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MODELING AND STRUCTURAL ANALYSIS OF AGRICULTURE WEEDER USING DIFFERENT MATERIALS

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ABSTRACT

Vegetable production faces a significant challenge in weed control, consuming valuable time and resources. Manual weeding, with its associated labor costs, time constraints, and monotony, proves inconvenient. To address this issue, a prototype mechanical weeding actuation system has been devised and constructed. This innovative actuator is designed to mechanize the control of intra-row weed plants. It incorporates a belt drive system, powered by an integrated engine, and a rotating tine weeding mechanism, driven by engine power. Tackling one of the most time-consuming tasks in agriculture, this mechanical approach presents a compelling alternative to manual labor. In agriculture, three primary methods are employed for weed control: mechanical, chemical, and biological. Once farmers recognize the benefits, they readily embrace mechanical weed control. Beyond simply eliminating weeds between crop rows, this method also maintains loose soil surfaces, facilitating improved soil aeration and water absorption capacity. Various types of mechanical weeders have been developed to enhance efficiency. Human-operated weeders relying on muscle power have limitations in terms of extended operation. The conventional method of hand weeding is time-intensive. To explore the potential for mechanization in the weeding process, a power-operated single-row active weeder will be designed and developed.

Introduction

The plant thrives in well-drained soil with moderate rainfall, yet it exhibits adaptability to wet conditions. Tapioca roots are sensitive to freezing temperatures, and optimal growth is observed in areas with ample sunlight. Remarkably drought-resistant, this crop can flourish even in extremely arid regions. The subterranean nature of its edible parts shields tapioca from pests, insects, and other animals. Cultivated primarily for its tubers, which boast a significant starch concentration, tapioca stands out as a hardy and resilient crop.

Figure 1manual weeder

These tubers serve as a global carbohydrate source and are utilized in the production of various medicinal products. Particularly vital to the economies of developing nations like India and South Africa, this crop thrives in low-fertility soils, exhibiting resilience in arid climates with low moisture content. Tapioca holds significance as a staple food in many regions worldwide and serves as a crucial livestock food supplement. Additionally, it contributes to the production of bio fuels such as alcohol blended fuels and biodiesel. In India, tapioca cultivation spans thirteen states, with the southern states playing a pivotal role due to their favorable climate. Weeds, classified as undesirable plants, pose a threat to farmland productivity. These small herbs, competing for nutrients with main crops, impede crop growth. Controlling the growth of these unwanted plants becomes imperative for optimal farmland productivity. Weeds, essentially plants growing in undesired locations and times, negatively impact agricultural welfare by reducing the utilization of farmlands and water resources. It is important to note that while all weed plants are undesirable, not all undesirable plants qualify as weeds. Managing these plants is crucial to safeguard agricultural productivity and resource utilization.

Evolution of weed cutter machine

A weed is essentially any plant that grows in an unsuitable location and time, causing more harm than benefit. The presence of weeds consumes a disproportionate amount of a farmer's time, acting as a hindrance to overall development. Weeding stands out as a critical farm operation within the crop production system, representing a significant but labor-intensive component. Approximately 25% of the total labor requirement (ranging from 900 to 1200 man-hours per hectare) during a cultivation season is attributed to weeding. The labor needed for weeding is influenced by factors such as the weed flora, intensity, timing of weeding, and worker efficiency. Any delay or negligence in the weeding process can lead to a substantial reduction in crop yield, ranging from 30% to 60%. In India, an annual expenditure of about 4.2 billion rupees is incurred to control weeds in the production of major crops. Recognizing the impact of weeds on agricultural productivity, efficient and timely weeding becomes crucial for maximizing crop yields and economic returns.

Mechanism of weeder

The components have been assembled according to the principles of our project. When the vehicle is set in motion forward, its blades enter the soil between rows of crops. To initiate the process, the engine is manually started. The engine's power is then transmitted from the engine shaft to the main shaft, where the cutter blades are mounted, through a belt and pulley arrangement. This action causes the cutter to rotate within the agricultural crop, effectively eliminating unwanted weeds. This mechanized approach significantly reduces the need for extensive manual labor, expedites the weed removal process, and is cost-effective and easy to operate. Following the mechanized weed removal, only one laborer is required to address any remaining weeds in the proximity of the plants. This streamlined process not only reduces labor efforts but also ensures efficient and timely weed removal, contributing to enhanced agricultural productivity.

Working of weeder

The components have been meticulously assembled in accordance with the principles of our project. As the vehicle advances, its blades penetrate the soil between rows of crops. The engine is initiated manually, and its power is seamlessly transferred from the engine shaft to the main shaft, housing the cutter blades, via a well-designed belt and pulley system. This mechanism sets the cutter in motion, effectively rotating within the agricultural crop and eliminating unwanted weeds. This streamlined process not only significantly reduces the need for extensive manual labor but also expedites weed removal, making it a cost-effective and easily operable solution. With this approach, a substantial amount of labor effort is minimized, and a greater number of weeds can be efficiently removed within a shorter timeframe. Subsequently, only one laborer is required to address any remaining weeds in the vicinity of the plants. Overall, this innovative system optimizes efficiency, reduces labor requirements, and simplifies the weed removal process in agricultural settings.

Advantages

- It poses no harm to crops.
- It minimizes the time required for weeding.
- The equipment is lightweight and easily portable.
- The materials used are readily available and can be easily acquired.
- The weeder is cost-effective and budget-friendly.
- It contributes to a reduction in labor costs on tapioca farms.

Literature review

1. "Exploring Novel Frontiers in Agricultural Weeding Robots: Challenges and Prospects" (2023): This comprehensive review delves into the contemporary landscape of robotic weeders, scrutinizing their design, control mechanisms, and overall performance. It sheds light on pivotal challenges such as weed identification, soil-robot interaction, and cost-effectiveness, while also charting a course for future research avenues in the realm of robotic weed control.

2. "Innovative Design, Analysis, and Optimization of Motorized Agricultural Weeding Tools" (2023): This paper conducts a thorough examination of existing motorized weeding tools and introduces a pioneering design with enhanced features encompassing maneuverability, versatility, and user-friendliness. Leveraging computer-aided design and finite element analysis for optimization, the study presents compelling

field test results that validate the effectiveness of the proposed design.

3. "Comparative Analysis of Weeders in Agriculture: A 2022 Perspective": This insightful review undertakes a comparative assessment of diverse weeders, encompassing manual, mechanical, thermal, and chemical variants. It scrutinizes their efficacy, cost implications, environmental footprint, and user-friendliness, with a prominent focus on advocating sustainable and selective weed control practices.

4. "Recent Strides in Designing Cost-Effective Agricultural Weeders: A 2022 Overview": This review zeroes in on budget-friendly weeding technologies tailored for small-scale farmers. It conducts a comprehensive analysis of various designs, fabrication materials, and performance attributes exhibited by cost-effective weeders developed in recent times.

5. "Advancements in Weed Detection and Control Techniques for Modern Agriculture: A 2022 Review": This review navigates the landscape of modern agriculture, examining how sensor technology and image processing have propelled intelligent weed detection and control. It explores diverse weed detection methodologies and assesses their potential integration with robotic weeding systems.

6. "Advancements in Machine Vision and Deep Learning for Precision Weed Identification in Agriculture: A 2023 Exploration": This review delves into the realm of computer vision and deep learning techniques, showcasing their role in achieving precise and real-time weed identification in agricultural fields. It provides an in-depth discussion on various sensor technologies and algorithms employed for weed detection across diverse crops and field conditions.

7. "Biomimetic Robotics for Sustainable Weed Control: Design, Control, and Field Performance Analysis": Presented in 2022, this paper introduces a robot inspired by natural weed-pulling mechanisms. It thoroughly analyzes the robot's design, control system, and its performance in field tests, emphasizing the potential of biomimetic robots in achieving precise and environmentally friendly weed control.

8. "Non-Herbicidal Weed Control Strategies for Organic Farming: A 2023 Review": This review critically assesses alternative weed control methods such as cover crops, mulching, and biological control agents. It evaluates their efficacy in the context of organic agriculture, emphasizing their potential to reduce herbicide use and minimize environmental impact.

9. "Exploring the Socioeconomic Impact of Weed Control Technologies: A 2022 Review": This comprehensive review scrutinizes the economic and social implications of diverse weed control methods, with a particular focus on their effects on small-scale farmers and rural communities. It underscores the importance of considering factors beyond weed control effectiveness, including affordability, accessibility, and gender equity.

Overview of project

Weed control is a labor-intensive task in agriculture, known to consume significant time. Studies indicate that weeds can lead to a 40% reduction in crop productivity. Various approaches, such as manual, chemical, and mechanical methods, are employed to manage weeds in farmlands. Among these methods, the mechanical approach is favored over manual and chemical alternatives due to its inherent advantages. This preference is rooted in the efficiency and benefits associated with mechanical weed control methods.

Problem identification & Objectives

In a tapioca farm, the presence of unwanted weed plants poses a challenge, and conventional weeding equipment proves laborious for effective control. There is a demand for a specialized design of a weeder tailored to tapioca farms that minimizes damage to the crop.

- ➢ Cost Efficiency: Minimize expenses linked to weed control on tapioca farmlands.
- ➢ Time Optimization: Streamline and reduce the time invested in weeding activities.
- ➢ Labor Reduction: Engineer equipment that diminishes human exertion in tapioca production, consequently lessening the demand for labor.
- ➢ Precision in Weed Removal: Develop mechanical equipment capable of effectively

eliminating weed plants in farms without causing harm to the crop, especially the tubers.

- Labor Streamlining: Decrease the need for additional labor during the weeding process.
- Affordable Implementation: Implement the equipment at a cost-effective and accessible price point.
- Comprehensive Soil Health Enhancement: Design a weeder for tapioca farms that not only eradicates unwanted plants but also promotes soil aeration, increasing porosity. This enhancement aids water percolation, ensuring optimal moisture content for crop growth.

Methodology

The project begins with a literature review and concludes with a result evaluation. The diagram depicts the design and fabrication project methodology.

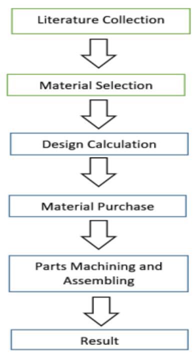


Figure 2 Methodology of project

Materials used

The equipment utilizes a standard bicycle wheel readily available in the market. The choice of a bicycle wheel is deliberate, considering its large diameter and lightweight nature. The decision to opt for a large-diameter wheel is driven by the fact that it requires minimal effort from the worker to operate the equipment. Additionally, the inherent lightness of the wheel contributes to an overall reduction in the machine's weight. The wheel is crafted from stainless steel, chosen for its weightlessness and ample strength to withstand stresses and loads during operation. Stainless steel, along with carbon fiber-reinforced plastic, is corrosion-resistant, making it ideal for use in farm lands. Given the high moisture content prevalent in farm environments, susceptibility to rust formation is a concern. However, the materials chosen for the wheel ensure resilience in the face of moisture, maintaining the equipment's durability even when in direct contact with the soil surface.

- STRUCTURAL STEEL
- CFRP

Validation of weeder tool

The calculation stage is undoubtedly pivotal, occurring post data acquisition. At this juncture, the essential torque magnitude necessary for executing the desired weeding operation is computed. The calculation involves considering several assumptions and factors that prove pertinent under diverse field conditions during operation.

Determination of required motor torque
Considerations:

1. Depth of tool = 6.739 mm

2. Contact area of a blade = 68.79 mm^2 3.

Soil resistance = 0.5

Now, from the value of contact area of a single blade, the total area of contact for all blades is given by,

Total contact area = 4 x 68.79 mm^2 = 275.16 mm^2

Total force required is calculated by using the following equation.

Force required = total blade contact area x soil resistance

Now, putting the values in the above equation we get,

F = 2.7516 x 0.5 = 1.375 kg f

F = 1.375 x 9.98 = 13.722 N

Designing of the model

The weeding tool presented comprises two key components: the blade and the mounting rotor. The design and analysis of the blade have been successfully concluded. While the rotor is not subjected to analysis due to minimal or no direct contact with the soil in typical operating conditions, it's essential to note that the blade undergoes continuous impact and wear during the weeding operation.

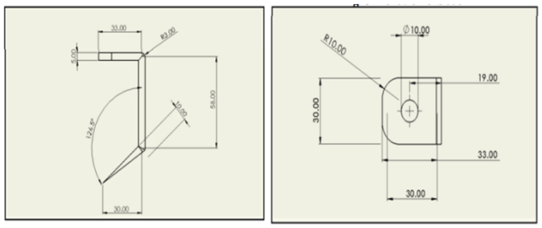


Figure 3 front views and top view of weeder blade

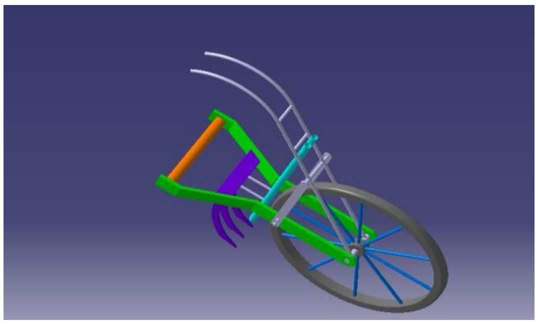


Figure 4 weeder machine products

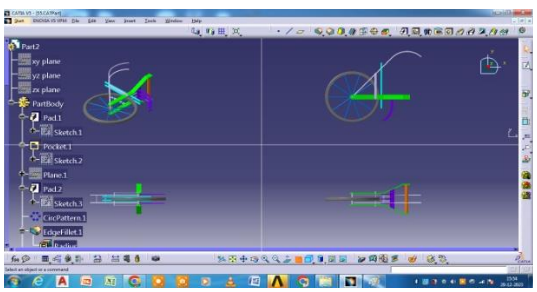


Figure 5 Multi sectional view of weeder machine

The basic steps involved in FEA

In mathematical terms, the structure under analysis is divided into a mesh of finite-sized elements, each having a simple shape. Within each element, the variation of displacement is assumed to be defined by straightforward polynomial shape functions and nodal displacements. Equations representing strains and stresses are formulated based on the unknown nodal displacements. These equations of equilibrium are then organized into a matrix form that can be easily programmed and solved on a computer. After incorporating the appropriate boundary conditions, the nodal displacements are determined by solving the matrix stiffness equation. With the known nodal displacements, it becomes possible to calculate element stresses and strains.

Basic Steps in FEA

- Domain discretization
- Imposition of boundary conditions
- Compilation of system equations
- Resolution of system equations
- Post-processing of results

Static structural analysis

Static structural analysis computes stresses, shear stresses, displacements, strains, and forces within structures subjected to loads that don't induce significant inertia and damping effects. This analysis assumes steady loading and response conditions, where the loads and the structure's response change slowly over time. The ANSYS WORKBENCH solver facilitates the execution of a static structural load. Various types of loading can be applied in a static analysis.

Results and discussion

This analysis aims to determine structural parameters, including stresses, strain, and deformation, in farm tiller equipment using CFRP. The observed results are illustrated in the figures below.

Mesh

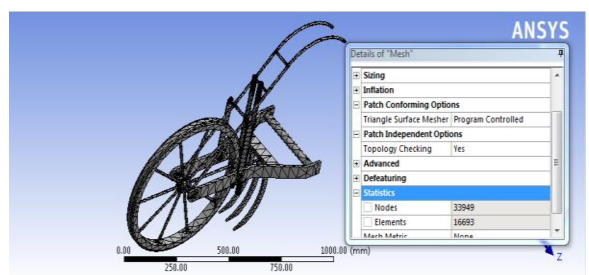


Figure 6 meshing

Nodes: 33949 and Elements: 16693

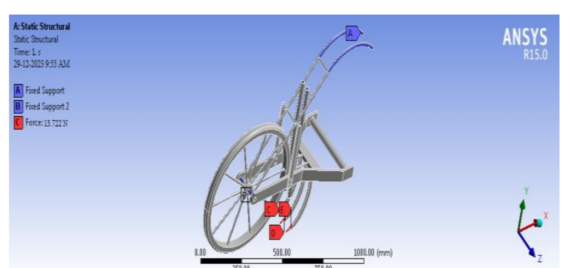


Figure 7 Boundary conditions

Von-misses stress

Presented here are the conclusive results for von Mises stress in both structural steel and CFRP. The maximum von Mises stress is recorded at 122.55 MPa for the structural steel material, while the advanced CFRP material demonstrates a more favorable lower stress value of 85.785 MPa.

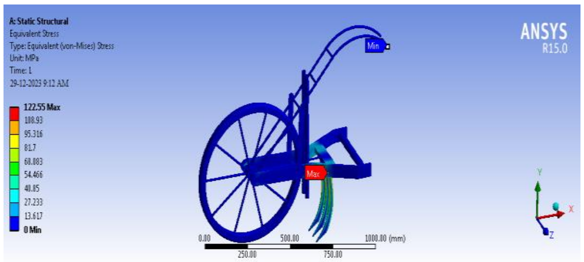


Figure 8 von-misses stress on structural steel

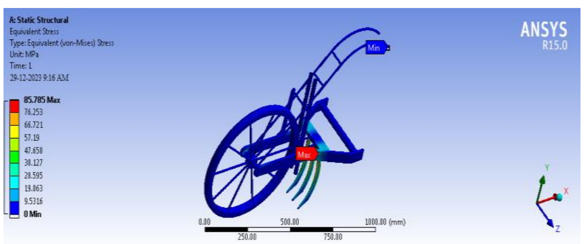


Figure 9 von-misses stress on CFRP

Total deformation

From the analysis standpoint, the ultimate total deformation results for both structural steel and CFRP are obtained. The structural steel material exhibits a maximum total deformation value of 2.89 mm, while the advanced CFRP material showcases a more advantageous lower value of 2.02 mm.

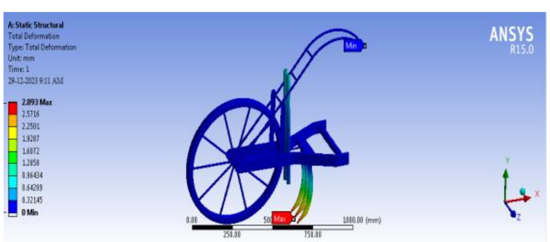


Figure 10 total deformations on structural steel

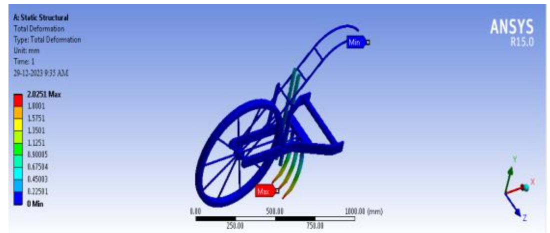


Figure 11 total deformations on CFRP

Equivalent elastic strain

From an analytical standpoint, we have arrived at the ultimate strain results for both structural steel and CFRP. The structural steel material exhibits a maximum total deformation value of 0.00061, while the advanced CFRP material demonstrates a more advantageous lower value of 0.00042.

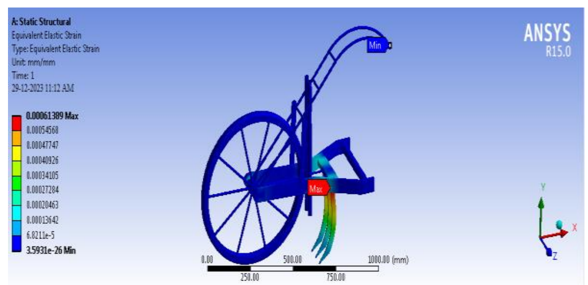


Figure 12 strain on structural steel

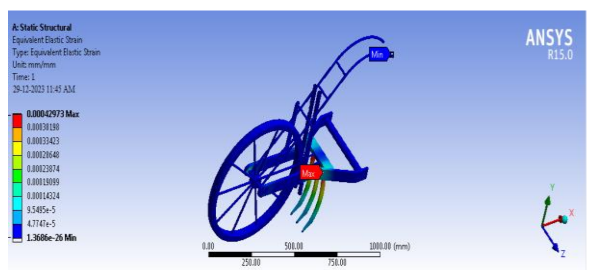


Figure 12 strain on CFRP

Shear stress

The conclusive shear stress results for both structural steel and CFRP are presented here. The structural steel material records a maximum shear stress value of 23.99 MPa, while the advanced CFRP material shows a more favorable lower shear stress value of 16.79 MPa.

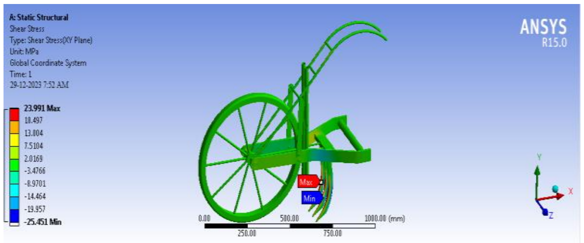


Figure 13 Shear stress on structural steel

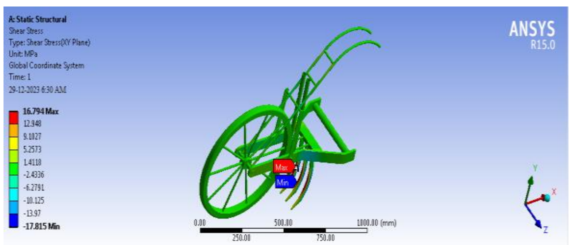
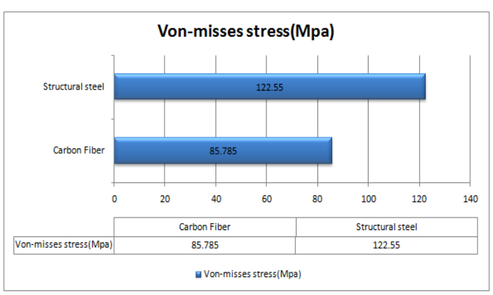


Figure 14 Shear stress on CFRP

Von misses stress graph

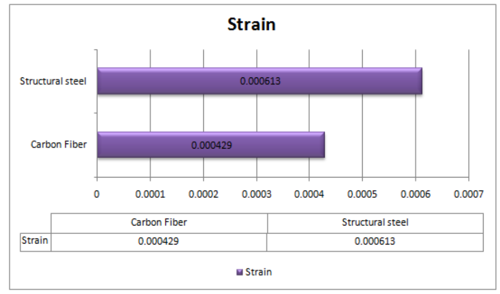
The graph below illustrates the variation of von Misses stress in two different materials: structural steel and CFRP. The simulations reveal the highest von Misses stress value for structural steel, reaching 122.55 MPa, while CFRP exhibits a comparatively lower stress value of 85.78 MPa along with lesser deformation.



Graph 1 maximum von misses stresses

Strain graph

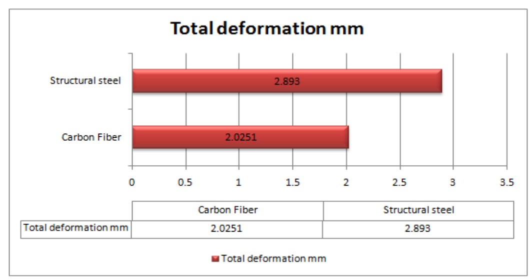
The graph below depicts the variation of strain in three different materials: Structural steel and CFRP. In these simulations, Structural steel exhibits the highest strain value at 0.000613, while CFRP demonstrates a comparatively lower strain value of 0.000429 along with lesser deformation.



Graph 2 equivalent strains acting on 2 materials

Total deformation graph

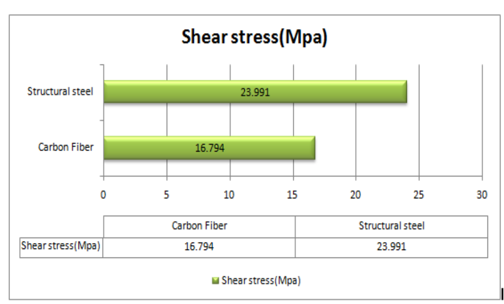
The graph below illustrates the variation in total deformations across three different materials: Structural steel and CFRP. In these simulations, Structural steel exhibits the highest total deformation value at 2.893 mm, while CFRP demonstrates a comparatively lower deformation value of 2.025 mm.



Graph 3total deformation acting on 2 materials

Shear stress graph

The graph below illustrates the variation of von Mises stress across three different materials: structural steel and CFRP. In these simulations, structural steel exhibits the highest shear stress value at 23.991 MPa, while CFRP demonstrates a comparatively lower shear stress value of 16.794 MPa.



Graph 4 shear stress acting on 2 materials

Conclusion

The weeder equipment tool is designed using CATIA Software, and the model is subsequently imported into ANSYS Software for structural analysis. This analysis aims to assess the material quality, considering both structural steel and advanced CFRP. By evaluating von Misses stresses, shear stresses, total deformation, and strain for both materials, a comparative analysis is conducted. The results, represented graphically, indicate that CFRP material exhibits lower stresses, deformations, and strain values than structural steel, as evidenced by their respective maximum values. Based on these findings, it is concluded that CFRP is the more suitable material for weeder equipment.

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