

## DESIGN OF A HANDLING SUPPORT DEVICE FOR A BACKPACK GRASS CUTTER USING SOLIDWORKS

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**Abstract.** The lawn mower is widely used due to its flexibility, but its use often causes ergonomic problems due to the load directly supported by the operator's body. Static loads and vibrations during operation have the potential to cause fatigue and reduce work comfort. This study proposes the design of a handling support device as a solution to help support the machine load and increase stability during use. The purpose of this study is to design and evaluate the structural strength of the lawn mower handling support device. The methods used include designing a three-dimensional model using SolidWorks and structural strength analysis using Finite Element Analysis (FEA) simulation with ASTM A36 Steel material and a load of 200 N. The simulation results show a maximum displacement of 1 mm and a minimum safety factor of 2 based on the software results, but the maximum stress reaches 362 MPa in critical areas so that design optimization is needed. This study shows that FEA simulation is effective for evaluating and refining designs before the manufacturing stage.

**Keywords:** A36; Finite Element Analysis; Grass Cutter; Handling Support Device; SolidWorks.

### 1. INTRODUCTION

The hand-held lawn mower is a piece of equipment widely used in gardening, plantation, and green space maintenance. This machine is chosen for its high mobility and ability to reach areas difficult for conventional lawn mowers. However, in practice, hand-held lawn mowers often present ergonomic issues, particularly regarding operator comfort and safety during prolonged operation. (Mujiono et al., 2018).

One of the main problems in using a hand-held lawn mower is the load supported directly by the operator's body. (Setiawan, 2024) Unergonomic working positions and machine vibrations can cause muscle fatigue, back and shoulder pain, and increase the risk of musculoskeletal injuries. These conditions not only impact operator health but can also reduce work effectiveness and productivity. (Bayu Satriyo et al., 2023).

Various attempts have been made to improve the comfort of using hand-held lawn mowers, such as the use of support straps and simple pads. However, these solutions still have limitations in distributing the load evenly and reducing vibrations transmitted to the operator's body. (Nota et al., 2025) Therefore, additional support equipment is needed that can hold and stabilize the position of the machine so that the load and force acting on the operator's body can be reduced.

Based on these issues, this study proposes the design of a handling support device for a hand-held lawn mower, aimed at improving ergonomics and operator comfort. The handling support device is designed as a support system that can help support the machine's load, reduce vibration, and provide a more stable working position during operation. (Widiyanto et al., 2021).

The design process for the handling restraint tool is carried out using SolidWorks software to produce accurate and easily evaluated three-dimensional models before the manufacturing

stage. Using SolidWorks allows designers to visualize the tool's shape, dimensions, and configuration in detail, reducing the potential for design errors.(Yusuf et al., 2019).

The objective of this research is to design a handling retainer for a hand-held lawn mower that is ergonomic, safe, and easy to use. Furthermore, this research aims to produce a tool design that can improve operator comfort and potentially increase work efficiency in operating a hand-held lawn mower.

## **2. LITERATURE REVIEW**

### *2.1 Hand-held Lawn Mower*

A hand-held lawn mower is a mechanical device used for maintaining vegetation in open areas, such as parks, plantations, and agricultural land. These machines generally use a fuel-powered or electric motor mounted on a carrying frame and are manually operated by the operator. The primary advantage of a hand-held lawn mower lies in its mobility and flexibility, especially for areas with uneven contours. However, the engine load and vibrations generated during operation can cause discomfort and fatigue for the operator.(Surjadi et al., 2022).

### *2.2 Ergonomics and Operator Workload*

Ergonomics is the study of the compatibility between humans, equipment, and the work environment with the aim of improving comfort, safety, and productivity. When operating a hand-held lawn mower, ergonomics are crucial because the operator must support the machine's weight for relatively long periods of time. Unergonomic working positions and uneven load distribution can lead to musculoskeletal disorders, such as back, shoulder, and arm pain. Therefore, designing assistive devices that can reduce the workload and improve operator posture is essential.(Hanafie et al., 2018).

### *2.3 Handling Aids and Load Restraint Systems*

Handling aids are designed to assist the operator in moving, supporting, or stabilizing loads during work activities. In the context of a hand-held lawn mower(Razali et al., 2024)Handling aids serve to distribute the machine's load more evenly and reduce the force acting directly on the operator's body. Using proper handling aids can increase comfort, reduce fatigue, and lower the risk of injury from prolonged, repetitive use of the tool.(Widianto et al., 2021).

### *2.4 Product Design Using SolidWorks*

SolidWorks is a computer-aided design (CAD) software widely used in engineering product design. This software allows for the creation of three-dimensional models, dimensional analysis, and initial design evaluation before manufacturing.(Pranata et al., 2025)In designing handling tools, SolidWorks is used to model the tool's shape and configuration in detail, resulting in a more precise and easier-to-develop design. Using SolidWorks also helps reduce design errors and accelerate the product development process.(Diinil Mustaqiem, 2020).

## **3. RESEARCH METHODS**

This research uses an engineering product design approach focused on improving the ergonomics and comfort of hand-held lawn mower operators. The research method is systematically structured, starting with user needs identification, tool design, and structural strength analysis using Finite Element Analysis (FEA) simulation.

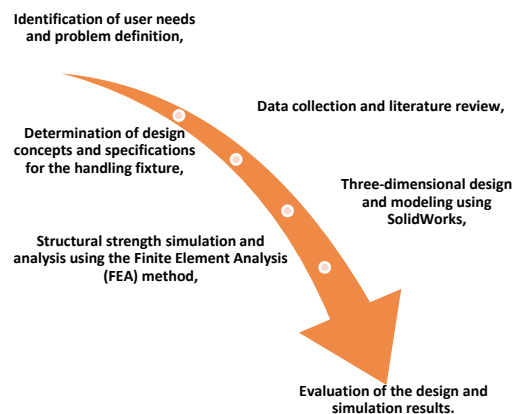


Figure 1. Flow chart

These stages are carried out sequentially to ensure that the resulting design is not only ergonomic, but also has adequate structural strength.

#### 1. Identifying User Problems and Needs

Problem identification was conducted through observations of the use of hand-held lawn mowers and a literature review related to ergonomics and operator workload. The main issues identified included uneven machine load distribution, unergonomic working positions, and potential fatigue due to static loads and vibration. Based on these problems, user needs were formulated, including a retaining device that can help support the machine load, increase stability during operation, and is safe and easy to use.

#### 2. Determination of Specifications and Design Concepts

The design specifications for the handling support are determined based on user needs and the technical limitations of the handheld lawn mower. These specifications include the tool's dimensions, load-bearing system, mounting mechanism, and material selection. The design concept focuses on ease of installation, the ability to distribute the load more evenly, and compatibility with the machine being used.

#### 3. Designing Using SolidWorks

The design of the handling restraint tool was performed using SolidWorks software by creating a virtual three-dimensional model of each component and assembly. This modeling was used to visualize the tool's shape, ensure dimensional conformity, and evaluate the component layout before further analysis.

#### 4. Simulation and Analysis Using Finite Element Analysis (FEA)

After the three-dimensional design was completed, a structural strength simulation was performed using the Finite Element Analysis (FEA) method available in SolidWorks Simulation. This simulation aimed to analyze the structural response of the handling equipment to working loads representing the machine's weight and the forces acting during operation.

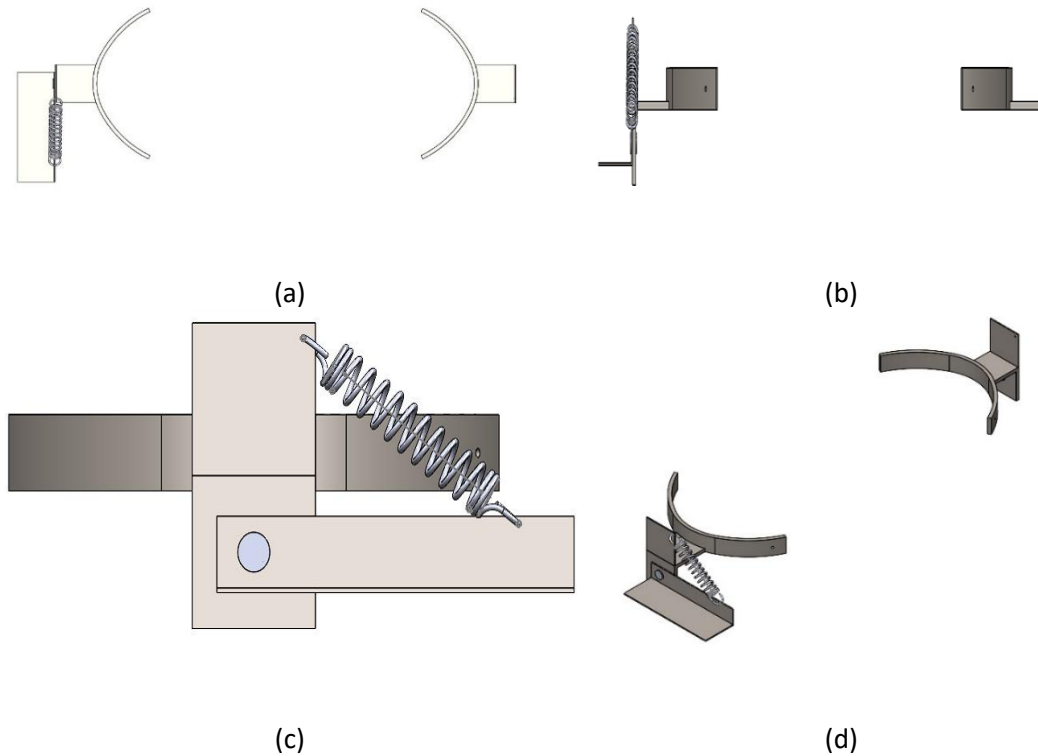
The parameters analyzed include stress distribution (von Mises stress), maximum deformation, and safety factor. Loads and boundary conditions are determined based on assumptions about actual operating conditions. Simulation results are used to assess whether the tool design can safely withstand the working loads without experiencing structural failure.

#### 5. Design Evaluation

The design evaluation was conducted based on FEA modeling and simulation results, comparing the maximum stress values to the strength of the materials used. Furthermore, the evaluation also considered ergonomics and ease of use of the tool. If necessary, the design was refined based on the evaluation results to achieve a safe and functional final design.

#### 4. RESULTS AND DISCUSSION

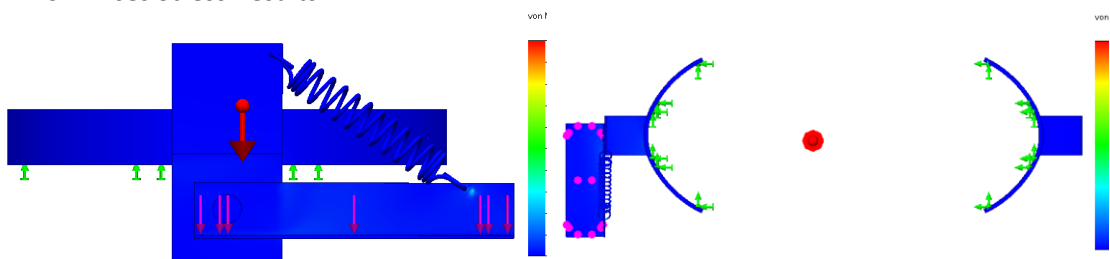
##### 4.1 Design, Materials, and Loading Conditions



**Figure 2.** Design of Handling Tool for Carrying Lawn Mower (a) Top View (b) Front View (c) Side View and (d) Isometric View

Finite Element Analysis (FEA) simulation was carried out on the design of a hand-held lawn mower handling retainer modeled using SolidWorks. **Figure 2.** The main component material in the simulation is set as ASTM A36 Steel. The working load is given at 200 N which represents the working force/load received by the restraint system during operation. Boundary conditions are applied to the support/fixation area according to the tool mounting point on the frame, while a force of 200 N is applied to the point/area receiving the main load (indicated by the force vector in the simulation model).

##### 4.2 von Mises Stress Results



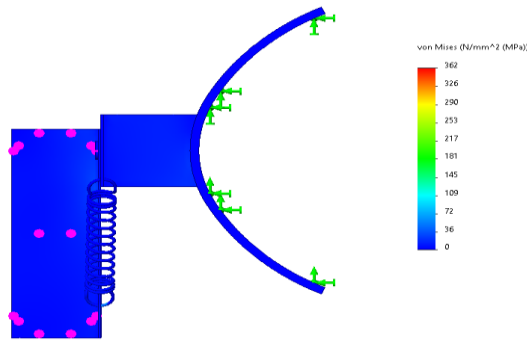


Figure 3. Stress

Voltage simulation results **Figure 3** shows the maximum von Mises stress scale of:

$$\sigma_{vm\max} = 362 \text{ Mpa}$$

Von Mises' formula (theoretical basis)

For the main voltage:  $\sigma_1, \sigma_2, \sigma_3$

$$\sigma_{vm} = \frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}$$

In SolidWorks Simulation,  $\sigma_{vm}$  calculated automatically for each element, and design evaluation uses critical values. The highest stresses generally occur at connection/constraint areas or areas of geometric change (sharp corners, bolt holes, cross-section transitions). This aligns with the phenomenon of stress concentration in bracket/handle components.  $\sigma_{vm\max}$

#### 4.3 Displacement Results (URES)

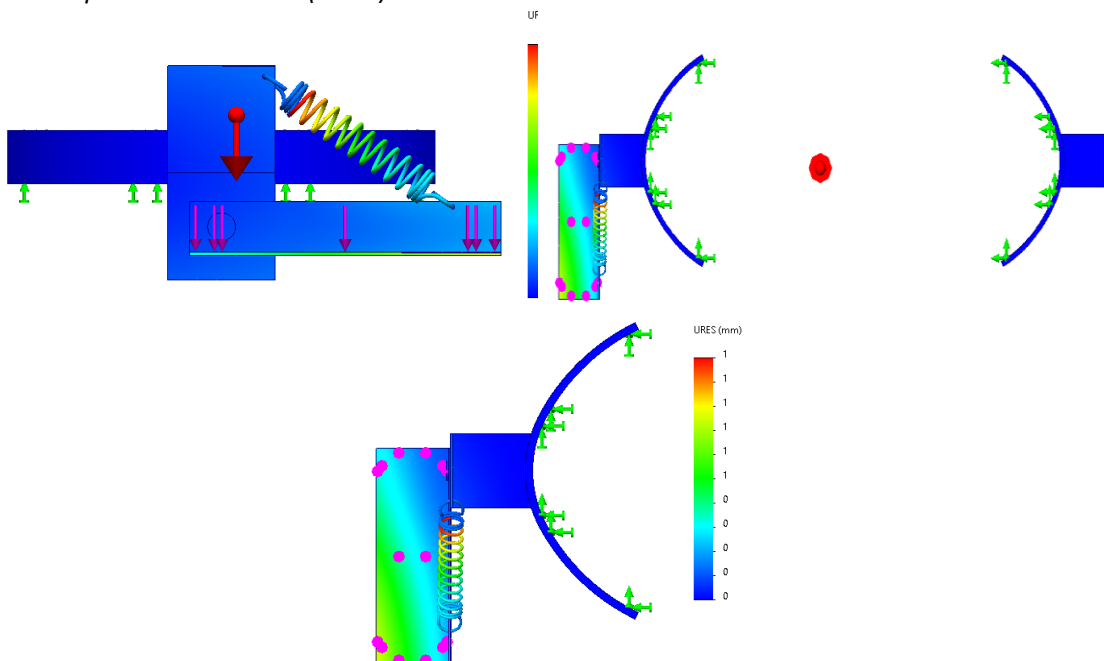


Figure 4. Displacement

Displacement simulation results **Figure 4** shows the maximum displacement:

$$\delta_{\max} = 1 \text{ mm}$$

Maximum displacement generally occurs at the point furthest from the support point. A value of 1 mm is considered small for a retaining/handling component as long as it doesn't interfere with operator clearance and comfort.

#### 4.4 Factor of Safety (FOS) Results

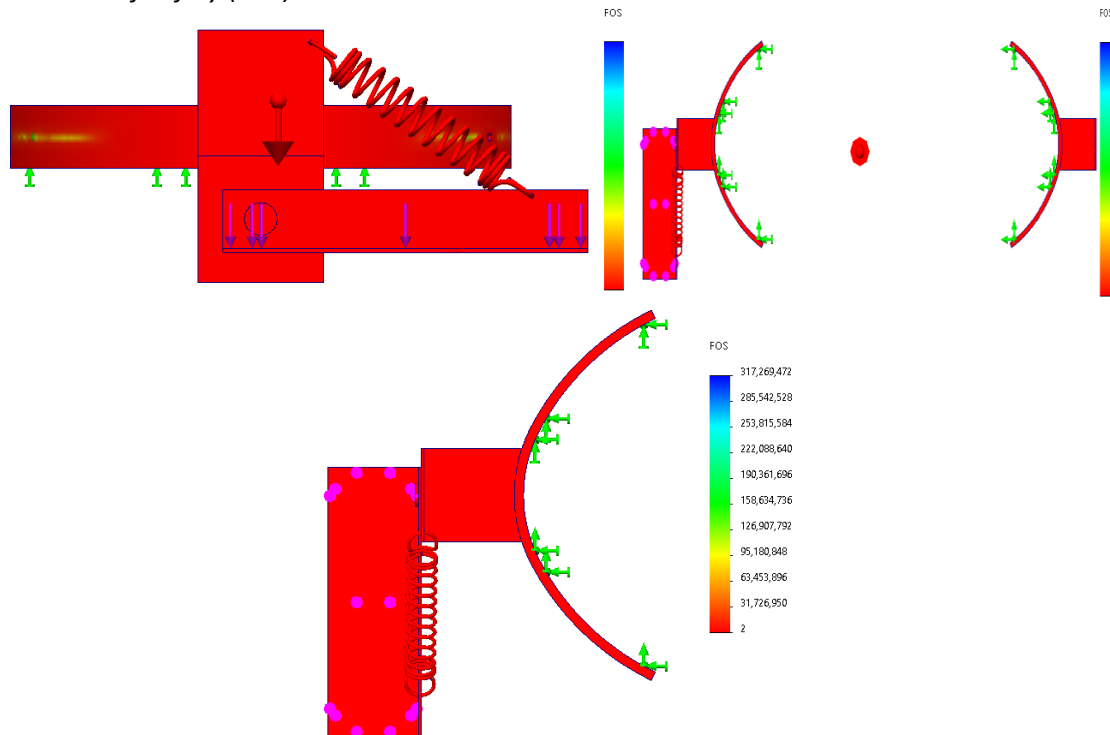


Figure 5. Factor of Safety

FOS plot results **Figure 5** in the simulation shows:

$$FOS_{\min} = 2$$

FOS formula (based on material yield – ductile)

$$FOS = \frac{S_y}{\sigma_{vm\max}}$$

with:

$S_y$  = yield stress of material (MPa)

$\sigma_{vm\max}$  = maximum von Mises stress (MPa)

##### 1. FOS Calculation

In general, ASTM A36 has a yield stress of around 250 MPa (a typical value often used in design analysis). Therefore:

$$FOS = \frac{250}{362} = 0.69$$

If the material is ASTM A36 and the maximum stress is 362 MPa, then  $FOS < 1 \rightarrow$  the design has the potential to yield at a load condition of 200 N.

2. Calculation of “ $S_y$  effective” from the results of FOS simulation (cross-check). Because the simulation results are written as  $\sigma_{vm,max}$  and  $FOS_{min}$ , then the effective yield stress is:

$$FOS_{min} = 2\sigma_{vm,max} = 363 \text{ Mpa}$$

$$S_{y,ef} = FOS_{min} \times \sigma_{vm,max}$$

$$S_{y,ef} = 2 \times 362 = 762 \text{ Mpa}$$

This value of 724 MPa is not characteristic of A36. It indicates one of the following conditions:

1. The material in the simulation study that produced  $FOS=2$  was not A36, but rather a material with a much higher yield, or
2. There are differences in the definition of FOS chosen (e.g. ultimate based rather than yield based), or
3. *Setup*The material in SolidWorks was not actually set to ASTM A36 in the study that produced the drawing.

#### 4.5 Design Implications and Improvement Targets

If the design target is  $FOS \geq 2$  with ASTM A36 material (yield  $\sim 250$  MPa), then the allowable stress is:

$$\sigma_{allow} = \frac{S_y}{FOS} = \frac{250}{2} = 125 \text{ MPa}$$

Compared to simulation results:

$$\sigma_{vm,max} = 362 > 125 \text{ MPa}$$

This means that a voltage drop of approximately:

$$\frac{362}{125} = 2.896 \approx 2.9$$

The improvement strategies are:

1. Increase thickness/section in critical areas,
2. Adding fillet radius to reduce stress concentration,
3. Move/add support points to reduce the moment,
4. Add ribs/braces to sagging areas,
5. Use materials with higher yields if dimensions cannot be enlarged.

At a load of 200 N, the simulation results show  $\delta_{max} = 1 \text{ mm}$  and  $FOS \approx 0.69$ . However, the safety factor evaluation against ASTM A36 indicates  $FOS \approx 0.69$ , so the design requires geometry/material optimization to meet more conservative safety targets.  $\sigma_{vm,max} = 362 \text{ MPa}$

## CONCLUSION

Based on the results of the design and simulation of Finite Element Analysis (FEA) on the handheld lawn mower handling support tool with ASTM A36 Steel material and a static load of 200 N, it can be concluded that the developed design has good structural rigidity. This is indicated by the relatively small maximum displacement value, which is 1 mm, as well as low strain energy, so that functionally the tool is able to maintain stability during operation.

The stress analysis results show that the maximum von Mises equivalent stress reaches 362 MPa and is concentrated at the connection area and the restraint points. This stress value is above the yield stress of ASTM A36 Steel, indicating that the current design configuration still has the potential for critical conditions to occur in certain areas.

Although the simulation results indicate a minimum safety factor of 2 based on the software criteria, manual verification of calculations based on the material's mechanical properties

indicates that the safety factor against material yielding still needs to be improved. Therefore, design optimization is needed to reduce stress concentrations and increase the structure's safety level.

Overall, this study demonstrates that a design method based on three-dimensional modeling and FEA simulation is effective for evaluating and refining the design of a handling restraint device prior to the manufacturing stage. The results can serve as a basis for further design development to achieve a safer, more ergonomic, and more reliable device.

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