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DEVICE WITH CHISEL-TYPE WORKING PARTS FOR MEASURING THE TENSION STRENGTH INDEPENDENTLY ON EACH WORKING PART OR VARIOUS GROUPS OF WORKING PARTS

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Abstract

The paper presents a device with chisel-type working parts for measuring the tensile strength independently on each working parts or on various groups of working parts, equipped with devices designed for separate measurement, intended for complex research of agricultural machinery in interaction with the soil. The proposed solution is new and is based on flexibility and allows the mounting of various working parts in various positions. The functional model developed with elements of novelty and innovation led to the elaboration of a patent application, which refers to a load-bearing structure modulated with multiple applications for tillage machines, on which active parts are mounted in different working variants, in order to extension of the period of use, depending on the size of the agricultural exploitations and the power of the tractor. The modular design of the device will allow the development of a range of flexible cultivators that can be configured to in order to use power sources (tractors) from 30 hp to 90 hp, allowing the manufacturer to expand its market.

Key words*: device, working parts, chisel, load-bearing structure, tensile strength measurement.*

INTRODUCTION

The paper presents an experimental model of device with chisel-type working parts for measuring the tensile strength independently on each working part, equipped with devices designed for separate measurement, which is intended for complex research of agricultural machinery in interaction with the soil, shown in Figure 1. Also, the experimental model can be transformed into an homologated prototype that will offer to agricultural technical equipment manufacturers a product destined to carry out agricultural works for the preparation of the soil and the germination bed with a series of advantages mentioned below.

Figure 1. Device with working parts - left view

MATERIALS AND METHODS

Components description of the device with working parts

The proposed solution is new and is based on flexibility and allows the mounting of various working parts in various positions (Figures 3, 5, 6 and 7).

Central frame

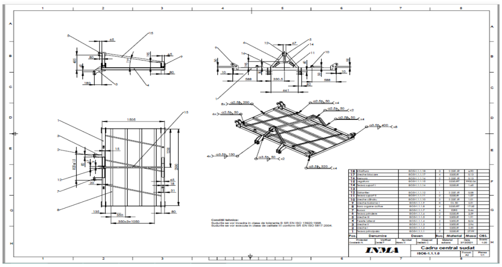

Figure 2. Welded central frame

Welded central frame, Figure 2 has the shape of a rectangle made of welded pipes, square of

80 x 5, 50 x 5 mm, three square profiles of 25, welded obliquely to strengthen the frame, eight ears for coupling the left - right side frames and two pairs of ears for coupling the hydraulic cylinders folding the side frames. It is provided at the front with a coupling triangle which ensures correct three-point fastening to the tractor's hydraulic lift.

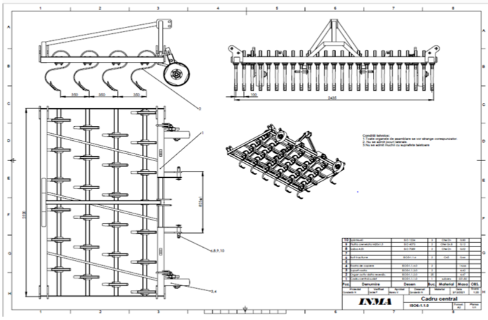

Figure 3. central frame

The central frame is presented in Figure 3. Also, at the front are provided two pairs of lugs for fixing the copying wheels left-right. On the central frame can be mounted a number of 24 active parts of various types, arranged in four rows with a distance of 400 mm, row and 100 mm between them in the direction of advance.

Left side frame

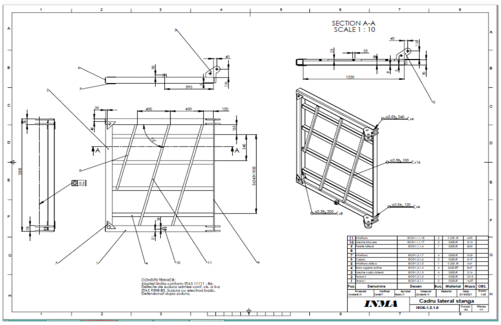

Figure 4. Left welded side frame

Left welded side frame, Figure 4 has the shape of a rectangle made of welded pipes, 80 x 5 square, 50 x 5 mm, three 25 square profiles, welded obliquely to strengthen the frame, four coupling ears with the central welded frame. The coupling ears with the welded central frame must be concentric with each other for easy coupling.

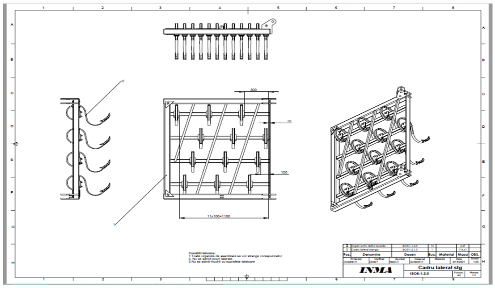

Figure 5. Left side frame

Left side frame, Figure 5 has the shape of a rectangle made of welded pipes, 80 x 5 square, 50 x 5 mm, three 25 square profiles, welded obliquely to strengthen the frame, four coupling ears with the welded central frame. On the left side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance. The coupling ears with the welded central frame must be concentric with each other for easy coupling.

Right side frame

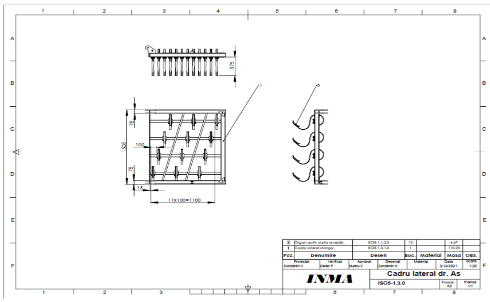

Figure 6. Right side frame

Right side frame, Figure 6 has the shape of a rectangle made of welded pipes, 80 x 5 square, 50 x 5 mm, three 25 square profiles, welded obliquely to strengthen the frame, four coupling ears with the central welded frame. On the right side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance.

Description of the device equipped with working parts

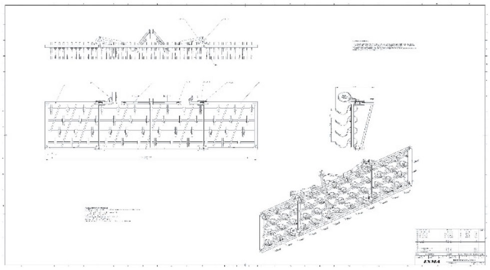

Figure 7. Working variant equipped with working parts

The device with working parts equipped with working parts, presented in Figure 7 consists of three frame modules on which are mounted active chisel-type parts with elastic supports. The active parts, in number of 48 pieces, are arranged in four rows, mounted at equal distances in a row, according to a verified scheme, namely the “cocor” scheme that eliminates clogging with processed soil.
On the central frame are mounted a number of 24 active parts, arranged in four rows with a distance of 400 mm, row and 100 mm between them in the direction of advance. On the left side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance. On the right side frame are mounted a number of 12 active parts, arranged in four rows with a distance of 400 mm per row and 100 mm between them in the direction of advance.
Figures 8a, 8b, 9 and 10 show images of the experimental model performed.

Figure 8a. Device with workig parts - right view

Figure 8b. Device with working parts - right view

Figure 9. Device with working parts – front view

Figure 10. Device with working parts – left view

RESULTS AND DISCUSSIONS

The experimental model was subjected to several series of analyses and simulations that used structural models with finite elements (Bathe, 2006; Seshu, 2012; Zienkiewicz & Taylor, 2014; Maksay & Bistrian, 2008).
The stages of structural analysis and simulation on structural models were classical one.
If the device meets the requirements of good functioning following the structural modeling and simulation, it can be executed. Otherwise, the dimensions materials, conditions, etc. used will be adjusted until the requirements are met (Blumenfeld, 1995; Cardei et al., 2012; Vladut et al., 2018).
Designed of the CAD/CAM model of the structure is done with the help of a 3D design program, for example Solid Works. (Lee, 1999; Rao, 2002; Zeid, 2009; Coticchia et al., 1993).

The main feature is the multiple modulation of the working widths, being able to operate in structures with different size and can be used by traction sources of small and large powers and can ensure a better protection of the soil to compacting.

Regarding the research, the device allows the evaluation of the effect of increasing the number of parts on the tensile strength in the same environmental conditions, can determine the effect of increasing the density of working parts in the structure and can compare the tensile strengths produced by different working parts. The device is designed for complex research of the interaction of agricultural machinery designed for soil work, is new and is based on flexibility and allows the mounting of various working parts in various positions (Figures 11, 12).

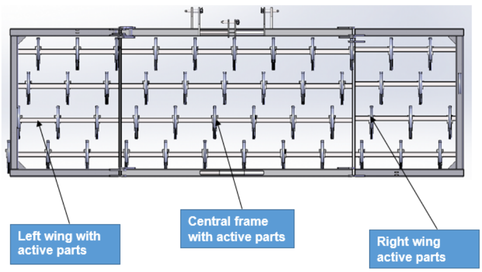

Figure 11. Device with active parts, working position

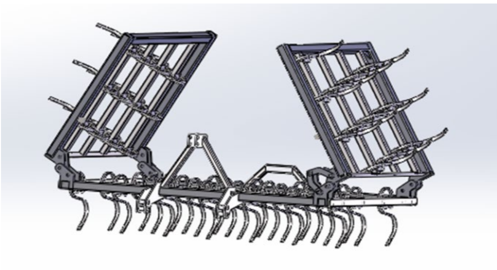

Figure 12. Device with active parts, transport position

Eliminating spacers or gaps and interferences.

The transformation of the CAD/CAM model into a CAD/CAE model is achieved by checking, detecting and eliminating the interferences between the component parts of a subassembly or the assembly from the product composition. To do this, select the subassembly or assembly to be checked, activate "Interference Detection" and command "Calculate", according to Figures 13 and 14.

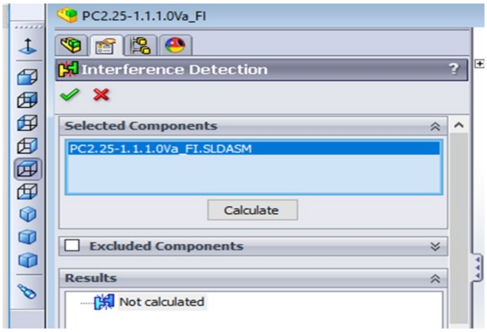

Figure 13. Interference detection

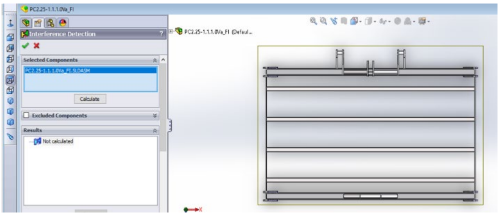

Figure 14. Central frame - verification, detection and elimination of the interferences

After accsessing the "Calculate" command, the interference detection is obtained and the interference areas are specified, and if they are not, one specifies: "No Interfereces", according to Figures 15-19.

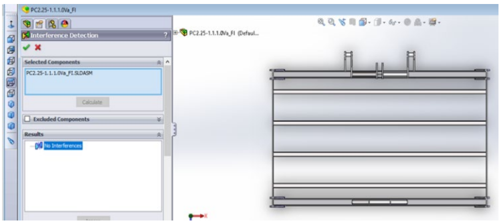

Figure 15. Central frame - interferences calculation

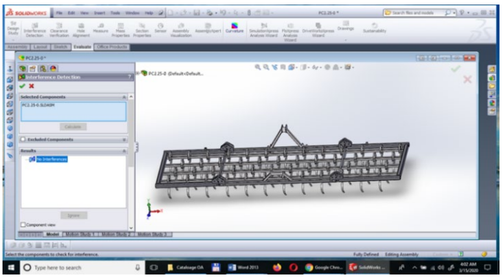

Figure 16. Device interference calculation

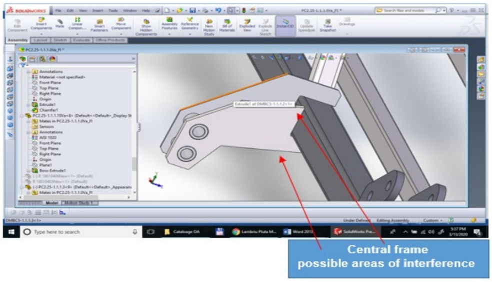

Figure 17. Detail of interference calculation

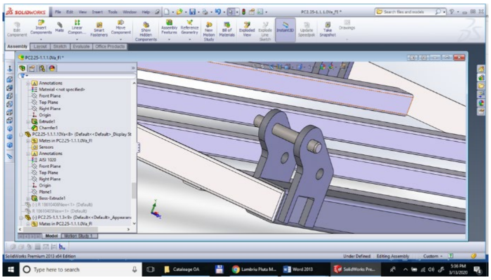

Figure 18. Gaps elimination

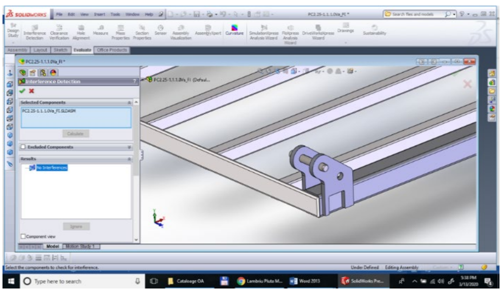

Figure 19. Device, interferences calculation (eliminated gaps)

Figure 20 shows the Assembly - Active parts + Support Bar which are assembled with tangent "mats" to eliminate interferences.

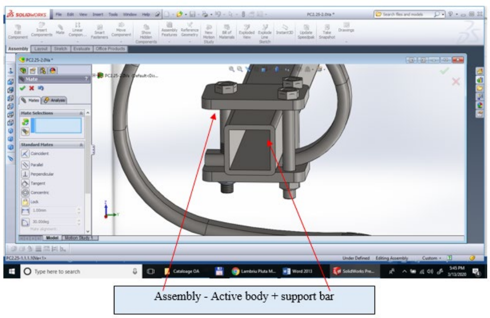

Figure 20. Interferences calculation by tangent "mats"

Figure 21 shows the "Assembly - Bolt bushing + baching plate" which are assemblies by removing the gaps between the outer diameter of the bushing and the coupling hole of the backing plate in order to eliminate the interferences.

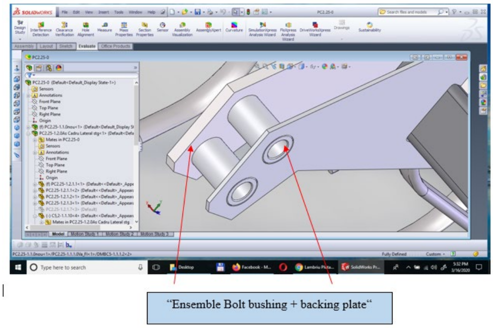

Figure 21. Gaps elimination

The experimental model of device with chisel-type working parts for measuring the tension strength independently on each working part or various groups of working parts it is realized with elements of novelty and innovation.
The experimental model contributes to the research of modern soil cultivation technologies.
The experimental researches that will be carried out with these devices can facilitate technologies with a minimum of innovative works and the effect of new working parts on some agricultural crops can be studied, as well as their economic efficiency.
The main novelty is a load-bearing structure modulated with multiple applications for tillage machines on which active parts are mounted in different working variants, in order to extend the period of use depending on the size of agricultural exploitation and the power of the tractor.
The structure is composed of a central frame supported by wheels for limiting the working depth and equipped with the central triangle for coupling, to which two side frames and can optionally be coupled on which the working parts are mounted.
The three frames are of modular construction, with the hinge system through which their coupling/decoupling can be easily modified, obtaining four variants of working widths, respectively a maximum one consisting of all

three frames: central, left side and right side and using the center triangle, two intermediates using the center frame or the two left and right side frames and the additional triangle, and the minimum width using only one of the side frames or the additional triangle.

From the researches carried out in the specialized literature on some similar elements, prospectuses, etc. it follows that there are agricultural equipments that have load-bearing structures on which active working parts with different working widths are mounted (eg SANDOKAN or GRATOR model by Maschio Gaspardo; KOMPACTOR or ZIRKON model by Lemken.

The disadvantages of this equipment are that the load-bearing structures are not modulated and do not allow obtaining other working widths (lower than the basic one).

Another disadvantage is the limitation of the working period being related to the size of the power of the tractors and of the agricultural exploitations on which it is used.

The technical problem solved is the realization of a modulated load-bearing structure for the variation of the working width of the basic structure in order to increase the utility of the equipment and to extend the period of use depending on the size of agricultural exploitations and the tractor power.

The central frame of the structure is supported by working depth limiting wheels, equipped with a central coupling triangle, to which they can be attached, through a system of hinges and hydraulic folding cylinders coupled in the hydraulic system of the tractor, two other left - right side frames also provided with an additional coupling triangle, frames on which the active parts are mounted in different working schemes.

During work depending on the working variant, either all three frames: central and two lateral for the maximum width can be easily mounted through the hinge system, using the central triangle, or the central frame for the intermediate width, or only the left or right side frames using the additional triangle for the minimum width, or both lateral frames, using the additional triangle for another intermediate working width.

Several structural mathematical models have been developed, such as:

MS1 - Structural model with finite elements BEAM3D type of the central structure (Figure 22);

MS2 - Structural model with finite elements SOLID type of the right wing;

MS3 - Structural model with finite elements SOLID type of the left wing (Figure 23);

MS4 - Structural model with finite elements SOLID type for the central body;

MS5 - Structural model with finite elements SOLID type for the entire experimental model structure;

MS6 - Structural model of the spiral spring work support with SOLID type finite elements (Figure 24);

The first model is one with 1D finite elements, developed entirely in the COSMOS/M structural analysis program. The structural mathematical models are CAD/CAE 3D models for the two wings of the structure, right and left, respectively.

Those two wings are neither symmetrical nor anti-symmetrical, due to the special distribution of the supports of the working parts.

This distribution (given by the series of the distances between two consecutive supports) is generated by the experience in operation of such equipment, which shows that the drainage of plant debris is much more fluent through this arrangement of the supports and, implicitly, working parts.

The MS1 model is the structural model of the central body. The most complex model is the MS5 model, the structural model of the entire load-bearing structure of the experimental model. The MS6 is a much simpler model, a structural model of a type of working support.

Further some mathematical models structurally designed are presented.

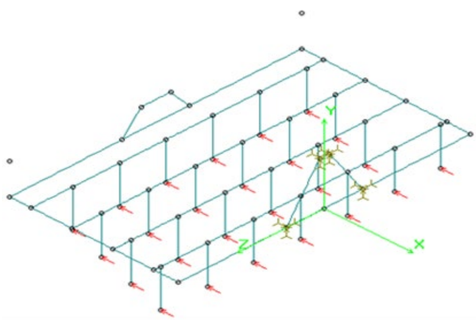

Figure 22. MS1 model -central body, 1D finite element model (BEAM3D)

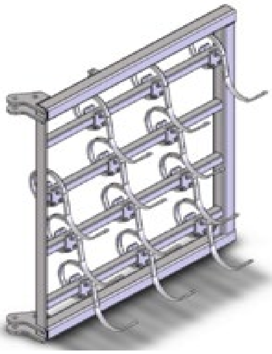

Figure 23. MS3 model - Left side frame

Figure 24. MS6 model - Structural model of the working parts supports

CADCAM models were created according to the design of the structure using classic CAD/CAM techniques with the SolidWorks program,

By design, these drawings have certain imperfections given by the tolerances allowed in the execution drawings or by the games imposed by the standard for the purpose of the good operation of the machine or its mounting.

Some of these deficiencies (structurally) are interferences (intersecting bodies or components), others are spacers or gaps (which are given by non-contact bodies).

Despite the fact that they are generally not natural, they are the simplest cases to solve, any additional links introduced to model the contacts being risky, which can have unpredictable consequences.

The transformation of CAD/CAM models into CAD/CAE models was done by eliminating interference and gaps. CAD/CAE models were analyzed (discretized, loaded and supported, then calculated).

All models were tested by static stresses in the elastic linear domain. This is the normal operating mode of the load-bearing structures of the tillage machines.

Simulations of other phenomena are possible on the same models: vibrations (calculation of eigenfrequencies), dynamic analysis, stability analysis, vibrations in transport, nonlinear analysis (which includes elasto-plastic calculation, irreversible plastic deformations, etc.).

All these models can be used to simulate various experimental conditions and to obtain information on the required traction source.

The left side frame, center frame and right side frame substructures were tested both separately and together.

Static analysis provides useful results in the decision of strength testing, but also additional information on certain areas that need to be revised in the technical drawing, respectively in the CAD/CAM model or even in resizing the structure or choosing other materials for certain components.

The reaction calculation also gives an idea of the tractor capacity required for each of the working variants.

Some of the main results of the structural analysis (modelling and simulation) are given in Figures 25-28.

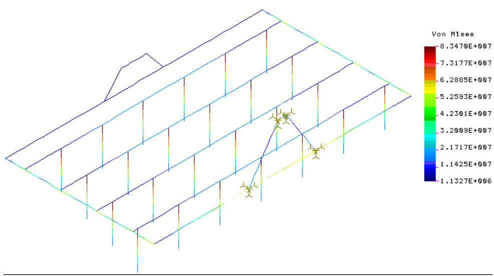

Figure 25. MS1 Model - Equivalent stress distribution in the structure (Pa)

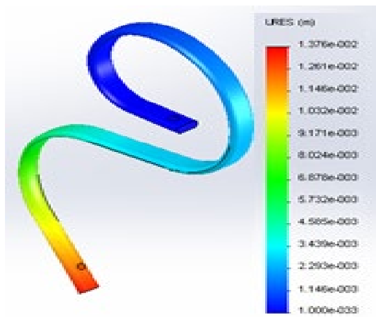

Figure 26. MS6 Model - The resulting relative displacement field in the structure (m)

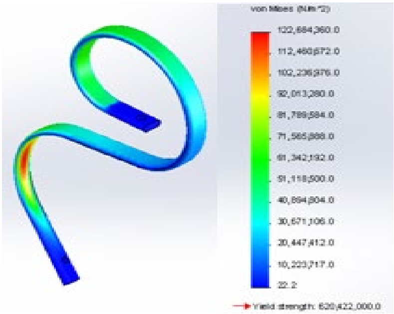

Figure 27. MS6 Model - Equivalent stress distribution in the structure (Pa)

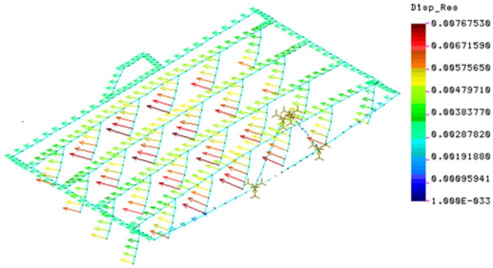

Figure 28. MS1 Model - The resulting relative displacement field in the structure (m)

After the virtual testing, the device behaves satisfactorily under the normal working conditions provided: work with organs specific to depths of up to 10 cm in plowed and discussed soil, in order to prepare the germination layer.
Under these conditions, the stresses calculated in the load-bearing structure ensure, using ordinary materials (with a plasticity limit around 220 MPa), a safety factor (coefficient) with a value of approximately 3, approximately 66% higher than the standardized one.
The structure was examined on a structural model in the integral version, but also on components, which are given by structural mathematical models on which the operation was simulated in different modulated working variants (left wing, right wing central frame, left wing coupled with wing right). A structural model of one of the work supports intended to be used in the experimental works was also tested. All these structural mathematical models led to the conclusion of a behavior characterized by a safety factor with a minimum value 3.

CONCLUSIONS

The experimental model of the device with chisel type working parts for measuring the tensile strength independently on each working part, equipped with devices designed for separate measurement was developed within the execution department of INMA, in accordance with the execution documentation ;
-All the technical prescriptions from the execution documentation were respected;
The execution model is operational and is prepared for conducting experimental research..
The novelty elements are the following:
- Modulation characteristic in various formations, which require different traction powers, formations equipped with different traction source fastening systems; (three working modules: independent central module, independent side wing, two independent side wings);
- Ability to mount various working elements, in various geometries on any variant;
- The possibility of working with maximum width having in composition the three frames;
- The possibility of working with intermediate width having in composition the central frame;
- The possibility of working with minimum width having in composition the lateral frame;
- The possibility of working with intermediate width having in composition two lateral frames joined by the hinges of the basic structure and towed with the additional triangle.
In the virtual testing, the experimental model working with specific organs behaved satisfactorily under the normal working conditions provided.

ACKNOWLEDGMENTS

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REFERENCES

Bathe, K., Finite, J. (2006). *Element Procedures*, Prentice Hall, Pearson Education, Inc.

Blumenfeld, M. (1995). *Introducere in metoda elementelor finite*. Editura Tehnica, Bucuresti.

Cardei, P., Constantin, N., Gradinaru, V., Marin, E., Manea, D., Matache, M., Muraru, V., Muraru, C., Pirna, I., Sfiru, R., Sorica, C., Stanciu, L., Vladut, V. (2012). *Analiza structurală şi materiale noi focalizate pe mecanică, mecatronică, mentenanţă şi exploatarea echipamentelor tehnice pentru agricultură şi industrie alimentară*, Editura Terra Nostra, Iasi.

Coticchia, M.E., Crawford, G.W., Preston, E.J. (1993). *CAD/CAM/CAE SYSTEMS*, Taylor & Francis.

Lates, M.T. (2008). *Metoda elementelor finite*. Editura Universitatii Transilvania Brasov.

Lee, K. (1998). *Principles of CAD/CAM/CAE Systems*, Pearson.

Maksay, S.I., Bistrian, D.A. (2008). *Introduction to the finite element method*. CERMI Publishing House, Iasi.

Posea, N., Iordache, S., Predescu, L., Costache, I. (2003). *Metoda Elementului Finit pentru structuri de rezistenta*. Editura Bibliotheca, Targoviste.

Rao, P.N. (2002). *CAD/CAM Principles and Aplications*, Second Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi.

Seshu, P. (2012). *Textbook of Finite Element Analysis*, PHI Learning Private Limited, New Delhi.

Vladut, V., Maican, E., Apostol, L., Ungureanu, N., Dumitru, I., Oprescu, R. (2018). Verification of stress by fem analysis/mechanical testing of agricultural mobile aggregates coupling devices. *INMATEH-Agricultural Engineering*, *54*(1), 39–46.

Zeid, I., Sivasubramanian, R. (2009). *CAD/CAM Theory and Practice*, Tata McGraw Hill.

Zienkiewicz, O.C., Taylor, R.L., Fox, D.D. (2014). *The finite element method for solid & structural mechanics*, Elsevier, e-book.