GAS Journal of Engineering and Technology (GASJET)

Volume 3 | Issue 6, 2026 Homepage: https://gaspublishers.com/gasjet-home/ ISSN: 3048-5800

Performance Evaluation and Optimization of Aluminium Can Crushing Machine Using Finite Element Analysis and Design Improvement Techniques

Akele, Sunday-Michael Gimahson; Ososomi, Sunday Asunumeh; Major, Paul and Iyore, Tommy

Mechanical Engineering Department, Auchi Polytechnic, Auchi, NIGERIA

Received: *10.05.2026* | ***Accepted:*** *07.06.2026* | ***Published:*** *14.06.2026*

***Corresponding Author:** Akele, Sunday-Michael Gimahson

DOI: *10.5281/zenodo.20686386*

Abstract **Original Research Article**

There is increasing demand for sustainable beverages Can disposal management and recycling technologies. This has led to the development of efficient aluminium Can crushing machine. This study presents the crashworthiness of piston-cylinder assemble and structural optimization of aluminium can crushing machine using finite element analysis in ANSYS Workbench. Static structural and explicit dynamic analyses were performed to investigate total deformation, stress distribution, strain energy, and factor of safety. Baseline design was optimized by reducing mass of components and material selection. The result showed that optimized crusher design achieved lower stress concentration, reduced structural weight, improved crushing efficiency, and enhanced durability compared to the baseline design configuration. The optimized design parameters reduced displacement by 10.5%, decreased stress concentration by 53.7%, reduced elastic strain by 49.3%, reduced machine weight by 20.45% and improved crushing efficiency by approximately 78.5% compared to the baseline design with 70.4%. This implies that the optimized crusher achieved significant can volume reduction while maintaining stresses below allowable material limits.

Keywords: Optimization, Aluminum Can Crusher, Baseline design, Optimized design, Finite Element Analysis, Structural Optimization.

1. Introduction

In our world today a lot of human consumables come in Cans and aluminium Cans are among these (Akele & Akuete, 2022). Aluminum Cans are widely used because they are lightweight, corrosion resistance and ease of recycling. So many food and drinks are packaged in Cans especially beverages drinks. And the disposability of these Cans after using the liquid content is a major problem because after used these empty Cans are usually stacked in bags thereby occupying the limited space. Hence the need for crushing machines to reduce the volume of Cans in the surrounding before taking them for recycling.

According to Bello et al. (2020). Most companies find it difficult to dispose of their used cans in hotels and canteens and to create enough storage space that is required. Sawant & Venkatesh (2016) stated that one problem facing the beverage industries is the problem of collapsing of aluminium cans that leads to decrease in profit. According to Buza (2014) beverage Cans recycling is the last stage

Citation: Akele, S.-M. G., Ososomi, S. A., Major, P., & Iyore, T. (2026). Performance evaluation and optimization of aluminium can crushing machine using finite element analysis and design improvement techniques. *GAS Journal of Engineering and Technology (GASJET)*, 3(6), 17-27.

of reducing, reusing and recycling Cans into raw materials. Can crushing machine a usable machines that can help to reduce the solid wastes pollution in the environment (Kshirsagar, 2014).

Akele & Akuete (2022b) designed crushing machines major problems are:

- Excessive structural weight
- High power consumption
- Uneven stress distribution
- Structural fatigue
- Reduced crushing efficiency

Finite Element Analysis (FEA) is a numerical method of analysis that provides an efficient method for predicting structural behaviour and optimization of machine components before fabrication. The optimization techniques integrated with FEA in this study will help to reduce material usage, improve crushing performance, and enhance machine durability.

Consequently, this study focuses on the optimization of an aluminium Can crushing machine initially designed by Akele & Akuete (2022) through numerical simulation and finite element modeling using ANSYS Workbench.

2 Objectives of the Study

The objectives of this study are:

- To model aluminium can crushing machine using SolidWorks software.
- To perform finite element analysis of the piston-cylinder assembly.
- To optimize crushing machine frame structure, shaft-crank arm assembly and piston-cylinder assembly.
- To reduce stress concentration and deformation in piston-cylinder assembly.
- To improve piston-cylinder assembly crushing efficiency and energy absorption.
- To minimize Can crushing machine weight while maintaining safety.

3. Literature Review

Optimization of crushing systems such Can crushing machines has gained attention in waste recycling structural engineering. Crushing machines using finite element method have showed that the optimization of crushing component geometry can reduce local stress concentration and an increase in crushing efficiency.

Akele & Akuete (2022a) used analytical method to determine Can crushing machine slider (piston) and crank arm relative position, velocity, acceleration, and accelerating force. The resulting slider velocity versus crank angle indicated that as the slider start from 0^o to 90^o the velocity increases with the increase of the crank angle before decreasing to -270^o to start increasing again. The velocity curve was observed to be smooth, which is an indication of absence vibration.

Akele & Akuete (2022b) designed and fabricated Aluminum crushing machine that is based on on the slider-crank mechanism. The machine was tested and evaluated for effectiveness and the evaluation results showed power input of 382W with piston velocity of 0.813m/s, crushing rate of approximately 2 Cans/sec, 70% Can volume reduction.

Esim & Benzer (2021) studied solid modeling and structural analysis of a foam crushing machine. Geometric optimization, linear static analysis of the machine parts maximum Von Misses stress, deformation, the factor of safety results were determined using ANSYS Workbench software. The results revealed that the material and structure of the design provide simple, reliable, and cost-effective production requirements, which are useful for industrial applications.

Bello et al. (2020) designed and fabricated a pneumatic can crushing machine that was able to reduce the volume cans by 70%. The results revealed the machine to be effective and efficient crushing between 15 and 20 cans per minute.

Sawant & Venkatesh (2016) study focused increasing the effectiveness of cans during impact loads. Study put impact loads thereby performing crash analysis of aluminium cans in order to determine how cans can withstand impact loads using FEM. All the parameters affecting can crush strength are evaluated using ABAQUS 14.0. The results revealed material thickness to be in direct proportion with the buckling strength or maximum load carrying capacity and crushing strength increases with increase in the thickness of sheet.

Rajesh et al. (2016) study entails the design and structure analysis of Can crusher. The designed Can crusher used mechanical single slider crank mechanism. The designed crusher was observed to be environmental friendly.

Gogoi et al. (2018) fabricated a Can crusher using single slider-crank mechanism that can reduce Can size by at least 70%. Two Can crushers were constructed. One is manually operated and the other a manual crusher model upgraded to an electrically operated one. Efficiencies and construction costs comparison was carried between the two Can Crushers. The electrically operated was observed to have higher efficiency and cost.

Sawant & Venkatesh (2016) fabricated Aluminum crushing machine, tested and evaluated its effectiveness. The resulting required power input was 382W with piston velocity of 0.813m/s. The crushing rate of the machine was approximately 2 Cans/sec, 70% efficient.

4 METHODOLOGY

4.1 Design Considerations

In designing and construction of a dual-operated Can crusher, the following factors were put into consideration in material selection (i) availability of raw and finished materials and components, (ii) strength of materials to be used, (iii) cost of the materials, (iv) machinability of the materials, (v) power requirement, (vi) maintainability and reliability of machine, (v) ergonomics, (vi) effectiveness of the machine, and (vii) reliability.

4.2 Design Specifications

In the designing of the crusher machine certain design specifications or factors were put into consideration. They include size, operating speed, expected efficiency of machine, forces on components.

4.3 Machine Description

Designed Can crushing machine consists of:

- Hopper
- Frame structure
- Half shaft- crank assembly
- Piston-connecting rod assembly
- Fixed cylinder
- Electric motor

4.4 Baseline Design Parameters

4.4.1 Geometrical Dimensions: Aluminum Can

Parameter	**Value**
Can height	124 mm
Can diameter	67 mm
Sheet thickness	0.12 mm

4.4.2 Material Properties: Aluminum Can Material

Property	**Value**
Material	Aluminum Alloy
Density	2700 kg/m³
Young's Modulus	69 GPa
Poisson Ratio	0.33
Yield Strength	276 MPa

4.4.3 Crushing Piston

Parameter	**Value**
Piston outside diameter	68mm
Piston length	150 mm
Piston thickness	5 mm
Piston mass	22kg

4.4.4 Crushing Cylinder

Parameter	**Value**
Cylinder length	250 mm
Cylinder outside diameter	76 mm
Cylinder thickness	5 mm

4.4.5 Frame/Piston/Cylinder Material

Property	**Value**
Material	Mild Steel
Density	7850 kg/m³
Young's Modulus	210 GPa
Poisson Ratio	0.30
Yield Strength	250 MPa

4.5 Governing Equations

Stress Equation

$$\sigma = \frac{F}{A}$$

Where:

σ = Stress

F = Applied force

A = Cross-sectional area

Strain Equation

$$\varepsilon = \frac{\Delta L}{L}$$

Where:

ε = Strain

L = Length

Optimization allowable stress:

$$\min(M) = \sum_{i=1}^{n} \rho_i V_i$$

Subject to:

$$\sigma_{\max} \leq \sigma_{allow}$$

4.6 Method of Solution

SolidWorks was used to separately model the geometry of the frame structure, the half shafts and the crank arm assembly and the complete assembly and imported into ANSYS 16.2 Workbench. ANSYS 16.2 was separately used to analyze frame structure, the half shafts and the crank arm assembly and the complete assembly. Performance evaluation and optimization are then performed on ANSYS explicit dynamics workbench by applying force with each analysis simulated to determine total deformation, equivalent (von Mises) stresses, elastic strains, and safety factors during the crushing.

4.7 Boundary Conditions

- Cylinder fixed on frame
- Crushing piston reciprocates horizontally with compressive force
- Can is compressed between piston and inner cylinder surface
- Crushing force is applied at constant rpm

4.8 Optimization Function

The optimization objective minimized structural mass while maintaining allowable stress.

4.8.1 Optimization Procedure

The optimization process involved:

- Baseline structural analysis
- Parameter variation
- Topology optimization
- Final optimized validation

4.8.2 Optimization Variables

The following parameters were optimized:

- Piston thickness
- Piston mass
- Cylinder thickness
- Cylinder mass
- Connecting rod diameter and mass
- Half shafts and crank diameter and mass
- Frame cross-sectional geometry
- Frame material
- Material distribution

4.9 Optimized Design Parameters

4.9.1 Geometrical Dimensions: Aluminum Can

Parameter	**Value**
Can height	124 mm
Can diameter	67 mm
Sheet thickness	0.12 mm

4.9. 2 Crushing Piston

Parameter	**Value**
Piston outside diameter	68mm
Piston length	100 mm
Piston thickness	3 mm
Piston mass	17.5kg

4.9.3 Crushing Cylinder

Parameter	**Value**
Cylinder length	200 mm
Cylinder outside diameter	76 mm
Cylinder thickness	3 mm

4.10 Modeling Geometries

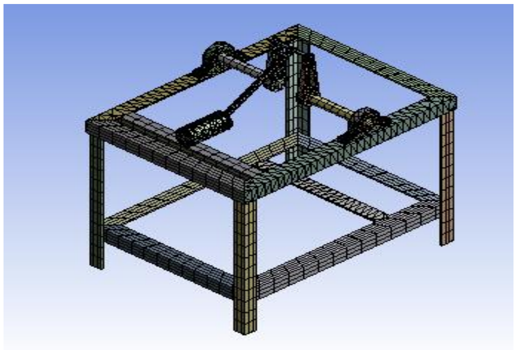


Fig 1: Assemble geometry and Mesh (Akele et al., 2026)

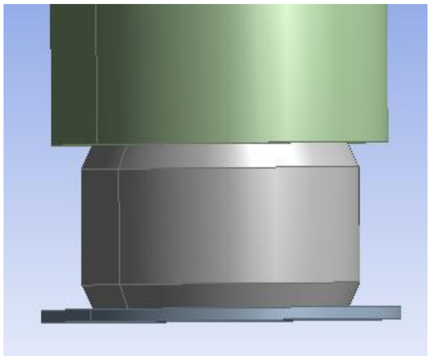


Fig 2: piston, Can and cylinder crushing surface

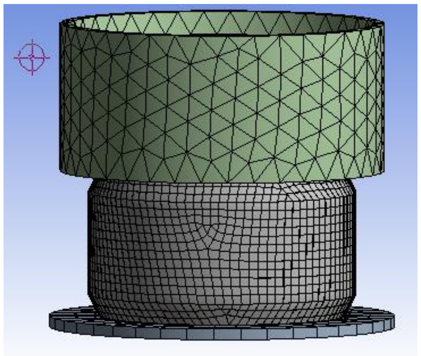
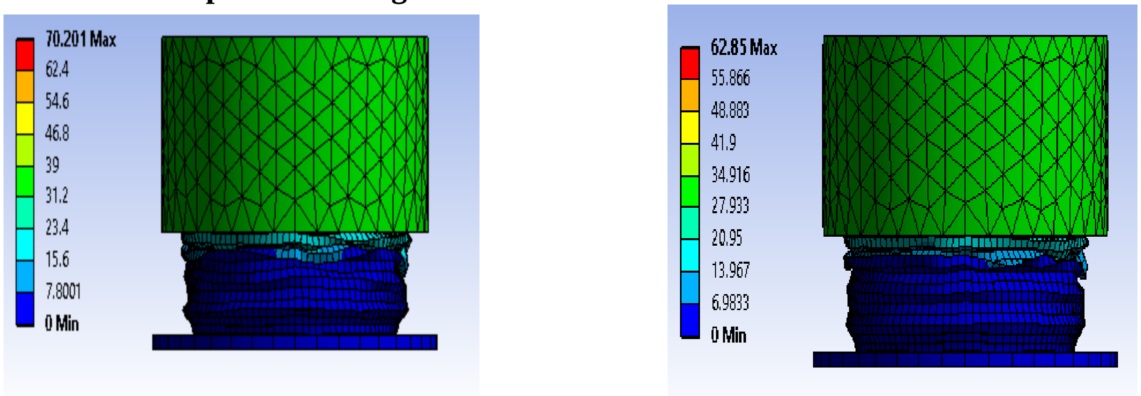


Fig 3: mesh

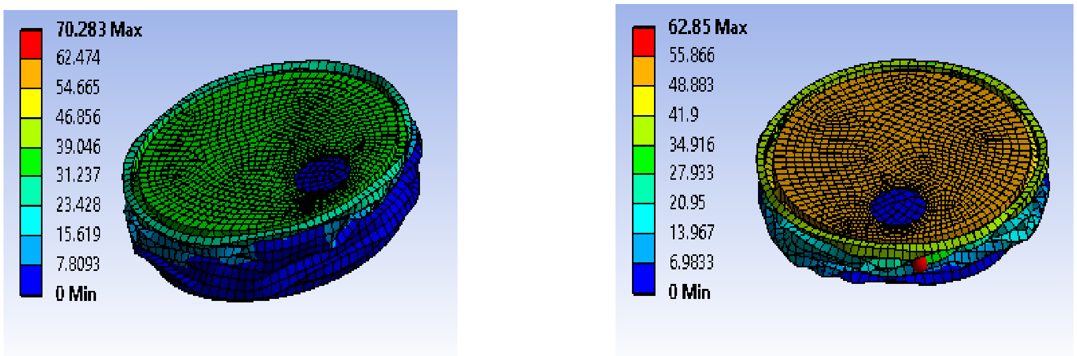
5. RESULTS AND DISCUSSION

Baseline and Optimized Designs FEM Contours



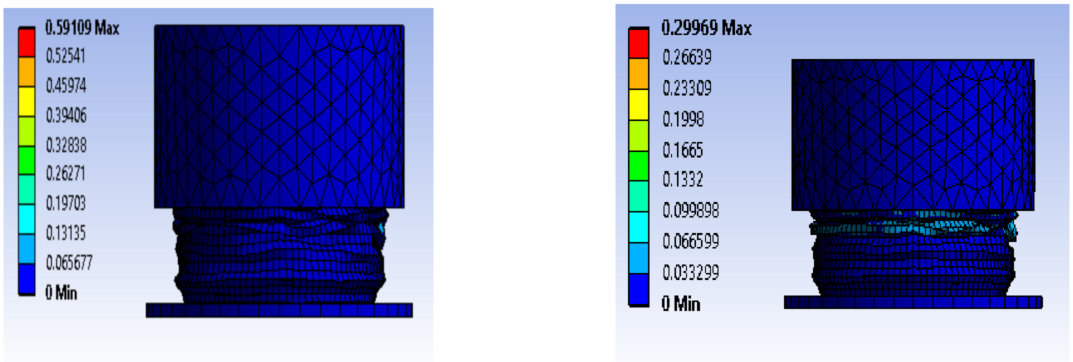
(a) Baseline design (b) Optimized design

Fig 4: Total deformation



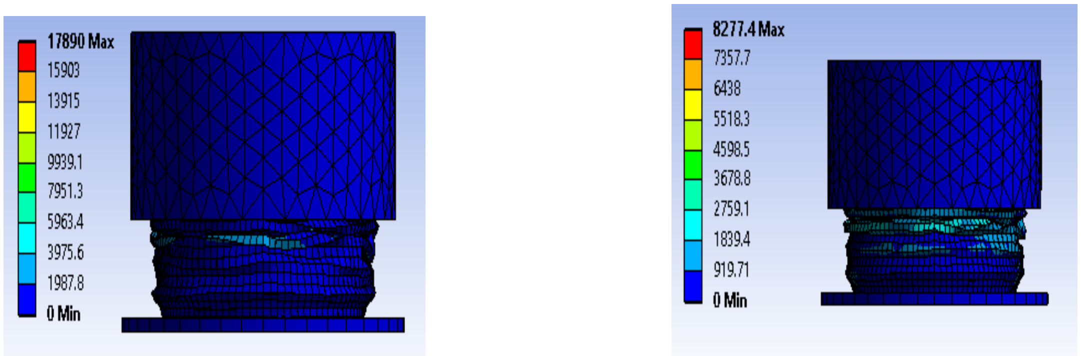
(a) Baseline design (b) Optimized design

Fig 5: Crushed Can



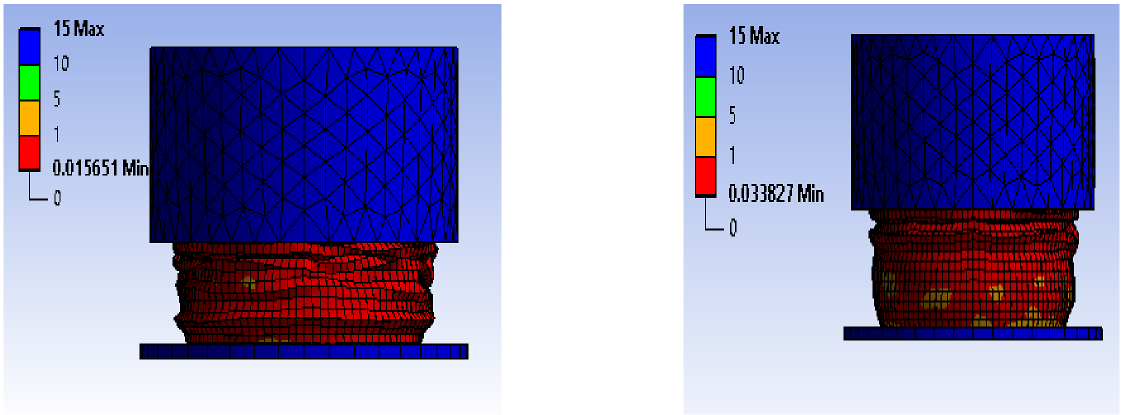
(a) Baseline design (b) Optimized design

Fig 6: Equivalent elastic strain



(a) Baseline design (b) Optimized design

Fig 7: Equivalent stress



(a) Baseline design (b) Optimized design

Fig 8: Safety factor

5.1 Baseline Design Results

Maximum Deformation

$$\delta_{baseline} = 70.2mm$$

Maximum Stress

$$\sigma_{baseline} = 17890\ MPa$$

Maximum Von-Mises Strain

$$\sigma_{baseline} = 0.5911\, mm / mm$$

Safety Factor

$$\alpha_{baseline} = 0.0157_{\min} - 15_{\max}$$

5.2 Optimized Design Results

Maximum Deformation

$$\delta_{optimized} = 62.85mm$$

Maximum Von-Mises Stress

$$\sigma_{optimized} = 8277.4MPa$$

Maximum Von-Mises Strain

$$\sigma_{optimized} = 0.2997mm / mm$$

Safety Factor

$$\alpha_{optimized} = 0.0338_{\min} - 15_{\max}$$

Displacement reduction achieved:

Displacement reduction

$$\delta_r = \frac{70.2 - 62.85}{70.2} \times 100 = 10.5\%$$

Stress reduction achieved:

Stress reduction

$$\sigma_r = \frac{17890 - 8277.4}{17890} \times 100 = 53.7\%$$

Strain reduction achieved:

Strain reduction

$$\varepsilon_r = \frac{0.5911 - 0.2997}{0.5911} \times 100 = 49.3\%$$

5.3 Weight Reduction

The optimized topology reduced machine mass from 22 kg to 17.5 kg.

Weight reduction:

Weight reduction

$$W_r = \frac{22 - 17.5}{22} \times 100 = 20.45\%$$

5.4 Crushing Efficiency Improvement

Crushing efficiency improved due to optimized contact geometry and force transmission.

Efficiency equation:

Baseline:

$$\eta_{crushing} = \frac{V_i - V_f}{V_i} \times 100 = \frac{124 - 36.7}{124} \times 100 = 70.4\%$$

Optimized:

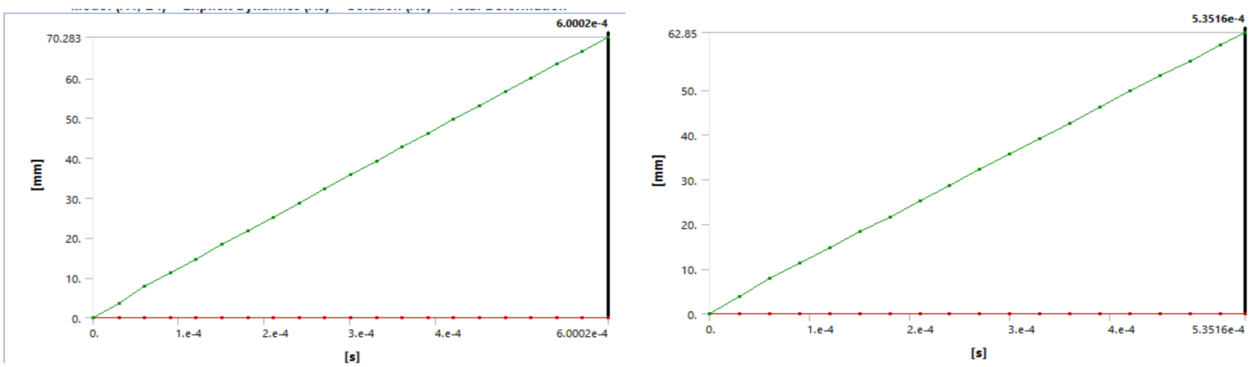
$$\eta_{crushing} = \frac{V_i - V_f}{V_i} \times 100 = \frac{124 - 26.6}{124} \times 100 = 78.5\%$$

5.5 Energy Absorption

Sources of energy consumption: The aluminium can absorbed significant crushing energy through progressive buckling deformation; while the electric motor used energy to overcome piston mass inertia/opposing force.

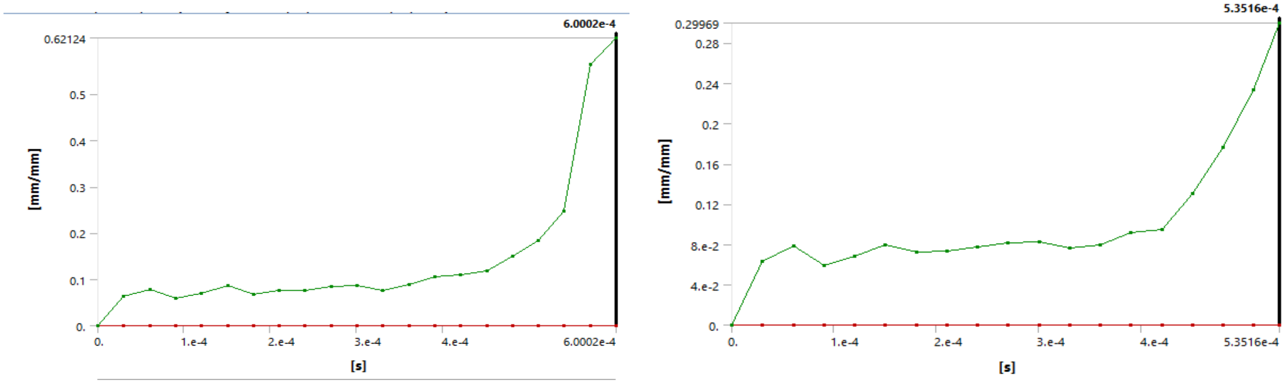
5.6 Comparative Analysis

Parameter	Baseline Design	Optimized Design
Maximum Deformation	70.2 mm	62.85 mm
Maximum Stress	17890 MPa	8277.4 MPa
Maximum Strain	0.5725 mm/mm	0.2997 mm/mm
Crusher Weight	22 kg	17.5 kg
Crushing Efficiency	70.4%	78.5%
Energy Consumption	High	Reduced



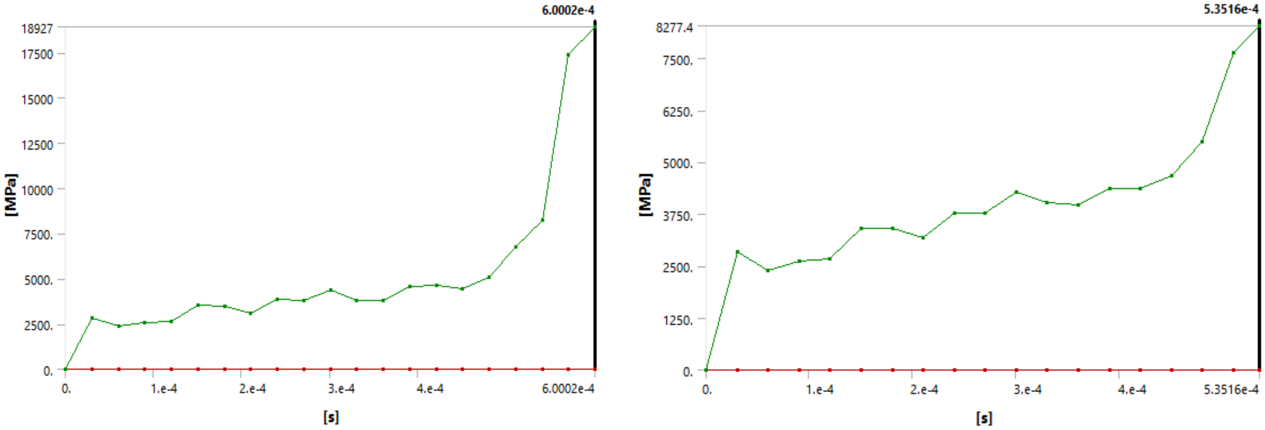
(a) Baseline design (b) Optimized design

Fig 9: Total deformation against timeline



(a) Baseline design (b) Optimized design

Fig 10: Equivalent elastic strain against timeline



(a) Baseline design (b) Optimized design

Fig 11: Equivalent stress against timeline

Fig 1 shows designed (Akele et al., 2026) and assembled Can crushing machine mesh in ANSYS workbench. In Figures 2 and 3 are shown piston-Can-cylinder geometry and mesh setups prior to Can crushing. In Fig. 4, baseline design and optimized design maximum total deformation of 70.20mm and 62.85mm respectively; while Fig 5 shows baseline and optimized crushed Can. Fig. 6 shows baseline design and optimized design maximum equivalent (von Mises) elastic strain of 0.59109mm/mm and 0.29969mm/mm respectively. In Fig. 7, baseline design and optimized design maximum equivalent (von Mises) stress of 17890Mpa and 8277.4Mpa respectively. Stress effect is seen to be high at the side of the Can. Fig. 8 shows baseline design and optimized design maximum and minimum safety factor of 15 – 0.015651 and 15 – 0.033827 respectively. Figures 9 -11 show baseline design and optimized design total deformation, elastic strain, stress growth with respect to time.

Furthermore,

- Displacement reduction achieved after machine optimization is 10.5%
- Stress reduction achieved after machine optimization is 53.7%
- Strain reduction achieved after machine optimization is 49.3%
- The optimized topology reduced machine mass from 22 kg to 17.5 kg resulting in 20.45% weight reduction
- Crushing efficiency improved due to optimized contact geometry and force transmission.
- Baseline crushing efficiency is 70.4%; while optimized machine crushing efficiency is 78.5%.
- Sources of energy consumption: The aluminium can absorbed significant crushing energy through progressive buckling deformation; while the electric motor used energy to overcome piston mass inertia/opposing force.

The optimized system demonstrated smoother force-displacement behaviour and reduced impact loading.

6. Conclusion

This study successfully evaluated the performance and optimization of previously designed aluminium Can crushing machine using finite element simulation analysis techniques. The optimized crusher design achieved lower stress concentration, reduced structural weight, improved crushing efficiency, and enhanced durability compared to the baseline design configuration. The optimized crusher can significantly improve aluminium recycling processes while minimizing operational costs and energy usage.

7. Recommendations

- Experimental validation should be performed using a prototype crusher.
- Fatigue and vibration analyses should be included in future work.
- AI-based optimization algorithms can further improve design efficiency.
- Composite materials may be considered for piston-connecting rod-crankshaft assembly for lightweight structures.

References

Akele, SMG. and Akuete, C (2022a). Analytical Evaluation of Aluminum Cans Crushing Machine. International Journal of Advances in Engineering and Management, Volume 4, Issue 8 Aug. 2022, pp: 1165-1171

Akele, SMG. and Akuete, C (2022b). Design and Construction of Aluminum Cans Crushing Machine. International Journal of Advances in Engineering and Management (IJAEM), Volume 4, Issue 10 Oct. 2022, pp: 102-107

Emir Esim, and Emre Benzer (2021). Structural Analysis of Industrial Foam Crusher Machine By Using Finite Element Method. European Journal of Science and Technology Special Issue 29, pp. 343-350

Bello, S.K., Bajela, G.G., Lamidi, S.B. and Oshinlaja, S. (2020). Design and Fabrication of Pneumatic Can Crushing Machine. International Journal of Advances in Scientific Research and Engineering, Volume 6, Issue 10, pp 154 – 161

Gogoi, B., Boruah, C., Kurmi, P., Bhuyan, J. And Begum, C.A. (2018). Fabrication Of An Aluminium Can Crusher Machine. A Project Report : Jorhat Engineering College, Jorhat.

Rajesh, R., Selvadurai, S., Sivakumar, S., Vino, M., and Veeramuthu, R. (2016). Design and Fabrication of Can Crusher. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Special Issue 8, pp 105 - 110

Sawant, D. A. and Venkatesh, M. A. (2016). Buckling And Crushing Analysis of Cylindrical Aluminium Cans And Optimizing The Parameters Effecting Crush Strength Using Fem. International Research Journal of Engineering and Technology, Volume: 03 Issue: 06, Pp 3081 – 3085