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Design and Construction of Aluminum Cans Crushing Machine

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ABSTRACT
The increasing presence of non-biodegradable waste materials, such as aluminum cans, in our home surroundings, on our streets and roads, bars, restaurants and hotels has adverse effects on our human existence and environment. Consequently, the paper highlights the design and manufacture of Aluminum Can crushing machine that aimed at reducing or eliminating the presence of used aluminum Cans in our environments. The method of approach involved preparing detail design of the machine parts, selection and purchase of materials locally, fabrication and assembling of the various parts in the mechanical workshops. The fabricated Aluminum crushing machine was then tested and evaluated for effectiveness. The results obtained showed gave required power input of 382W with piston velocity of 0.813m/s. The crushing rate of the machine was approximately 2 Cans/sec, 70% efficient, durable and rigid and able to withstand vibrations, and of self-loading capability. The Aluminum Can Crushing Machine was fabricated, tested and its performance evaluated. The Aluminum crushing machine was observed to be effective, portable and operator friendly requiring minimum human effort to perform the function for which it was designed.

Keywords: Aluminum Cans, Crushing, recycling, environment pollution

I. INTRODUCTION

In our world today a lot of human consumables come in Cans. In Nigeria so many food items are packaged in Cans especially beverages and alcoholic drinks. The disposability of these Cans after using the contents has with time become a major problem to our communities. In some places like households, restaurants, hotels, eateries and so on these empty Cans are mostly stacked into bags which eventually occupied the limited space or are thrown around the immediate environment and streets to constitute nuisance to the society.

One way of reducing the number of Cans littering the streets to recycling used Cans. Aluminum Cans can be recycled into new aluminum Cans or other products. For the former, aluminum Cans recycling is usually preceded by processes such as collecting, transporting, sorting and so on; while for the later, the processes involved would be collecting, crushing, transporting, and so on . According to Buza (2014) recycling is the last stage of reducing, reusing and recycling (3Rs) into raw material for other products. Recycling saves energy and money, as a source of raw materials, prevents environmental pollution, and creates jobs. With the increase of human population and ecosystem empty aluminum Cans today are sources of problem of environmental degradation and depletion of natural resources are likely to cause disease. The existing crushers are heavy ones and these crushers are excessively used for crushing materials at big industries and manufacturing plants for crushing cars, stones, metal components, etc., Moreover, these crushers are hydraulically and pneumatically operated and are feasible if very high amount of crushing forces are required for crushing a material. The operating costs of these crushers are very high as it requires continuous power, continuous maintenance as this involves hydraulic fluid or compressors kits, etc. These type of high end crushers are not necessary for small recycling plants and is not affordable to many people. It requires proper maintenance as the hydraulic fluid needs to be changed constantly on time basis. It also requires skilled labor for operation. (Senthil et. al., 2016).

A Can crusher is one of the most usable machines that can help to reduce the environmental pollution in the world. (Kshirsagar, 2014). Waste management and disposal is a tedious task when it comes to large quantity of Cans which results from huge consumption. With waste management

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problem is also embedded with the problem of transporting Cans to the recycling plants, which requires huge amount time and money. Gogoi et al. (2018) exerted that Can Crushers are widely applied in mechanical and allied industries such as beverage industries and in scrap dealers' shop to crush Cans made of different materials into smaller sizes a process that leads to the reduction in transportation cost and to save space. Therefore, crushing the Cans can help to maintain eco-friendly environment. (Chakule, 2020).

Rajesh et al. (2016) study reported the design and structure analysis of Can crusher. The study discussed processes like design, fabrication and assembling procedures which was the main purpose of the study. The designed Can crusher used mechanical single slider crank mechanism. The designed crusher was observed to be environmental friendly. Nagarajan et al. (2017) fabricated a manually operated Can crushing machine that incorporated a "quick return mechanism" for crushing two Cans separately at the same time by crushing a one Can during piston forward stroke and the other Can at the return stroke of the piston. The incorporated "quick return mechanism", which is an inversion of slider-crank mechanism, is to converts rotary motion into reciprocating motion. 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. Kumar et al. (2017) designed Can crushing machine that uses slider-crank mechanism with two sides crushing ability. The designed Can crusher is based on existing vertical crushing machines. A lot of tests were carried out to validate the crushing machine and its components. Results showed the machine and its elemental parts to function well. Qais et al. (2015) designed and constructed a Can crusher that is automated and uses mechanical single slider and microcontroller and sensor. The designed Can crusher was observed to function well. Devmane and Aloni (2017) design was mainly carried out in order to understand the fundamental knowledge of designing, mechanism and fabrication. The designed model has wide usability for crushing Cans and bottles. The designed Can crusher functions by holding a Can between two parallel solid surfaces and apply force on the Can by single slide mechanism that is driven by electric motor. Thus, by bringing the two solid surfaces together, the Can is eventually crushed. The Can crusher is designed aid recycling, easily maintained and eco-friendly also. Elfasakhany et al. (2012) Can crusher was constructed based on knowledge in horizontal and vertical crushing designs. The designed Can crushing machine is made up of hardwares (like mechanical structure, servomotor, light sensor, arduino microcontroller, and pneumatic system) and software (such as maestro for operating and controlling different system components). Testing and validation of the machine indicated that the crusher operated well. Khanapure et al. (2015) designed and fabricated Dual Stroke Aluminum Can Crusher. The special feature of the design is the automatic removal of crushed Cans from the crushing point and the automatic feeding of Cans to be crushed.

The above survey on Can crushing machine shows that a lot of studies and designs have been carried out over the years in other countries.

In this project aluminum Can crushing machine is designed and constructed with the aim of reducing the volume of aluminum Can by approximately seventy percent (70%) before transporting for recycling. Reducing the size of the Cans before transportation will greatly reduce the cost of transportation and ensure ease of handling.

II. METHODOLOGY

A mechanism is that part of a machine which contains two or more pieces so arranged that the motion of one compels the motion of the others, all in a fashion prescribed by the nature of the combination. In the setting of the methodology of this project two mechanisms were used. These mechanisms are:

2.1 Single-slider crank mechanism: Single slider-crank mechanism converts rotary motion of crank into reciprocating motion of piston. Single slider-crank mechanism consists of such links as frame, cylinder, crank, connecting rod and piston.

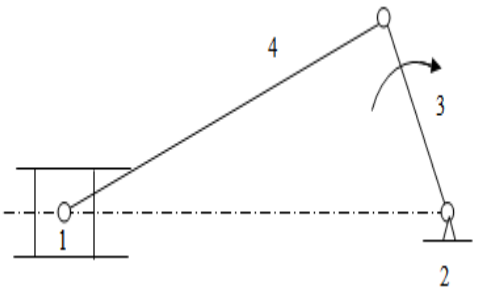

Fig. 2.1: single slider-crank mechanism

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2.2 Sprocket-chain drive mechanism: Sprocket-chain drive mechanism is a power transmission mechanism consisting of two or more sprockets of different sizes to transmit electrical power into mechanical power of the single slider-crank mechanism.

In the final 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.

In 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.

2.3 Main component parts

Frame: The frame is made of angle bar.

Fig. 2.2: the frame

Angle bar: Angle bar is an L-shaped mild steel bar (3mm and width of 1½ ×1½ inches) that is used to construct the frame of the crusher as well as the Can loader, bin holder and electric motor mounting.

Fig.2.3: Angle Plate

Sprocket chain: Sprocket chain (roller chain) is used for the transmission of mechanical power. Sprocket chain is driven by a sprocket.

Fig.2.4: sprocket chain and small sprocket

Sprocket: Sprocket is a wheel with teeth around its circumference. The teeth are designed to mesh with the sprocket chain track. And power is transmitted from one sprocket to another via the meshing chain.

Fig.2.5: big sprocket and plummer block

Plummer block: Plummer block is a block that carries a bearing in it for supporting a rotating shaft. Plummer blocks are usually mounted on a frame by means of strong bolts and nuts.

Electric Motor: This is the prime mover of the crushing machine. The electric motor converts electrical energy from the main supply into mechanical energy required by the slider-crank mechanism. For this project work a single-phase induction motor with 0.5horse power and speed of rating of 960rpm is used.

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Fig.2.6: electric motor

Crank: A crank is an arm that is attached at right angle to a shaft met to rotate. Crank was constructed from a mild steel bar. The crank helps to convert rotary motion of the electric motor via the shaft into reciprocating motion of the slider.

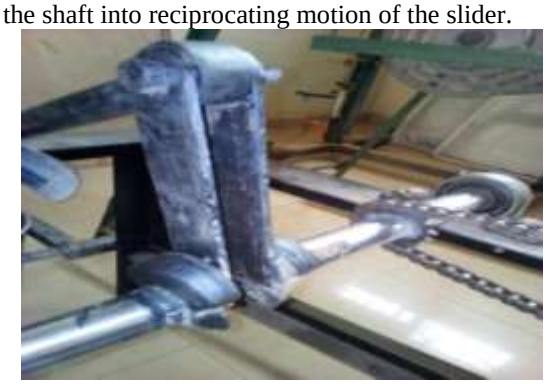
Fig.2.7: cranks and half-shafts

Shaft: Shaft is made of mild steel and is used to transmit power from the transmission to the crank which is welded to it at one end, Fig.2.8. The crusher is designed to function with two half shafts ((diameter 20mm and length of 600 m) that are linked together by crank and pin arrangement.

Connecting rod: The connecting rod connects the piston at one end to the crank at the other end via piston pin and crank pin respectively, Fig.2.8. Thus, they form a simple mechanism that converts rotary motion into reciprocating motion.

Piston: Piston (of diameter 6mm and thickness 5mm) is cup-like component made of aluminum alloys that is used to crush the Can against a rigid closed end of the cylinder.

Cylinder: The cylinder is the basic curvilinear geometric shapes.


Fig.2.8: assembled Can crusher

2.4 Ancillary components: Bolts and nuts: Bolts and nuts are fasteners used to rigidly hold two parts together. Collecting bin: The collecting bin is simply a removable plastic bucket that is purchased off shelf.

Washers: Washers are thin disk-shaped plates with a hole at the center through which bolt is passed for even distribution of load of bolt and nut

III. DESIGN ANALYSIS AND EVALUATION

3.1 Design specifications

Can: diameter D_c = 67mm, length L_c = 124mm
Piston: diameter D_p = 68mm, mass m_p = 22kg
Crank length r = 180mm = 0.18m
Connecting rod length L_{cr} = 305mm = 0.305m
Sprockets: small sprocket number of teeth T_s = 19,
Big sprocket number of teeth T_b = 43
Electric motor: power (P), ½ hp; speed (n), 180 rpm; cycle, 50; voltage, 230volts

To determine the force required to crush a can up to 70%, we take the help of a machine. In this machine, we take 4 plates of mass 5 kg to crush the can. Therefore, total mass required =5×4=20 kg

3.2 Design calculation

For manually operated Can Crusher

(i) Calculation of piston force to crush 1 Can

Force, F_p = mass x acceleration due to gravity
= m_p x g = 22 x 10 = 220N (i.e. a force of 220N is required to crush 1 Can in 1rev and reducing by 70% in length)

(ii) Calculation of lever speed (rpm)

The big sprocket has 43 (T_b) teeth and the small sprocket has 18 teeth (T_s).

$(n_b)/(n_s) = T_s / T_b$
$n_b = (T_s)/(T_b)$ x n_s = (19/43) x 180rpm = 79.5rpm ≈ 80rpm
n_b = speed of lever = 80rpm

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Note that it takes 1rev to crush 1Can, therefore 80 Cans will be crushed in 80rev in 1 minute.

(iii) Calculation of torque on the lever

Torque, T = Force (F_p) × length of lever (r)

T = 220 x 0.18 = 39.6N.m ≈ 40N.m

(iv) Calculation of power transmitted

Power, P = 2 x π x n_b x T/60 = (2 x π×80 × 40)/60 = 335.10W (electric motor of ½hp (382W) was selected for this design).

3.3 For electric motor powered Can crusher

Force required to crush 1 Can, F_p = 220N (calculated)

Torque on big sprocket, T = 40N.m (calculated)

Note: theoretically it takes 80 Cans will be crushed in 80rpm.

3.4 Performance evaluation

The designed Can crushing machine is a versatile machine in the sense that it can also be manually operated in the event of power or electric motor failure.

Performance evaluation of the Can crusher is highlighted in Tables 5.1 and 5.2.

Table 3.1: comparison between electric motor driven and manually operated

Description	Electric motor driven	Manually operated
Effort required	Low	Very high
Efficiency	Low	High
Rate of Cans crushed per minute	10	80
Effectiveness	70% (average)	75% (average)
Speed of slider	Low	Very high
Torque	Low	Very high

Table 3.2: expected result versus actual result

Criteria	Expected Results	Actual Results
Reliability	70% crushed	75% crushed
Durability: manufactured from mild steel and stainless steel	Rigid and able to withstand vibrations	100%
Self-loading	To be able to automatically load the Cans for crushing at a rate of 20Cans/min.	Crushing rate 18Cans/min.
The crushed Cans Collector	Each Can must drop inside a collector after crushing.	100%

IV. RESULTS AND DISCUSSION

When manually operated the Can crushing machine can crush a Can with a force of 220N 1rev reducing the length by 70%. The crushing rate of the machine is approximately 80 Cans/minute, that is 2 cans can be crushed in 1sec. The efficiency of the machine is 70%, that is the length of of a can is reduced by 70%, which makes crushed Cans handling easy. The machine frame was designed from mild steel angle bar for durability and rigidity.

V. CONCLUSION

The Aluminum Can Crushing Machine was designed and fabricated, and then tested to evaluate its performance. The crushing machine was observed to be effective. Essentially, the Aluminum Can crushing machine portable and operator friendly; minimum human effort is only required for loading and offloading of Cans. Finally, the machine is found to be able to perform the function for which it was designed.

VI. RECOMMENDATION

It is here recommended that for future modifications the materials used for this fabrication of the piston-cylinder arrangement be put under consideration as good material selection will help reduce friction, eventually, wear of these parts. Also, attention should be given to how to reduce vibration of the frame when the electric motor is working.

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