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DESIGN AND CONSTRUCTION OF A PAPER SHREDDING MACHINE

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***Abstract*—This paper shredding machine was designed to solve problems on identity theft, fraud, cost of disposing of paper and ease of paper recycling by properly shredding sensitive documents. The machine frame was made of mild steel and was designed to have a dimension of 525mm x 400mm x 200mm. Also, the shafts and the cutting blades were made of medium carbon steel while its method of production involved processes such as metal forming, welding, machining, and use of mechanical fasteners. The machine, designed to shred a maximum of 15pieces of paper at a single pass, was found to have performed satisfactorily well and met the intended aim and objectives. It is operated using 75watts (0.075kw) electric motor which provides the necessary force and speed required for shredding the paper into chads. The machine is easy to operate and cheap to maintain.**

Keywords—Paper disposal, Design, Shredding, Documents security

I. INTRODUCTION

Paper is formed from wood pulp. The wood pulp is compressed to form a flexible thin sheet. The thin layer of intertwined fibre is paper (Hunter, 1943). Paper is the substance that forms a document and hence often contains sensitive information. It is necessary to prevent this information from getting to the wrong hands. The way forward was to destroy paper in a way that its content is of no use before discarding. This requires many studies to produce a device to serve this purpose. This is the origin of the paper shredding machine. Paper was invented in China, in 105 AD, by the Chinese Eunuch Ts'aiLun. After the Chinese discovered paper, it took 500 years for paper to be used in Europe and through the years, the necessity for the paper to be destroyed rose to a high degree. By the 20th century, the paper was very popular and needed in almost every human activities. It is use cuts across personal needs to industrial/company use. Moreover, then, in 1909, almost 6000 years after the invention of papyrus, the first Paper Shredding machine was invented by a man called Abbott Augustus Low.

Although his invention was never developed to a product, his design was implemented in offices and other places where paper need to be discarded and destroyed in a way that there will be no information leak. He did not develop beyond his initial prototype creation, so he is not recognised as the first inventor of the paper shredding machine. However, he is still a notable inventor in American history, second only in patent holdings to Thomas Edison (Randorf, 2002). The First Recognized invention of the paper shredding machine was credited to a German-born Adolf Ehinger in 1935. Unlike the American inventor, he saw the need for the paper shredder to be manufactured. He had a lot of documents (anti-Nazi propaganda) whose information need to be kept confidential. It was in this moment that Adolf Ehinger knew that he needed to create a machine that would render confidential papers unreadable to shred his anti-Nazi propaganda to avoid the inquiries of the authorities.

The confidential documents could be removed from the trash, reassembled and read, which may lead to corporate espionage. In the Enron Accounting scandals, it was discovered that most documents were wrongly fed into the shredder, making the process of shredding not giving the desired result. Horizontal paper passing through the shredder is an efficient way to ensure that useful information is rendered useless after passing through the shredder. For this reason, modern shredding machines are capable of cutting paper to tiny bits even smaller than a length of a staple. To destroy private, confidential, or sensitive documents, both public and private organisations, businesses, and individuals employ shredders. It is critical that most sensitive document which includes but not limited to bank account statements, credit cards information that can be hijacked by criminals are shredded. Libin Samuel et al. (2014) designed a waste shredder which can be considered too complicated for documents. Though, it can shred any form of agricultural waste. Also,

Nithyananth et al. (2014) proposed a machine to improve the traditional agro waste disposal method that dump waste to decomposed naturally to using a shredder that chops these waste and converts into nourishing fertiliser. The proposed machine is an attachment to a KAMCO Tera-track 4W tractor, which provides the shredder input power and support. The cutting blades are of different types (rotary, triangular, screw blades) to suit chipping and powdering operations.

Olukunle (2016) on his study to improve the process of reducing post-consumer plastic waste accumulation. He designed a system with specially selected parameters to improve existing machines.

Glogowska and Rozpedowski (2016) look further into mechanical shredding of polymeric materials. It presents a test for determining the influence of size and shape of sieve opening in the shredder on parameters and properties of obtained recyclate. The parameters considered include electrical consumption, shredder chamber temperature, recyclate temperature. Properties of recyclate considered are the geometric size and bulk density.

Screenivas et al. (2017) consider the lifestyle of people and the way they performed their activities. He focused on the design and developing of a machine to shred leaves into powder to prepare vermin compost.

Zhuang et al. (2017) Carried out a study to initiate the use of analytic hierarchy process with graph theory and matrix approach to help an organization choose the best shredder that suits their establishment or use. It presents an effective and easy to apply an approach to choose from alternatives. Manufacturers can also make use of this approach for her analysis.

Siddiqui et al. (2017) studied in details, the design and procedure of paper shredder machine. The various part from frame, transmission and cutting system were separately studied in details. The study centred on the types, profiles, dimensions, alignment, advantages and disadvantages of the different parts type. The study also covers the design of the 3D model of various part Dassult systems SOLIDWORKS and its motion study and stand analysis in ANSYS 15. Stripper finger component was incorporated in work to resolve the issue of a strip of paper returning with the blade.

Ayoola (2008) designed a shredding machine with a shredding capacity of 7sheets per pass. This work, however, aimed at achieving a shredding capacity of 15 sheets in one pass.

Ankit et al. (2018) designed an atomise paper shredder, which is more economical, time-saving and applicable. The machine closes limitation such as time reduction, more paper shred per time. Paper backflow along cutting blades is eliminated, reduce noise and vibration.

2. MATERIALS AND METHOD

The following are the significant parts that make up the paper shredding machine.

The machine frame.

Shredder support

Drive shaft assembly

Cutting blades

Gears

Electric motor

The left and right base

A. Material selection for component design

According to Ukwuaba (2015), material selection depends on some operating conditions. Some of the conditions or factors considered in selecting materials are:

Pressure and load involved

Operating temperature

Availability

Cost

Functionality

With those above, material requirements and their properties in view, the following materials were selected for the design of components concerned.

Medium carbon steel was selected for the shaft and cutting blade designs because of its carbon content of about 0.45 to 0.5% which gives hardness and strength to resist torsion effect, excellent wear resistance (Khurmi R.S. and Gupta J.K.,2012), reliability and minimum cost.

Mild steel was selected for the machine frame design because of its carbon content (which ranges from about 0.15% to 0.3% and makes it be easily shaped and machined), availability at minimal cost, and ease of welding due to its specific properties.

The material selected for the gear design was plastic because of its availability, low cost compared to metals, excellent corrosion resistance, lightweight, and ease of fabrication.

B. Tools/machines used during the design and construction of the paper shredding machine

a. Grinding machine: The grinding machine with the aid of a cutting disc was used for cutting of the mild steel pan as well as the shaft to the required dimension.

b. Machine: The folding machine was used to fold the mild steel sheet metal into a rectangular shape.

c. Tape: A tape rule was used to measure the mild sheet metal and shaft.

d. Steel chalk: steel chalk was used to mark out the measured length of the mild steel sheet metal; medium carbon steel shaft, as well as other components, used that required measurement.

e. Vernier Caliper: The vernier calliper was for measuring the internal diameter of the blade and gears.

f. Vice: The bench vice was used mainly for holding the workpiece during the cutting operation.

g. Drilling machine: the drilling machine was used to drill holes on the hopper.

h. Electric Arc Welding Machine: Electric arc welding machine was used for welding the machine frame and the hopper.

i. Riveting gun: Riveting gun and pin were used to fasten the rollers and hinges to the machine frame.

C. Parts designed

The following parts were designed to obtain the required paper shredding machine.

a. Electric Motor: The electric motor has forward rotation by transmitting the required power for the shredding of the paper. The power rating of the electric motor used for this project was 75watts (0.075kw) rotating at a speed of 1450rev/min.

b. Drive Shaft Assembly: The shaft used for designing of this project was made of medium carbon steel rod having a circular shape. The steel rod was machined on a lathe to obtain a hexagonal shape, as shown in fig. 1 below. Two shafts were used in designing the paper shredding machine, one of which is the main shaft while the other is the driven shaft.

c. The Blades: The blade is a circular cutting blade that does the actual shredding of the paper into strips. For this design, a medium carbon steel material with a thickness of 1.5mm was used for the blade. The internal diameter of the blade was designed on a lathe to obtain a hexagonal shape, as shown in fig. 2 below so that the designed shaft could fit in. A total of 112 washers were designed, and 56 washers were mounted on each shaft.

d. Gears: The gears used for this project were made of plastic materials. Four sets of gears with different diameters and sizes were machined on a lathe. The first gear directly connected to the electric motor was designed to have four teeth with a diameter of 6mm, the second gear was designed to have 13 teeth with a 30mm diameter. The third gear was designed to possess 37 teeth with 56mm diameter, while the fourth gear was designed to have 42teeth with 42mm diameter. Fig. 3 below shows a typical spur gear used for the design of a paper shredder from solid works.

e. Machine Frame: The machine frame is the main part of the paper shredding machine that serves as the base foundation for which another machine component especially the moving parts. This design's frame was made of mild steel material of 2mm thickness, and it was designed to have a dimension of 525mm×400mm×200mm as shown in fig. 4 below. The construction of the machine consists of the mainframe, left base, right base, shredder support and gear support.

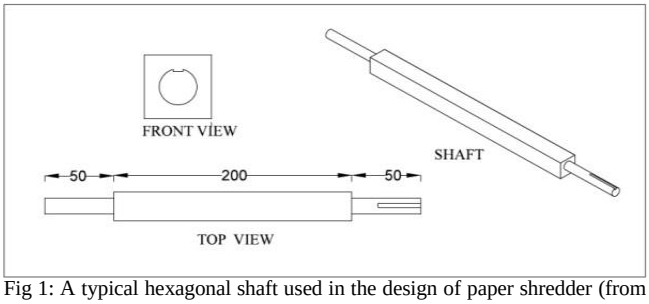

Fig 1: A typical hexagonal shaft used in the design of paper shredder (from solid works, 2015 edition).

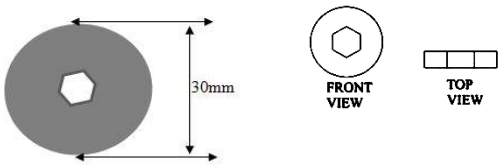

Fig 2: Typical blade used in this paper shredding machine (Solid works, 2015 Edition).

f. Shredder Support: The shredder support was made of mild steel with a thickness of 2mm (as shown in fig. 5 below) formed by laser cutting and bending. The shredder support was mounted on top of the machine frame, and it holds the base on the top side of the static blade holder.

g. The Left and Right Bases: The left base serves as anchoring of the main shaft's left side while the right base serves as an anchor for the right side, the holder gear transmission and an electric motor mounting.

D. *Constructional procedures*

The following steps were carried out sequentially in producing the machine paper shredding machine.

a. Marking Out: The purchased mild steel material and other metallic parts were measured using a tape rule and marked according to design specification with the aid of steel chalk. The dimension 525mm×400mm×200mm was measured and marked.

b. Cutting: The marked sections of the mild steel material were cut out from the purchased bulk material according to specification with the aid of a grinding machine using a cutting disc.

c. Folding: The cut off parts that required folding were folded with the aid of a folding machine to obtain a 90degrees angle.

d. Welding: Tack welding was done to join the folded edges as well as the cut-off parts together after that welding was carried out by Manual Arc Welding (MMAW) process with E6013 electrode. The electrode specification was 60000psi.

e. Deslagging: Chipping hammer and wire brush were used to remove the impurities from the welded frame after welding operation was completed.

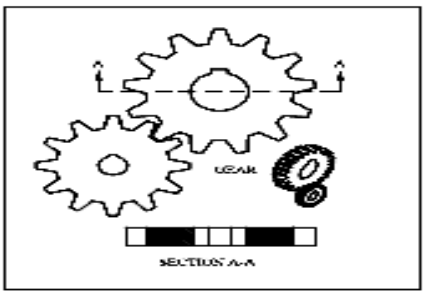

Fig 3: A typical spur gear used for the design of a paper shredder from solid works, 2015 edition.

f. Drilling: Drilling operation was performed in the section of the machine frame that required drilling after welding was completed. A drilling bit of 5'' was used for the drilling machine to drill holes in the hopper and the machine frame.

g. Riveting: The supporting rollers that tend to aid the movement of the machine were joined to the machine frame with the aid of a riveting gun and pin. Four rollers were fixed to the machine frame. Also, two hinges were riveted to the door of the machine frame.

h. Machining: Other components of the paper shredding machine such as the gears, blades, and shafts were designed on a lathe machine by the design specification drawn in the template.

i. Fitting of the Cutting Blades: After machining of the blades, gears and shaft. The cutting blades were fitted on two shafts, as shown in fig. 6 below. A total of 112 blades were mounted on both shafts each carrying 56 blades. A spacer was fixed between every of the four successive blades installed to prevent movement from the position during operation.

j. Fitting of the Gears: The gears were fitted mechanically to the ends of the shafts. Four gears were fitted in the machine, one of which was connected to the electric motor while the others were connected to the ends of the shafts. The first gear of smaller diameter and a reduced number of teeth was designed to connect with the second gear of 13 teethes and 30mm diameter so that both move in the opposite direction.

k. Installation of the Electrical System: The electric motor of 75watts (0.075kw) was connected to the drive shaft, and other electrical connections such as the wire and plug were connected as well. The electric motor was mounted inside the shredder support.

l. Mechanical Fasteners: The electric motor was fastened to the shredder support as well as the shafts with the aid of M4 bolts and nuts to provide a firm grip of the motor and shaft.

m. Fitting of the Rollers: Four rollers were fastened mechanically to the base of the frame, to allow movement of the machine frame from one location to another.

n. Painting: The completed machine was painted with dark green oil paint to improve its physical appearance.

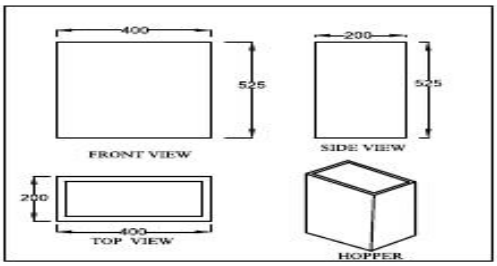

Fig 4: Machine frame from solid works, 2015 edition.

E. Design calculations of paper shredding machine

The specifications of the gears are as follows:

Motor gear = 4 teeth with 6mm diameter.

First gear = 13 teeth with a 30mm diameter.

Second gear = 42 teeth with 42mm diameter.

Third gear = 37 teeth with a 56mm diameter.

Cutting washer diameter = 30mm

Cutting washer thickness: 1.5x4= 6mm

Cutting washer hole: hexagonal shape (cross flat 12mm cross corner 14mm)

Length of the shaft on driver gear: 300mm

Length of the shaft on driven gear: 250mm

Spacer thickness: 6mm

Paper director: 4mm

The normal speed of motor: 1450rpm

Electric motor power rating: 75watt (0.75kw)

Voltage: single phase 220volts

Frequency: 50Hz

To Calculate the Speed of Shredder:

To get the speed of each gear: N1/N2 = d2/d1

For first gear having diameter:30mm

Motor gear (D1) diameter = 6mm

Speed of motor gear (N1) = 1450rpm

Speed of first gear (N2)=1450/N2= 30/6

N2 =(1450 × 6)/30 = 290rpm

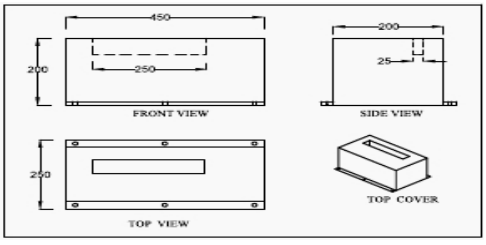

Fig 5: Shredder support from solid works, 2015 edition.

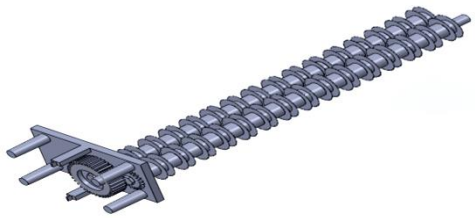

Fig. 6: Assembled cutting blades and gears from solid work, 2015 edition.

For second gear (D3) having diameter 42mm speed of second gear =?

Diameter of first gear =30mm

Speed of first gear = 290rpm

290/N3 = 42/30

N3= (290 ×30)/42 = 207.1rpm

For the third gear (D4) diameter = 42mm

Speed of second gear = 207.1rpm

207.1/N4 = 56/42

N4= (207.1 ×42)/56 = 155rpm

The final speed of the third gear determines the speed of paper shredder.

Torque on shaft: T = (P ×60)/2N = (0.075 ×60)/(2 ×3.142 ×155) = 0.0046N-m

Max number of paper = 20

Allowable number of paper = 15

Weight of one paper = 80g

20 paper = 1600g

5 paper = 1200g

1g = 0.0098N

1kg = 9.81N

F.S = (maimum load of paper)/(allowable working load)

Maximum load = 1600g (15.68N)

Allowable load = 1200g (11.76N)

F.S = 15.68/11.76 = 1.33

The cutting process will occur if the cutting force on each shredder blade exceeds the tear strength of the paper. The cutting forces required on each shredder blade are;

Fi = (K_s x S)/1000g

Fi = Cutting force per paper (kg)

Ks = Tear strength of A4 paper (N) = 550mN

S = maximum paper load (kg) = 0.005kg

g = gravity

Fi = (550x 0.005)/1000.81=0.027kg = 0.27N

The designed paper shredding machine has an opening on top through which paper is initially fed into the jaws of the shredding mechanism as shown in fig. 7.

Fig 7: Paper Shredding Machine Designed

3. RESULT AND DISCUSSION

PERFORMANCE EVALUATION

The operation of the machine was carried out immediately after it has been designed and constructed. The machine was powered by an electrical source; it was observed that the electric motor provided the necessary electrical energy and the gears transmitted the electrical energy into mechanical energy which consequently reduced the speed of the electrical motor to the desired speed required by the paper shredder to successfully shred the papers into strips. He designed machine was put to the test, and it performed excellently well as it was able to shred the required paper of 15 sheets effectively. Sandwiched between the strip forming rollers, which is made up of intermeshing washers, the washers grip and draw the paper sheet, and then formed strips. The output of the process is discarded. It is worth noting that readily available materials (cheap but having high strength and endurance) were used in designing this project to minimise the manufacturing cost, also reduce the complexity of the paper shredder.

This paper shredding machine proved to have performed satisfactorily and met the intended aim and objectives, as stated earlier. Hence, it will be useful in shredding papers into incomprehensible waste both at homes, offices and industries.

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