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Design and Manufacture of Waste Paper Shredding Machine

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ABSTRACT: Waste management has become paramount in our society today as the amount of waste generated is on the increase. Waste management assists not only a concern in the area of handling the waste materials but also in recovering most of them. The recovering of waste papers saves the forest trees because the percentage of virgin pulp required for paper production will be reduced. To aid the recovering process, waste paper shredders are needed at collection centre's to help them shred the papers for easy baling and transportation to recycling centre's.

A review of paper sources, the recycling process and various existing paper shredding machine was conducted. Two design concepts based on the drive system were developed and concept A was selected for detailed design. The machine was manufactured using the secondary manufacturing process, and tested for performance. The results obtained showed an approximate efficiency of 84.8 percent. This shows that the machine has good performance.

KEYWORDS: Waste, Paper, Shredding, Baling.

I. INTRODUCTION

Over the years, the amount of domestic solid wastes had grown steadily, in part because of increasing population, but more so because of changing lifestyles and the increasing use of deposable materials (Bernard, 1981).

Studies show that the waste generated by a city is generally composed of materials such as paper, food waste, glass, metals, wood, plastics, rubber and leather and textile (Igbinomwanhia, 2009).

However, the proportions vary greatly depending on the generator (commercial, residential, schools, market places) and the time of year (Igbinomwanhia, 2011).

The paper waste which is one of the components of the solid waste may pose some problem to humanity such as:

i. Filling the dump site quickly because most of the paper wastes are not recycled.

ii. Generating methane gas as a result of its decomposition with other waste; although this can be source of energy but in this country where such machinery to harness this gas is not available, it becomes a serious problem because methane is dangerous to breathe and can create a fire hazard. Also methane contributes more on global warming (Louis, 2009).

The high volume of paper waste is also as a result of how it is packaged and disposed. Some residents and offices do not have the facility to package these papers to reduce their volume and as such dispose them indiscriminately especially in the areas where environmental sanitation monitoring is not serious. This causes waste papers to be littered all over the place which can be an eye sore.

It is in this regard that the shredding machine is of high value. Waste paper shredding makes baling easy and help to reduce the volume that a waste paper will occupy in a waste bin drastically. Not only that it reduces the volume, the shredded paper which ordinarily is supposed to be taken to dump site can serve useful purposes. It has been shown that recycling one ton of news paper eliminates three cubic meters of landfill (Jodi, 1989). The shredding machine is also important because confidential documents that are no long useful can be shredded and disposed. Ordinary people burn these documents which is not a good practice because it pollutes the environment.

II. MATERIALS

The materials used for this research work is based on economic requirement which has to do with the cost of the material, fabrication requirement which refers to the workability and weldability of the materials and the service requirement which refers to the properties of the material like strength, toughness, corrosion resistance, resistance to heat, etc

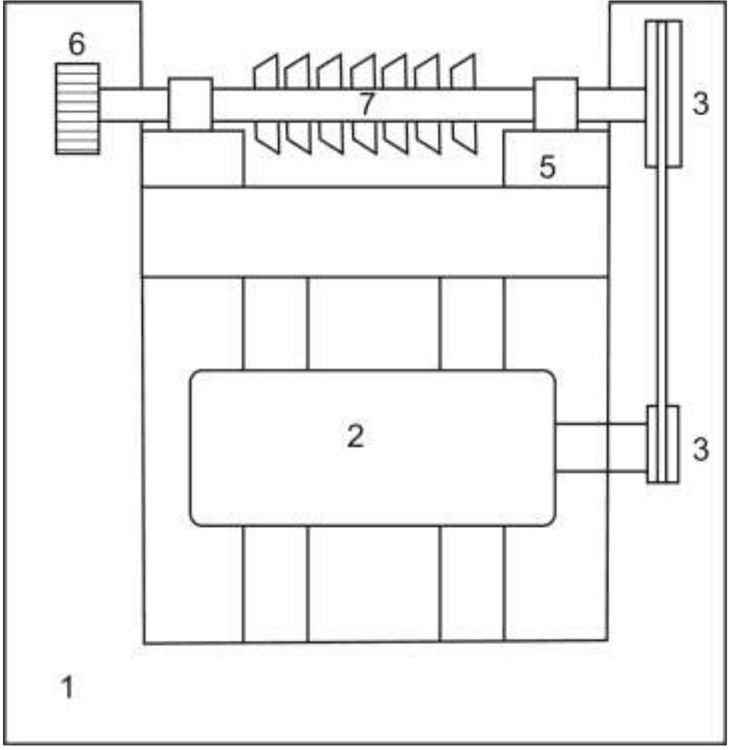
Table 1. Summary of the choice of material selected

Part	Material	Justification
Shaft	Mild steel	It has good strength It can be machined easily It is affordable
Base and Main frame	Mild steel	It has good strength It can be machined easily High resistance to deformation
Belt	Reinforced rubber	It has good strength
Pulley	Mild steel	It has good strength It can be machined easily It is readily available
Spur gear	Telflon	It is cheap and can be easily machined
Bearing	High Carbon Steel	Has good wear and corrosion resistance. It also hard and tough

CONCEPTUAL DESIGN

DESIGN CONCEPT A: Shredding machine with belt drive for the transmission of power

This concept comprises the main frame which provides support. The components of the system include cutting blades, electric motor which is the source of power, motor support, motor and shaft. Other components are pulleys, rubber belt through which the power from the motor is transmitted to the shaft carrying the blades (blades are distributed evenly on the shaft), the bearing housing (shaft support) and the spur gears which help to transmit the rotary motion of the first shaft to the second shaft.



Legend

1 Mainframe

2 Prime Mover

3 Pulleys

4 Rubber belt

5 Shaft Support

6 Gears

7 Shaft with blades

8 Motor Supports

Fig. 1: The Schematic Diagram of Design Concept A

DESIGN CONCEPT B: Shredding Machine with Gear Drive for Transmission of Power

Legend

1. Main frame
2. Prime mover
3. Spur gear
4. Bearing housing
5. Shaft with blade
6. Motor support

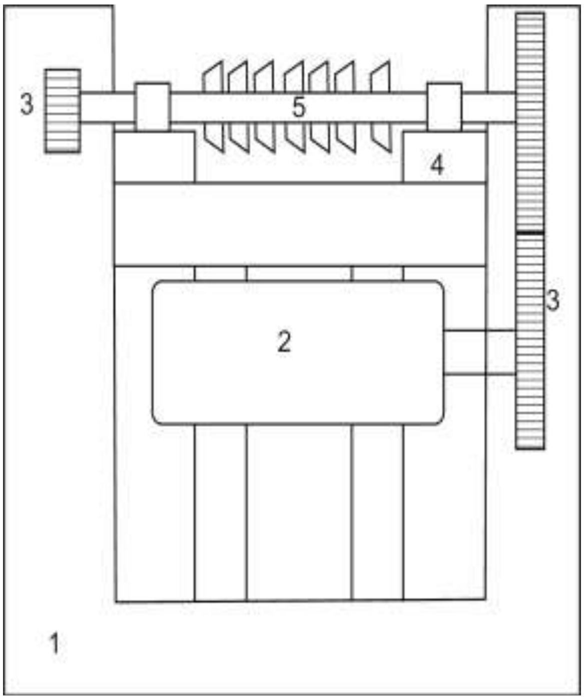


Fig.2: The Schematic Diagram of Design Concept B

This model consists of the mainframe which supports the machine. It applies a gear mechanism for the transmission of power from the electric motor to the cutting blade. Here a gear box is required which may pose some complications. The main shaft on which the blades are machined also transmits the rotary motion to the second shafts via spur gear. The rotary action of the two shafts brings about the cutting of papers which runs between them.

SELECTION OF DESIGN CONCEPT

Design concept A was selected for detailed design based on its simplicity, maintainability and economic reason.

DESIGN CONSIDERATION

Determination of cutting force
Power determination
Machine torque
Shaft diameter
Gear module
Bearing selection

DETAILED DESIGN

Cutting force

Cutting force (F_c) = τ x t - -------------------- 1

Tensile strength = 3.6N/mm
Shear strength (τ) = 80% of tensile strength
τ = 80/100 x 3.6 = 2.88N/mm.
Considering a thickness of 2mm
F_c = 1.42 x 2 = 5.76N
Using a factor of safety of 3
F_c = 5.76 x3 = 17.28N
Considering the shaft as one with uniformly distributed load,
The force at the cutting spot is 17.28N and it is distributed at interval of 12mm on the shaft with the cutting blades

$P = \frac{aq}{n+1}$ (Onyeyili, 1998) --------------------------------------2

n = The degree of parabola =0

$q = 17.28N/12mm, \quad a = 320mm$

$\therefore \quad p = \frac{1728 \text{ x } 320}{12} = 460.8N$ = total cutting force

Cutting power (P_C) = total cutting force (F_{TC}) x cutting speed (S_C)
P_C = 460.8 x 0.28 = 129W
Using a factor of safety of 3 from standard values
P_C = 129 x 3 = 387W
Transmitted power (P_T) = cutting power (P_c) + power loss in belt (P_{LB})
+ power loss in gear (P_{Lg})+ power loss in bearing (P_{Lb})

$P_T = 386 + 0.05\,P_T + 0 + 0.62$
$P_T - 0.05\,P_T = 387.62$
$0.95\,P_T = 387.62$
$P_T = \frac{387.62}{0.95}$
$P_T = 408.02W$

$\text{Torque} = (T_1 - T_2)$ −−−−−−−−−−−−−3

$T_1 = \sigma a$
$T_1 = 1.14 \text{ x } 10^6 \text{ x } 1.0 \text{ x } 10^{-4}$
$T_1 = 114N$

$T_2 = e^{\frac{T_1}{\left(\frac{N\theta}{\sin\ \beta}\right)}}$

$T_2 = \frac{114}{6.74}$

$T_2 = 16.9N$

Torque = $(114-16.9) \text{ x } 60 \text{ x } 10^{-3}$= 5.83Nm
Bending moment (BM) = 375.9 x 160 – $(157.6 \times 170) = 33352Nmm$
For rotating shaft load gradually applied $K_m = 1.5;\ K_t = 1$
For solid shaft having no axial loading, ASME CODE equation is given by

$d^3 = 16/\pi\tau\sqrt{(K_m M)^2 + (k_t T)^2}$ --------------------------4

$T_{e = \sqrt{(K_m M)^2 + (k_t T)^2}}$

$T_e = \sqrt{(1.5 \times 33352)^2 + (1 \times 5830)^2}$

$T_e = 50366 \text{ Nmm}$

$d = \left(\frac{16 \text{ x } T_e}{\pi\tau}\right)^{1/3}$

τ = 40N/ 〖mm〗 ^2

$d = \left(\frac{16 \text{ x } 50366}{\pi \text{ x} 40}\right)^{1/3}$

d = 18.6mm
Using a standard diameter of 25mm

$$m = \left(\frac{F_t}{sk\pi^2 y}\right)^{1/2} \text{--}5$$

$$F_t = 433N, K = 4, y = 0.104, A = \frac{140MN}{m^2}$$

$$m = \left(\frac{433}{140 \text{ x } 10^6 \text{ x } 4\text{x } \pi^2 \text{x } 0\,.104}\right)^{1/2}$$

$m = 0.87$ mm, Using a standard module of 3mm

From SKF general catalogue page 31 we have
For L_{10h} = 20,000 hours, rotational speed of 900rpm.
The ratio of basic dynamic load rating to the equivalent dynamic bearing load is given as
$^C/_P = 10.3$
C = 10.3xP
P= 1 x F_{rA} = 375.9N
Therefore, C = 10.3 x 375.9 = 3872N

Description of the Shredding Machine
The machine is made up of the following major components; electric motor, main shaft, main frame, bearing, pulley, gear, cover plates and bolt and nuts.

Electric motor: It is the prime mover of the machine which is powered by an electric output source. In this research work, a single phase motor in used.

Main Shaft: The main shaft is made of mild steel of diameter 25mm and 320mm long. The cutting blades are integral part of the shaft.

Main Frame: The main frame provides support for the components of the machine.

Bearings: Dip groove ball bearings are used in this machine and they are located at both ends of the main shaft in order to reduce friction.

Cover plates: It is used to cover the components housed in the main frame

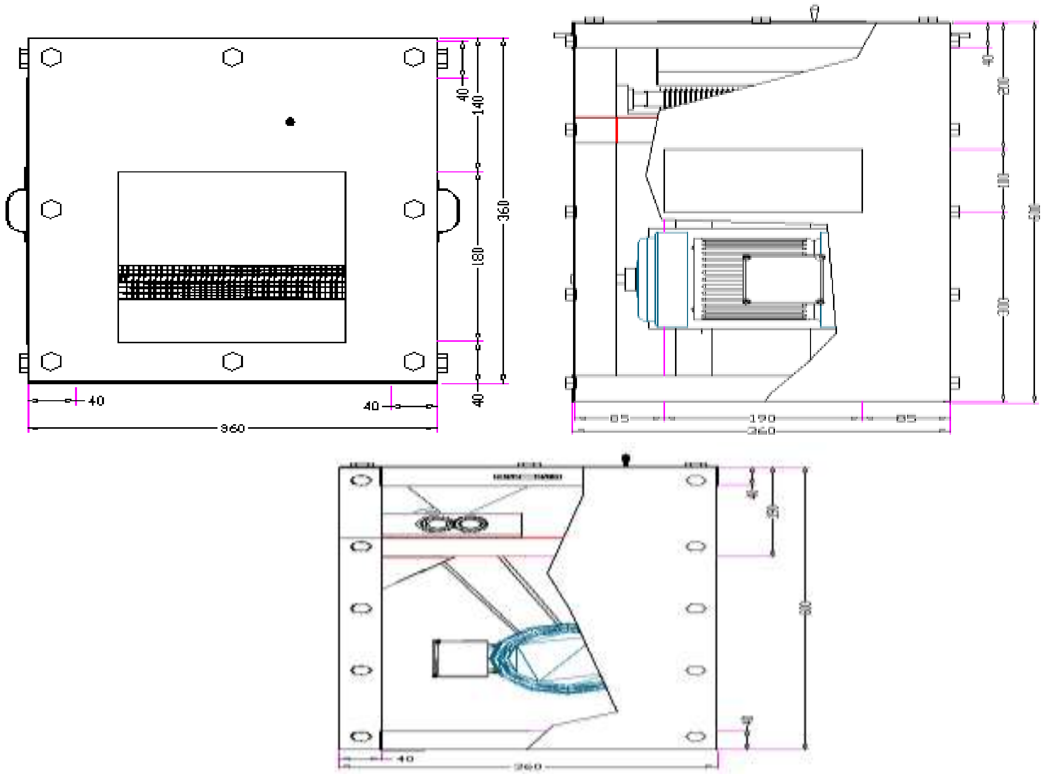


Fig.3: Orthographic view of the machine

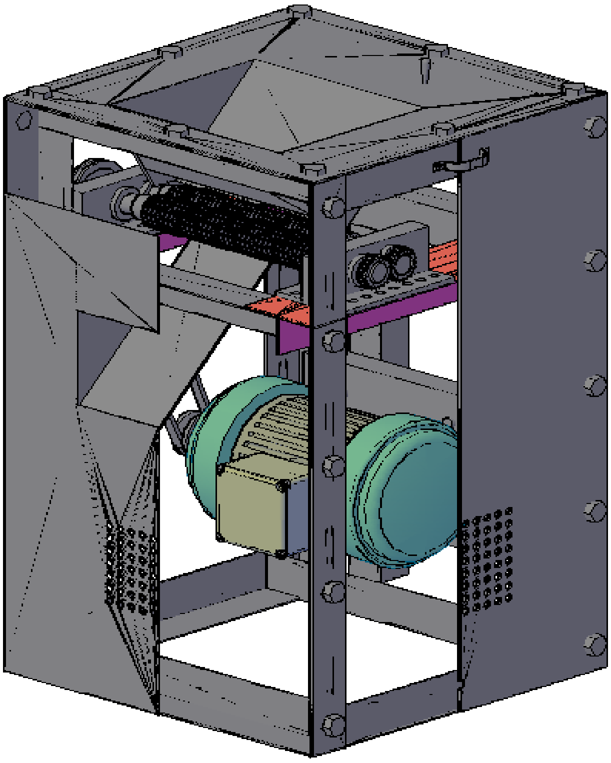


Fig.4: Rendered cut away view of the machine

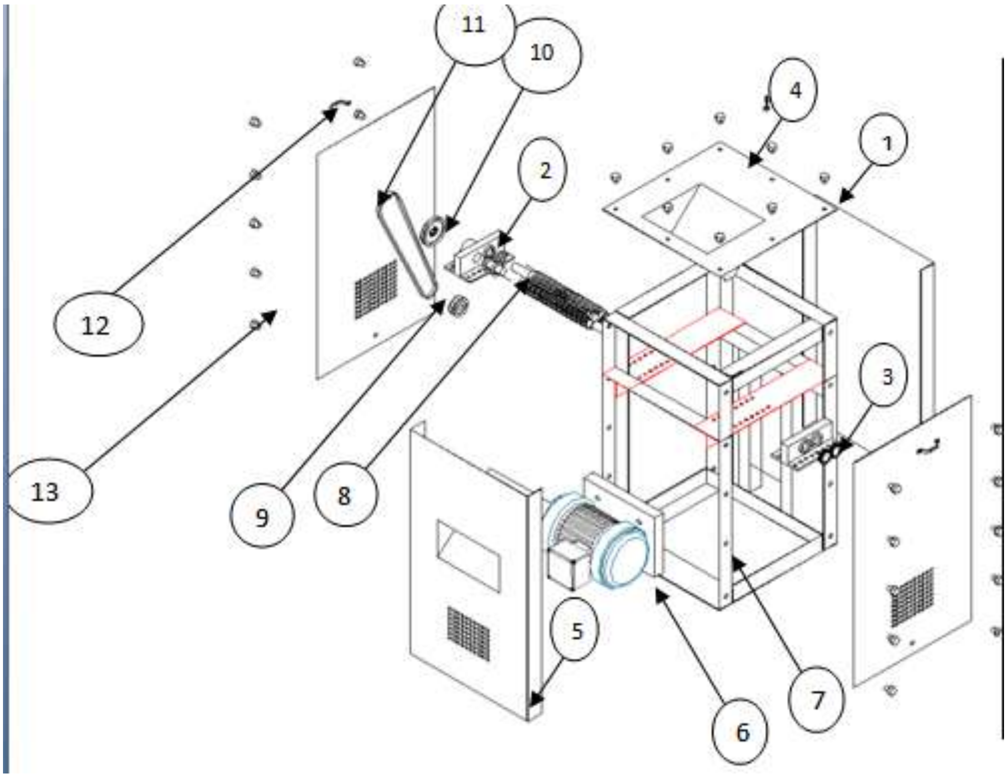
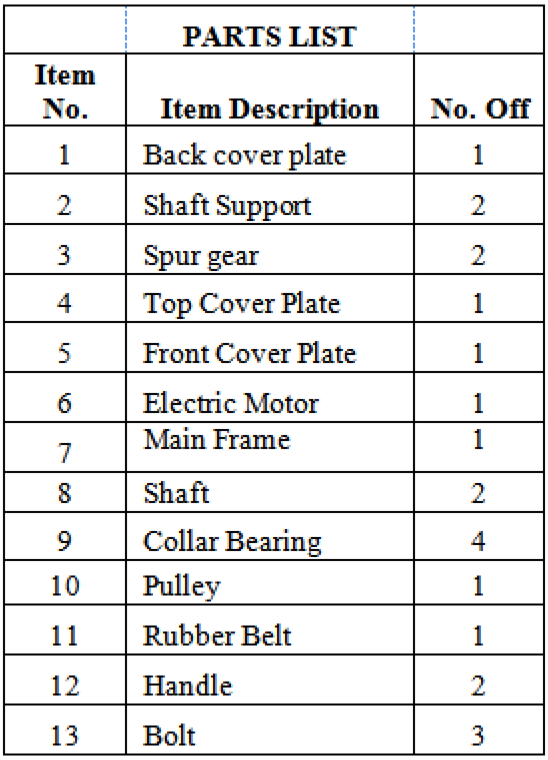


Fig.5: Exploded view of the machine



	PARTS LIST	
Item No.	**Item Description**	**No. Off**
1	Back cover plate	1
2	Shaft Support	2
3	Spur gear	2
4	Top Cover Plate	1
5	Front Cover Plate	1
6	Electric Motor	1
7	Main Frame	1
8	Shaft	2
9	Collar Bearing	4
10	Pulley	1
11	Rubber Belt	1
12	Handle	2
13	Bolt	3

Fabrication Process

1. Cutting mechanism

a. The shaft carrying the blades, was turned to a diameter of 50mm and stepped down to 25mm diameter from both ends to a length of 40mm

The blades were then machined on the shaft using a special tool.

b. The bearing housing which is rectangular in shape is faced using the lathe machine to the appropriate dimension. Holes of diameter equal to 45mm were drilled on them to accommodate the collar bearing before they were welded to a plate with holes drilled accordingly which will enable them to be fixed on the mainframe. The shaft supports are four in number.

c. The gear: The two gears were machined on a milling machine according to the specifications.

d. The key ways were cut on the gears and the shafts using the shaping machine.

e. The keys were fabricated according to the specifications.

2. The mainframe: The required angle bar steels were cut to size, grounded to remove the sharp edges and welded to form the mainframe and the motor support.

The cover plates: They were cut to size and grounded to remove sharp edges as well. The inlet of the paper is formed on the top cover plate while the outlet is formed on the front. Vent holes of diameter 10mm were drilled on the two side cover plates.

III. TESTING AND RESULT

PERFORMANCE TEST

The performance of the design was carried out on the machine by shredding a given quantity of paper.

PROCEDURE

A given quantity of paper was shredded and the time taken was recorded. The mass of the paper shredded was measured and recorded and the mass of paper not shredded was measured and recorded as well. The result is shown on table 2 below

Table 2: Time Taken to Shred a Given Quantity of Paper

S/N	Mass of paper feed [kg]	Work Time[minutes]	Mass of paper Shredded[kg]	Mass of paper not Shredded[kg]	Percentage Efficiency
1	2.49	10	2.1	0.39	84

2	5.18	20	4.4	0.78	85
3	7.78	30	6.6	1.18	85

IV. DISCUSSION OF RESULT

Like any other design, this work was not expected to attain 100% efficiency in operation. There are possible unforeseen weaknesses or faults which may have occurred during the fabrication of the machine (Igbinomwanhia, 1995). Such faults when discovered will be taken care of in the subsequent redesign as design as a continuous process. It was observe that when waste paper of low strength was shredded part of it clogged to the cutting blades which contributed to some of the errors. Notwithstanding, the errors found out here is within error limit for paper shredders.

From table 2 above, we can extrapolate that the machine will shred about 13.2kg of paper in 1hour and 2.39kg are not shredded. This implies that if the machine works for 6 hour in a day, a maximum of 79.2kg papers will be shredded and about 14.2kg not shredded

Table 3: Quantity of Paper Shredded in Eight Working Hours

S/N	Work Time (hours)	Mass of paper feed [kg]	Mass of paper Shredded[kg]	Mass of paper not Shredded[kg]
1	1	15.56	13.2	2.36
2	2	31.12	26.4	4.72
3	3	46.64	39.6	7.04
4	4	62.24	52.8	9.44
5	5	77.80	66.0	11.80
6	6	93.36	79.2	14.16
7	7	108.92	92.4	16.52
8	8	124.48	105.6	18.88

Efficiency of machine= ((amount of paper shredded)/(Total amount of paper shredded)) ×100
Efficiency = (79.2/93.36)x100 = 84.8%

V. CONCLUSION

1. The design and manufacture of the paper shredder with locally available materials was successfully carried out.
2. The machine was tested and the results revealed that the machine has 84.8 % performance which is a good performance.
3. This project contributed to the development of local technology which is the essence of Engineering.

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