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RESEARCH ON THE DEVELOPMENT OF AN INNOVATIVE VIBRATORY SYSTEM FOR IN OPERATION AND MANUFACTURING PLOUGHS

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Abstract: The use of modern agricultural ploughs, along with conservation techniques and alternative seeding systems, remains at the forefront of achieving better agricultural yields and therefore the success of any tillage operation. In this context, it becomes a priority to find a new, original solution regarding the constructive–functional modification of the agricultural plough with the maintenance of performance, and above all, at the same time, with the significant reduction of fuel consumption and implicitly CO_2 emissions. Knowing the technological challenges, a group of researchers from the enterprise IRUM S.A. in effective collaboration with the research organization INMA Bucharest and UTCN have created an innovative vibrating system intended for ploughs in operation and manufacturing within an innovative technological project financed by the Operational Competitiveness Program (POC). This paper presents the research carried out on the development of the innovative vibratory system for agricultural ploughs within the design, optimization and virtual testing activities using specialized CAD–CAE programs to analyze the robustness and performance of the prototype. Research results have contributed to reducing design validation time and manufacturing costs.
Keywords: vibrating system, agricultural plough, fuel reduction

1. INTRODUCTION

At the European level, agricultural farms have in mind the promotion of tillage technologies that are oriented towards the management of natural resources (soil, water) (Gusev, 2020). This will lead to the reduction of greenhouse gas emissions, which is one of the main challenges today (Mielcarek–Bocheńska and Rzeźnik, 2021).

The Commission's Green Deal presented in 2019 proposed moving to a 50% to 55% emissions reduction target by 2030, as well as a 'net zero' greenhouse gas target in 2050 (Montanarella and Panagos, 2021).

In the process of combating climate change, currently considered in international specialized forums as representing a potentially irreversible threat to society and our planet (Mikhaylov et al., 2020), the adoption of measures to reduce greenhouse gas emissions in compliance with the objectives and principles of The United Nations Framework Convention on Climate Change and the Kyoto Protocol (Breidenich et al., 1998), constitutes a fundamental component of the policy of the company IRUM SA, the research organization INMA Bucharest and the higher education institution Technical University of Cluj–Napoca, for solving the sustainability problems faced by promoting innovation in the field of agricultural machinery manufacturing.

The reduction of CO_2 emissions is an essential aspect in the development of agricultural machines (Cui et al., 2018) and especially of plows intended for plowing because, in addition to fertilizing and protecting crops, plowing is crucial for success in sustainable agriculture (Andersen et al., 2016).

The use of modern plows, along with conservation techniques and alternative seeding systems, remains at the forefront of better yields and therefore the success of any tillage operation (Tsoraeva et al, 2021). In this context, it becomes a priority objective to find a new, original solution regarding the constructive–functional modification of the agricultural plow with the maintenance of performance, the significant reduction of fuel consumption and implicitly CO_2 emissions, for example: the vibration of the working bodies (Vasilenko et al., 2021).

Thus, the enterprise IRUM S.A. in effective collaboration with the research organization INMA Bucharest and UTCN have designed an innovative vibrating system intended for plows with bodies in operation and in production within a project financed by the Operational Competitiveness Program (POC) (Gheorghe et al., 2023).

2. MATERIALS AND METHODS

The experimental research on the design of a prototype of an innovative vibrating system intended for plows with small bodies in operation and in production (Figure 1), was carried out by INMA Bucharest in effective collaboration with the enterprise IRUM SA and the higher education institution Technical University of Cluj–Napoca.

Figure 1 – Prototype of an innovative vibrating system for plows with bodies in operation and in production

The prototype of the innovative vibrating system for plows with bodies in operation and in production consists of a new electromagnetic vibrating solution and innovative electronic control elements, which were chosen after studies by the UTCN implementation team to drive into operation to the decrease of the traction force of agricultural plows depending on the characteristics of the soil, the level of precipitation and the thermal regime.

The main characteristics of the new electromagnetic vibrating solution, which is the direct current industrial motovibrator type MVE 200/3N–23A0–12V, are presented in table 1.

Table 1. Technical characteristics of the photovoltaic panel

Model	MVE 200/3N–23A0–12V
Current voltage, V	12
Engine power, kW	0,16
Maximum vibrating mass, kg	200
Speed, rot/min	3000
Engine mass, kg	7,2

Figure 2 shows an aspect of the MVE type direct current industrial motovibrator that was mounted on the three bodies of the reversible plow manufactured at IRUM SA.

Figure 2 – Industrial direct current motovibrator type MVE mounted on the three bodies of the reversible plow

3. RESULTS

After the stage of creating the 3D geometric models in the 3 constructive variants for the support of the MVE type direct current industrial vibrator (table 2), we moved on to the stage of structural analysis with the help of the structural simulation application SOLIDWORKS SIMULATION (https://www.solidworks.com/), which involved importing the geometry of the model Performed 3D, defining the material, defining appropriate constraints on the discretizations, running the program to calculate the analysis of Von Mises stress, displacement, relative elongation, factor of safety and viewing the results in the form of diagrams.

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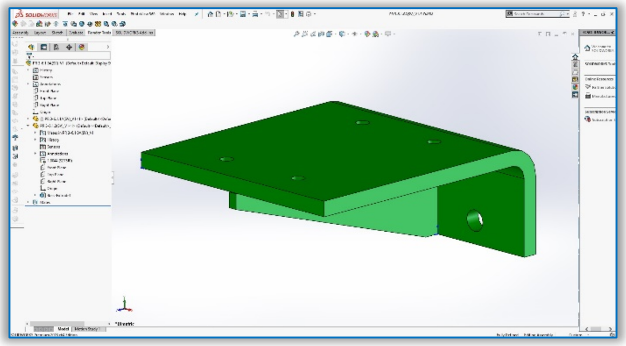
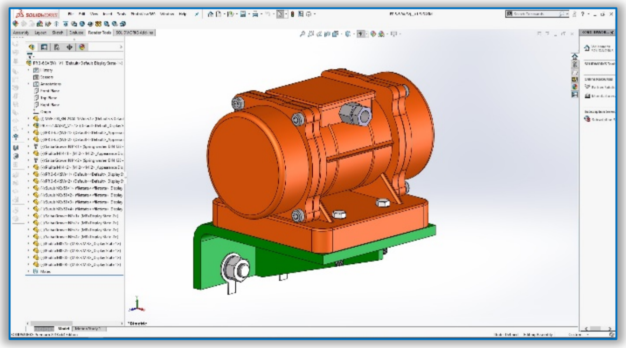
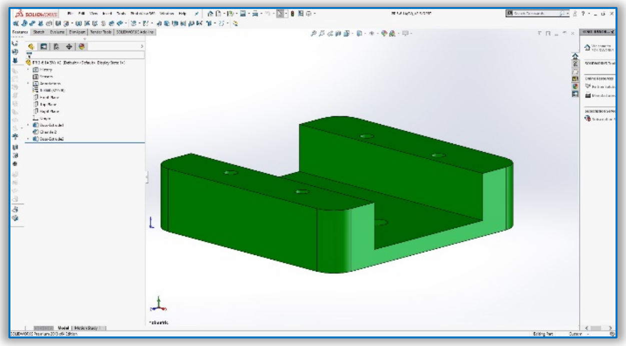
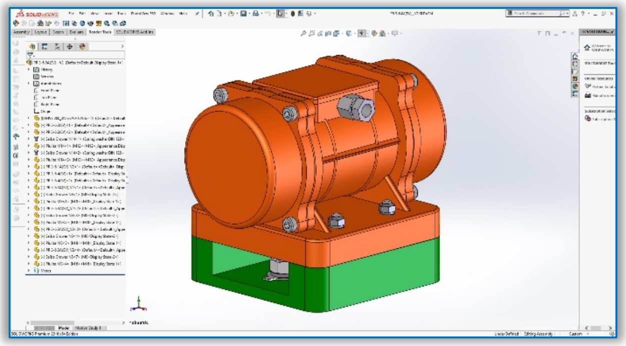
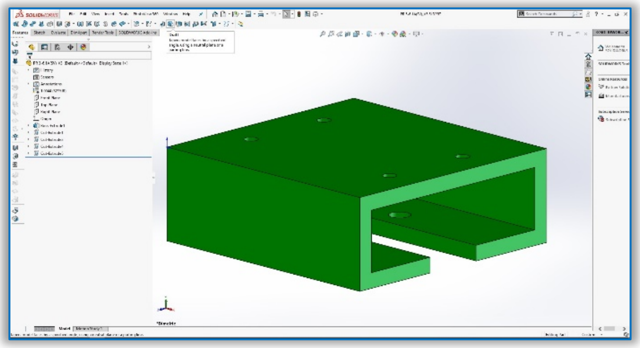
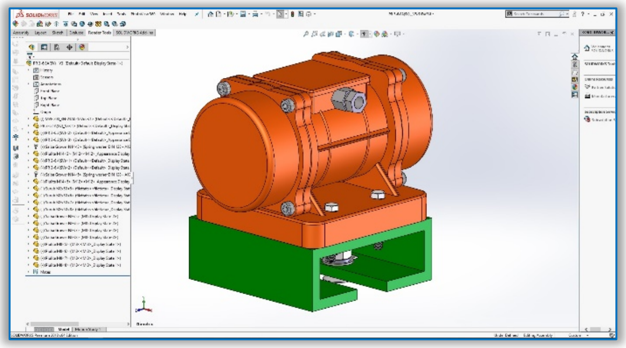
Table 1. 3D geometric models for the support of the industrial direct current motovibrator type MVE

Constructive variants for the support of the direct current motovibrator type MVE	Variants of mounting the direct current motovibrator type MVE on the support
 V1	 V1
 V2	 V2
 V3	 V3

The constructive optimization method assumed the following operations:

- selecting the static option as the analysis type, solid for the discretization type and the FFEPlus solver;
- the selection of some materials from the SolidWorks library and the automatic assignment of these properties to the main landmark, the side knife, the element that during work is most subject to the wear process. For any type of finite element analysis using SolidWorks–Simulation it is indispensable to assign a material. In order to carry out the linear static analysis of the lateral knife–type working body, where the stresses and deformations of a loaded structure can be evaluated, the following characteristics were essential: Tensile / compression modulus of elasticity (E), Tensile / shear modulus of elasticity (G) or Poisson's ratio.
- applying the appropriate load in accordance with the actual mode of operation (from operation, the simulation scenario was adapted accordingly). The load was applied at the points corresponding to the mode of operation;
- using the meshing procedure to decompose the model into discrete elements. Generaly, a finite element model is defined by a mesh, which is completely made of a geometric arrangement of elements and nodes. Nodes represent points, where characteristics are calculated, such as displacements;

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— running analysis study to calculate stress, factor of safety and displacement, which is based on geometry, material, load, constraint conditions and discretization type.

After running the analysis studies, the results for the three constructive variants of the support of the direct current industrial motovibrator type MVE V1, V2 and V3 could be viewed for comparison (Figures 3, 4 and 5).

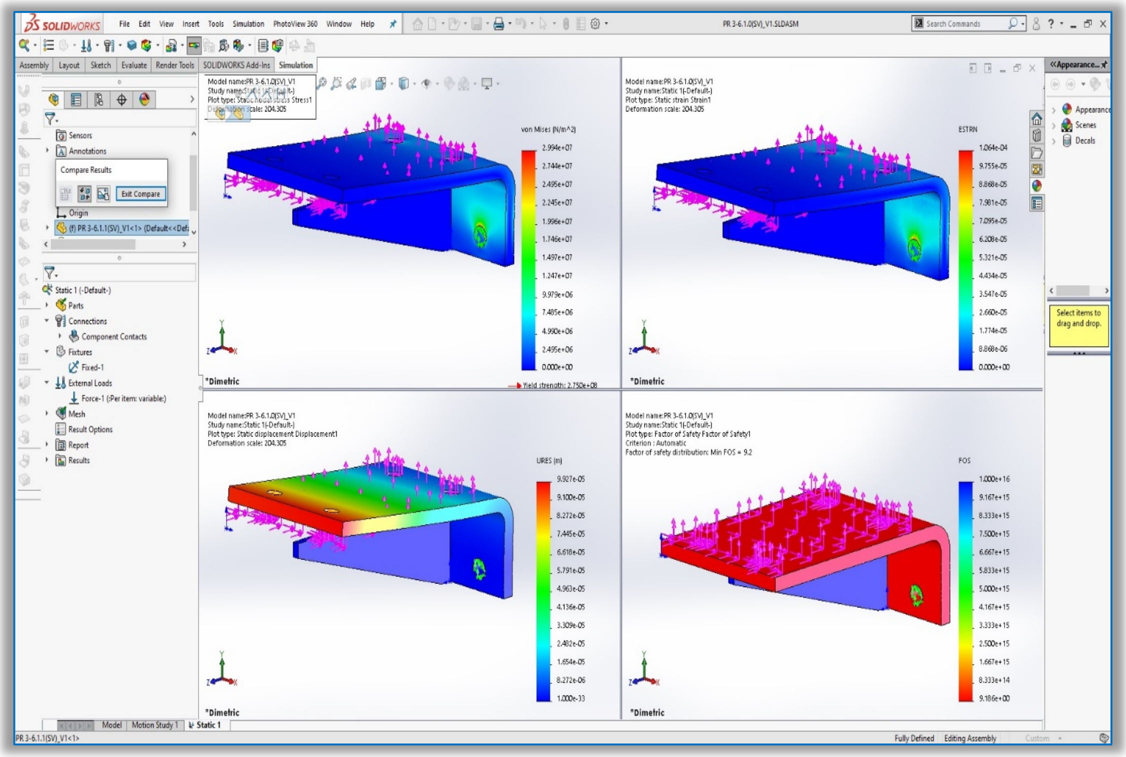

Figure 3 – Sequence during the comparison of the results of the V1 configuration appearing on the screen in the form of the Von Mises stress intensity distribution, the specific strain intensity distribution, the relative displacement field distribution and the power factor distribution

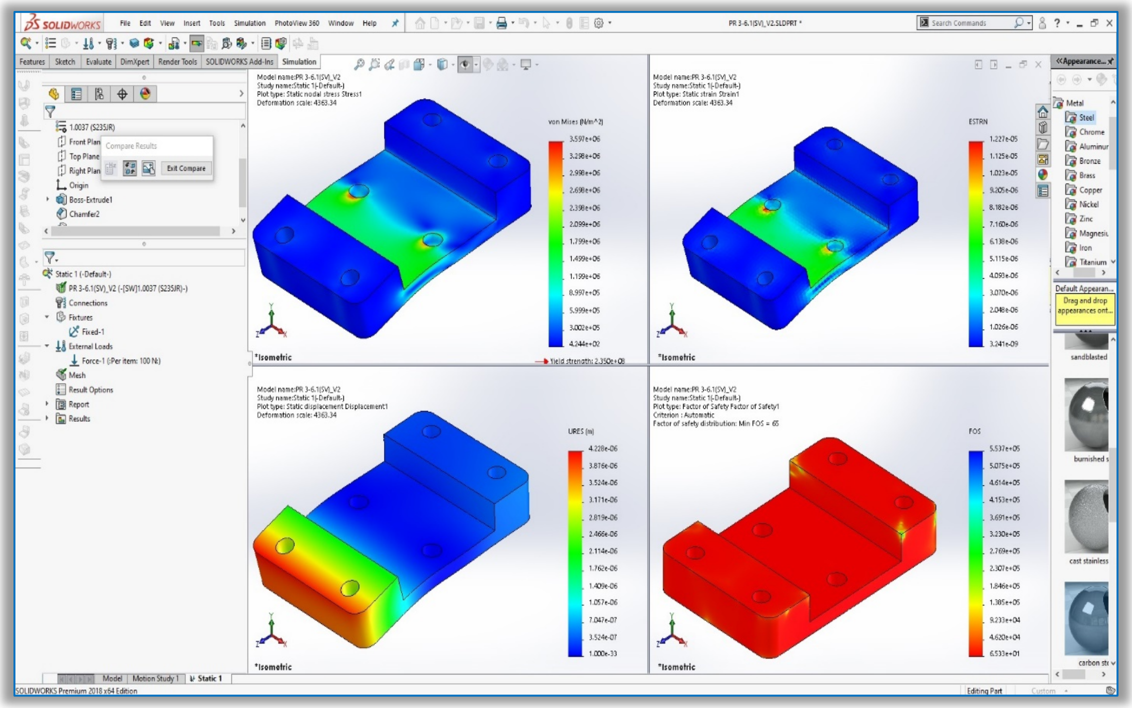

Figure 4 – Sequence during the comparison of the results of the V2 configuration appearing on the screen in the form of the Von Mises stress intensity distribution, the specific strain intensity distribution, the relative displacement field distribution and the power factor distribution

The results of the analysis based on technical–economic criteria in the choice of the constructive solution for the support of the direct current motor vibrator top MVE are presented in table 2.

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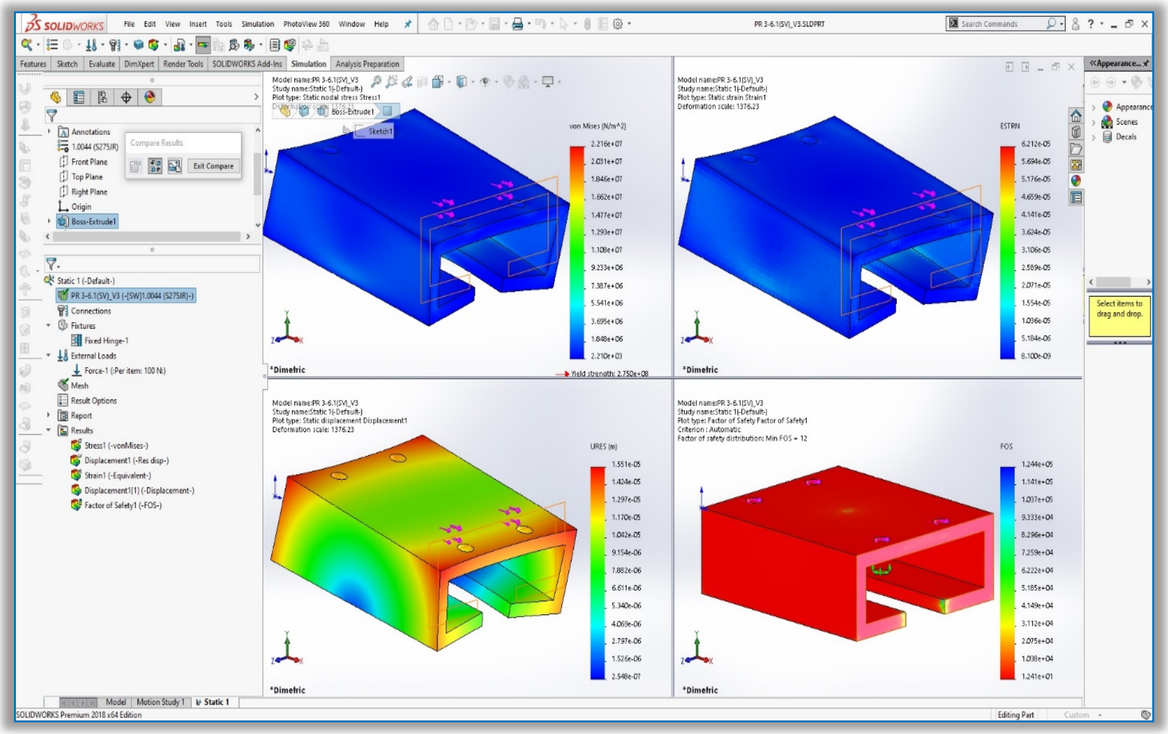
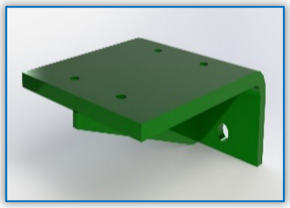
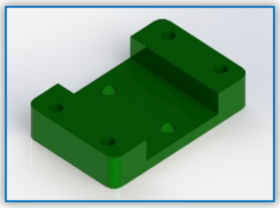
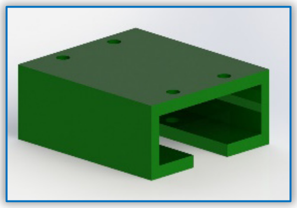


Figure 5 – Sequence during the comparison of the results of the V3 configuration appearing on the screen in the form of the Von Mises stress intensity distribution, the specific strain intensity distribution, the relative displacement field distribution and the power factor distribution

Table 2. The results of the analysis on technical–economic criteria

Name	Unit of measurement	Constructive values		
		V1	V2	V3
				
Safety factor	–	9,2	65	12
Estimated price (https://www.baduc.ro/)	lei / m^2	245,25	1880	459,77
The report: Price / Safety factor	–	27,25	28,92	38,34

The comparison of these indicators led to the choice of the optimal variant (configuration V1 was chosen), which has the lowest ratio Price / Safety Coefficient: 27.25).

The use of the constructive geometrical configuration V1 for the support in the mechanical component intended for mounting the direct current motovibrator on any tiller of any type of reversible three–body plow in operation or manufacture gives it properties with good mechanical resistance, high tenacity, very good hardness and a price/quality ratio based on the Win–Win (win–win) concept of the customer–supplier relationship.

The technical–economic indicator (material consumption per unit of safety coefficient) proposed for the analysis of the choice of the optimal variant, which is represented by the price ratio and the safety coefficient, contributes to the reduction of the design validation time and leads to the reduction of manufacturing costs.

4. CONCLUSIONS

- The results of the research allow useful recommendations for farmers who wish that the agricultural plows they have and which are intended for the basic work of the soil (turning the furrow, loosening, shredding and leveling the soil), can be equipped with innovative vibratory systems, so that they lead to a fuel economy, with reduced CO_2 emissions, ensuring the protection of the environment and biodiversity;

- In support of the company IRUM SA, for the continuation of the experimental demonstration research of the prototype of the innovative vibrating system, the members of the contract implementation team will come from the research organization–INMA Bucharest and the higher education institution–Technical University of Cluj–Napoca for the purpose of dimensioning optimum mechanical and electrical component subassemblies;
- The implementation of the activities of the prototype creation, experimentation and approval project will continue to be supported administratively, technically and financially by the company IRUM SA as the project coordinator, following as their main result "an innovative vibrating system intended for plows with small bodies in operation and in manufacturing", to be presented as a new product in its own portfolio.

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[11] *** https://www.solidworks.com/product/solidworks–simulation
[12] *** https://www.baduc.ro/

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