SOLIDWORKS 3D PARAMETRIC MODELLING TECHNIQUE FOR ROOT CUTTING EQUIPMENT DECLINING GROWTH OF SHOOTS IN ORCHARDS

MARINELA MATEESCU[1], EUGEN MARIN[1], VALENTIN VLĂDUŢ[1], DRAGOŞ MANEA[1], GABRIEL GHEORGHE[1], PETRU CÂRDEI[1], ALEXANDRU TUDOR[2], SORIN BORUZ[2], ION SĂRĂCIN[2], FLORIN STOIAN[2]

[1]/National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, Romania
[2]/University of Craiova, Faculty of Agriculture, Craiova, Romania

Keywords: knife disc, root cuttings, CAD, FEA structural analysis

ABSTRACT

This work was focused, by using computer aided engineering application (SolidWorks) and structural simulation (SolidWorks SIMULATION), on obtaining a technical and economic strength indicator used in the analysis of metallic material choice from which is made active body large diameter disc knife type, that equips the technical equipment for soil tillage on trees row, while cuttings root for moderating growth of shoots and precision foliar fertilization. For this purpose, on the 3D parametric modeling were selected from the software library various metallic materials, followed by finite element analysis (FEA) which was carried out to simulate the distributions of stress and strain on the body active. Based on the resulting data, were determined the reports price / coefficient of resistance for the materials analyzed. Comparing these indicators led to the selection of a material that has high resistance under a price as low as possible. Analysis based on technical and economic choice of a metallic material reduces the time validation of the design, by eliminating the realization and physical testing, and allows management to determine the existing resources in the company in order to use their total for achieve economic and financial results as high.

INTRODUCTION

Development of computer hardware and software specialized technology computer aided design (CAD) and structural analysis (FEM) enables design engineers to solve complicated problems in the field of agricultural machinery, using and numerical methods in a virtual way without realizing physical manufacturing and laboratory-field testing. [4]

In December 1993, SolidWorks founder Jon Hirschtick, has appointed a team of engineers to design a 3D CAD technology more accessible. They have managed to create the first 3D CAD software capable of operating on a Windows platform to run that technology was not need expensive hardware and software systems. The first version of SolidWorks software was launched in 1995. DassaultSystèmes acquired the company in 1997. Currently, DassaultSystèmes SolidWorks Corp. offers a complete toolkit to create, simulate, publish and manage data, optimizing innovation and increase productivity engineering resources. All these solutions work together to enable companies to design products in a faster, more efficient and better. Continuing to implement its motto of "ease of use" company DS SolidWorks Corp. has created new product extensions, including SolidWorks SIMULATION that allows each engineer to perform simulation structural parts and assemblies using finite element analysis (FEA), to improve, to validate the performance and reduce the need to build costly prototypes. Design engineers primarily use simulation to determine the structural strength and stiffness of a product by comparing the stress and deformation of the components. [5]

Optimal design for the development of farm machinery for mechanized systems maintenance in horticulture is linked directly or indirectly properties of metallic materials constituting the active bodies.

In practice, the choice of metallic materials (metals and alloys) requires a technical analysis, and economic, structural performance and mechanical properties of failing to ensure their widespread use.

It is therefore very important to find a technical and economic strength indicator to be used in the analysis based on technical and economic choice of metallic materials used in construction machinery.

Analysis of resistance and rigidity of the active body through structural analysis method is an alternative easy and simple to interpret quality technical equipment. [1]

Resistance criteria are known to be taken into account by designer's specialists, namely:
- Wear resistance;
- Resistance to damage by shock or a very large force.

In practice, because it takes time, wear resistance is very difficult to determine, it is important in the selection of the material (and possibly shape).

In this context, the paper presents research conducted using finite element analysis (FEA) to determine tension and deformation taking into account the action of a large external forces.

They were made for different metallic materials from which it is possible to achieve knife disc from technical equipment to work the soil in the row of fruit trees, along with cuttings root for moderating the growth of shoots and foliar fertilization precision that was designed to INMA Bucharest.

Based on the data obtained were calculated resistance coefficients and determining the reports price / coefficient of resistance for those materials has resulted in a technical and economic indicators of resistance that can be used in the analysis based on technical and economic choice of a material metal, to reduce design validation time by eliminating achievement and physical testing and obtaining economic and financial results as possible.

MATERIAL AND METHOD

Technical equipment for soil cultivation row of fruit trees, root cuttings while moderating the growth of shoots and precision foliar fertilization (fig. 1), is intended to execute following works:
- plowing a strip at a distance from the trunk to maintain a loose soil surface;
- root pruning at a distance from the trunk to preserve trees and maintaining low waist root growth within the nutrition space of each tree;
- precision foliar fertilization.

The technical equipment comprises an active organ type disc knife of large diameter, which is rigidly mounted on a metal frame via a support provided with a guide articulated and means of regulating the working depth and lock the cutting direction vertical. [2]

Pushing it into the soil is achieved due to equipment mass that can be adjusted by adding additional mass mounted on the frame for obtaining a suitable working depth. Because it penetrates lis edge profile and cut slightly into the soil to a depth adequate root system and a precise distance from the trunk.

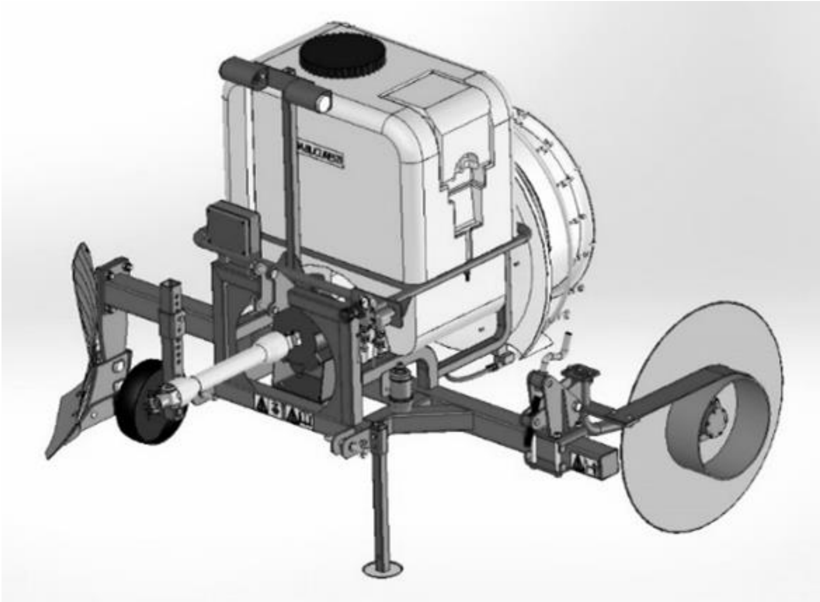


Figure 1.Technical equipment for soil cultivation row of fruit trees, root cuttings while moderating the growth of shoots and precision foliar fertilization

Disc cutter diameter *D* (fig. 2, a) is given by equation (1):

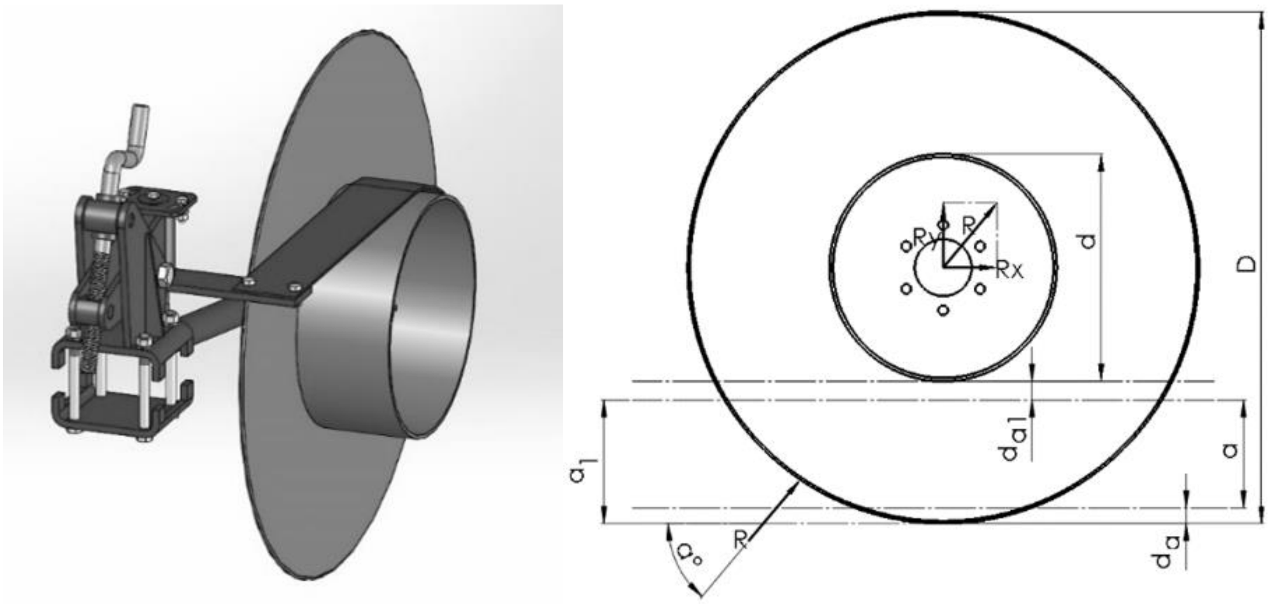
$$D = 2(a + d_a + \frac{d}{2} + d_{a1}), mm \qquad (1)$$

where: *a* is the working depth, in mm (a=260 mm);

d - flange disc diameter (d = 0,25D);

d_a=15 mm; d_{a1}=25 mm, from safe operating conditions.

From the analysis of similar construction, large diameter disc blade diameter varies between 800 ... 900 mm. Disc thickness of 5 ... 6 mm and sharpening angle of 15 ... 30 °. The angle α formed by the force R to the horizontal is 45 ... 55°.



a. **b.**

Figure 2. Active body type large diameter disc knife

During work, R force acts on the disc - the resultant of the elemental cutting forces (fig. 2, *b*).

$$\bar{R} = \overline{R_X} + \overline{R_Y} \qquad (2)$$

R_x resistance opposed to disc movement is:

$$R_X = K \times a_1 \qquad (3)$$

where:

K is the resistance per meter working width specified in disking with heavy disc harrow; K = 4000…8000 N/m [6];

$a_1 = a + d_a$= 260 mm.

For the analysis based on technical and economic choice of metallic material of construction body active type knife disc of large diameter fitted to the machinery for soil tillage row of trees, while cuttings root for moderating the growth of shoots and foliar fertilization of accuracy, the following steps were carried out:

- *finite element analysis (FEA) by using the simulation structural SOLIDWORKS SIMULATION,* which involved importing the geometry achieved with the application of Computer Aided Engineering (SolidWorks), defining material, defining appropriate restrictions meshing, calculation analysis to determine tensions under the effect of loads applied and viewing results; [3]
- *determination of price reports / coefficient of resistance* for those materials in the library software;
- *choice of material showing high resistance in terms of a price as low as possible.*

RESULTS AND DISCUSSIONS

The first step in using finite element analysis consisted in building the model (3D) for large diameter disc knife. Figure 3 presents an axonometric isometric view of the CAD model created with the Solidworks 2013. The input data for FEA analysis were as follows:

- outer diameter: D = 800 mm;
- disc flange diameter: d = 200 mm;
- large disk thickness: g = 6 mm
- angle α formed by the force R with horizontal: α = 50°;
- resultant of the cutting elementary forces (after all calculations): R = 3000 N.

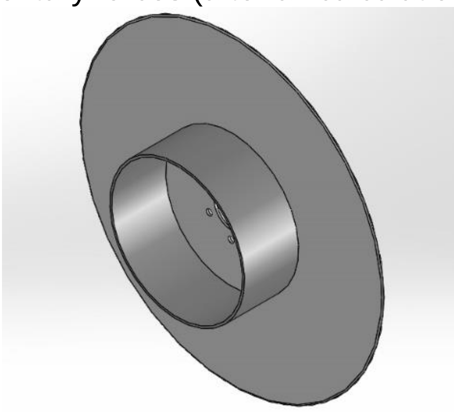


Figure 3. Axonometric isometric CAD model view of large diameter disc cutter

Static analysis involved:

- selection options as static type analysis, solid meshing and solver for the type of FFEPlus (fig. 4);

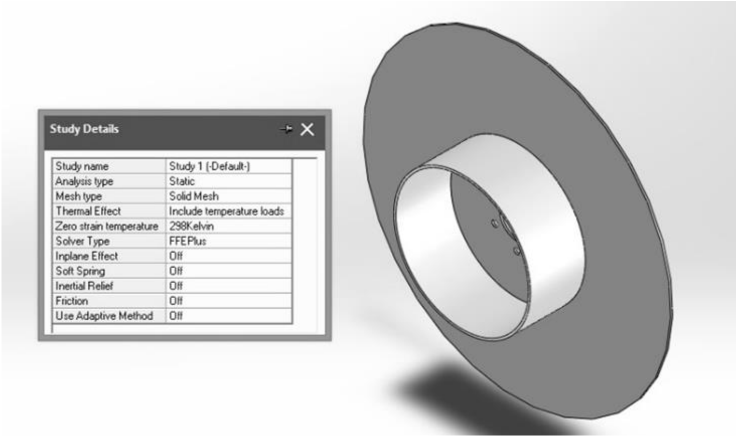


Figure 4. Selection options as static type analysis, solid meshing and solver for the type of FFEPlus

- the selection of some materials from SolidWorks 2013 library and automatically assigning these properties (Table 1) defining characteristics of the material (fig. 5);

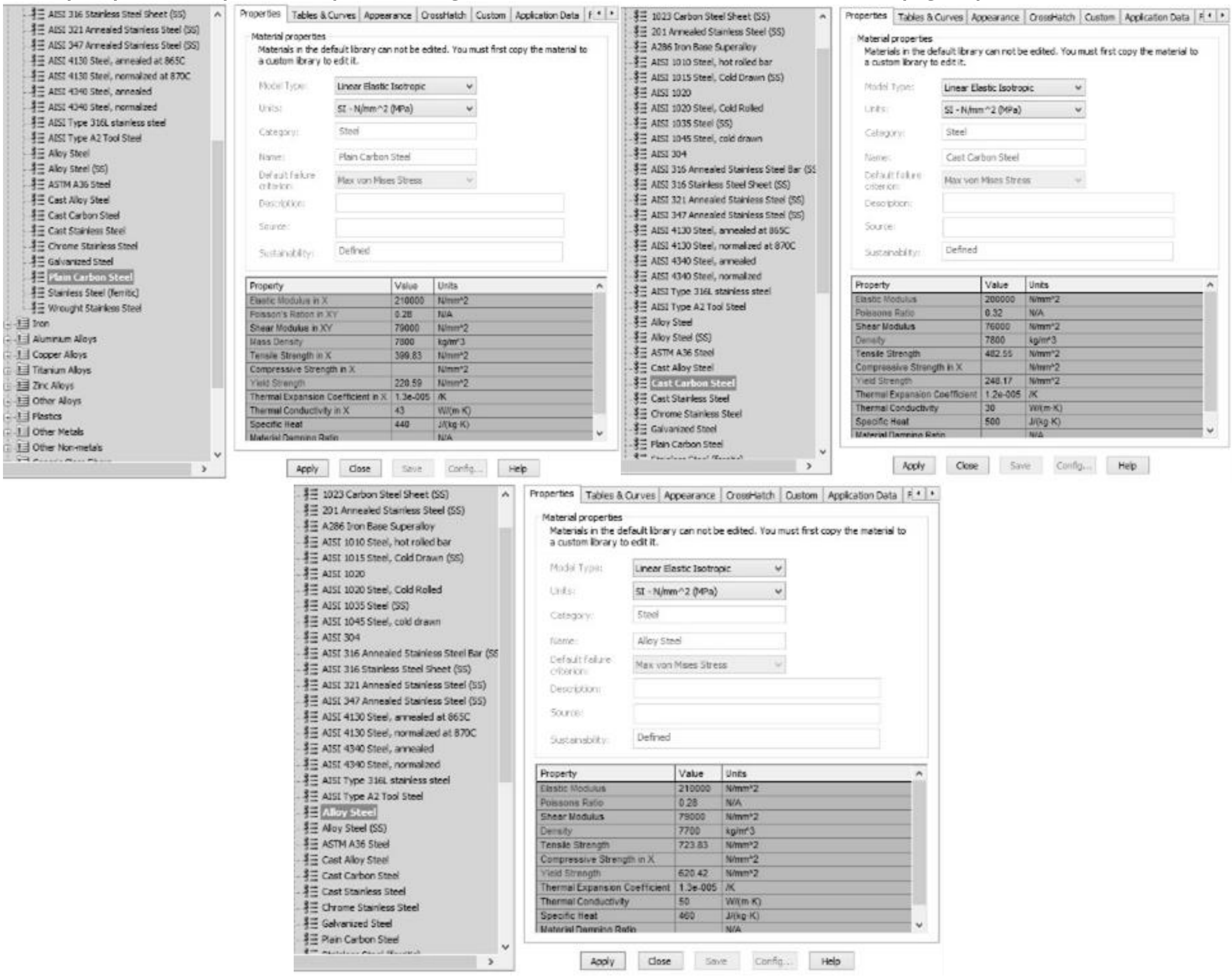


Figure 5. The selection of some materials from SolidWorks 2013 library

Table 1

Properties of the selected material

Material	Drip limit (σ_c) (N/mm^2)	The limit of traction (σ_r) (N/mm^2)	Poisson's ratio	Modulus tensile / compressive (E) (N/mm^2)	Tensile modulus / shear (G) (N/mm^2)
M1	220,590	399,83	0,28	210000	79000
M2	248,170	482,55	0,32	200000	76000
M3	620,420	723,83	0,28	210000	79000

- application load corresponding elementary resultant cutting forces *R*. According to real mode of operation (operating) of large diameter disc cutter, scenario simulation was adjusted accordingly. The load was applied at the appropriate angle *α* formed by the *R* force with the horizontal (figure 6).

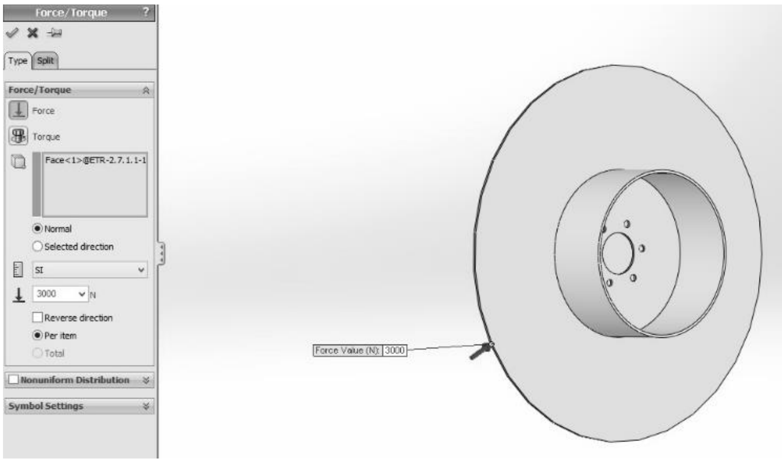


Figure 6.Application load corresponding elementary resultant cutting forces R

- use network procedure ("meshing procedure") to break down the model into discrete elements. In general, a finite element model is defined by a network that is fully realized, a geometric arrangement of elements and nodes. Nodes are points where features are calculated, such as displacements (fig. 7).

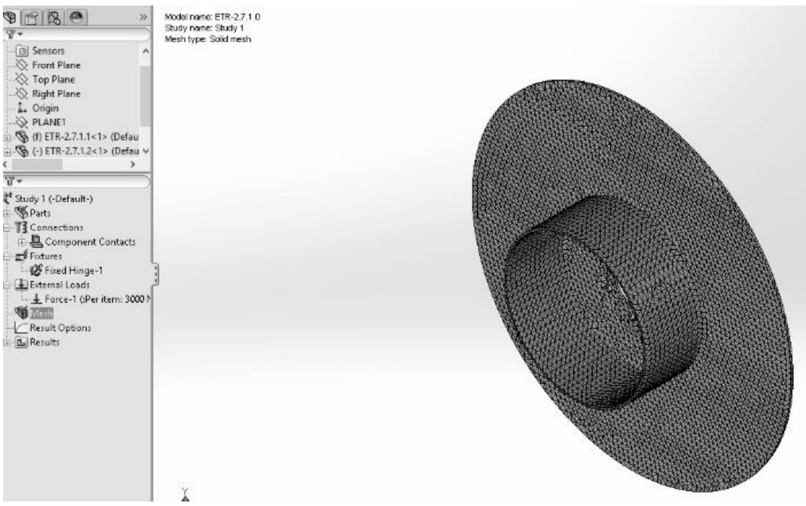


Figure 7. 3D Model meshed into a finite element network

- running study analysis to calculate the tensile and displacement based on geometry, material, load conditions and type of meshing restriction. After running analysis studies, the results can be viewed to compare (fig. 8, 9).

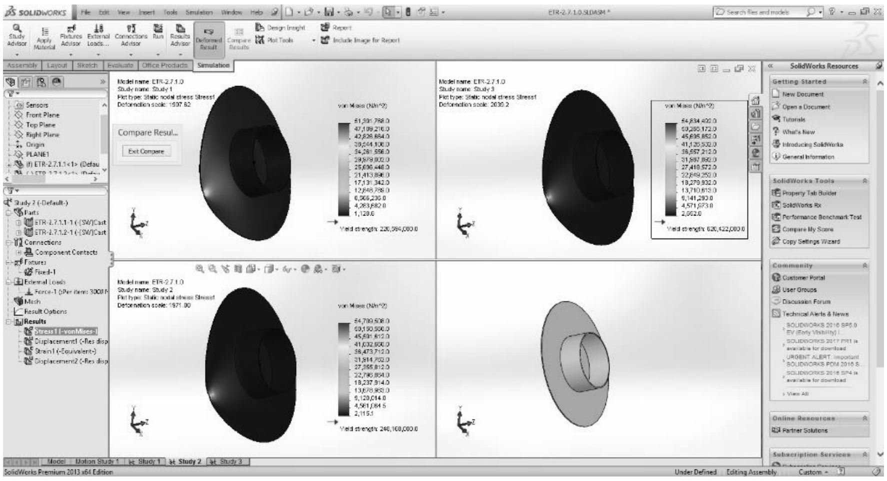


Figure 8.Sequence during comparison studies and results appear on the screen as tensile von Mises distribution

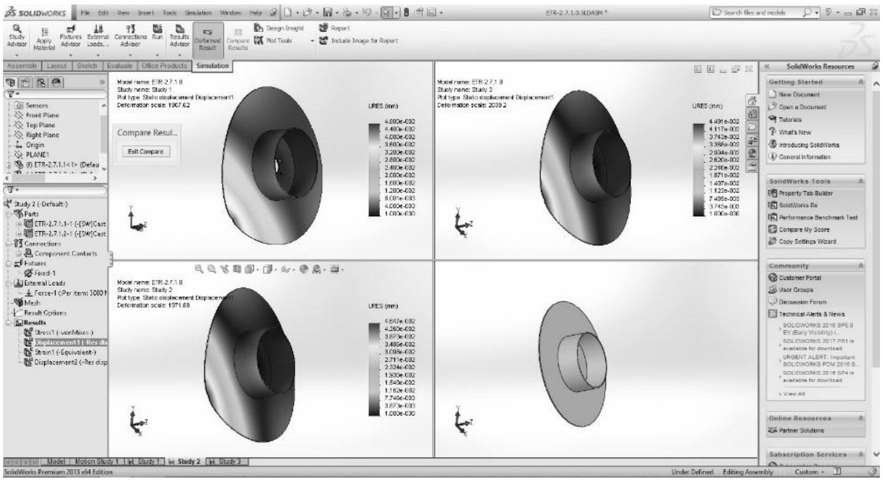


Figure 9.Sequence during comparison studies and results appear on the screen displacement distribution

Results of the analysis based on technical and economic choice of metallic material of construction body active type disc knife of large diameter, fitted to the machinery for soil tillage row of trees, while cuttings root for moderating the growth of shoots foliar fertilization accuracy, are shown in table 2.

Table 2

Results of the analysis based on technical and economic choice

Name	**Unit of measurement**	**Value**		
		Material 1 (equivalent rolled steel)	**Material 2** (equivalent quality steel)	**Material 2** (equivalent alloy steel)
vonMises	N/mm^2 (MPa)	51.391768	54.709508	54.834492
Resultant displacement, mm	mm	4.8×10^{-2}	4.647×10^{-2}	4.491×10^{-2}
Safety factor	-	4.292	4.536	11.314
Price	lei cu TVA / m^2	111.91 [7]	118.08 [7]	942 [8]
Price / safety factor	-	26.074	26.066	83.259

From the results shown in Table 2 revealed that the lowest technical and economic indicator is 26.066, which led to the choice of metallic material of the disc knife "*blackboard* *hot rolled executed in accordance with EN 10051, allied S355J2 + N according to EN 10025*", which has a high resistance in terms of a price as low as possible.

CONCLUSIONS

- The application of computer aided engineering (SolidWorks) and structural simulation (SolidWorks SIMULATION) offers design engineers a solution to perform finite element analysis (FEA) to determine the distribution of stress and deformation under the action of external forces;
- The technical and economic indicator, which is proposed to analyze the technical and economic criteria when selecting a metal material, helps reduce design validation time and enables economic and financial results as good.

ACKNOWLEDGE:
The results presented in this article were obtained with support of the Ministry of National Education and Scientific Research, the National Authority for Scientific Research and Innovation (ANCSI), the NUCLEU Programme, contract no. 8N / 09.03.2016, project PN 16 24 02 01.

BIBLIOGRAPHY

1. M. Lăutaru, T. D. Babeu, 2011, *The simulation using the finite element method to test the outer compression coil spring bogie Y 32 R XI,* Multidisciplinary National Conference with International Participation, Professor Dorin Paul - founder of Romanian Hydropower, Sebes.
2. E. Marin, P. Toderaşc, D. Manea, A. David*,* 2015,*Technical equipment for tilling the soil and root pruning row of trees*,Patent application RO-BOPI 6/2015, din 30.06.2015, http://pub.osim.ro/publication-server/pdf-document?pn=ro130291%20ro%20130291&idocid=6956&iepatch=.pdf.
3. D. Nedelcu, 2007, *Stress Analyse of an Admission Valve with Finite Element Method*, Analele Universității "Eftimie Murgu" Reșița, Anul XIV, Nr. 1, pp 139÷144
4. M. Topakci, H.K. Celik, M. Canakci, A.E.W. Rennie, I. Akinci, D. Karayel, 2010, *Deep tillage tool optimization by means of finite element method: case study for a subsoiler tine*, J. Food Agric. Environ., 8 (2), pp. 531–536
5. SolidWorks Product Document, 2013, *SolidWorks Simulation 2013 On-Line User's Guide, SolidWorks Software Corp*., USA.
6. Şandru, A., 1983, *Operation of agricultural machinery*, Didactic and Pedagogic Publishing House, Bucharest.
7. *** http://www.baduc.ro/Metalurgice/TABLA-PENTRU-CONSTRUCTII/TABLA-NEAGRA-LBC
8. *** http://www.altdepozit.ro/tabla-inox-p-2734.html