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Resistive behavioral assessment of the multi–plow MAU–250 working implement

Análisis del comportamiento resistivo del implemento de trabajo del multiarado MAU-250

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Abstract

The present work has as fundamental purpose the determination of the tensional state of the Multi-Plow working implement, for which different actions were implemented using the software Solidwork version 2010. Initially it was elaborated the graphic model of the working implement and the contour conditions were specified as well as the materials of the different components and, the implementation of efforts to the receptors. A Vertisol soil was used since it is considered that its resistance to cutting makes it adequate to perform experiments on the characteristics of working implements for agriculture machines. The Von Mises tensions were determined, together with the displacement that they provoke and the maximum tension supported by each element that was compared with the elastic limit of the material. Finally, there was an optimization study with the purpose of reducing the effects of the working implement weight on soil compaction.

Key words: Agricultural tilling, tensional state, displacements.

Resumen

En el estudio se determinó el estado tensional del implemento de trabajo del Multiarado MAU-250, para lo cual se efectuaron diferentes cálculos partiendo del uso del graficador Solidwork versión 2010. Inicialmente se construyó el modelo gráfico y se especificaron las condiciones de contorno, así como los materiales de fabricación de los distintos componentes y la aplicación de los esfuerzos a los receptores. Se utilizó un Vertisol ya que se considera que estos suelos por la resistencia al corte son adecuados para realizar ensayos sobre las características de los elementos de trabajo en maquinarias agrícolas. Se midieron las tensiones Von Mises, además los desplazamientos que estas provocan y la máxima tensión que soporta cada elemento fue comparada con el límite elástico del material. Finalmente se efectuó un estudio de optimización con el propósito de reducir los efectos del peso del implemento sobre la compactación de los suelos.

Palabras clave: Maquinaria de trabajo, laboreo agrícola, estado tensional, desplazamientos, multiarado.

Introduction

The multiplow MAU-250 is an implement of minimum tillage developed and widely used in Cuba in several crops. In 1989 it was awarded by the Academy of Sciences of Cuba. Among its components and characteristics, there are a scarifier that cuts vertically the soil and a grille in "V" shape for horizontal cuts, that has a trapezoidal structure with a combination of positive and negative angles in its components, this allows the work on a floating position to break, decompact and soften the plowed soil.

Bouza (1996) considers that the advantages and benefits of its use are the following:

- It does not flip the soil, reestablishing the ecological equilibrium and natural fertility, additionally it increases the organic matter and agricultural yields.
- It increases the physical properties of the soil like structure, water retention capacity and bulk density.
- It doubles the working capacity of the tractor and reduces up to 50% the fuel consumption because it requires lower traction potency than a conventional plow.
- Reduces the production costs and saves up to 30% in herbicide consumption.
- Eliminates the soil compaction by creating a porous soil that allows water storage and deep root growth.
- Contributes to avoid the soil erosion.
- Favors the superficial levelling and weed control.

According to Leyva (2009) the multi-plow is one of the technological alternatives that is more appropriate for minimum tillage in sugar cane crops, since it has the advantage of plowing without the prism type inversion. This is an adequate alternative for the primary soil preparation, therefore it can be used instead of the disk plow because it does the same work but, with better quality and low energy consumption; this is observed in the reduction of the bulk density, with the advantage of a higher theoretical speed and working width and, lower fuel consumption per area with low unitary effort.

Nonetheless the cited advantages, it is interesting to perform actions in order to get fewer effects in soil compaction when using tillage tools, especially when the soil is wet or saturated and is more prone to deformation.

For the above mentioned, this research had as objective to determine the states of tension and deformation of the tool or working implement of the MAU-250 multi-plow. For this, the Finite Element Method (FEM) applied with frequency in the last times in the determination of tensional states of parts or elements of agricultural machinery. Pereira da Silva (2013) performed a static study on the tensional state of the structure of an automotive-type coffee harvester, where is demonstrated the good use of the FEM. Palma and González (2012) used this methodology in studies with tractor racks to analyze their behavior and observe the possibility of improvements. Niemczewski *et al.* (2014) using FEM and the SolidWork Simulation software studied the structural behavior of the chassis of the four lines sowing machine for family agriculture, finding that the validated results were effective for this kind of work. Dragic *et al.* (2013) determined the tensional state of a protective frame for a tractor with traction potency of 65 kW used in fruit harvesting, the simulation of the behavior of this element by the SolidWork Simulation software revealed satisfactory results. The previous result shows the effectivity of the MEF application in work related to the resistive behavior of the agricultural machine components.

Materials and methods

Description of the multi-plow MAU–250

The components of the multi-plow are shown in the Figure 1 and the details of the working tool are in Figure 2.

Determination of the tensional state

To determine the tensional state to which the working tool is subjected when plowing the soil the following process was used:

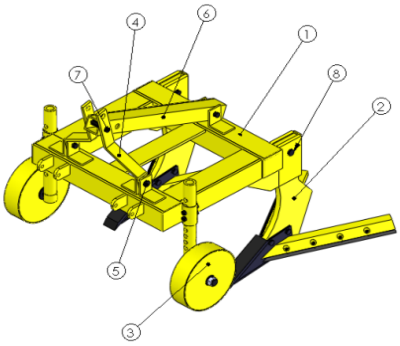

Figure 1. View of the parts of the multi-plow MAU-250

Part	Denomination	Code	Material	Quantity
1	Frame	01-00-00PE	—	1
2	Working implement	02-00-00PE	—	2
3	Field wheel	03-00-00PE	—	2
4	Brace	01-00-01	AC-1020	2
5	Slider I	00-00-02	AC-1035	2
6	Brace II	00-00-03	AC-1020	1
7	Slider II	00-00-04	AC-1035	2
8	Pin III	00-00-05	AC 1035	2

Graphic model. The Solidwork version 2010 grapher was used which allows obtaining tridimensional models and, the simulation to the efforts that can be applied to a tool based on the use of the finite element model. In the modelling process in each part were assigned materials according to the data on Figure 2.

Declaration on the contour conditions. For the simulation, it was determined that the study on the analyzed set should be of static type, since there were

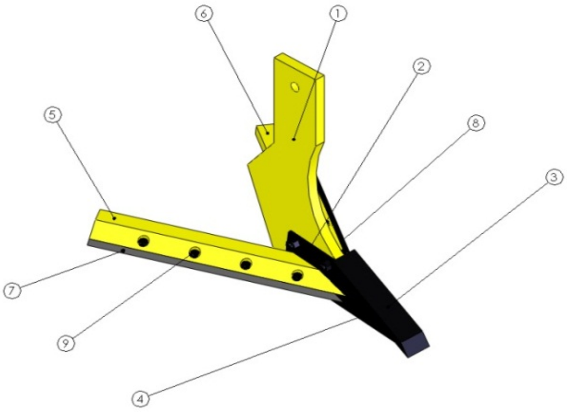

Figura 2. General view of the working implement.

Part	Denomination	Code	Material	Quantity
1	Scarifier	02-00-01	AC-1020	1
2	Fixer	02-00-02	AC1045	2
3	Chisel	02-00-03	AC-65Mn	1
4	Basal plate	02-00-04	AC-65Mn	1
5	Right blade holder	02-00-05	AC-1020	1
6	Left blade holder.	02-00-06	AC-1020	1
7	Right blade	02-00-07	AC-65Mn	1
8	Left blade	02-00-08	AC-65Mn	1
9	Screw and nut M16	02-00-09	AC1035	8

not consistent data that allow a dynamic study. With this postulation were declared the conditions of the contour applying the restrictions to the model that define the subjection of the parts that compose it (Figure 3) .

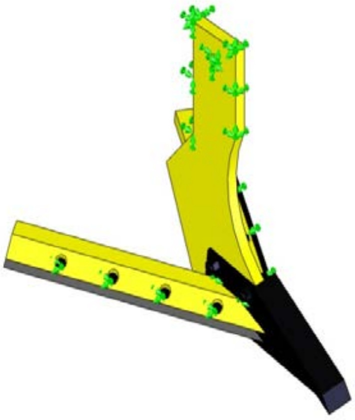

Figure 3. Definition of the model restrictions.

Application of loads. In the model it was considered that the resistance to cutting is an index of the possibilities to prepare the soil and gives an idea on the necessary strength for this labor (Figure 4) and therefore, the energetic cost for tilling. On a compacted Vertisol this index is estimated to be between 2.40 and 2.76 x 10^5 N/m^2 in the profile at a depth between 10 and 30 cm (Reyes Mora, 1980).

Coulomb (1876), cited by Santana and Fuentes (1998), established that the break of soil by the cutting effort happens on a plane where the tangential or cutting tension applied is equal to the cohesion of the soil particles and, to the friction force generated by the relative displacement of the surfaces that are formed.

Vertisol soils, for their limit properties, result suitable for test of agricultural machinery, in especial the tilling; additionally, because of the surface that they occupy they are representative of the largest part of Cuban soils (Agafonov, 1978; Betancourt *et al.,* 2007; Martin *et al.,* 1987). In this study was found that the arrow is the element that begins the soil breaking and because there are not available data on the traction force measured in the field, it was possible to take the existing data of the resistance to cutting for Vertisol type of soils (2.76 x10^5 N/m^2) as the pressure that is supported by its components. In consequence, it was decided that the applied load will be of 3.31 x 10^5 N/m^2 considering a security factor [n] = 1.2.

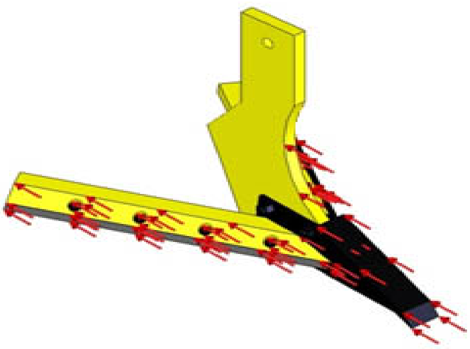

Figure 4. Loads acting on the working implement.

Meshing. In the Figure 5 are the details of the characteristics and mesh type used in the model.

Comparison of the tensions obtained with the elastic limit of each part. Using the ISO-Superficies tool were identified the model parts that supported the maximum tension indicated in the resulting tension graph.

Analysis of the displacement caused by the tensions. The displacements that occur in the working tool were identified, which allows the evaluation of the displacements as agents that act changing the objective service of the analyzed tool.

Proposal for optimization

Taking into account that the impression showed that the scarifier is oversized, it was considered that if the results of the tensional state study were favorable, an optimization study will be applied to obtain a variant with less thickness, which will be positive to reduce soil compaction and, therefore, operational costs.

The evaluated thickness were 24 and 48, additionally, it was analyzed the effect of the lateral efforts that were assumed as 30% of the effort to which the scarifier was subjected as result of the cutting force required to break the soil. It is important to point that the value of 30% of the cutting force, was selected taking into account the security factor [n] = 1.2 that was previously applied in the determination of the tensional state of the working implement.

Results and discussion

Determination of the tensional state

The values of the tensional state measurement to which the working implement was subjected can be observed in the Figure 6. The maximum tension was 17,704,922 N/m^2, that when compared to the elastic limit of each part, is noticed that in any case this value was higher than the elastic limit estimated in the values of the same Figure.

The analysis of the displacement allows concluding that those that occur when the tensions above mentioned act are not

Figure 5. Meshing of the model.

Characteristics of the mesh applied to the model.	
Mesh type	Solid mesh
Meshing used	Standard mesh
Jcobian points	4 points
Element size	22.1 mm
Tolerance	1.10 mm
Mesh quality	Quadratic elements of high order
Total number of nodes	20827
Total number of elements	11787
% of distorted elements	0

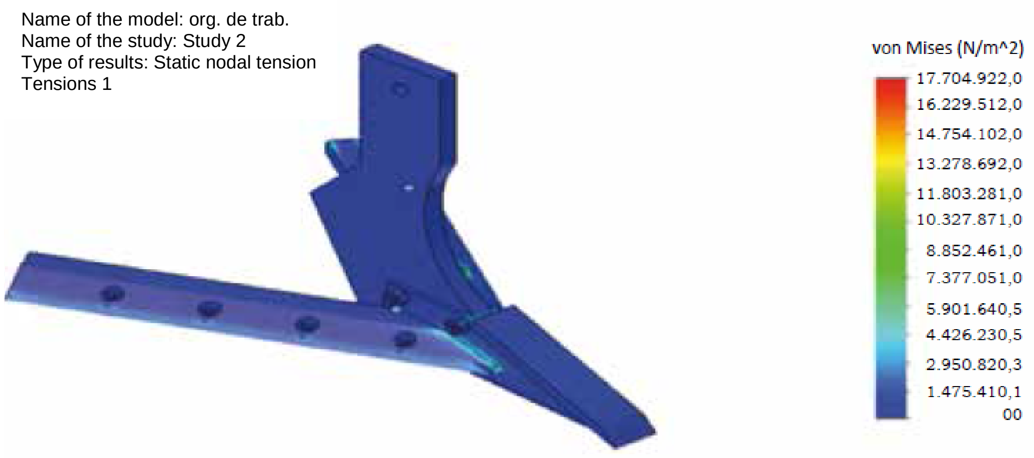

Figure 6. Tensional state of the working implement of the multi-plow MAU 250.

Comparison between the elastic limit and the maximum tensión in the working implement.

Denomination	Elastic limit (N/m²).	Maximum tension (N/m²)
Scarifier	351,571,000,0	17,704,922
Fixer	530,000,000,0	
Bassal plate	620,421,997.8	
Chisel	620,421,997.8	
Left blade holder	351,571,000.0	
Right blade holder.	351,571,000.0	
Left blade	620,421,997.8	
Right blade	620,421,997.8	

significant, they do not negatively affect the service goal of the working tool and the higher magnitude happens on the part called chisel (Figure 7).

The results established that the working implement can be subjected to the optimization process because the efforts and displacements caused by the soil resistance to cutting are under their resistance capacity; therefore, an optimization process was performed on the scarifier considering a working depth of 0.35 m.

Proposal for optimization

In the Table 1 are shown the values that resulted from the optimization of the working tool.

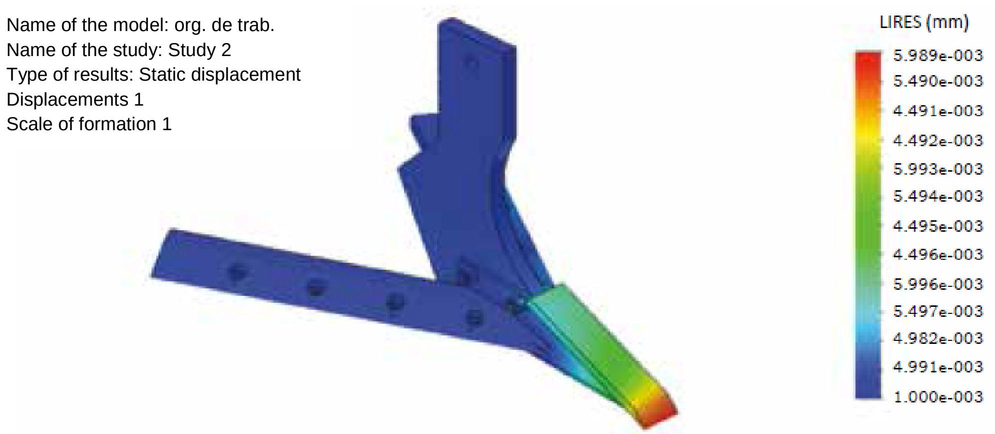

Figure 7. Displacements caused by the tensions on the working implement.

Table 1. Dimension and tensión values of the effort optimization test on the working implement of the multi-plow MAU-250, in three different scenarios.

Variable	U	Optimal	Scenario 1	Scenario 2	Scenario 3
Dimension	Mm	24	24	28	32
Tension-1	N/m^2	3.16x10^8	3.16x10^8	2.35x10^8	1.99x10^8

It is observed that the optimal scenario for the tensional state analyzed happens with a 24 mm scarifier, which represents a weight reduction of 25% in comparison the scenario 3 that is the original variant. The validation of the optimal variant is given by the results that are in Figure 8 of the Von Mises tensions, where is confirmed that it is possible to use a scarifier with this thickness. In the Figure are observed on circles, the zones for maximum tension, where it is recommended to attenuate them by reinforcement with bezels.

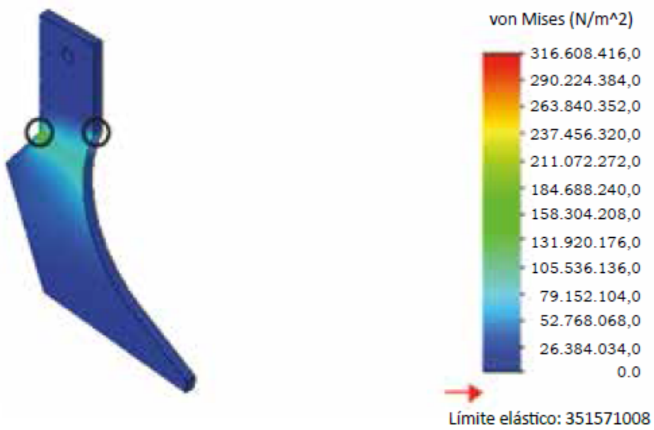

Figure 8. Von Mises tensions in the optimal variant.

Conclusions

- The tensional stage to which the working implement of the multi-plow MAU-250 is subjected, does not affect the work that it normally performs because the efforts apply do not surpass the elastic limit of the parts of the working tool.
- The displacements presented are not significant and are caused by the tensions that do not exceed the elastic limit of the working implement.
- It is possible to reduce the scarifier thickness to 4 mm, which reduces the operational costs and weight effects on soil compaction.

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