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DESIGN AND ANALYSIS OF A PAPER SHREDDER MACHINE

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Abstract: A paper shredder machine is a device that can shred documents such as paper and plastic into small strips or shreds. Private companies use it to shred confidential private documents or other sensitive documents into small strips or rubble. Thus, these machines help secure information effectively and waste to the environment. The article offers an alternative to the design and calculation of a shredder model. In addition, the options for optimizing the cutting blade and evaluating the strength of machine parts are also discussed to ensure the reasonable of the model. The analysis results are carried out with CATIA software. The results can serve as a prerequisite for an optimal model of the shredder that will go into series production in the future.

1 Introduction

A paper shredder machine is a device that can shred documents such as paper and plastic into small strips or shreds. Private companies use it to shred confidential private documents or other sensitive documents into small strips or rubble. Thus, these machines help secure information effectively and waste to the environment [1,2]. Depending on the intended use, shredders can be divided into household shredders and industrial shredders. Therefore, paper shredders are often classified as consumer shredders as they are the most used by consumers. In the office or at home the paper shredder consists of two small cutting shafts fitted with alternating cutting blades, compact design for easy moving of rooms. Help keep office space more organized and tidy when waste documents are released immediately. By limiting the number of landfills, documents and paper can be more easily transported to the recycling center after destruction, which helps protect the environment [3-6]. Nowadays, the demand for document shredders is increasing day by day. Using a paper shredder becomes easier when you can use a paper shredders at home. Many different design techniques have been explored for shredder machine designs for various purposes [7-11]. The article offers an alternative to the design and calculation of a shredder model. In addition, the options for optimizing the cutting edge and evaluating the strength of machine parts are also discussed to ensure the reasonable of the model. The analysis results are carried out with CATIA software. The results can serve as a prerequisite for an optimal model of the shredder that will go into series production in the future.

2 Method and problem statement

The design problem is to build a model of a paper shredder, the parts of which meet the requirements for size and performance, besides the resulting products are pieces of paper. High-security scrap paper. A seen in Figure 1 a paper shredder machine consists of three main parts: base frame; cutting system; transmission system. Cutting system includes shaft, blade, washer, gear. Drive system: Motor drives the cutting system, auxiliary gear.

Working principle: Electric motor (1) converts into mechanical energy, transmits torque to main shaft (2), gear (3) on main shaft transmits torque through gear (4), shaft (5) rotates. The two axes rotate in opposite directions. Evenly distributed blades (6) are attached to each shaft. Alternating blades cut paper into pieces of equal size

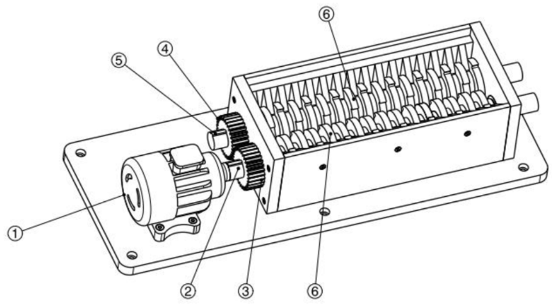

Figure 1 The 3D prototype of the paper shredder machine

Design calculation of shredder details:

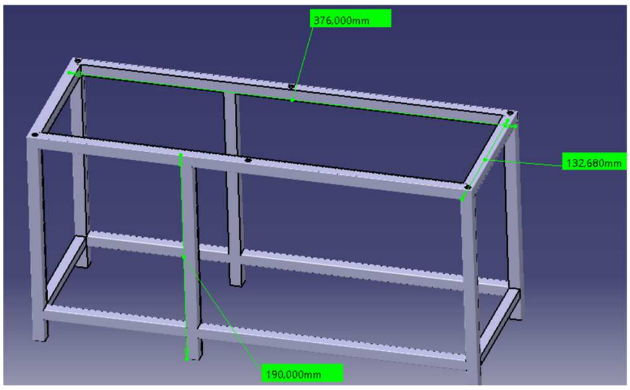

Figure 2 The tripod

Dimensions (Figure 2): 376x132.68x190 (mm)
The weight of the shredder is 12 kg.
The vibration force acting on the tripod is: P = 120 N.

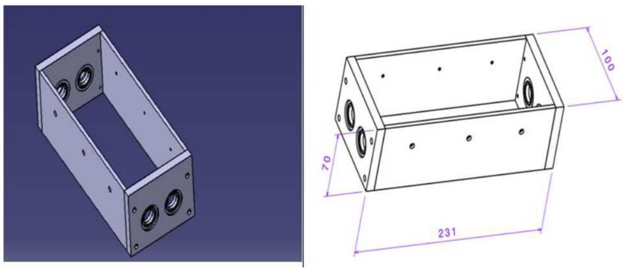

Figure 3 The frame

Frame: Supporting parts for shafts, blades and gears, fastened with bolts.

The frame (Figure 3) has dimensions of 231x100x70 mm, with length(l) = 231 mm, width(w) = 100mm and height(h) = 70 mm

2.1 Blade design

The cutting system consists of a shaft, cutting blade, washer and gear. The blade is a blade with 3 cutting edges, circular hole design with a diameter of 18 mm, mounted on the main shaft and the spindle moves together. The optimized cutting blade design concentrates tension, mass thereby reducing the load on the shaft.

Figure 3 shows the original unmodified 3D design of the blade. The cutting blade is a circular blade with three cutting edges with a round hole in the middle that attached to the spindle and moves the spindle. This blade is used to cut paper in the vertical direction. However, there was a problem of stress concentration at the bend.

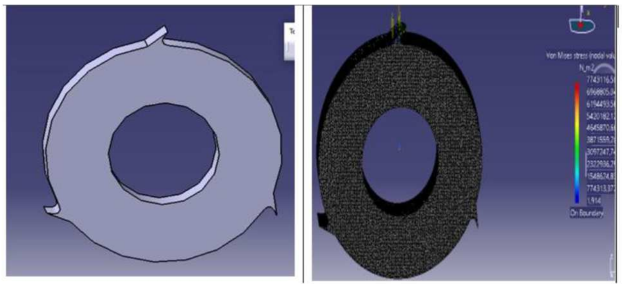

Figure 4 Original blade with stress distribution

Figure 4 shows the modifications in the blade design. Therefore, some modifications have been made, stress concentration problem was solved by creating a tangent in a side edge. However, although stress reduction has been fixed to avoid blade breakage, the mass is heavier than the blade at the first time m = 0.049 kg (Figure 5).

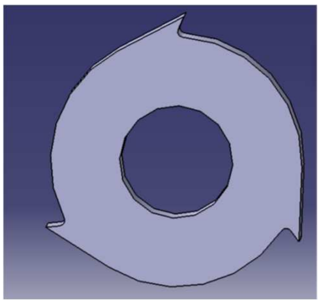

Figure 5 Blade redesigned the first time

Figure 6 shows in this revision, the weight of blade has been reduced. In the first, two blades are made with a circle of diameter d = 40 mm and with a single center. In the design the size has been reduced to m = 0.047 kg, instead of a radius of 20 mm with a common center, this blade is designed in such a way that it creates arcs of 20 mm radius and are three different arcs. whose center is the vertex of an equilateral triangle, is the center of the hole attached to the major axis. Blade thickness equal to 6 mm, made of steel and distance from blade to center r equal to 21.75 mm.

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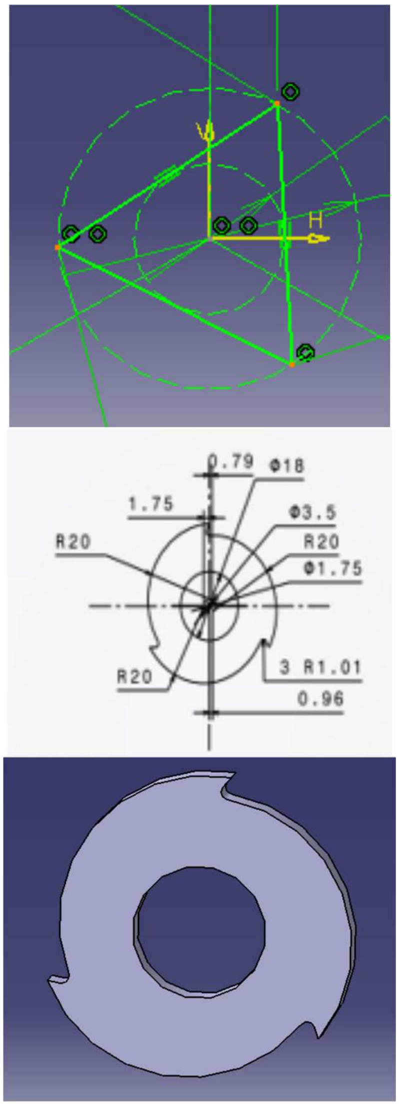

Figure 6 Final design shape cutting blade

2.2 The power calculation

The engine speed can be determined from the shear stress of the paper and the amount of paper. Shear stress is the result when a force is applied to a product that cause shear deformation of the material in a plane parallel to the direction of force application. When cutting paper, the shear stress value of the blade is greater than the allowable shear stress value of the paper

Shear stress is express by (1):

$$\tau = F/A \qquad (1)$$

where

τ : shear stress (N/mm^2)

F : Force applied, combined force of two blades (N) (2)

A : Cross-sectional area(mm^2)

$$F = (M \times a)/r^2 \qquad (2)$$

M : Paper cutting torque (N-mm)

r : Radius of the tool from the center, based on Catia software (mm)

a : Distance between two cutting shaft centers, a = 37 mm

We have (3):

$$\tau = (M \times a)/(r^2 \times h \times t) > \tau_g \qquad (3)$$

$\tau_g = 250$ Kpa , allowable shear stress of paper.

Then (4)

$M > (\tau_g \times r^2 \times h \times t)/a =$
$(250 \times 10^{-3} \times 21.75^2 \times 297 \times 0.3)/37 = 284.79$ = (N-mm) = 0.28479 (N-m) (4)

t is the thickness of 10 sheets of A4 paper which size is 210x279 (mm)

ω: angular speed(rad/s); take M = 0.5(N-m)

Power of the required torque transmission shaft (5):

$$P = M \times \omega = 0.5 \times 120 = 60\ W \qquad (5)$$

2.3 Spidle design

The spindle is the rotating machine element and is used to transmit power from one part to the other. Components such as blades and gears are mounted on it. The shaft has a diameter of d = 18 mm, the universal joint and the circular hole of the blade are 18H7/r6. Calculation and selection of materials for the working shaft to ensure durability.

The blade is mounted on the shaft, the shaft is subjected to the force of the knife's gravity causing bending. When the shaft is subjected to bending, the bending stress is given by (6):

$$\sigma_b = (M_b y)/I = (M_b(d/2))/(\pi d^4/64) = 32M_b/\pi d^3 \quad (6)$$

In which

σ_b : bending stress (N/mm2)

M_b : bending monent (N-mm)

d : diameter of shaft (mm)

I : moment of inertia of the cross-section about the neutral axis (mm^4)

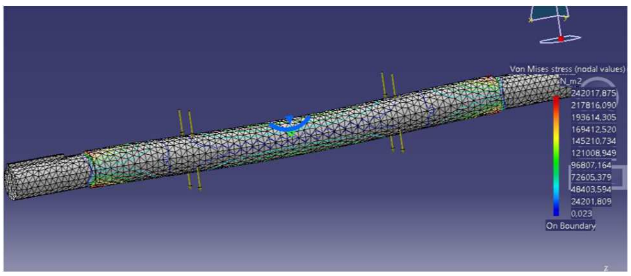
Figure 7 Evaluation of bending stress with Catia

The shaft is not only bent, but is also subjected to torque when driven by the rotating motor, which creates torsional

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stress (Figure 7). The torsional shear stress is given by the formula (7):

$$\tau = M_t\, r / J \qquad (7)$$

where:
τ : torsional shear stress at the fibre (N/mm2).
M_t : applied torque (N-mm).
r : radial distance of the fibre from the axis of rotation (mm).
J = polar moment of inertia of the cross-section about the axis of rotation (mm4).

When the shaft rotates to transmit torque, the power transmitted by the shaft (8)

$$P = (2\pi n M_t)/(60\times10^6) \qquad (8)$$

n: number of revolutions of the shaft (rpm), ω= 120 rad/s so n = 1145 rpm.

And then we have (9)

$$M_t = (P\times60\times10^6)/2\pi n = (60\times10^{-3}\times60\times10^6)/2\pi\times1145 = 500.1 \text{ (N-mm)} \qquad (9)$$

Steel is usually chosen as the material for the shaft construction. Assume that the material of the shaft is steel with the permissible plastic limit Syt = 250 Mpa.
According to maximum shear stress theory (10)

$$\tau_{max} = (16/\pi d^3)(\sqrt{M_b{}^2+M_t{}^2}) = (16/\pi 18^3)(\sqrt{139^2+500.1^2}) = 0.45\ MPa \qquad (10)$$

We have τ_{max} < ½ (Syt) and therefore shaft ensures strength

2.4 Blade system

As can be seen in Figure 8, the blades are evenly distributed, the cutting edge of the blades makes an angle of 40 degrees

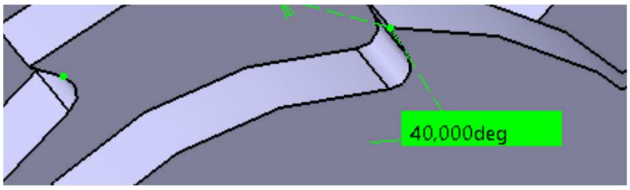

Figure 8 Angle between the two cutting edges of the two blades

When all the blades (2) are applied to the paper first then an equal force, immediately followed by the blade (1). Thanks to this distribution, only half of the cutting edges interact with the shredded paper. With such arrangement, the noise of paper tearing will be greatly reduced. Alternating distribution of cutting blades, evenly distributing cutting forces to each cutting edge as shown in Figure 9.

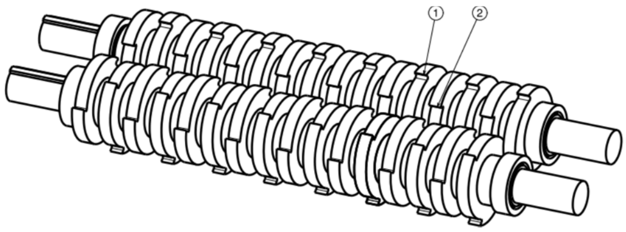

Figure 9 Blade system

The advantage of alternating cutting edges is to reduce the load on the gear when there is a large force, as all blade have cutting edges that are applied to the paper so that the gear will last longer. It also cuts a large amount of paper smaller.

3 Result and discussion

The machine model is completely assembled and simulated on Catia software as shown in Figure 10. The machine model proposed in the study can destroy 10 sheets of A4 paper at the same time, shredding paper in the form of shreds has a high level of security. In addition, the machine can also destroy other materials such as plastic in small form. and medium, CD… Blade is designed to reduce stress concentration and tool weight, helps to reduce the stress on the spindle

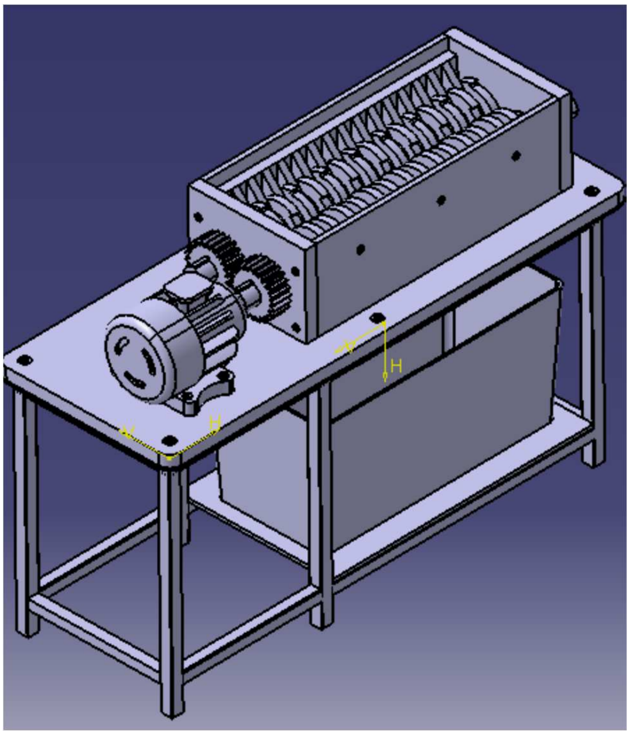

Figure 10 The final prototype of a shedder machine

4 Conclusion

The paper presents an alternative to the design and calculation of a shredder model. The shredding machine performance results also indicate that the machine could be very useful in the office or at home for shredding medium sized paper. The machine is therefore recommended for use by small and medium scale entrepreneurs working on recycled plastic. In addition, the options for optimizing the cutting edge and evaluating the strength of machine parts are also discussed to ensure the reasonable of the model. The analysis results are carried out with CATIA software.

The results can serve as a prerequisite for an optimal model of the shredder that will go into series production in the future.

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