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ASPECTS OF COMPUTER-AID MODELING AND DESIGN

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ABSTRACT

The project aims at 3D modeling and computer-aided design of a modern row harrow with rotating active elements. Using the Autodesk Inventor platform, the main stages are completed: modeling of components, applying geometric constraints, and assembling the assembly. The parts are made parametrically, allowing rapid adaptation to various crops and row widths. The modular design facilitates the configuration of the machine according to needs. Optimization aims to reduce weight and simplify the structure, while maintaining high efficiency. By using CAD functions, a precise, flexible, and adaptable equipment is obtained for the field conditions.

KEYWORDS: 3D modeling, Autodesk Inventor, agricultural machinery, rotary tiller, modular design

1. INTRODUCTION

1.1 BACKGROUND TO THE NEED FOR MODERN ROW HARROWS

Modern agriculture is undergoing an accelerated transformation process, in which the requirements for high yield, environmental protection, and economic efficiency are becoming priorities. In this context, precision agricultural [2] machinery plays an essential role, ensuring high-quality work with minimal impact on natural resources. Row harrows, especially those with rotary knives, align with these requirements, offering solutions adapted to both large-scale farms and those specialized in precision agriculture.

1.2 THE ROLE OF COMPUTER-AIDED DESIGN IN THE DEVELOPMENT OF SMART HARROWS

Computer-aided design (CAD) has become an indispensable tool in the development process of modern agricultural machinery. The use of CAD platforms, such as Autodesk Inventor, allows engineers to create precise models [3],[4], visualize assemblies in the virtual phase, and optimize structures before actual production. Benefits include reduced development time, virtual testing of mechanical behavior, and rapid adaptation to varying market requirements.

1.3 PURPOSE OF THE PAPER

This paper aims to demonstrate how computer-aided design contributes decisively to the development of a modern row harrow, using rotary harrows as a constructive model. We will go through the key stages of the design in Autodesk Inventor, we will highlight the essential aspects of design optimization, and we will propose innovative solutions to improve the performance of the machine.

Through this approach, the paper aims to provide a clear perspective on the advantages of using computer-aided design in the field of agricultural engineering, in a technical and applied format, intended for engineers and specialists interested in innovation in agriculture.

2. DESCRIPTION OF THE CONSTRUCTIVE MODEL OF ROTARY HARROWS

2.1 GENERAL STRUCTURE OF THE MACHINE

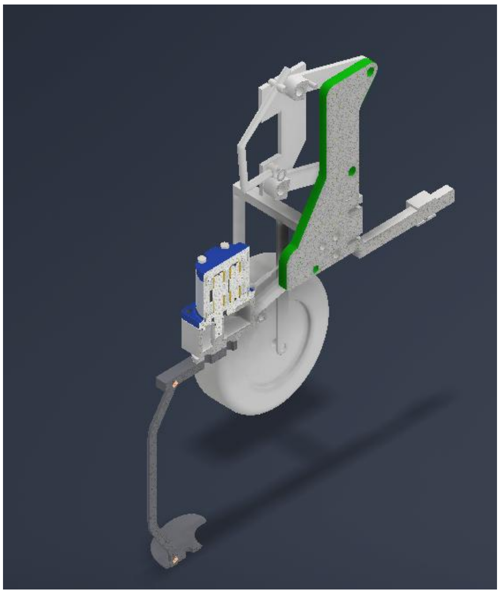

Figure 1. Rotary tiller section

The analyzed constructive model, the row harrow, is designed to perform precise harrowing work directly between plants, without affecting them. The general structure consists of a robust metal frame on which the active assemblies and guidance systems are mounted. The modular design allows for rapid adaptation to different crops and widths between rows FIG.1.

2.2 MAIN COMPONENTS AND THEIR OPERATION. THE BASE FRAME – PROVIDES STRUCTURAL SUPPORT AND ALLOWS ADJUSTMENT OF THE WORKING WIDTH.

Active organs – movable blades or discs, capable of automatically retracting when sensors detect the presence of the cultivated plant. The sensor system – optical or infrared type, which identifies the position of the plants and controls the movement of the active organs.

The drive mechanism, electronically controlled, ensures the rapid and precise movement of the blades between plants.

Together, these components work in sync to ensure harrowing between plants without the risk of damaging the crop, which represents a technological leap compared to classic harrows.

2.3 FEATURES COMPARED TO CLASSIC WEEDERS

Unlike traditional weeders, which perform the work mechanically, without distinguishing between the plant and the weed, the machine benefits from an intelligent detection and actuation system. This feature gives it:

- High precision in the work performed.
- Total protection of the cultivated plants.
- Adaptability to various crops, by simply recalibrating the sensors.

It is exactly the kind of model that arouses the interest of those passionate about innovation in precision agriculture, opening the way to new improvements and applications.

3. ASSISTED DESIGN STAGES IN AUTODESK INVENTOR

3.1 MODELING OF INDIVIDUAL COMPONENTS

The design process of the weeding machine in Autodesk Inventor begins with the three-dimensional modeling of the individual components [4],[5]. Each part is made using fundamental functions fundamentale precum such as Extrude, Revolve, Loft and Sweep that allow to generate solids with precise geometry. This is to ensure design flexibility, and the modeling is done parametrically, using commands such as Parameters to define variable dimensions and Equations to maintain proportional relations between elements. This approach allows for rapid adjustment of components according to the requirements of different crops.

3.2 APPLYING CONSTRAINTS AND RELATIONSHIPS

To ensure the dimensional and functional correctness of each component, geometric constraints are applied using commands such as Constraint, Mate, Flush, and Insert. These relationships control the position and orientation of each part, ensuring that the assembly is assembled correctly and operates in sync.

Additionally, using parametric constraints allows for the automation of design changes, so that adjusting a major dimension automatically updates all associated components FIG.2.

3.3 ASSEMBLING THE MASTER ASSEMBLY

After the individual components are modeled, they are integrated into a virtual assembly using the Assembly environment in Autodesk Inventor. The Place Component and Constrain commands are used to position and secure the parts in the correct relationship to each other.

In this step, interactions between active bodies, sensors, and the base frame are verified to prevent collisions and ensure smooth system operation [6][7].

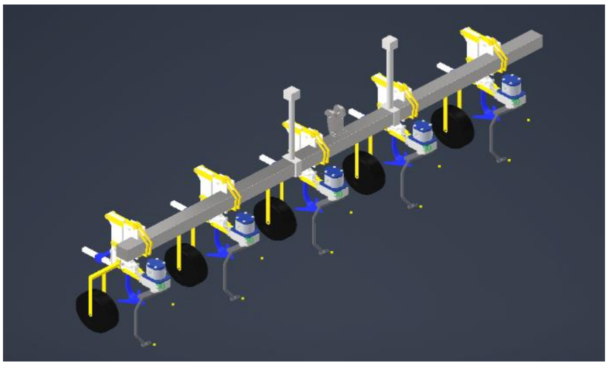

Figure 1. Overall picture

3.4 ASSEMBLY OPTIMIZATION AND VERIFICATION

Through integrated analysis functions, such as Interference Detection and Contact Set, the assembly is verified to identify possible interferences or geometric non-conformities. Design optimization involves the use of the iLogic module to automate configurations and Design Accelerators to select standardized elements (bearings, screws, axes).

3.5 PREPARATION OF TECHNICAL DOCUMENTATION

The last stage of the process involves the generation of manufacturing documentation, using the Drawing module. This allows the creation of 2D technical drawings, extracted directly from the 3D model, with automatic dimensions (Retrieve Dimensions) and parts tables (Parts List). Thus, the documentation delivered is precise, complete, and ready for production.

By rigorously applying these steps, the design of the In-Row Weeder machine becomes a controlled, efficient, and adaptable process, supporting the creation of a competitive product in the field of modern agriculture.

4. KINEMATIC AND STRUCTURAL ANALYSIS

4.1 SIMULATION OF THE MOVEMENT OF ACTIVE ELEMENTS

To validate the correct functioning of the In-Row Weeder machine, a kinematic analysis is performed using the Dynamic Simulation module in Autodesk Inventor. This simulation allows the evaluation of the trajectories of the active organs, verifying that they accurately avoid the cultivated plants during movement.

By applying Rotational Joint and Sliding Joint type movements, the opening and closing of the active blades are simulated, in correlation with the signals provided by the detection sensors. The results confirm the correct synchronization between detection and actuation, eliminating the risk of collision with the plants.

4.2 VIRTUAL TESTING OF COMPONENT STRENGTH

The structural analysis is performed using the Stress Analysis function, which allows the simulation of real-world load conditions by applying stresses equivalent to those encountered in the field. Estimated working forces, derived from typical operating scenarios in intensive agricultural environments, are applied to both the active components and the supporting frame. These forces are introduced in critical directions to simulate the actual stresses experienced during operation. The built-in calculation modules process these inputs to determine the distribution of internal stresses, strain, and potential points of deformation or failure across the entire assembly.

Following a comprehensive set of simulations under various loading conditions, the results indicate that the structural integrity of both the frame and the mobile components remains within acceptable safety thresholds. The materials and design choices ensure that all elements operate within their mechanical limits, with a safety factor that aligns with the harsh and repetitive demands of intensive agricultural use. This confirms the reliability and durability of the system under prolonged stress, minimizing the risk of structural failure and ensuring a long operational lifespan.

5. ESSENTIAL ASPECTS REGARDING DESIGN OPTIMIZATION

5.1 REDUCING THE WEIGHT OF THE ASSEMBLY

By using the Material Substitution function and the topology optimization modules, it was possible to reduce the total weight of the assembly without compromising strength. The selection of materials such as aluminum alloys for the secondary frame and light steel for the active parts contributes to reducing mass and increasing energy efficiency.

5.2 INCREASING ROW WORK PRECISION

Work precision is optimized through advanced sensor calibration and the use of strict parametric constraints in the virtual assembly. Also, the integration of fine-tuning mechanisms allows for rapid adjustment of the working width and tillage depth depending on the specific crop.

5.3 ADAPTABILITY TO DIFFERENT CROPS AND SOIL TYPES

The modular design allows for easy adaptation of the machine to different row spacings by simply replacing or repositioning the active components. The control system of the moving parts is programmable, ensuring compatibility with a wide variety of crops and soil conditions.

These optimizations ensure not only improved field performance but also reduced operating costs and extended machine life.

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