



Material Analysis of Mauser M18 Pure Max Type Weapon Stock Using Finite Element Analysis

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ABSTRACT

This study compares three materials (beech wood, ABS resin, and PP resin) for the Mauser M18 Pure Max rifle stock using the Finite Element Analysis (FEA) method. Through 3D modeling and static load simulations (recoil of 16,118 N and 1.5× load), data on stress, strain, safety factor, and displacement were obtained. Under normal loading, beech and ABS were safe (safety factors of 1.34 and 1.91), while PP was unsafe (0.42). At 1.5× load, only ABS remained within acceptable limits (safety factor = 1.28), while beech and PP exceeded yield strength. In conclusion, ABS resin is the most optimal material for the rifle stock due to its superior mechanical strength, durability, and safety.

INTRODUCTION

The rifle stock, commonly referred to as the buttstock or shoulder stock, is an essential component of small arms that provides structural support and serves as the main interface between the weapon and the shooter. Its primary functions include transferring recoil forces to the shooter's shoulder, stabilizing the firearm during aiming, and improving overall shooting accuracy. A well-designed stock is crucial for achieving comfort, durability, and operational performance, especially under repeated recoil loads. Recoil itself is a dominant factor influencing additional firearm movement during and after each shot, which in turn affects precision (Andrey Koptug et al., 2020).

The importance of selecting the right stock material lies in balancing strength, stiffness, and weight. An optimal material ensures the structural integrity of the weapon while minimizing deformation under recoil forces. In addition, ergonomic and environmental considerations—such as durability against humidity, temperature fluctuations, and long-term wear—play a vital role in determining the suitability of stock materials for modern firearms.

In the small arms industry, the design and material selection of a rifle stock are critical factors that directly influence weapon performance, user comfort, and service life. Appropriate material choice affects shot accuracy, recoil management, and ergonomic comfort during use. The Mauser M18 Pure Max, a widely used bolt-action rifle, is therefore a suitable candidate for further study aimed at optimizing stock materials and identifying weaknesses in the original design to develop an improved stock—e.g., lighter weight or added functional features. This rifle employs a three-lug bolt action with a 60° bolt lift, a configuration that enables smooth and rapid cycling while providing sufficient clearance for mounting large optics without interference from the bolt handle. Materials used for stock construction strongly determine the rifle's physical and mechanical characteristics. Stocks may be fabricated from wood, resins, metals, or polymers, each imparting distinct trade-offs in strength, stiffness, weight, and durability.



Figure 1. Mauser M18 Pure Max Weapon

THEORETICAL REVIEW

Numerous studies have examined firearm stocks from both material and design perspectives. Traditionally, hardwoods such as walnut and beech have been widely used due to their natural strength, aesthetic value, and workability. However, wood presents several limitations, including susceptibility to moisture, variability in mechanical properties, and relatively high weight.

The development of polymer-based alternatives, such as Acrylonitrile Butadiene Styrene (ABS) and Polypropylene (PP), has provided new opportunities for lightweight and durable rifle stocks. ABS, in particular, is

valued for its impact resistance, dimensional stability, and suitability for mass production via injection molding. PP, on the other hand, offers low cost and excellent chemical resistance but has lower stiffness and strength compared to ABS.

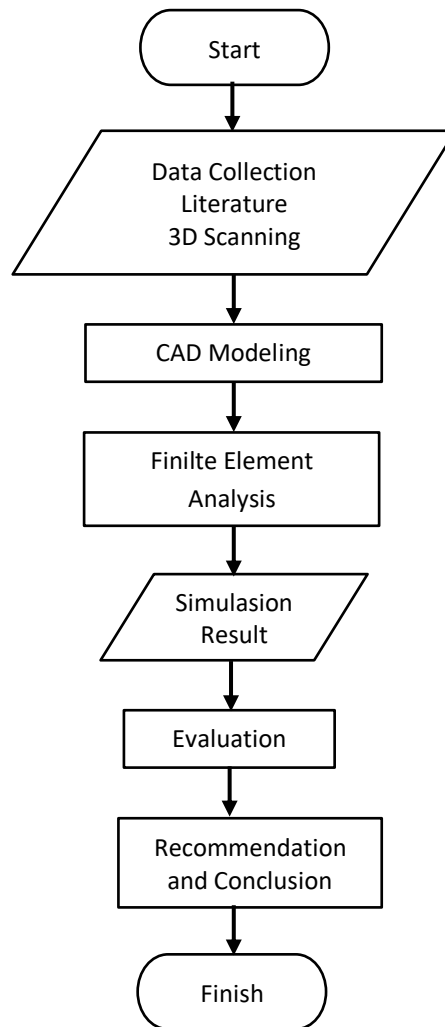
Several finite element analysis (FEA) studies on firearm components highlight the significance of numerical simulation in evaluating stress distribution, deformation, and safety factors under recoil conditions. Research by Kobayakov et al. (2019) emphasized that computational methods can effectively predict weak points in rifle stocks before physical prototyping. Finite Element Analysis (FEA) is a numerical technique used to analyze the behavior of complex structures subjected to different loading conditions by dividing them into smaller, more manageable elements and analyzing each element separately (Amiebenomo et al., 2023). Meanwhile, studies on hybrid materials – combining polymers with fibers such as glass or carbon – demonstrate enhanced stiffness-to-weight ratios and improved fatigue resistance (Rahul et al., 2021).

In summary, the literature indicates a transition from traditional wood stocks to engineered polymers and composites, driven by the need for lighter, stronger, and more reliable firearm components. This research builds upon those findings by conducting FEA-based evaluation of three candidate materials – beech wood, ABS resin, and PP resin – for the Mauser M18 Pure Max rifle stock.

3D scanning, or three-dimensional scanning, is a technology that captures data points on the surface of a workpiece. A 3D scanner is used to acquire geometric data of a product in the form of a set of point clouds. These points are then processed in CAD software to generate a three-dimensional model of the product, either as a surface model or a solid model (Pujiyanto & Virdhian, 2014). With its ability to produce accurate and detailed digital models, this technology enables researchers to conduct more in-depth analyses and make better-informed design decisions. The application of 3D scanning in this study is expected to improve efficiency and effectiveness in developing a more advanced and ergonomically optimized rifle stock design.

METHODOLOGY

This study aims to determine the mechanical properties of three different types of materials for the Mauser M18 Pure Max type rifle stock and determine the material to be used in the Mauser M18 Pure Max type rifle stock. The three types of materials are beech wood, Acrylonitrile Butadiene Styrene (ABS) resin, and Polypropylene (PP) resin. The research methodology was structured systematically to evaluate the mechanical performance of different stock materials through simulation and analysis. The stages are outlined as follows:



Data Collection

Conducting a review of relevant literature on gun butt design, materials used, and finite element analysis techniques. This includes journal articles, books, and technical documents discussing the characteristics of beech wood, Acrylonitrile Butadiene Styrene (ABS) resin, and Polypropylene (PP) resin. A comprehensive literature review was conducted to obtain references related to rifle stock materials, focusing on mechanical properties such as tensile strength, yield strength, and elastic modulus. In addition, a 3D scanning process of the Mauser M18 Pure Max rifle stock was performed to capture accurate geometric data as the basis for modeling and simulation.

Table 1. Material Properties of Beech Wood, ABS and PP

Material	Yield Strength	Density	Elastic Modulus	Tensile Strength
Beech Wood	53,62 N/mm ² (MPa)	560 kg/m ³	11800 N/mm ²	125,40 MPa
ABS	68,9 N/mm ² (MPa)	1070 kg/m ³	2410 N/mm ²	40 MPa
PP	25,00 N/mm ² (MPa)	930 kg/m ³	1800 N/mm ²	33,22 MPa

Initial Rifle Stock Design

The geometry obtained from 3D scanning was reconstructed using CAD software. Several design variants were generated by substituting the base material with three alternatives: beech wood, ABS, and PP. The CAD models ensured dimensional accuracy and provided input for the finite element analysis.

Finite Element Analysis (FEA)

Structural simulations were carried out using the finite element method. The stock models were meshed, boundary conditions were applied at the receiver interface, and static forces were applied to simulate recoil (16,118 N nominal and 24,000 N elevated load). Output parameters included Von Mises stress, displacement, strain, and safety factor.

Simulation and Analysis of Results

Stress distribution maps and deformation contours were compared across materials, focusing on maximum stress, displacement, and safety factor.

Evaluation and Material Selection

Based on the analysis, recommendations are provided regarding the optimal stock material selection for the Mauser M18 Pure Max. Includes suggestions for material selection and necessary design modifications. A conclusion is drawn from the study, covering key findings, contributions to weapon design development, and suggestions for further research in this area.

RESULTS AND DISCUSSION

3D Scanning Results

A 3D scanner is used to capture geometric data in the form of a point cloud from the Mauser M18 Pure Max weapon. The initial point cloud data has X, Y, and Z coordinates at different positions. Therefore, it must go through a registration/fitting process. Each point cloud data needs to be cleaned of noise. The resulting point cloud is processed using Rafidform software to create a 3D model of the Mauser M18 Pure Max weapon, including both surface modeling and solid modeling. Each cleaned data is then merged to obtain a single point cloud data set with X, Y, and Z coordinates. This merged data is then subjected to polygon optimization to produce a continuous polygon mesh, as shown in the image.



Figure 2. Results of 3D Scanning of the Stock

CAD Design Modeling

CAD (Computer Aided Design) modeling is performed using software. From the 3D scanned point cloud, which has been processed using Rapidform software, the next step is to further process the point cloud into a 3D model using CAD software, as shown in the image.



Figure 3. Results of 3D Modeling

Finite Element Analysis (FEA)

Finite element analysis is carried out to obtain static loading results in the form of σ (stress), SF (Safety Factor) and δ (deflection), this is done to determine how optimal the mechanical properties of the three types of materials are using beech wood material, Acrylonitrile Butadiene Styrene (ABS) resin material and Polypropylene (PP) resin. In this simulation process, several stages are carried out, the first is defining the material in CAD software, namely using Beech wood material, Acrylonitrile Butadiene Styrene (ABS) resin material and Polypropylene (PP) resin as in the image below.

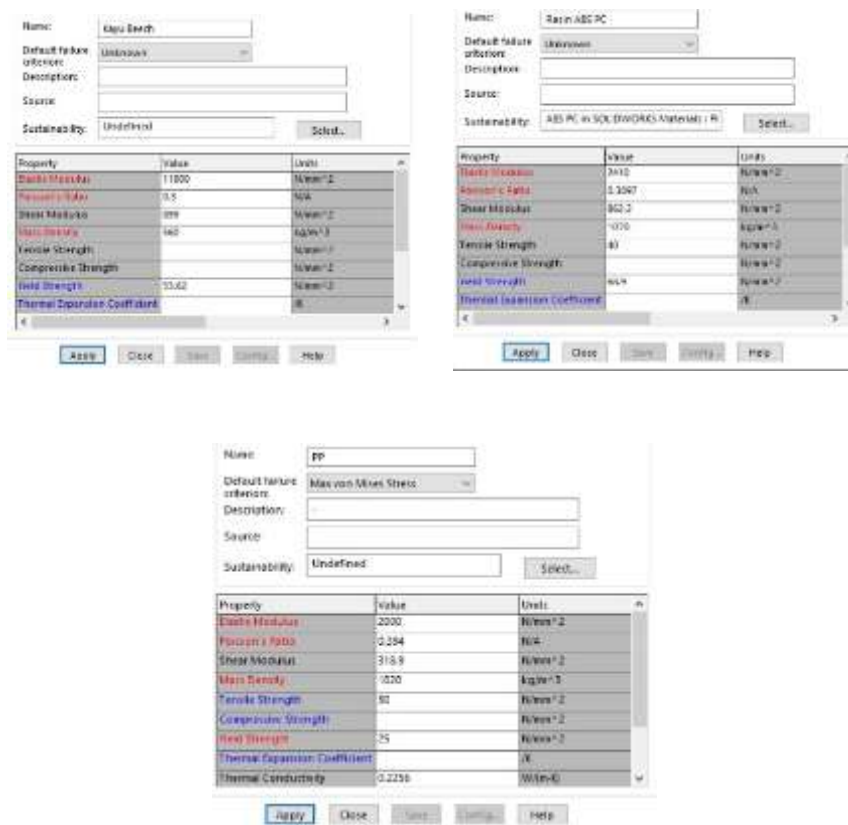


Figure 4. Mechanical properties Materials

The second stage is to determine the support point (fixed support) with a fixed geometry type located at the rear of the weapon stock, as shown in Figure 5.



Figure 5. Fixed Geometry Support Point

The third stage is to input the load (external force) received by the stock, including the force from the weight of the weapon supported by the stock of 2.9 kgf and the force from the repulsion of the ammunition when fired (recoil) which corresponds to the caliber .308 Win or 7.62 x 51 mm, namely 16118 N which is obtained from:

Average Gas Pressure (P): $3600 \text{ kg/cm}^2 = 3.53 \times 10^8 \text{ Pa}$

Bullet Diameter (d): $7.62 \text{ mm} = 0.00762 \text{ m}$

Bullet Cross-Sectional Area (A) = $\pi r^2 = 3.14 \times 1.45 \times 10^{-5} = 4.56 \times 10^{-5} \text{ m}^2$

Therefore, The Recoil Force (F) = $P \times A = (3.53 \times 10^8) \times (4.56 \times 10^{-5}) = 16118 \text{ N}$

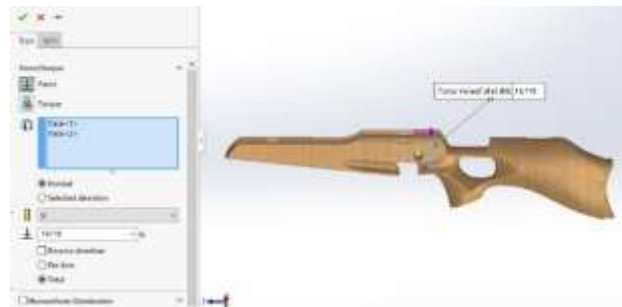


Figure 6. Force defining

The next step is to determine the mesh processing using the Curvature-based mesh method.

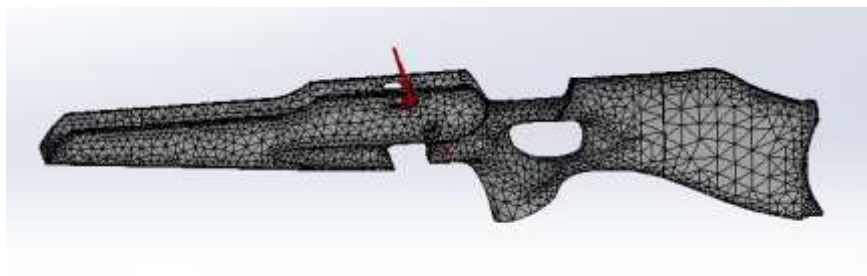


Figure 7. Meshing Determination

The results of the stress simulation (von mises stress) of the three different types of materials are shown in the image with the following results:

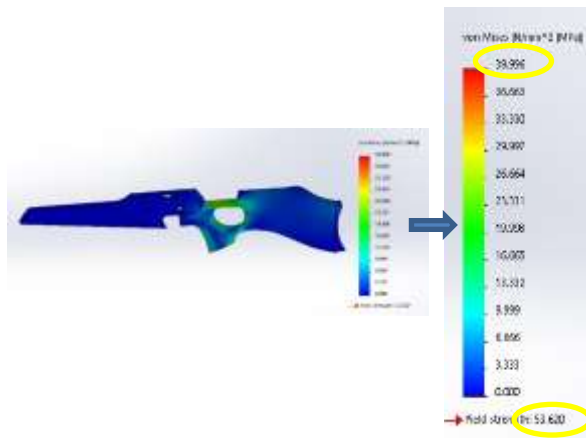


Figure 8. Simulation Result Stress of Beech Wood Material

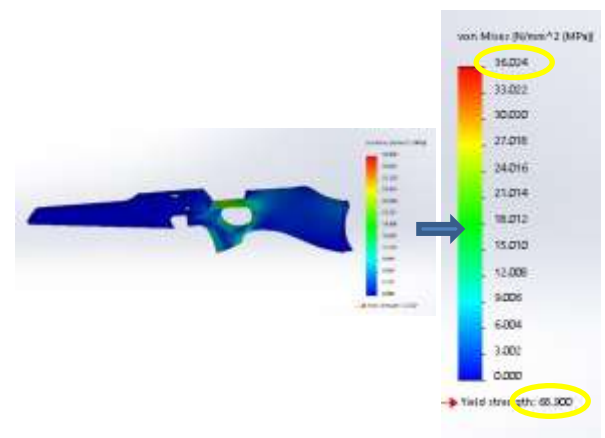


Figure 9. Simulation Result Stress of ABS Material

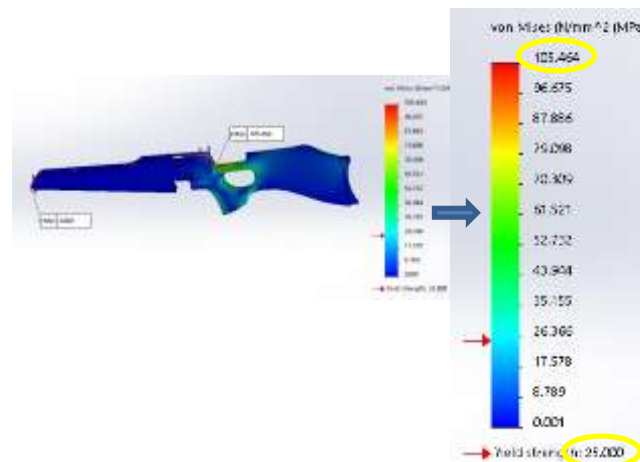


Figure 10. Simulation Result Stress of PP Material

The results of the displacement simulation of the three different types of materials are shown in the image with the following results:

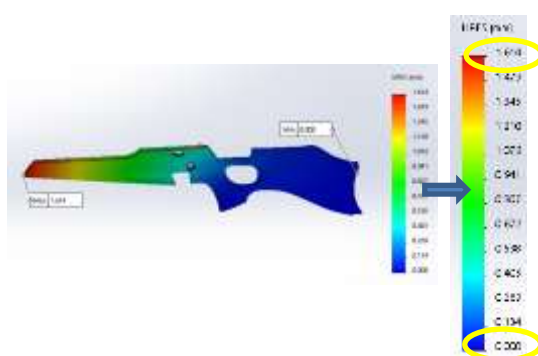


Figure 11. Simulation Result Displacement of Beech Wood Material

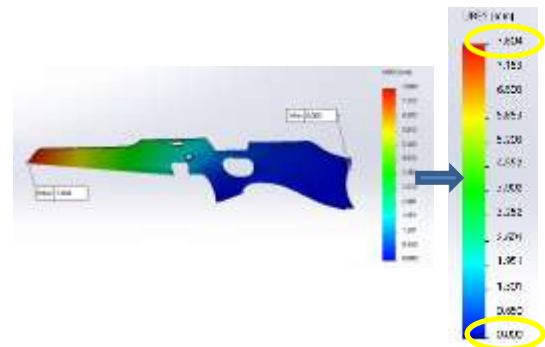


Figure 12. Simulation Result Displacement of ABS Material

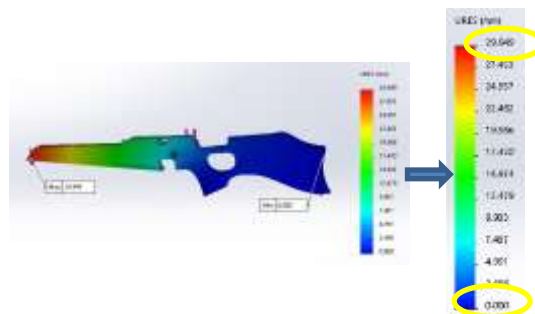


Figure 13. Simulation Result
Displacement of PP Material

The results of the strain simulation of the three different types of materials are shown in the image with the following results:

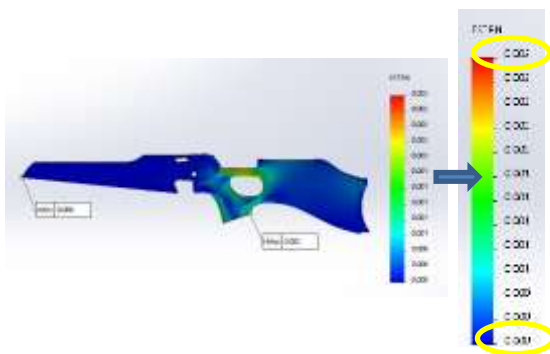


Figure 14. Simulation Result Strain of
Beech Wood Material

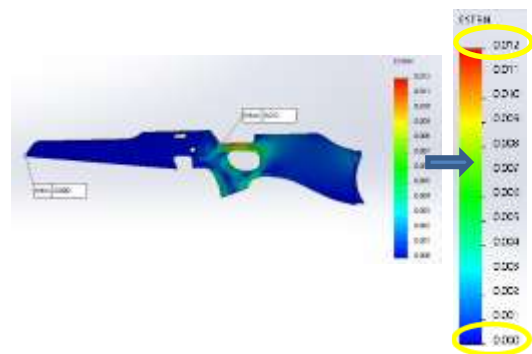


Figure 15. Simulation Result Strain of
ABS Material

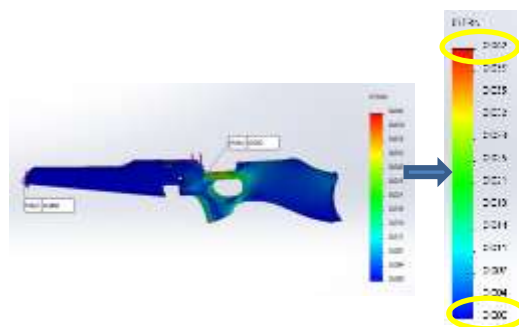


Figure 16. Simulation Result Strain of PP
Material

The results of the safety factor simulation of the three different types of materials are shown in the image with the following results:

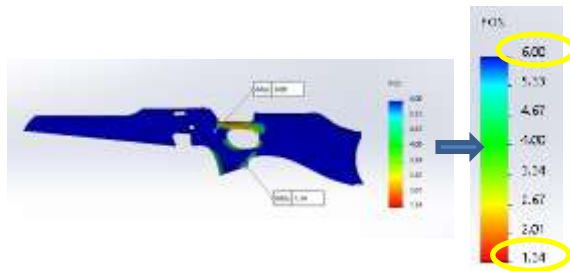


Figure 17. Simulation Result Safety factor of Beech Wood Material

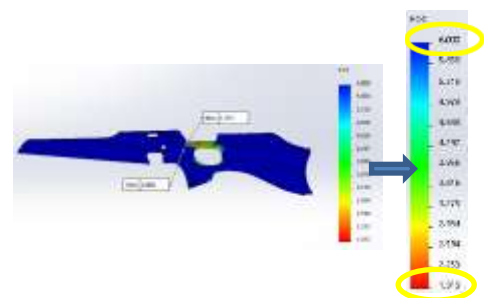


Figure 18. Simulation Result Safety factor of ABS Material

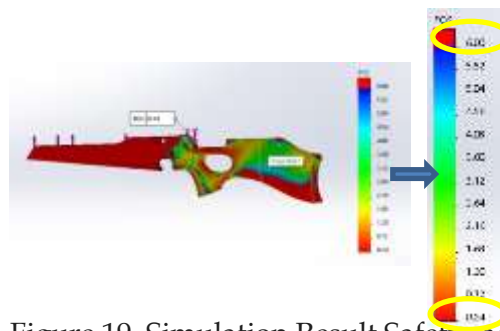


Figure 19. Simulation Result Safety factor of PP Material

Comparative Analysis of Static Loading Simulation Results

The results of static loading simulations using software on the Mauser M18 Pure Max rifle buttstock with the specified load and the selected materials: beech wood, ABS, and PP, yielded the data shown in Table 1.

Table 2. Static Loading Simulation Result Data

Result	Beech Wood		ABS		PP	
	Min	Max	Min	Max	Min	Max
<i>Von Mises Stress</i>	0	39,99	0	36,02	0	105,46
<i>Displacement</i>	0	1,61	0	7,80	0	29,94
<i>Strain</i>	0	0,002	0	0,012	0	0,042
<i>Safety of Factor</i>	1,34	6	1,91	6	0,24	6

Stress Analysis Under Nominal Loading (16,118 N)

1. **Beech Wood:** The maximum Von Mises stress recorded was 39.99 MPa, with a safety factor of 1.34. These values indicate that beech wood can withstand nominal recoil but has a relatively narrow safety margin.
2. **ABS Resin:** The maximum stress was 36.02 MPa, with a safety factor of 1.91. ABS demonstrated better resilience compared to beech wood, making it safer for sustained use.

3. **PP Resin:** The maximum stress reached 105.46 MPa, exceeding the material's yield strength. The safety factor was only 0.42, indicating that PP is unsuitable for use under nominal recoil conditions.

These results suggest that ABS and beech wood remain viable under normal operational loads, whereas PP resin is structurally inadequate.

To comprehensively evaluate the mechanical performance of the rifle stock, it is necessary to conduct a re-analysis of the loading conditions applied to the three candidate materials. In this study, the recoil force exerted on the Mauser M18 Pure Max stock was increased by a factor of 1.5 from the nominal condition, resulting in an applied load of 24,000 N. This adjustment was implemented to simulate more extreme operational scenarios and to assess the stock's structural reliability under elevated stress conditions.

The results of the von Mises stress simulation with a load of 1.5 times the normal load for the three different materials are shown in the figure, with the following results:

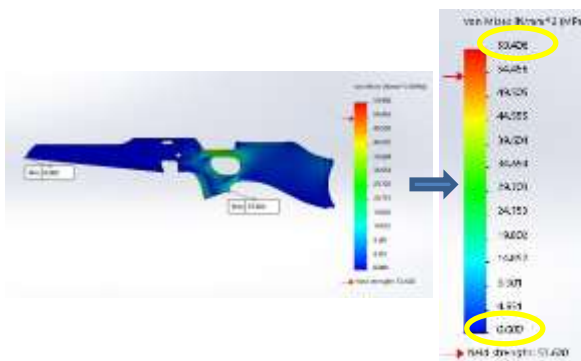


Figure 20. Simulation Result Stress of Beech Wood Material

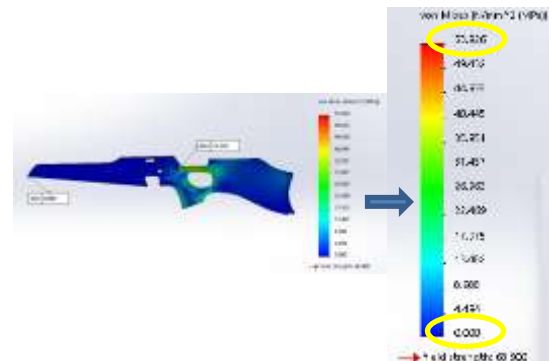


Figure 21. Simulation Result Stress of ABS Material

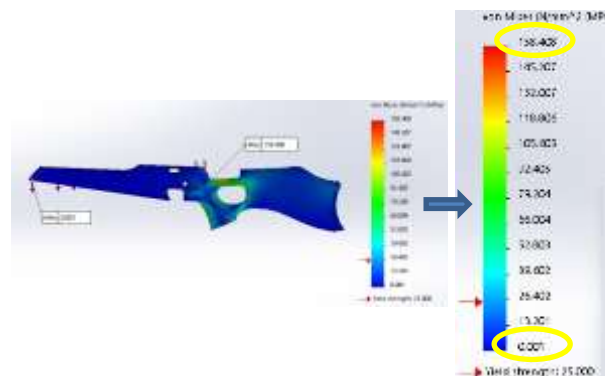


Figure 22. Simulation Result Stress of PP Material

The results of the displacement simulation with a load of 1.5 times the normal load for the three different materials are shown in the figure, with the following results:

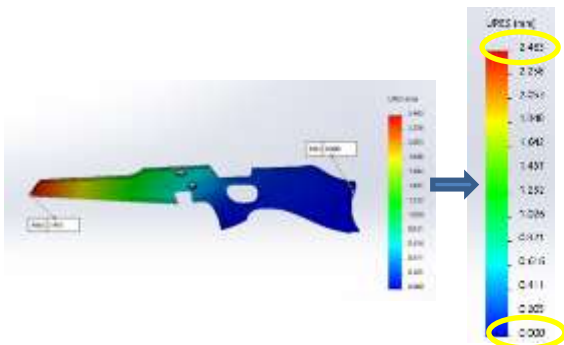


Figure 23. Simulation Result Displacement of Beech Wood Material

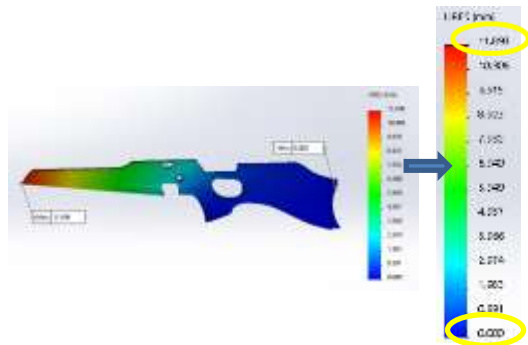


Figure 24. Simulation Result Displacement of ABS Material

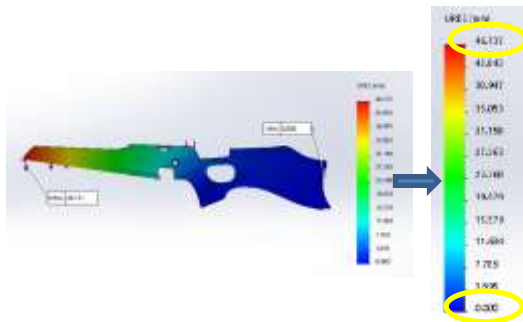


Figure 25. Simulation Result Displacement of PP Material

The results of the strain simulation with a load of 1.5 times the normal load for the three different materials are shown in the figure, with the following results:

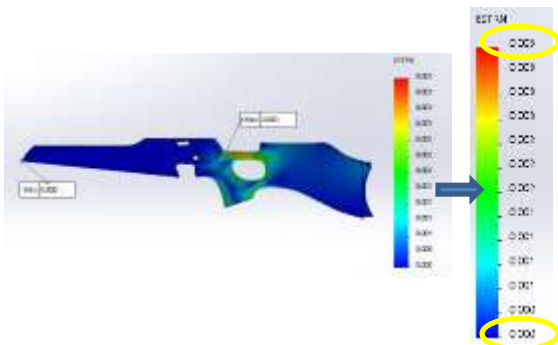


Figure 26. Simulation Result Strain of Beech Wood Material

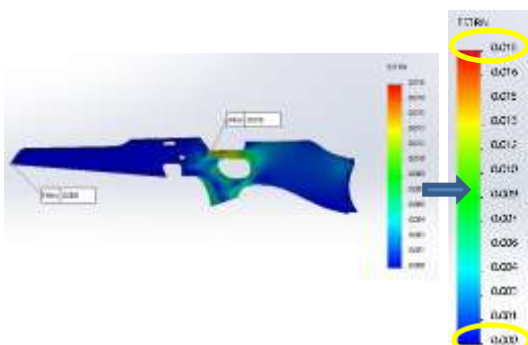


Figure 27. Simulation Result Strain of ABS Material

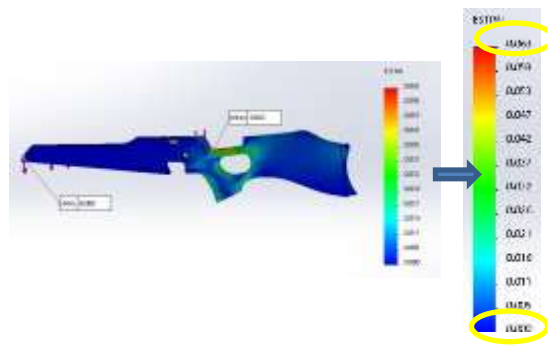


Figure 28. Simulation Result Strain of PP Material

The results of the safety factor simulation with a load of 1.5 times the normal load for the three different materials are shown in the figure, with the following results:

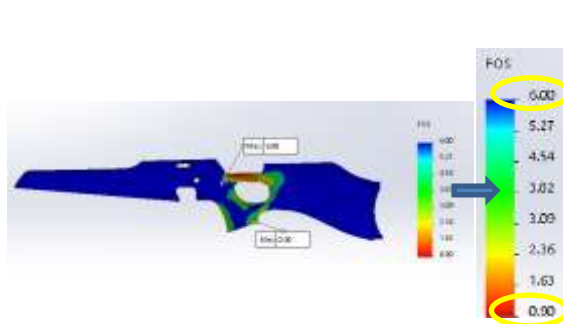


Figure 29. Simulation Result Safety factor of Beech Wood Material

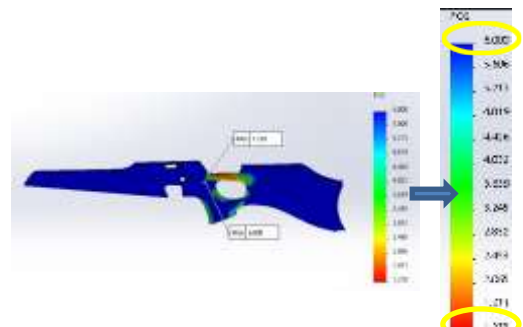


Figure 30. Simulation Result Safety factor of ABS Material

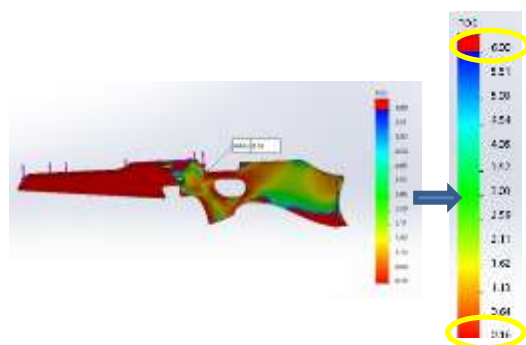


Figure 31. Simulation Result Safety factor of PP Material

The results of the static loading simulation with the load increased 1.5 times from normal conditions for the three different types of materials obtained data which can be seen in Table 2.

Table 3. Static Loading Simulation Result Data

Result	Beech Wood		ABS		PP	
	Min	Max	Min	Max	Min	Max
<i>Von Mises Stress</i>	0	59,40	0	53,92	0	158,40
<i>Displacement</i>	0	2,46	0	11,89	0	46,73
<i>Strain</i>	0	0,003	0	0,018	0	0,063
<i>Safety of Factor</i>	0,9	6	1,28	6	0,16	6

Stress Analysis Under Elevated Loading (24,000 N)

1. **Beech Wood:** Maximum stress increased to 59.40 MPa, with a safety factor of 0.9. This indicates failure under elevated loading conditions.
2. **ABS Resin:** The maximum stress was 53.92 MPa, with a safety factor of 1.28, which remains acceptable. ABS demonstrated sufficient strength to withstand higher-than-normal loads.
3. **PP Resin:** Stress values rose to 158.40 MPa, resulting in a safety factor of only 0.16. This confirms structural failure and unsuitability for practical use.

Under extreme conditions, only ABS resin maintained performance within acceptable safety limits.

Overall, the discussion highlights that ABS resin provides the most reliable performance. Its combination of high strength-to-weight ratio, structural stability, and manufacturability via injection molding makes it the most suitable candidate for the Mauser M18 Pure Max stock. While beech wood can still be considered under nominal conditions, it lacks sufficient resilience under higher loads. PP resin, on the other hand, is not viable as a structural material in this application.

CONCLUSION

Based on the design and finite element analysis results for the Mauser M18 Pure Max rifle stock, conducted using CAD and finite element analysis software, the following conclusions can be drawn:

1. Acrylonitrile Butadiene Styrene (ABS) resin is the optimal material for the Mauser M18 Pure Max rifle stock. This material provides the best balance between mechanical strength, durability, and safety, both under normal and critical loading conditions.
2. Beech wood can be used under normal loads, but is unable to withstand higher loads.

3. Acrylonitrile Butadiene Styrene (ABS) resin has proven superior because it can withstand both normal and critical loads with an acceptable level of safety.
4. Polypropylene (PP) resin is not suitable for use as a stock material due to its stress exceeding the elastic limit and a very low safety factor.

RECOMMENDATIONS

Several recommendations are proposed for future research and development:

1. To obtain more accurate results in finite element analysis, it is necessary to adjust the mesh quality, both in terms of mesh element size and mesh element type.
2. Redesign the 3D modeling of the stock to obtain more optimal results.
3. Explore fracture mechanics and fatigue life of ABS under repeated recoil.

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