materials used

Mechanical property	**Value**		**Unit of measurement**
	S235JR	**E335**	
Elastic Modulus	**2.1e+11**	**2.1e+11**	N/m^2
Poisson’s Ratio	**0.28**	**0.28**	-
Shear Modulus	**7.9e+10**	**7.9e+10**	N/m^2
Mass Density	7800	**7800**	kg/m^3
Tensile Strength	**3.6e+08**	**5.5e+08**	N/m^2
Yield Strength	**2.35e+08**	**2.75e+08**	N/m^2
Thermal Expansion Coefficient	**.1e-05**	**1e-05**	Kelvin

The total force acting on the subassembly ”Seeder support” was determined taking into account the mass of the seeder in the general assembly ”Cultivator seeder for sowing directly into stubble”. Thus, the total force corresponds to the value of 3600N.
The value of this force was applied for the two static studies corresponding to the materials S235JR and E335, with the help of the Simulation module in the software SOLIDWORKS® Premium 2018 (fig. 4).

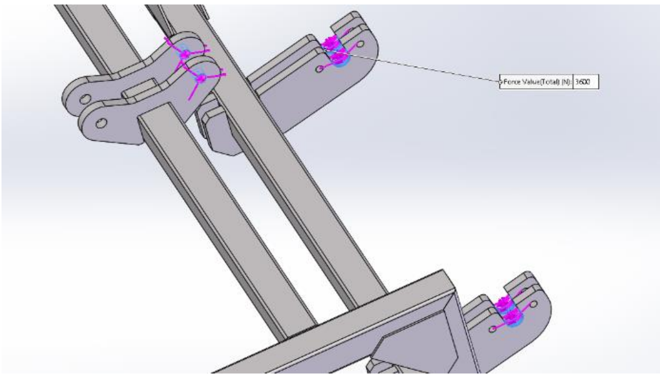

Fig. 4. Applying the force of 3600 N

The discretized finite element model of the subassembly ”Seeder support” is presented in fig. 5.

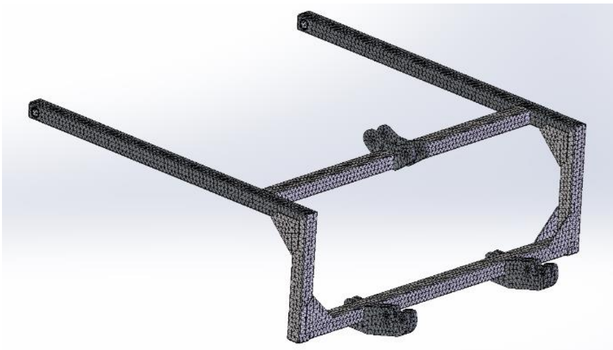

Fig. 5. Finite element discretization of the geometric model

After discretizing the mesh with finite elements, the simulation was performed, the results of which are presented below.
After the simulation, the design program provided the obtained results in graphical form; the geometric pattern is divided into areas of a certain color, each area comprising the region of the geometric pattern where the analyzed dimension has the value specified in the color legend on the right side of the screen.

3. Results

For the subassembly model ”Seeder support”, modeled and analyzed are presented below the results obtained from the simulation in SOLIDWORKS® the Simulation module.
Thus, table 2 shows the values of equivalent von Mises stresses, equivalent displacements and deformations in the welded metal construction resulting during the defined stresses, which are the same in both working regimes.

Table 2: Values of equivalent von Mises stresses, equivalent displacements and strains

Name	Type	Min	Max
Displacement 1	URES: Resultant Displacement	0.000e+00 m Node: 53	2.218e-03 m Node: 77472
Stress 1	VON: von Mises Stress	1.599e+03 N/m^2 Node: 81546	1.687e+08 N/m^2 Node: 72169
Strain1	ESTRN: Equivalent Strain	5.238e-09 Element: 38215	3.197e-04 Element: 34863

Analyzing this data, it can be seen that the largest displacements of nodes in the subassembly structure ”Seeder support”, appear on the peak of the torques in both working regimes (as expected), its maximum value being of 2.218×10^{-3} (fig. 6).

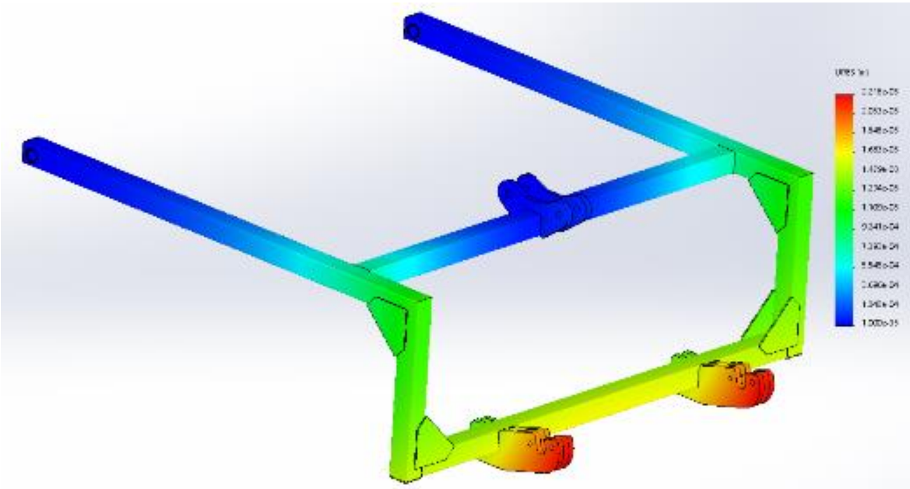

Fig. 6. The values of the displacements occurring in the structure during the two working regimes

Fig. 7 shows the values of the equivalent stresses in the structure of the subassembly ”Seeder support”, stresses calculated according to the von Mises criterion.

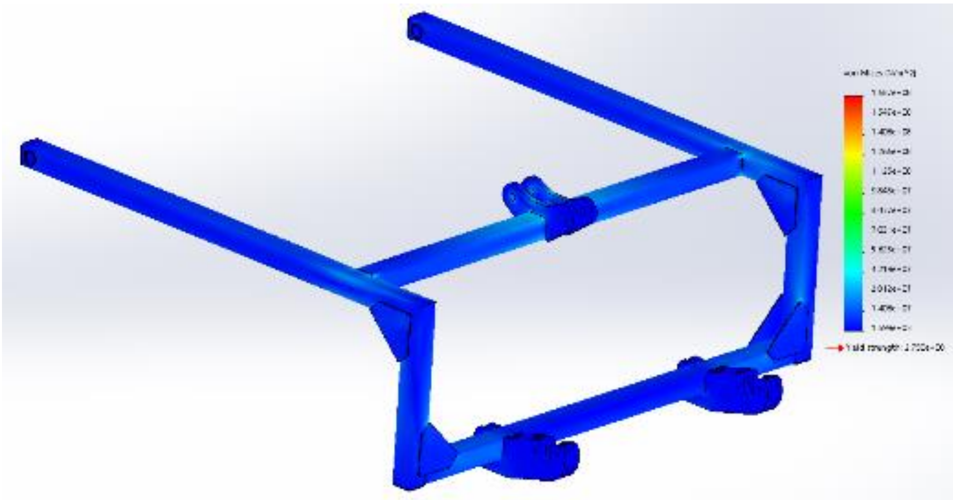

Fig. 7. The values of the von Mises equivalent stresses appearing in the structure during the two working regimes

Analyzing table 2 it can be seen that in the structure of the sub-assembly ”Seeder support”, stress concentration points appear, located in the upper area of the lugs for the tie rods at the joint with the metal mounting pipe. The values of the equivalent von Mises stresses created at these points are 1.687×10^{8} Pa in the case of the first working regime and the second working regime.
The values of the equivalent deformations that appear in the structure as a result of the stress to which the subassembly ”Seeder support” is subjected. So, the maximum equivalent strain occurs at the same points of stress concentration, the value of the strain being of 3.197×10-4 in the case of the first working regime and the second working regime (fig. 8).

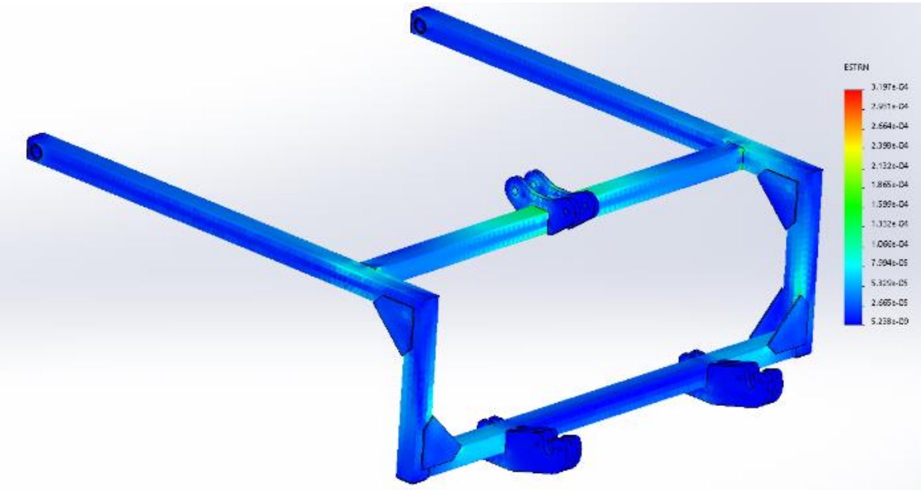

Fig. 8. The values of the equivalent deformations appearing in the structure, during the two working regimes

Table 3 shows the values of the safety coefficient appearing in the subassembly ”Seeder support”, during the demands defined for the two working regimes.

Table 3: Safety factor

Name	Type	Min	Max
Factor of Safety 1	Automatic	1.393e+00 Node: 72169	1.470e+05 Node: 81546
Factor of Safety 2	Automatic	1.630e+00 Node: 72169	1.720e+05 Node: 81546

4. Conclusions

The minimum value of the safety coefficient had values of 1.393 and 1.630, respectively. For supporting metal structures, the safety factor must have values between 1.0 and 1.8.
Thus, it can be said that the subassembly ”Seeder support” it is oversized, but the decision was made that in the physical execution, a metal pipe with a thickness of 4 mm instead of 3 mm should be used, to increase the resistance to dynamic stresses during work.
The results of this work are primarily aimed at designers of agricultural machines for tillage, but not only.

Acknowledgments

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