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CONSIDERATIONS REGARDING 3D MODELLING AND FINITE ELEMENT ANALYSIS OF A CULTIVATOR TYPE EQUIPMENT

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Abstract: Although it has been neglected in recent years, cultivation is once again finding its place in the field of agricultural crop management. The basic activities carried out by farmers in modern agriculture include plowing, opening the top layer of the soil and mechanical removal of weeds. Tools such as harrows or cultivators are used for these activities. This work presents in the first phase the modeling of a cultivator that can be mounted on an agricultural tractor with a power of up to 20 kW. The 3D model of the cultivator was analyzed in a second phase using a specialized software, Autodesk Inventor Professional 2020. The finite element analysis aimed at highlighting the behavior of the cultivator type equipment during the work process, a very important aspect for the specialists in domain who must permanently ensure that the operation of these machines is carried out at optimal parameters. Following the analysis, the results chosen for visualization were the stresses and deformations of the cultivator's work equipment, as well as the displacements of the structure nodes.

Key words: AutoDesk Inventor, 3D model, finite elements analysis, work process, optimal parameters.

1. INTRODUCTION

The One of the requirements for the steady and healthy growth of any people or nation is the abundant supply of food. The ground can be made to produce by properly cultivating the soil and plants suitable for food [1].

Agricultural machinery and installations, together with energy sources, ensure the mechanization of work processes in agriculture. They must ensure the performance of some quality works, in optimal periods, being diversified according to agricultural crops, type of soil, relief, animal species, work technologies.

Mechanization is the action of replacing human or animal physical labor with machines, aggregates or agricultural facilities [2], [3].

The agricultural machine is the work machine used to perform one or more works in the production processes in agriculture, in optimal conditions from an agrotechnical point of view. Agricultural machinery is equipped with various devices, mechanisms and systems to be able to perform certain operations specific to the applied technology [1].

Cultivators fall into the category of agricultural machinery for tillage, along with plows, cutters, diggers, harrows, combine harvesters, soil tillers [1], [4].

The cultivators are intended for the execution of the following works:

❖ partial cultivation of the soil (hoeing) for the destruction of weeds;
❖ the total cultivation of the soil for the preparation of the germination layer for sowing or planting;
❖ the second hoeing of agricultural crops;
❖ opening the gutters for watering;
❖ incorporation of fertilizers into the soil;
❖ shallow and deep loosening of the soil.

The versatility of a cultivating section comes from the fact that an efficient cultivator can work at the same high parameters in a wide variety of vegetable crops. Good ground clearance allows cultivation operations to be carried out even in the advanced stages of plant grows [2], [3].

Among the most important advantages that cultivators bring are:

- elimination of the soil agglutination effect;
- reducing the need for water;
- reducing the effect of soil erosion due to water activity;
- reducing the number of passes and the amount of fertilizer used.

The cultivators have different models, from the mounted ones to the tractor to the most popular ones that are attached to the three-point connection. Figure 1 shows some models of cultivators known and used for years. The disadvantage would be that most of them have a considerable weight of about 200 kg [5].

At present, agriculture and the fruit farm industry have a tendency to use different types of tractors for ancillary work. An example is mini-tractors that support and replace heavy tractors whenever their

weight and size could interfere with work performance. Tractors of this type are used with light and small cultivator models [1].

(a)

(b)

(c)

(d)

Fig. 1. Cultivator models [5].
PC10 series cultivators; b) multi row cultivator; c) pre-sowing cultivators; d) Synkro T 3-row trailed stubble cultivators

2. CASE STUDY

The present study, conducted in the Autodesk Inventor Professional 2020 software, shows the modeling of a cultivator that can be mounted on an agricultural tractor with a power of up to 20 kW. The main modeling hypothesis was to keep the weight of the device low but also to ensure the necessary durability at the same time. The modeling also makes it possible to attach the cultivator to the three-point link to a category 1 tractor.

The essential elements of the modeled cultivator are:

- ✓ support framework;
- ✓ spring teeth;
- ✓ clamps;
- ✓ screw and nut.

The main element of the cultivator proposed for modeling is the support frame consisting of two longitudinal elements made of rectangular steel pipe measuring 80×60×4 mm and three rows of 50×50×3 mm beams welded on the longitudinal elements.

The side faces of the frame are made of 70 × 8 mm steel platband and are welded on the sides at the ends of the cross sections. In the front section of the frame there are two pins and the top point of the link which is the three-point link of the cultivator.

The upper section of the three-point clamping system is connected to the rear cross member of the frame with the 60×40×4 mm rectangular pipe, which acts as an angle support and thanks to which the structure is reinforced.

Figures 2, 3, 4 show the component parts and Figure 5 shows their assembly to form the supporting frame.

The mounting points for attaching a cooperating tool are welded to the rear section of the frame.

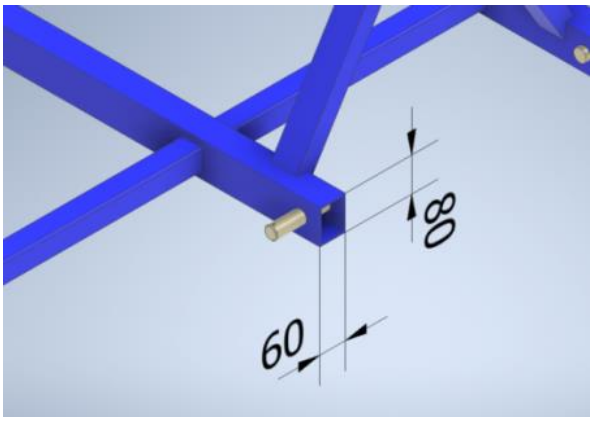

Fig. 2. Rectangular steel pipe
80 × 60 × 4 mm

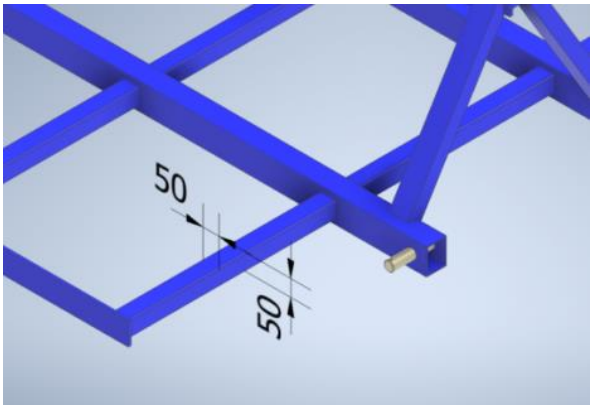

Fig. 3. Beams 50 × 50 × 3 mm

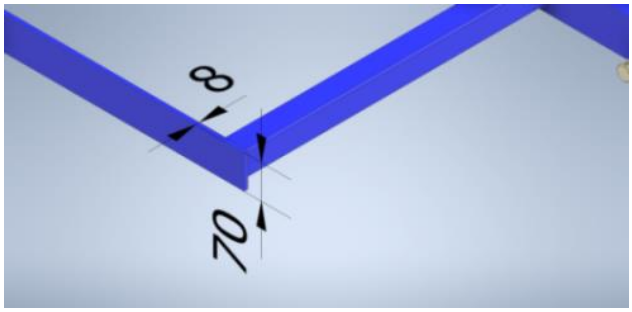

Fig. 4. Steel platband 70 × 8 mm

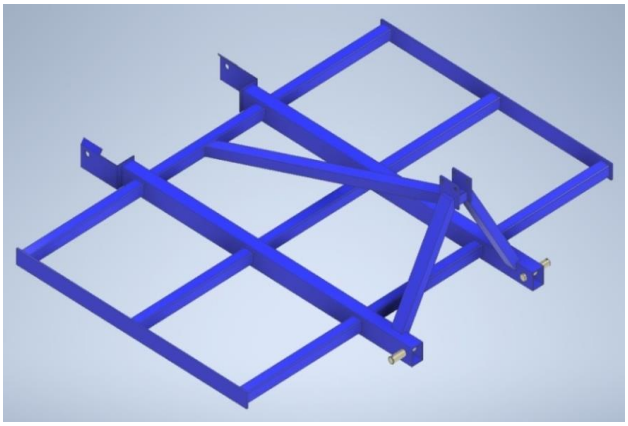
Fig. 5. Cultivator frame

The mounting points for attaching a cooperation tool are welded to the rear section of the frame. The mounting point is made of a bar 10 mm thick and 90 mm high, with a space provided for the placement of the cooperation tool pin. Mounting protection consists of screwing a locking device that secures the position of the pivot of the cooperation tool. The method of mounting the cooperation tool is shown in Figure 6 [1].

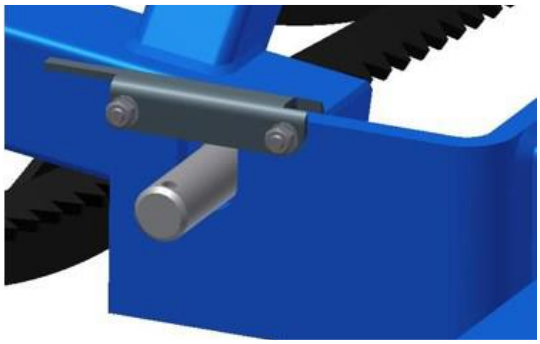
Fig. 6. Locking device in the closed position [1]

After the frame modelling, we proceeded to model of a spring tooth.

Teeth or flexible spring-type organs are the working organs of the cultivator. When they are in operation, they vibrate strongly, which improves their effect on the soil and makes it possible to extract weeds. They were selected from the Kongskilde catalog.

The tooth (1) is fixed with an M12 × 80 screw (2) to the clamp (3), which is placed on the crossmembers of the frame (Figure 7).

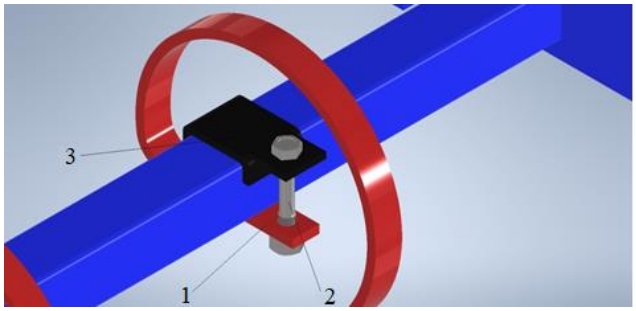

Fig. 7. The method of fixing the tooth on the frame: 1 – tooth; 2 - screw-nut; 3 – clamp

The catalogs in the literature were used to choose the model of the tooth (knife) (Figure 8) and the clamp (Figure 9) [6].

The cultivator assembly modeled with the elements described above is shown in Figure 10.

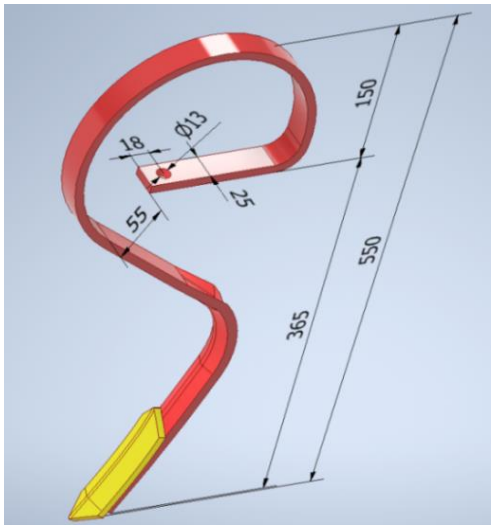

Fig. 8. Tooth (knife) [6]

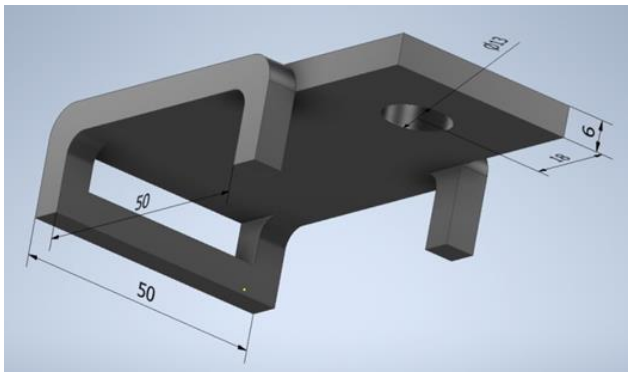

Fig. 9. Clamp [6]

Further, the present paper proposes a static analysis of the stresses and strains that occur in an element of the frame consisting of a beam 50 × 50 × 3 mm on which are mounted two knives (teeth), using clamps and screw-nut assembly. This variant of analysis was chosen because it represents a simpler calculation model compared to the whole cultivator and the calculation volume is smaller.

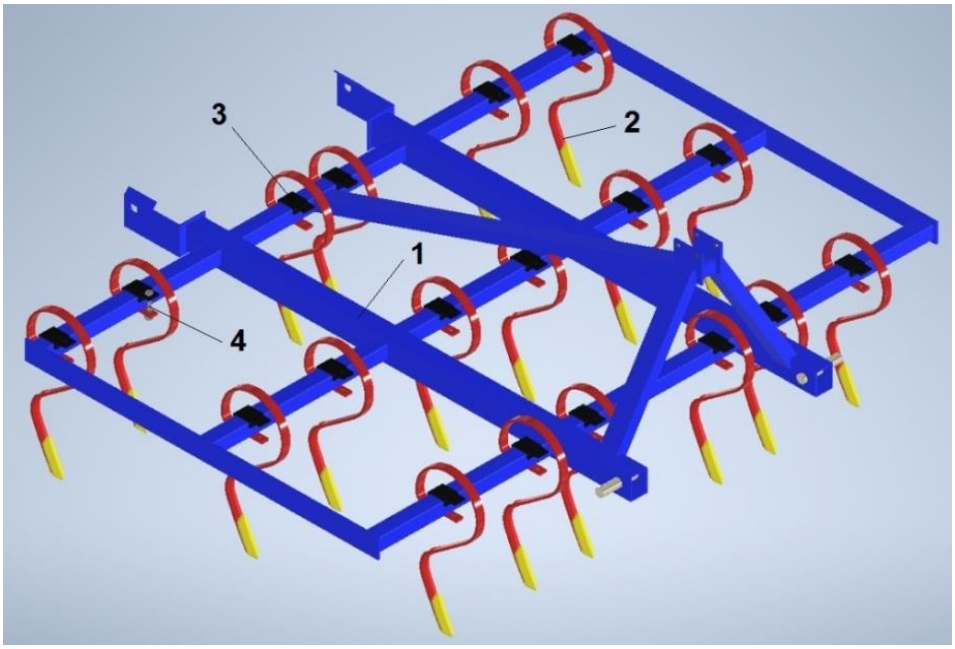

Fig. 10. Cultivator assembly with basic elements:
1 - support framework; 2 - spring teeth; 3 - clamps; 4 - screw and nut.

Finite element analysis was performed using the Autodesk Inventor Professional 2020 software analysis tool.

The support is of embedding type, applied on the end surfaces of the beam (according to the real case of fixing the beam to the ends on the rectangular steel pipe 80 × 60 × 4 mm) (Figure 11).

The solicitation is of pressure type applied on the cutting side of the teeth (knives) and having the value of 0.015 MPa. The value of the applied pressure was chosen after consulting the literature, taking into account the specific resistance to digging for equipment working in category I or II soils (clay sands, topsoil) (Figure 11) [7,8,9].

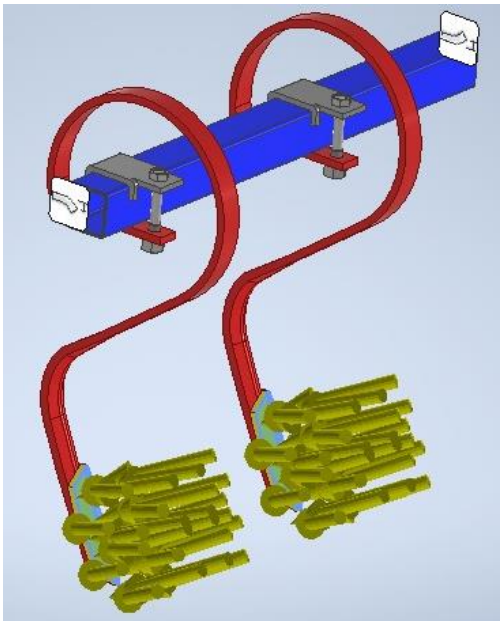
Fig. 11. Support and loading conditions applied to the analyzed element

After performing the analysis, the Inventor software provides the user with a set of results. In the post-processing stage the user chooses and interprets the results that he considers representative for the analyzed case, based on experience and knowledge. In this case, the following have been selected for viewing:

- the stresses that develop in the analyzed element during the work process (Figure 12);
- the deformations of the structure, generated by previous stresses (Figure 14);
- the displacements of the structure nodes (Figure 15).

In order to better observe the areas where significant stresses develop, a detail is presented in Figure 13.

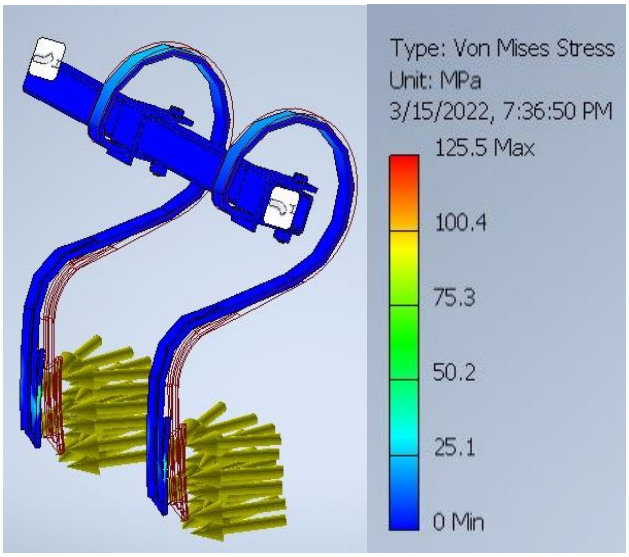

Fig. 12. Visualization of the stress state of the analyzed element

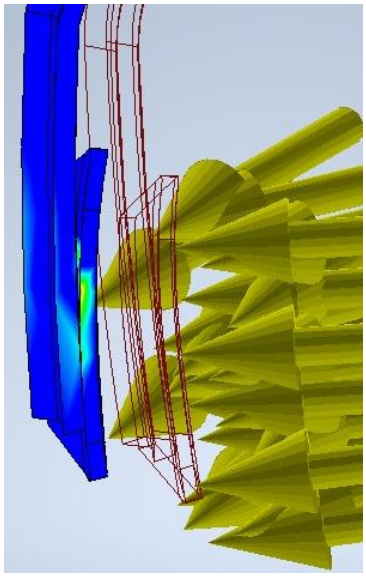

Fig. 13. Detail from the area of stresses with significant values

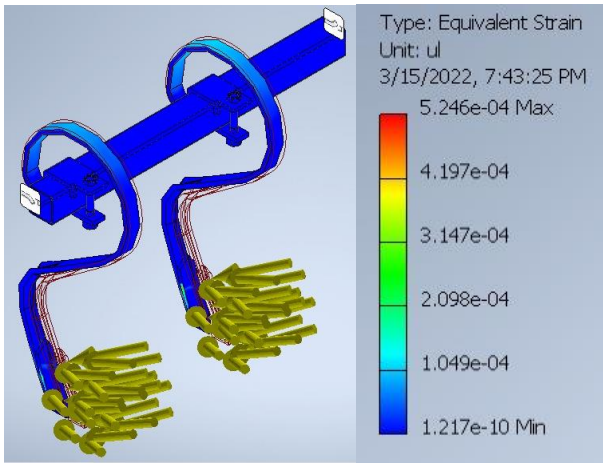

Fig. 14. Visualization of the deformations of the analyzed element

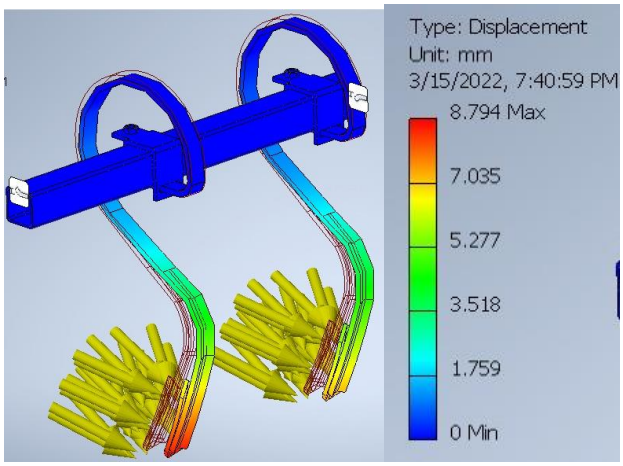

Fig. 15. Visualization of the node displacements on the analyzed element

Using the values of the stresses and of the displacements of the nodes provided by the Inventor software, a graph of the variation of these parameters was drawn up in Microsoft Excel, variation represented in Figure 16.

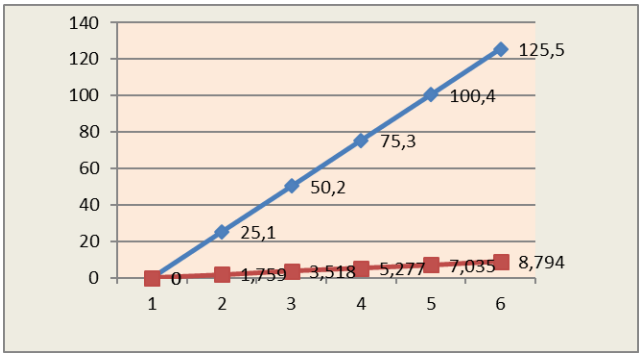

Fig. 16. Variation of stresses and node displacements on the analyzed element

3. CONCLUSIONS

This paper is in line with the current trend of using various mini-machines for auxiliary work in agriculture and the fruit farm industry. An example is mini-tractors that support and replace heavy tractors and are used with light and small cultivator models.

This paper aims to model and analyze such a light and small cultivator that can be attached to a mini-tractor. The advantages of this type of cultivator are:

✓ small mass (under 170 kg);

✓ use of cheap materials (steel profiles);

✓ designed to be mounted on a three-point connection to the tractor (according to DIN ISO 730-1).

The goal of engineering design is to get "the best" system possible for practical purposes. A strength structure must meet certain efficiency criteria (strength, rigidity, economicity). In this sense, the structure is modeled and analyzed until all the required efficiency criteria are met.

Modeling and finite element analysis of the cultivator type equipment followed in this paper a process of optimization in terms of material consumption.

From the finite element analysis, three important aspects were chosen for visualization:

❖ the stresses - with the highlighting of their maximum value, which appears in the dangerous section; this is a very important aspect, because knowing the dangerous section or sections of a structure, engineers can take steps to strengthen that structure so that it can withstand the solicitations;

❖ the deformations of the analyzed structural element - represent the variations of the geometric dimensions in the vicinity of a point of the studied structure, as a result of the solicitations applied on it; it is also a very important aspect, because the deformations of the structure, if it acquires high values, lead to its destruction, because the bodies yield as a result of the deformations;

❖ the displacements of the nodes on the analyzed structural element - represent the changes of the points position of a solid body, as a result of its deformation under a certain stress; the displacements

of the structure nodes are important to know because, based on these displacements at the nodes, which are offered by the finite element software, can be determined the deformations of the structure and implicitly the stresses which solicite the structure (based on Hooke's generalized law).
The present study can be continued and developed in order to optimize according to other criteria of this type of agricultural machinery.

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