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Senior Design Project Report

Paper Shredder Design

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

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Abstract

Nowadays, even though it is the era of technology and everything could be made in a soft-copy, hard-copies of A4 paper are still widely used and indispensable in every industry, every home, and every work office. However, hard-copy papers eventually need to be disposed in a proper way to not damage the environment and also to be reused again. The best way is to cut (shred) the paper in small pieces in order to recycle it easily.

In this project, the goal of the team is to design a paper shredder with a DC motor, gears and two shafts with blades that are able to cross-cut paper in small, standard sizes (DIN P-4) for recycling purposes. Moreover, some papers are top-secret or classified papers (read & destroy) and shall not be leaked or read by people whom are not involved. Thus, shredding these papers in small sizes will be good for recycling purposes and will be excellent for securing classified papers and information and guarantees nothing will be leaked.

Acknowledgments

Foremost, it is the team's honor to be under the supervision of our advisor Dr. Fraj AlShmri with his great experience in the field of Mechanical Engineering, the team members would like to thank him for his support in this project. Moreover, the team members would like to thank every single one helped with an advice or facilitate the team's way to the finalize this project.

List of Acronyms (Symbols) used in the report

Acronym / Symbols	Definition	Unit
N	Rotational Speed	RPM
D	Dimeter	mm
T	Torque	N. m
P	Power	W
C	Number of blades	#
F	Force	N
p	Pressure of a single A4 paper	N / m^2
n	Number of A4 paper (s)	#

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Chapter 1: Introduction

1.1 Project Definition

Paper shredder is a machine that is used to cut unwanted paper into small pieces in order to get rid of the paper. It is basically a mechanical machine that that uses a DC motor to rotate gears that are connected to two shafts covered with sharp metal heads all around. The shafts rotate in opposite directions, while the paper gets shredded when it goes between them. Paper shredder is widely used in offices to dispose papers as waste and also to shred some classified and secret papers in sensitive areas like the military.

1.2 Project Objectives

The main important objectives in this project are:

1- Design a paper shredder strong enough to handle up to 5 stacked papers.

2- Design a safe paper shredder that is safe to use for the end user.

3- Ensure that the shredded paper is recyclable according to a standard.

4- Design a removable storage compartment where the shredded paper can be stored.

5- Design shredding blades that are able to shred paper into small pieces.

1.3 Project Specifications

This shredder is used for security purposes and recycling. Furthermore, the shredder uses a verified shredding standard by the Netherlands' based website called recycling.com. Moreover, the standard is internationally approved.

Table 1: Part Specifications.

Part	Features
Motor Gear (Input)	N_{motor} = 6684 RPM D_{motor} = 9mm Teeth count= 7
Second Gear (Output)	N_2 = 40.16 RPM D_2 = 57mm Teeth count= 41

Single Cutting Blade Force	$F_{cutting}$ = 0.27 N
Total Cutting Force of The Shredder	$F_{cutting,\ total}$ = 29.16 N
Maximum Number of Paper in each cut	5 papers, F_{paper} = 24.79 N
Torque on the shaft	T = 119.97 x 10^{-3} kN.m
Suction fan	N_{Fan} = 500 – 1500 RPM Voltage = 12 V
Material used in shaft and blades	AISI 304 Stainless-steel

1.4 Applications

The main applications for the project are:

1. Allows the user to dispose of paper very simply and effectively
2. Can be used by government organizations, banks, and corporate offices to dispose of documents containing sensitive information
3. Can be used by environmentally aware people who care about recycling
4. Is easily accessible for use in any capacity to effectively dispose of waste paper

Chapter 2: Literature Review

2.1 Project background

Since ancient Egyptian times around 4000 B.C., man has had the need to write, just as there is a need for written documents today. Memoirs, notes and messages, religious documentation, and just plain stories were written on walls, clay, animal hides, and waxed tablets, they were the only materials available at the time and they were mostly solid objects making the process of discarding any unwanted material nearly impossible, that is until papyrus was invented [4] [12]. Papyrus is a material that resembles the paper we use today, just a little thicker, and just like the paper that is used today, its main purpose was to be used as a writing surface. But even still, with both papyrus and paper alike, the process of discarding the material was a manual task that was time-consuming for large documents, didn't do a good job of destroying the written information, and on top of that, it was harmful to the environment.

In 1908 New York, U.S.A., an entrepreneur by the name of Abbot Augustus Low invented and patented the first paper shredding machine, which he called "Waste Paper Receptacle" as he realized the need for a more compact method of disposing paper. During his lifetime, he only got to create one working prototype but was never able to make a second, as he passed away in 1912, and therefore the finished product was never made either and was soon forgotten about [4] [9].

In 1935 Balingen, Germany, a toolmaker named Adolf Ehinger who was secretly against the Nazi regime, used to write down his feelings and thoughts surrounding this topic, but he feared exposure and so he set out a goal of changing the way that he discarded material. He got his inspiration from a kitchen utensil, the pasta maker, which was a popular tool in Germany. He used the same concept as the hand-cranked pasta maker to make a manual paper shredder, which he then improved and tweaked and eventually added an electrical motor to [4] [9] [12]. In 1936, he patented his work and was determined to make a success out of this invention. This success came during troubled times in the 1940s amidst the World War II period where paranoia was running high and secrecy was of the utmost importance. He began selling the product across the country and then expanded and started selling internationally to governments and embassies [12]. His product was given another sales boost during the 1950s due to the Cold War. He then started a company around this invention and his business continued to flourish even in the years that followed the war.

Paper shredders became popular since then, but they were mostly utilized by government organizations to destroy private, confidential, or otherwise sensitive documents and it was very rare to find them in use outside of government bodies, that is until the mid-1980s, with a rise of identity theft crimes and growing privacy concerns, paper shredders then became more popular among regular individuals.

2.2 Previous Work

This project report is one of the best and most recent reports for designing a paper shredder. It has been done by the Department of Mechanical Engineering in Federal University of Petroleum Resources in Nigeria. Moreover, it has been published in Journal of Multidisciplinary Engineering Science and Technology (JMEST). It was mainly built for security causes and at the same time for recycling [1]. The following are the significant parts that make up the paper shredding machine: The machine frame, shredder support, drive shaft, cutting blades, gears, electric motor and the left and right base [1]. The idea is that the DC motor will rotate the gears, the gears will rotate the shafts in opposite directions, the shafts have cutting blades that will cut the paper when it goes between the shafts. Figure 2.1 shows the design of gears and cutting blades in SolidWorks [1].

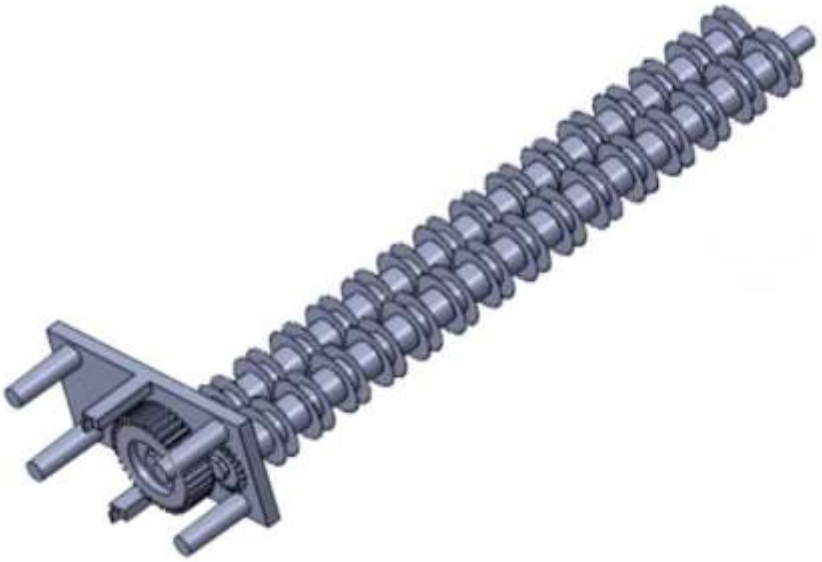

Figure 1: Designing cutting blades and gears in SolidWorks

The Designers of the shredder selected mild steel for the frame, plastic for the gears and medium carbon steel for the rest of the parts according to these factors: Pressure and load involved operating temperature Availability, cost and functionality [1]. The table below show the highlights of the important parts of the shredder.

Table 2: Shredder items & details

Item / Part	**Details**
Electric Motor	Power = 0.075kW Rotational speed = 1450 rev/min
Shafts	Hexagonal Shaped, Length = 300 mm
Cutting Blades	Thickness= 1.5mm, Hexagonal Shaped, Number= 56/each shaft
Spacer	Between every 4 blades
Gear 1 (connected to motor)	Diameter = 6 mm, four teeth
Gear 2	Diameter = 30 mm, 13 teeth
Gear 3	Diameter = 56 mm, 37 teeth
Gear 4	Diameter = 42, 42 teeth

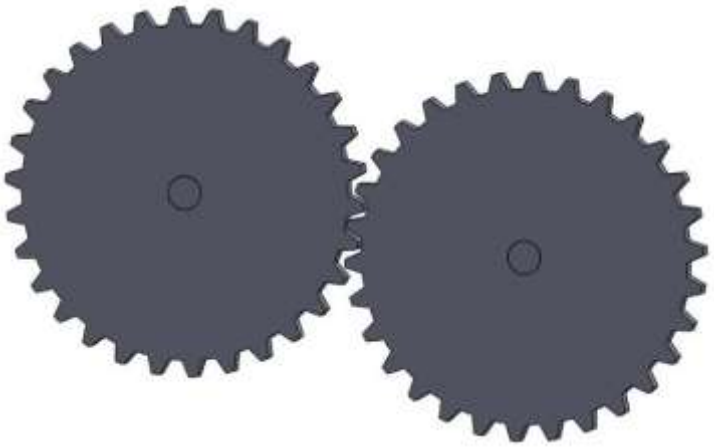

Figure 2: Typical gear design in SolidWorks

The final paper shredder has dimensions of 525mm x 400mm x 200mm and could shred up to 20 papers at once [1].

Figure 3: Reference paper shredder shape

2.3 Comparative Study

“Take the best that exists and make it better” Henry Royce. Our idea is far from original, Paper shredders has been in use for nearly two centuries in that time there has been many designs. This has no only gave us the ability to find and study multiple design ideas for paper shredders, but also it gave us the ability to find out what makes a design better than rest. Furthermore, it expanded our knowledge in paper shredder design. Three paper shredder projects were studied and analyzed.

The first project is about Mechanical Shredder made by a team in the Northern Arizona University, their idea is to make a mechanical paper shredder that relies on no electricity whatsoever. The main goal of their project was to design a shredder that is reliable, human driven and has no electrical components. They have multiple design ideas but ultimately decided on retrofitting an AmazonBasics 12-Sheet Cross-Cut Paper and Credit Card Home Office Shredder as seen in figure 4. Their team then took apart the Shredder and examined the shredding mechanism. They also removed the electric motor from the shredder. While their team was examining and analyzing the shredding mechanism figure 5, they found out that they can design and make a handle and attach it directly to the shaft which would in turn operate the entire system. In conclusion their prototype has met some of their objects which are briefly discussed in the table 3 below:

Table 3: Mechanical shredder Objects, Results & Remarks

Objectives	Results	Remarks
Budget of 100 $	91.76 $	Inexpensive nearly 9% less than the total budget.
36 pages/min	20 pages/min	Their system was very top heavy, this happened because of the reduced weight in the bottom as they have removed the electric motor.
10 pages/iteration	4 pages/ iteration	The shredder can go beyond 4 pages in one go; however, it becomes increasingly difficult to operate the handle. So, they agreed on 4 paper to make it easy to operate.
Can shred Credit cards	Yes	The shredder was able to shred credit cards and CDs with little to no effort
Can shred CDs		

Figure 4: AmazonBasics 12-sheet, cross-cut paper,

Figure 5: Existing Mechanism

The second similar project to our project is about paper shredder design, the team working on this project are from Capital university of science and technology Pakistan. Their idea was to improve on an existing paper shredder. The paper shredder that are trying to work on had couple of problems. These problems are:

1- The design of the paper shredder made it generate more noise because of extreme vibration.
2- The cutters used in the paper shredder are not reliable method of disposing confidential or sensitive papers, because it was easy to assemble the shredded papers.
3- There was a problem that caused the paper shredder to jam as paper moved along the blades.

So, the team redesigned the paper shredder using a program called ANSYS. They used the program to calculate the stress and the total deformation. Figure 6 and figure 7. In conclusion, their paper shredder has poor safety because their shredding machine is open and every moving part of the machine is open and it would be very easy to cause injuries. Their shredding machine is also limited to ten papers at the same time.

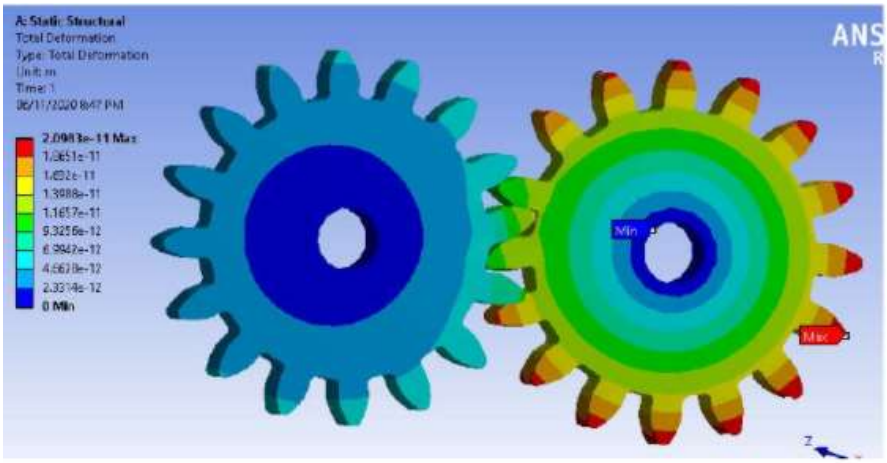

Figure 6: Stress

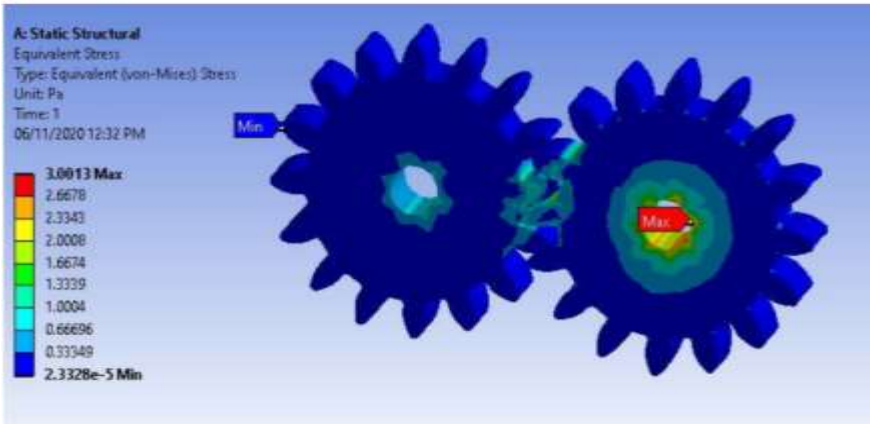

Figure 7: Total deformation

Chapter 3: System Design

3.1 Design Constraints and Design Methodology

3.1.1: Geometrical Constraints

In the paper shredder design, there was no gear standards the team could follow clearly. However, the team based their work on a paper shredder that was referenced on a Netherlands based website that is called recycling.com. Furthermore, the website has multiple standard paper shredders that are not only verified by the recycling companies, but also recommended for security purposes. Moreover, due to the covid-19 lock downs. The team also faced a great difficulty in finding suitable workshops that satisficed the needs of the project. Also, the ordering online was unreliable as the market faced massive delays due to the pandemic.

3.1.2: Sustainability

For the paper shredders to last a long time, there are a few steps that can be taken to ensure the longevity of the machine's life as well as maintain the desired level of performance. The most important one is to schedule regular checkups and/or repairs, which include emptying the paper shredder, cleaning it, and lubricate as well to make sure that it is running at its optimum level and peak performance.

3.1.3: Environmental

With the growing concerns for our environment, taking steps towards protecting it, to ensure a brighter future, is now more essential than ever before. One way to protect the environment is to reduce the amount of unrecyclable waste and to promote the act of recycling as a whole. One of the easier materials to start on is paper, as it is an abundant material that is frequently used in workplaces and even in individual homes, and considering how much it is used in the day-to-day, a small change in our habits will lead to greater change and will make a significant difference in getting towards that shared goal. By using a paper shredder, it would be the first step in the paper recycling process, as it destroys papers and reduces them to very small pieces before even reaching the recycling centers, making reprocessing much easier [2].

3.1.4: Social

Most government sectors, companies, and individual people care about their private and/or confidential information, most of which is present in paper format, shredders can help in destroying those papers and preventing them from falling into unwanted hands, thus providing a level of protection and a sense of security and safety.

3.1.5: Economic

Making paper is a costly process, from labor costs and machine costs, to transport and fuel costs, all of these along with others factors contribute to the overall cost of paper production. By shredding and recycling paper, the production costs will decrease, as the demand for new paper to be produced will decrease. Moreover, the overall environmental effect will help reduce further costs in the long term as it will minimize the need for potential future environmental repair costs [5].

3.1.6: Safety

The safety and privacy of information is one of the core reasons of using a paper machine. By shredding confidential or otherwise private documents, it relives the stress of security concerns and ensures that there are no traces left behind for unwanted eyes to take a look.

3.1.7: Ethical

In today's networked society, people entrust companies and businesses with their private information, with faith that their information is going to be kept safe. By simply using paper shredders, businesses have an easy method of discarding documents without compromising the client's security, and in turn keeping their promises to their customers by ensuring that their private information would not be leaked [3].

3.2 Engineering Design standards Engineering

Engineering standards should be followed in each component of our system. In this section, each component that has been selected for the project is defined. The selected components are screws, gears, blades, and the motor. The screw standard has been taken according to ANSI metric. The gears standard has been taken according to ISO. The motor has been taken from Ronning-Motor Brand. Ronning-Motor is a company based in China specialized in manufacturing all kinds of universal motors, dc and induction motors. See the table below.

Table 4: The used standards for each part used in the paper shredder

Components	Engineering standard	Details
Screws	ANSI Metric	B18.6.3, Fed. Spec. FF-S-92, Fed. Spec. QQ-P-416, MS35206-207, NASM35206
Gears	There are no gear standards	-
Blades	Security cutting standard	DIN P-4
Motor	ISO 9001	U5420
Shafts	Security cutting standard	DIN P-4
Fans	There is no standard	140mm computer fan

3.2.1 Screws

2 type of screws have been used:

Screws type 1:

- Length: 13 mm
- Head Dimeter: 4 mm
- Head Height: 1.5 mm
- Driver style: Phillips

Screws type 2:

- Length: 9 mm
- Head Dimeter: 6 mm
- Head Height: 2 mm
- Driver style: Phillips

3.2.2: Gears

Four gears have been used:

1- Motor Gear: is a double gear.

Side A: is directly connected to the motor.

- Side A Type: Helical Gear
- Side A Teeth count: 37 teeth.
- Side A Root diameter: 28 mm
- Side A Tip diameter: 32 mm
- Side A thickness: 11 mm

- Side A tooth depth: 2 mm
- The reason the team used helical gear on side A of this gear, is because helical gears are ideal for reducing the noises generated by the movement. Furthermore, helical gears are more able to handle the extremely high RPM coming from the motor [1].

Side B: is directly connected to Gear 1.

- Side B type: Spur gear.
- Side B teeth count: 7 teeth.
- Side B Root diameter: 9 mm
- Side B Tip diameter: 15 mm
- Side B Thickness: :10 mm
- Side B Tooth depth: 3 mm

2- First gear: is a double gear

Side A: is Directly connected to Side B of the motor gear:

- Side A type: Spur gear.
- Side A teeth count: 28 teeth.
- Side A root diameter: 38 mm.
- Side A Tip diameter: 45 mm
- Side A thickness: 7.5 mm
- Side A tooth depth: 3 mm

Side B: is Directly connected to Side A of the Second gear.

- Side B type: Spur gear.
- Side B teeth count: 6 teeth.
- Side B root diameter: 6.5 mm.
- Side B Tip diameter: 13 mm
- Side B thickness: 15 mm
- Side B tooth depth: 3 mm

3- Second Gear is a double gear.

Second gear is also directly attached to the first shaft and is responsible for moving the shaft

Side A: is directly connected to Side B of the first gear.

- Side A type: Spur gear.
- Side A teeth count: 41 teeth.
- Side A root diameter: 57 mm.
- Side A Tip diameter: 63 mm
- Side A thickness: 4 mm
- Side A tooth depth: 3 mm

Side B: is directly connected to the third gear.

- Side B type: Spur gear.
- Side B teeth count: 9 teeth.
- Side B root diameter: 15.5 mm.
- Side B Tip diameter: 23.5 mm
- Side B thickness: 6 mm
- Side B tooth depth: 4 mm

3- Third gear:

Third gear is directly connected to side B of the second gear. Furthermore, it's also responsible of moving the second shaft.

- type: Spur gear.
- teeth count: 9 teeth.
- root diameter: 15.5 mm.
- Tip diameter: 23.5 mm
- thickness: 6 mm
- tooth depth: 4 mm

3.2.3: Blades & Shafts

The blades are designed to be able to produce DIN P-4 standard paper cross-cut that are equal or less than 6mm wide, and equal or less than 160mm^2 size. This standard produce papers that are easier to recycle because their relative size when compared to higher security standers of the micro-cut. DIN P-4 standard shredders produce approximately 400 particles which provides high security for confidential data when shredding. Furthermore, DIN P-4 provides shredded paper stacks that are easier to recycle when compared to higher security levels. [10].

3.2.4: Motor

The motor is manufactured by Ronning-Motor company, the specifications of the motor are:

- Shaft length: 14 mm
- Shaft teeth type: helical
- Diameter: 45 mm
- Length: 96 mm
- Armature core length: 26 mm
- Armature core width: 54 mm

3.3 Theory and Theoretical Calculations.

3.3.1: Calculating Gears Rotational Speed

Given a motor speed N_{motor} = 6684 RPM, the motor speed will rotate the first gear (N_1), then the first gear will rotate the second gear (N_2), then N_2 will rotate the third gear, which is the speed of the paper shredder because it is directly connected to the driver shaft. The transmission of speed between the gears (Compound Gears) is determined by the following relationship [11]:

Output speed = (Input Speed) (Product of Transmission Teeth / Product of Receiving Teeth) (3.1)

Where the input speed is N_{motor} = 6684 and the number of gears teeth are according to the SolidWorks design.

$$\text{Output Speed} = (6684)\ [\ (37 * 9) / (7 * 28 * 6 * 41)]$$
$$= 46.16 \text{ RPM}$$

The third gear speed (N_3) = the speed of the paper shredder = 46.16 RPM

3.3.2: Torque on The Shaft

Torques on the shaft depends on the power of the motor and the speed of the paper shredder (N_3). It is calculated by the following formula [11]:

$$T = (P \times 60) / (2\pi \times N_3) \qquad (3.2)$$

Where P is the motor power P_{motor} = 579.9 watt (0.5799 kW) and N_3 is the paper shredder speed N_3 = 46.16 rpm.

Thus, the torque on the shaft:

$$T = (0.5799 \times 60) / (2\pi \times 46.16) = 119.97 \times 10^{-3} \text{ kN.m}$$

3.3.3: Cutting Force

The cutting process of the paper (A4) happens only when the force for the blades is bigger than the tear force of the paper. According to [11] each blade should have a cutting force of $F_{cutting}$ = 0.27 N. In this design there are 54 blades in each shaft, so in total there are 108 cutting blades in two shafts. The total cutting force for this shredder is equal to:

$$\mathbf{F_{cutting,\ total} = 0.27 \times C} \qquad \mathbf{(3.3)}$$

Where 0.27 is the cutting force for each blade to cut A4 paper, and C is the total number of blades in the paper shredder.

Thus, the total cutting force of this paper shredder:

$$F_{cutting,\ total} = 0.27 \times 108 = 29.16 \text{ N}$$

3.3.4: Maximum Number of Paper in Each Cut

According to [8], the force required to cut a number of A4 paper is given by the following equation:

$$\mathbf{F_{paper} = n \times p \times 2\pi} \qquad \mathbf{(3.4)}$$

Where n is the number of paper in each cut, p is the pressure force of a single A4 paper and it equals to p = 0.78909 N / m^2 [8].
Moreover, the $\mathbf{F_{paper}}$ should be less than $F_{cutting,\ total}$ in order for the blades to cut the paper.
So, the condition is $\mathbf{F_{paper}} <$ 29.16 N. Thus, the maximum number of papers is:

$$F_{paper} = 5 \times 0.78909 \times 2\pi = 24.79 \text{ N} < 29.16 \text{ N}$$

The paper shredder can shred up to 5 A4 papers in each cut.

3.3.5: Material Selection:

The material used for the blades and the shaft is the standard stainless steel AISI 304. The following figure shows the different properties of the material. Moreover, this material is widely used because of its low cost and its availability. This material is a popular choice in paper shredder applications because of its high strength and ductility, it is also easily manufactured, furthermore, it is highly reliable and its maintenance and repairs are easy and cost effective.

Figure 9 :The used AISI 304 stainless-steel shaft and blades

	304 *(Typical values at 20°C)*
Density	8 g/cm³
Elastic modulus	193 GPa
Hardness, Brinell	215 HB
Tensile strength	500-700 MPa
Yield strength	190 MPa
Elongation	40%
Coefficient of thermal expansion	1.72E-5 1/K
Thermal conductivity	16.2 W/(m·K)
Melting point	1450°C
Specific heat capacity	500 J/(kg·K)
Electrical resistivity	0.73 x 10^6 Ω·m

Figure 8: AISI 304 stainless-steel properties

3.3.6: Summary

Table 5: Summary

Part	Features
Motor Gear	N_{motor} = 6684 rpm
Third Gear (Connected to the shaft)	N_3 = 46.16 rpm
Single Cutting Blade Force	$F_{cutting}$ = 0.27 N.
Total Cutting Force of The Shredder	$F_{cutting,\ total}$ = 29.16 N
Maximum Number of Paper in each cut	5 papers, F_{paper} = 24.79 N
Torque on the shaft	T = 119.97 x 10^{-3} N.m

3.4 Product Subsystems and selection of Components:

The figure [10] Show the exploded assembly of the project. The various parts of the project can be seen. The parts of the project are the shafts, blades, gears and two bases. The assembled system is showed at figure [12]. Each blade has four teeth to cut papers up to DIN P-4 standard, furthermore each blade has a cavity in its inner radius to allow the shaft to slide through the blades. The blades also have small teeth in the inner radius to prevent them from rotating without intention. The two shafts are 27mm long and have 18 cavities to allow the inner teeth of the blade to slide through them and, prevent them from rotating without intention. The two bases are designed to hold the two shafts, gears and the motor in place. The gears are not only designed to transfer the rotation from the motor to the shaft, but also designed to reduce the RPM coming from the motor.

Figure 10: Exploded Assembly of the system

Figure 11: Assembled system

3.5 Manufacturing and Assembly:

In terms of selecting the material, the blades, shafts, and one of the gears are all made out of stainless steel AISI 304 which is the standard, the first gear and the motor gear are made out of plastic to reduce noise and vibration. The outer body of the shredder was chosen to be made out of aluminum as it is a lightweight material that is reliable and widely available. The shredding process starts at the DC motor (Figure 13) that provides 0.560 HP that then produces rotational motion through the motor gear, which in turn causes the other gears to rotate until it reaches the final gear which is responsible for the rotation of the two shafts.

The gear system chosen was the compound gear system, which has an advantage over the pulley gear system as it is more efficient for this particular application, as it produces less speed which is what is needed here. The pair of shafts used here help increase the cutting force, as well as provide a smaller cut, which in turn, increases security. The shredding shafts hold the blades (Figure 15) that are responsible for the shredding. In some cases, the blades that are used are made out of stronger materials but for this application, stainless-steel is strong enough.

Figure 15: Motor

Figure 14: Gears

Figure 12: Blades

Figure 13: Fan

Figure 16: Final Prototype

Chapter 4: System Testing

In this project, the main interest was to calculate the rotation speed of the shaft gear (second gear) using a Tachometer Laser. The testing is simply conducted by using a special type of sticker that is used to stick on the rotational object (gear), then aim the laser at it, as it passes the sticker, the laser is reflected back to the device, showing the real RPM of the gear. The experimental result may differ as compared to the theoretical numbers due to many possible reasons, which include friction, which affects the rotation process, and the weight of the gear which could also be a factor as the weight of the material used for the gears may be different to the one in the theoretical calculation.

Figure 17: Tachometer Device with Stickers

According to the experimental results, the rotational speed of the third gear is 40 rpm < 46.16 RPM due to the reasons mentions above. This number makes sense as it is close to the theoretical calculation in chapter 3. Moreover, the dimension of the shredded paper is 0.9 * 1 mm which is ideal for both security as well as recycling. Moreover, the use of plastic gears was an effective solution to reduce the noise coming from the rotation of the motor, and the helical gear design helped reduce the vibration.

Chapter 5: Project Management

5.1 Project Plan

In this project, a plan was set out at the beginning of the semester and was followed throughout, which is the Gannt Chart plan. This chart shows each task that needs to be accomplished until the point of finalizing the project. However, the dates were flexible for the most part as some milestone submission dates were altered throughout the semester. The table below shows the dates that were set out in the Gannt Chart.

Table 6: Project Plan

#	Tasks		Start	End
1	Chapter 1: Introduction		20/9/2020	02/10/2020
2	Chapter 2: Literature Review	Project Background	20/9/2020	02/10/2020
		Previous Work		
		Comparative Study		
3	Chapter 3: System Design	Design Constraints and Design Methodology	7/10/20202	29/10/20202
		Engineering Design standards		
		Theory and Theoretical Calculations		
		Product Subsystems and selection of Components		
		Manufacturing and assembly		
4	Chapter 4: System Testing & Analysis	Experimental Setup, Sensors and data	20/11/2020	8/12/2020
		Results, Analysis and Discussion		

5	Chapter 5: Project Management	Project Plan	20/11/2020	8/12/2020
		Contribution of Team members		
		Project Execution Monitoring		
		Challenges & Decision Making		
		Project Bill of Material & Budget		
6	Chapter 6: Project Analysis	Life Long Learning	20/11/2020	8/12/2020
		Impact of Engineering Solution		
		Contemporary Issues Addressed		
7	Chapter 7: Conclusion & Recommendation	Conclusion	20/11/2020	8/12/2020
		Future Recommendation		
8	Design of Prototype	Fan Shape	15/10/2020	20/11/2020
		Cavity		
		Location		
9	Parts Purchase	Suction Fan	15/11/2020	20/11/2020
		blades		
		Gears		
		Shaft		
10	Manufacturing	Outer Aluminum body	15/11/2020	20/11/2020
		Installing the suction fan		
		Integrating all parts		
11	Testing	Shredding test	25/11/2020	6/12/2020
		Examining gears & blades	25/11/2020	6/12/2020
		Examining stability of outer Aluminum body	25/11/2020	6/12/2020
		Examining the suction fan	25/11/2020	6/12/2020

Table 7: Tasks and assigned members

#	Tasks	Assigned Members
1	Chapter 1: Introduction	Omar & Omran
2	Chapter 2: Literature Review	All
3	Chapter 3: System Design	All
4	Chapter 4: System Testing & Analysis	All
5	Chapter 5: Project Management	Mohammad
6	Chapter 6: Project Analysis	Abdulrahman
7	Chapter 7: Conclusion & Recommendation	Omar
8	Design of Prototype	Omar & Omran
9	Parts Purchase	All
10	Manufacturing	Abdulrahman
11	Testing	Mohammad

5.2 Contribution of Team Members

Team meetings were held weekly, sometimes reaching over three meetings a week. In the meeting, tasks were discussed and the work was divided between the team members based on their availability. After the meeting was held, each member had a task to accomplish, knowing exactly what is required of them and what needs to be done. The table below illustrates each team member's contribution.

Table 8: Tasks the contribution of the members

#	Tasks		Assigned	Cont. %
1	Chapter 1: Introduction		Omran & Omar	100%
2	Chapter 2: Literature Review	Project Background	Mohammad	100%
		Previous Work	Omar	100%
		Comparative Study	Omran & Abdulrahman	50% Each
3	Chapter 3: System Design	Design Constraints and Design Methodology	Omar	25%
			Omran	25%
			Mohammad	50%
		Engineering Design Standards	Omran	90%
			Omar	10%
		Theory and Theoretical Calculations	Omar	60%
			Omran	20%
			Abdulrahman	20%
		Product Subsystems and Selection of Components	Omran	33%
			Abdulrahman	34%
			Mohammad	33%
		Manufacturing and Assembly	Abdulrahman	100%
4	Chapter 4: System Testing & Analysis	Experimental Setup, Sensors and Data	All	100%

		Results, Analysis and Discussion	All	100%
5	Chapter 5: Project Management	Project Plan	Omran & Omar	50% Each
		Contribution of Team members		
		Project Execution Monitoring		
		Challenges & Decision Making		
		Project Bill of Material & Budget		
6	Chapter 6: Project Analysis	Life Long Learning	Abdulrahman & Mohammad	50% Each
		Impact of Engineering Solution		
		Contemporary Issues Addressed		
7	Chapter 7: Conclusion & Recommendation	Conclusion	All	100%
		Future Recommendation		
8	Design of Prototype		Omar & Omran	50% Each
		Calculation		
		SolidWorks	Omran	100%
9	Parts Purchase	Blades	All	100%
		Gears		
		Shafts		
		Suction fan		
		Motor		
10	Manufacturing	Outer Aluminum Body	Abdulrahman	100%
11	Testing	Shredding & gears & Stability	All	100%

5.3 Project Execution Monitoring

During the project, meetings were consistently held between the team members as well as the advisor. Almost all meetings were held online. As for the advisor, the team mostly communicated with them through email, but also sometimes through online meetings. The table below shows how the team monitored the activities.

Table 5.4: Dates of the activates and events

Time/Date	Activities/Events
Weekly	Meeting with group members
Biweekly	Meeting with the advisor and co-advisor
20/11/2020	Finishing prototype
12/11/2020	Midterm presentation
25/11/2020	Test the system
8/12/2020	Final Submission of the report
17/12/2020	Final presentation

5.4 Challenges & Decision Making

In this project, a lot of difficulties were faced but the team was determined and was able to pass all these difficulties. Some of the difficulties the team faced might include:

1. There is no specific standard design for paper shredders.
2. Finding a proper workshop.
3. Meeting challenges.

5.4.1 No Standard Design for Paper Shredders

According to the research that has been done in this project the team couldn't find one common standard for the different parts of the shredder. There are possible reasons for this issue. One of them is that paper shredders have different levels of security, and each level has a specific size for the shredded paper. However, this size of shredded paper could be accomplished by different types of blades. The second possible reason is that one of the objectives of shredding paper is to be recycled. And different recycling processes might require different sizes or shapes of the shredded people. Moreover, Different countries might put different standards of their own in their offices.

5.4.2 Finding A Proper Workshop

The team members faced some difficulties in finding a suitable workshop that manufactures the different parts of the shredder in standard/certified material. The reason for that is many workshops have limited their services and their worktime due to COVID-19.

5.4.3 Meeting challenges

In order to follow the "safety first "rule, almost all meetings and decisions were made online. In the beginning, this was a challenge, as face-to-face meetings were essential before the pandemic. However, when it comes to execution (buying/building parts) the team members tried as much as possible to let only one member finish the task or two members meet with face masks, abiding by the safety regulations.

5.5 Project Bill & Budget

The project bill of the design is in the table below. All the project has been done in Saudi Arabia and in Saudi Riyal. The table below shows all costs of the project.

Table 9: Project bill.

Part	Costs
DC Motor	120 SAR
Gears & Blades & Shafts (AISI 304)	720 SAR
Tachometer Laser	90 SAR
Suction Fan	100 SAR
Outer Aluminum Body	120 SAR
Banner	190 SAR
Brochures	100 SAR
Total	**1440 SAR**

Chapter 6: Project Analysis

6.1 Life-Long Learning

In this project, all the team members have learned new things in the research process. The team has learned more details about gears, blades, and shafts. The team also learned about the types of paper shredders and different levels of security. Moreover, the team learned how to divide work, manage time, and overcome obstacles. The experience that the team acquired is very valuable and is sure to help in any and all future projects.

6.1.1 Software Skills

One of the standards / major tasks of any engineering project is to learn the software related to the project, most importantly SolidWorks. The team members even though have not finished the CAD course but they managed to learn more and fast to be able to finish the model in order to build it. Moreover, the team has also used Word for the report and PPT for the presentations.

6.1.2 Hardware Skills

In this project, one of the hardware skills the team learned is calculating the rotational speed (RPM) of the gears using a Tachometer laser. The process is simply by using a special sticker that reflects the laser coming from the Tachometer while the gears rotate. The Tachometer is digital and thus the RPMs of the gears will show directly in the device. Moreover, the team has also used some electrical knowledge in order to install the suction fan in the shredder.

6.1.3 Time Management Skills

Time management is significant in any project or plan. The team members tried to balance the project and its requirements, as well as the other course duties and requirements. In every meeting, the team members declared their status regarding their availability during a specific period. The team members carefully followed the Gannt chart to complete each milestone in a timely manner. The methods that were used to communicate and manage tasks were WhatsApp, Discord, and Google meetings. Moreover, the team communicates directly with the advisor once each task is done.

6.1.4 Project Management

The team members were committed to always be in touch in order to manage the project and its tasks. In each week, the team members gather in Google meetings or Discord to plan for the coming task. The team might have three or four meetings in a week depending on how urgent the case is or how heavy the task is, and some meetings lasted for over four hours. In the end, the team successfully finished all the tasks on time.

6.2 Impact of Engineering Solutions

This Project has multiple benefits in different aspects. It will be useful to society as well as the economy, and it will be extremely useful for the environment.

6.2.1 Society

This project is useful for society, especially in the military and government section, and is very helpful for the hospitals in the medical sector. This project will help in terms of security. The military, government bodies, and hospitals frequently use paper shredders to destroy sensitive documents, ensuring safety and security.

6.2.2 Economy

This project is helpful to the economy, as it helps recycling companies in their recycling process of paper and encourages the continued safe disposal of it and its reuse to produce a new product in an environmentally safe way.

6.2.3 Environment

This project plays a significant role in saving the environment. It greatly helps in protecting the environment, land, air, and sea by cleanly disposing of papers, which eliminates the need for burning paper or using other harmful methods of disposal. So, shredding paper and disposing of it in the right way, and choosing to recycle, will help save the earth's environment and its inhabitants.

6.3 Contemporary Issue

Here in Saudi Arabia, the educational services, the medical services, and all government services are still mostly using hard copies of A4 paper. Even big companies are still dependent on hard copies of A4 paper in most cases. Thus, there is an essential need to dispose of paper in the right manner, especially that recycling bins are not widely used in the country except in Aramco facilities that have special bins for recyclable materials. This project might be a temporary solution to dispose of paper properly until the recycle bins become everywhere.

Chapter 7: Conclusion

7.1 Conclusion

In conclusion, the team members chose this project gladly with persistence to complete it and to learn from it, and to help people and society. The team members have used their knowledge from different courses, especially in Dynamics, Mechanical Engineering Design III, and Manufacturing Methods. The team applied the skills of researching effectively, applied time management skills in tough times and critical periods of COVID-19. Moreover, the team was able to put its special fingerprint on this project by installing the suction fan and to design the shredder piece by piece in the SolidWorks and build the prototype accordingly. When it comes to the difficulties, the team was able to find a suitable design for the shredder and was able to find a good workshop, and team members got used to online meetings.

7.2 Future Recommendation

There are various ways to make this project better. The first one is to select materials with better mechanical properties than AISI 304. The project could also be better when using different gearing systems and increasing the DC motor power. Choosing an outer body made of plastic will be much better than using an outer body made of Aluminum. Finally, the team recommends using paper shredders when there is a need to dispose of paper properly without damaging the environment or creatures or whenever there is a need to destroy sensitive papers.

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