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# Development of a Crusher Machine for Recycling of Aluminium Can Waste

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**Abstract:** *The inspiration behind this design came from the festivals, wastage in malls, canteens and parties where people gather and consume a lot of canned drinks and these cans have to be recycled and be further used by the industries. The design of an aluminium can crusher was carried out to effectively crush aluminium cans of 33cl to obtain a percentage reduction in length of 70% which increases the production rate of aluminum cans by using the crushed cans as scraps and reduces environmental pollution resulting from aluminum cans waste. Construction of the machine was achieved. This machine when commercialized will certainly meet the need of various industries that are into production of aluminium cans and also for individuals who desire to be entrepreneurs in the area of recycling of aluminium cans. The crusher has the capacity to crush one can per second. The machine's test performance was found to be 77.5%.*

**Keywords:** *Crusher, recycling, aluminium cans, waste, environmental pollution*

## INTRODUCTION

Recycling is one of the areas that rapidly increases day by day in Nigeria. Aluminium cans are one of the important products which are being recycled on an increasing scale. For carrying out this recycling, can crushers are used. For recycling of these cans, manual operation is being carried out in industries, which is a time-consuming process and ultimately it leads to the reduction of production rate. Aluminium can recycling is the process by which scrap aluminium can be re-used in products after its initial production. The process involves simply re-melting the metal, which is far less expensive and energy intensive than creating new aluminium through the electrolysis of aluminium oxide ($Al_2O_3$), which must first be mined from bauxite ore and then refined using the Bayer process. The global aluminium recycling market was valued at approximately 5 billion Dollars in the year 2020 and is expected to grow at a compound annual growth rate (CAGR) of around 6% from 2021-2027. In Nigeria, aluminium waste and scrap recycling market was valued at Five Hundred Billion Naira in the year 2023 and is expected to grow around 15% from 2024-2026 (Murray *et al.*, 2023). Elfasakhan *et al.*, (2012) presented a new design. This can crusher which can crush a single can at a time consists of a hardware and software. The hardware includes mechanical structure, servomotor, light sensor, microcontroller and pneumatic system.

The pneumatic system has been used instead of an electrical motor since electrical motor with the needed specification (torque and horsepower) is very expensive. The software is the maestro for operating and controlling different system components. More *et al.,* (2013) have presented a review on study of jaw plates jaw crusher which tells us that crushers are major size reduction equipment used in mechanical, metallurgical and allied industries which crushes different types crushing is automatic, no manual supervision is necessary for the whole process. Vending mechanism is introduced in project marketing and to create public. Wakchaure *et al.* (2016) have presented a paper on design and fabrication of automatic can crusher using double acting cylinder for pneumatic system and IC's .

Furthermore, Shinde *et al.,* (2017) carried out the study of a can crushers and the various mechanisms employed. Some of the technological aspects like robust design, volume reduction was successfully implemented. Overall, the project was very enriching in terms of technical fabrication and design process. The current prototype reduces the volume of cans by 65 %. Auto feed mechanism have trouble due to speed which needs some improvement in near future. Saif *et al.,* (2014) have proposed a paper on fully automatic can crusher using pneumatics and microcontroller sensor. Khanapure *et al.,* (2014) have presented a paper which provide crushing action in both the strokes thus making it a dual stroke can crusher and provide automatic falling of crushed cans and automatic feed of new cans to be crushed so as to keep the crushing area free from human intervention thus providing safety to the operator. Kumar *et al.,* (2016) have presented a paper about fabrication of mechanical crusher which would help to crush the used juice cans, paint cans and punched sheet metal waste. The crusher is designed to operate on a crank and slotted lever mechanism and the power for the electrical operation of the crusher is taken from an electrical motor. This crusher crushes the cans effectively and the manufacturing as well as the maintenance cost is very less which is suitable for small recycling plants. Patel *et al.,* (2016) have presented a paper on design and fabrication of automatic can crusher and vending machine using cam and follower mechanism. Orhorhoro *et al.,* (2016) researched on performance analysis of locally design plastic crushing machine for domestic and industrial use in Nigeria. A plastic crushing machine designed and fabricated from locally sourced materials were used to crushed plastic materials mainly to reduced plastic wastes dumped across Nigeria cities. Performance analysis was carried out on the plastic crushing machine and the efficiency was calculated as 85.16% while the average machine through put capacity was determined as 0.112kg/sec.

From the above research papers, we have found that a number of methods are used for fabricating the can crusher including pneumatic system with IC's, motors etc. Pneumatic can crushers use automation reducing human intervention. However, the use of air compressor, valves and pipelines make the equipment more expensive which is not suitable for small scale recycling plant. We have decided to employ the use of a hydraulic jack which works on the principle of Pascal's law. When the plunger reciprocates with the aid of a gear pump then the oil from the reservoir is sucked in to the plunger cylinder during stroke of the plunger through the suction valve. This pressured oil compresses the available cans occupying the crushing chamber. After the crushing is completed, then the oil is rushed in to the reservoir. This method is efficient and suitable for local production due to its lower production cost.

## MATERIALS AND METHODS

### 2.1 Material Requirements and Selection

Mild Steel is selected for shaft, frame, nut, connecting rod, cylinder, motor seating, hopper, and bolt for its affordability, high strength, good machinability, and high wear resistant property. Grey cast iron is selected for the spur gear because of the free graphite in its structure acts as lubricant, good casting characteristics, high compressive strength, wear resistance and excellent machinability.

### 2.2 Design Assumptions and Specifications

The assumptions made during the design of this crusher were based on the American Society of Mechanical Engineers (ASME) code.

i. Density of steel ($D_s$)=7.86410kg/m$^3$
ii. Allowance shear stress of steel=55.8MN/M2
iii. A combined shock and fatigue factor for bending $K_m$=1.5 (for rotating shaft)
iv. Combined shock and fatigue factor for torsion $K_t$=1.0 (for rotating shaft)
v. Twisting moment factor $C_t$=1.0
vi. Shear modulus of rigidity (G) of steel =7.93N/m$^2$
vii. The maximum permissible tensile stress maybe taken as 112Mpa for shafts without allowance for keyways
viii. 84Mpa for shafts with allowance for keyways
ix. The maximum permissible shear stress maybe taken as56Mpa for shafts without allowance for keyways

## 2.3 Design Calculations

*Gear Train*

Speed ratio = $\frac{N_1}{N_2} = \frac{T_2}{T_1}$ (1)

*Shafts*

Shafts subjected to twisting moment only.

$\frac{T}{J} = \frac{\tau}{r}$ (2)

$J = \frac{\pi}{32} \times d^4$ (3)

$T = \frac{\pi}{16} \times \tau \times d^3$ (4)

*Electric Motor*

Hence,

Power (P)= $T \times \omega$ (5)

## 2.4 Configuration of the Machine

As shown in Fig. 1 is the front view and plan of the crusher machine.

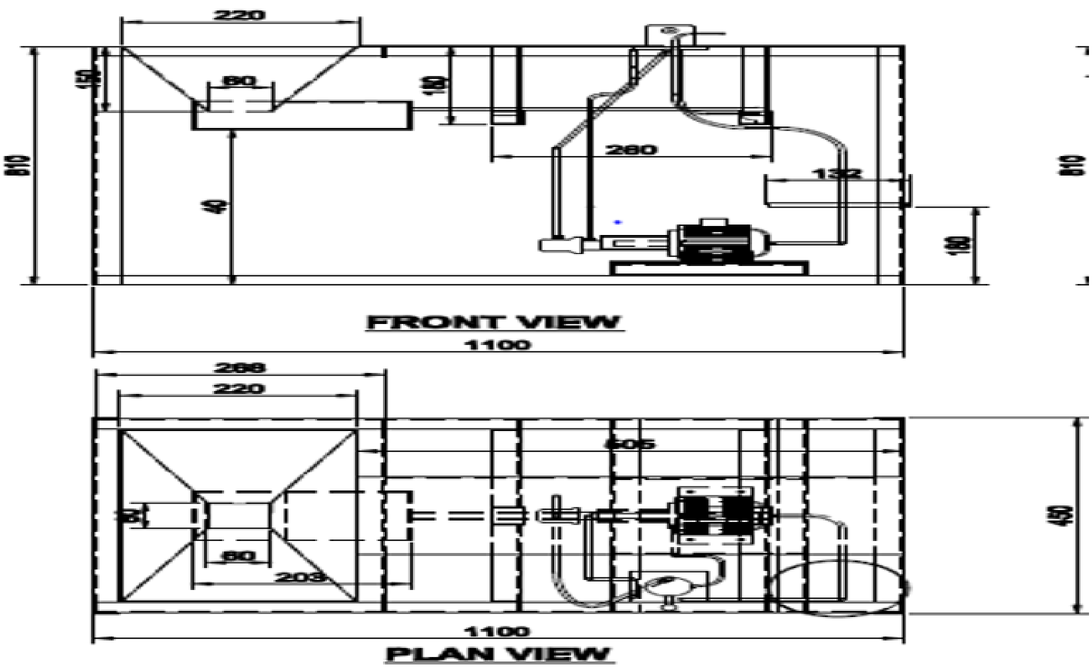


Fig 1. Front and plan view of the crusher machine



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Fig. 2 and Fig. 3 show the sectional views labeled descriptions of parts.

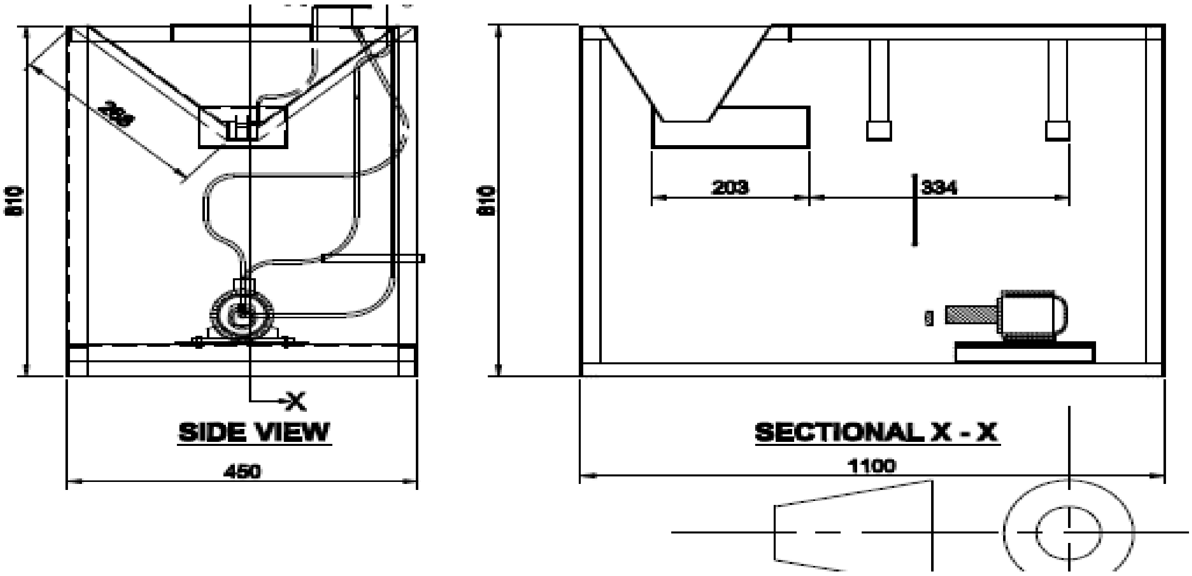


Fig. 2 Sectional view

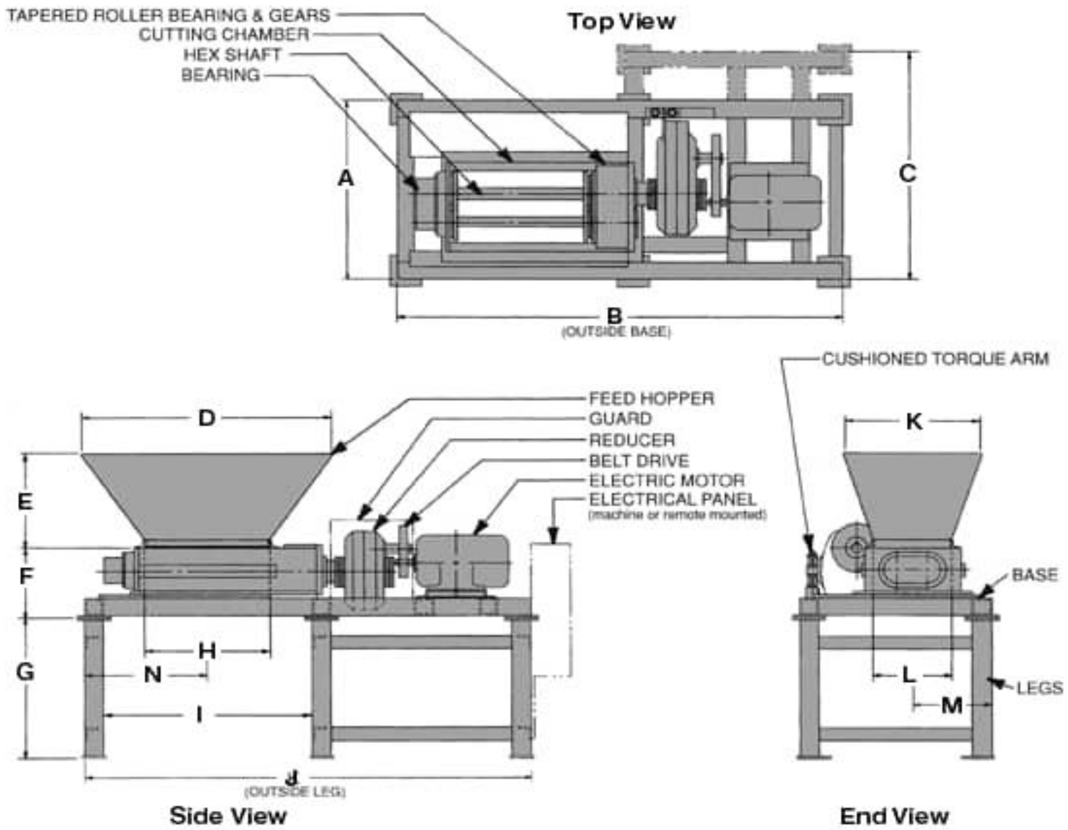


Fig. 3 Labeled descriptions of parts

Fig.4 shows the pictorial view of the crusher

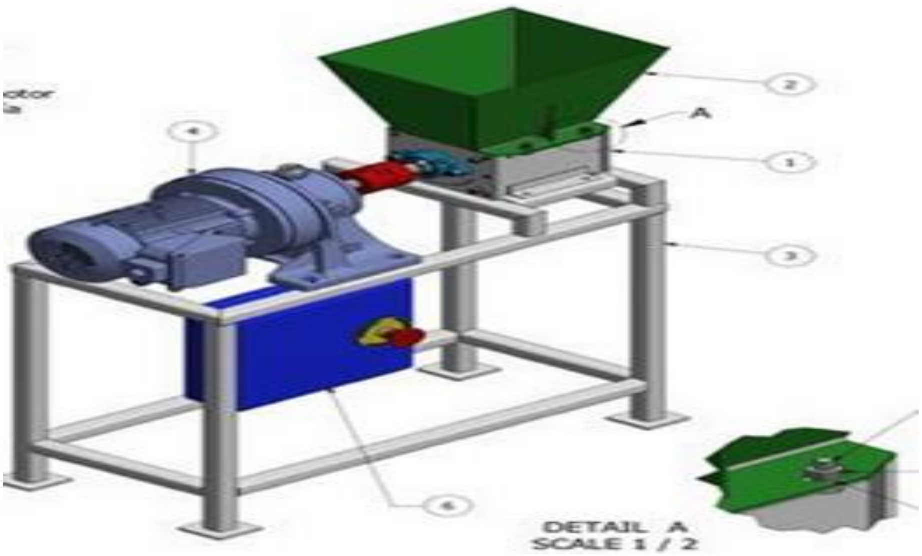


Fig. 4 Pictorial view of the crusher

## 2.5 Fabrication Details

i. First, marking out of the dimensions of the base plate and the hopper from a mild steel plate.
ii. The frame was constructed to dimension using appropriate tools (scriber, tape, hack saw)
iii. The angle bar length was joined together using arc welding to precision.
iv. The holes were drilled on the base metal using template for precision and accuracy
v. The electric motor was mounted on the base of the frame with the aid of bolts and nuts to hold it firmly to the base to avoid vibrations and wobbling.
vi. The fluid reservoir was mounted on the top of the frame with the aid of bolts and nuts.
vii. The hopper to accommodate the aluminium cans during loading was also welded to the base plate.
viii. The electric switch was also mounted on the base plate and the necessary connections were made.

Table-1 shows the Bill of Engineering Measurements and Evaluation (BEME)



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Table-1 Bill of Engineering Measurements and Evaluation (BEME)

| ] | PARTS | MATERIAL | DIMENSION (mm) | QTY | UNIT PRICE (N) | TOTAL PRICE(N) |
|---|---|---|---|---|---|---|
| 1 | Electric motor | N/A | 1hp | 1 | 125,000 | 125,000 |
| 2 | Hydraulic jack | Cast iron | N/A | 1 | 70,000 | 70,000 |
| 3 | Control switch | N/A | N/A | 1 | 5,000 | 8,000 |
| 4 | Angle bar | Mild steel | 1900x1200x5 | 1 | 7,000 | 7,000 |
| 5 | Square pipe | Mild steel | 1220x35x5 | 2 | 2,500 | 5,000 |
| 6 | Bolts, nuts and washer | Mild steel | M14 | 12 | 100 | 1,200 |
| 7 | Hack saw | Stainless steel | *Medium* | 2 | 2,000 | 4,000 |
| 8 | Hopper | Mild steel | 600x145x2 | 1 | 10,000 | 10,000 |
| 9 | Shaft | Mild steel | Ø30 | 1 | 26,000 | 26,000 |
| 10 | Anti rust spray | Chemical | N/A | 2 | 1,500 | 3,000 |
| 11 | Paint | Chemical | N/A | 2 | 1,050 | 1,100 |
| 12 | Fluid reservoir | plastic | 4 litres | 1 | 5,00 | 5,00 |
| 13 | Cylinder | Mild steel | 230x150x3 | 1 | 4,500 | 4,500 |
| 14 | Top plate | Mild steel | 900x550x6 | 1 | 27,500 | 27,500 |
| 15 | Electrodes | N/A | N/A | 2 | 1,500 | 3,000 |
| 16 | Workshop charges | N/A | N/A | N/A | 50,000 | 50,000 |
| 17 | Miscellaneous | N/A | N/A | N/A | 10,000 | 10,000 |
| 18 | Transportation | N/A | N/A | N/A | 30,000 | 30,000 |
| | Grand Total | | | | | 374,150 |

# RESULTS AND DISCUSSION

## 3.1 Test Procedures

The following steps were taken during testing of the crushing machine.
Step 1: The cans and collection container for the crushed cans were provided and the machine was in a good condition.
Step 2: The machine was connected to power.
Step 3: The jack was set so that it was at its maximum backward stroke to allow the loading of the cans.
Step 4: The hopper was then loaded with cans.
Step 5: The machine was switched ON using the control switch and the operation was timed with a stopwatch.
Step 6: The machine was then switched OFF using the control switch after crushing all the cans in the hopper.
Step 7: The time of crushing the cans were then recorded and the process was repeated in order to get the average time required for crushing each can (i.e., the feed rate).

3.2 Test Analysis

From the test carried out, 8cans of aluminium was fed through the hopper for series of times and the result recorded in the table above.

Based on the results obtained, it was found out that the average time for crushing of eight (8) cans was 7secs.

$$Feed\ rate = \frac{No.\ of\ can\ crushed}{Average\ crushing\ time} = \frac{8}{7} = 1.143$$

∴ Feed rate = 1can / sec.

Based on the result obtained from the above table, it was found out that the average time for loading 8cans was 11secs.

$$Loading\ time\ per\ can\ = \frac{Average\ loading\ time}{No.\ of\ cans\ crushed} = \frac{11}{8} = 1.375\ sec/can$$

Therefore, to fully load the hopper for each batch of operation containing 37cans, loading time = 37 x 1.375 = 51secs.

$$Percentage\ reduction\ in\ length\ of\ the\ can$$
$$= \frac{Original\ length(before\ crushing) - final\ length\ (after\ crushing)}{Original\ length} \times 100\%$$
$$= \frac{115\ mm - 35\ mm}{115\ mm} \times 100\% = 70\%$$

The results obtained is shown in Table-2.

Table-2 Test Result

| S/N | No. of Cans | Crushing Time (Sec) | Loading Time (Sec) | No of Properly crushed can | Machine throughput Capacity = $\frac{Number\ of\ can}{Crushing\ Time}$ | **Machine Efficiency=** $\frac{Properly\ crushed\ can}{No\ of\ can}\times 100\%$ |
|---|---|---|---|---|---|---|
| 1 | 8 | 7 | 11 | 5 | 1.14 | 62.5 |
| 2 | 8 | 7 | 12 | 6 | 1.14 | 75 |
| 3 | 8 | 6 | 10 | 7 | 1.33 | 87.5 |
| 4 | 8 | 8 | 11 | 6 | 1.00 | 75 |
| 5 | 8 | 7 | 11 | 7 | 1.14 | 87.5 |
| ∑ | | 35 | 55 | | | |
| Average | | 7 | 11 | | | 77.5 |

Based on the result obtained, the average crushing time for one can is 1 sec. This implies that 60 cans can be successfully crushed for every one hour which is faster and cheaper for small scale industry in Nigeria and Africa at large. The machine has an overall efficiency of *77.5%* which makes it viable to be used in a recycling plant. Also, we have been able to construct the crusher at a reduced cost that can effectively crush aluminium cans to increase production rate of aluminium cans by using the crushed cans as scraps and to provide an environment free of littered aluminium cans. This method of crushing is more effective than when cans are manually crushed.

## CONTRIBUTION TO KNOWLEDGE

A crusher machine was successfully developed and fabricated in Nigeria which helps to reduce importation of similar machines into our dear country and also, provide an environment free from aluminium cans making the environment a habitable place for all. This work has enhanced our Indigenous Technology.

## CONCLUSION

The crusher machine for recycling aluminium cans was made up of simple components that are durable and affordable for a small-scale industry. It has an overall efficiency up to 77.5% and ability to crush a unit of can for every second.

## CONFLICT OF INTEREST

There is no conflict of interest for this research work.

## ACKNOWLEDGEMENT

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