IPRO 321
Product Development and Testing of Paper Shredder Innovations

Final Report
Spring 2008

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Team
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Introduction

IPRO 321: Product Development and Testing of Paper Shredder Innovations has been offered at IIT for four consecutive semesters. There has been a great deal of progress made in the Spring 2007, Summer 2007, and Fall 2007 semesters and Spring 2008 is no different.

Through working with Professor Mostovoy and Professor Maurer, the Spring 2008 semester has learned a great deal about the parts of a paper shredder and how to design of a more reliable paper shredder.

Background

Paper shredders have been used in the office environment for many years. Once sold and used exclusively in offices, paper shredders can now be found in consumer's homes. With identity theft as the fastest growing crime in the United States, there is a high demand for reliable and efficient paper shredders at reasonable prices

Spring semester 2007, President Mr. Seth Lewis of the Manhattan Group came to IIT seeking advice regarding the improvement of his paper shredder. The paper shredders are manufactured in China and sold throughout the world, including the United States. Each year, over a million Royal Brand paper shredders are sold.

Research shows that consumers seek quiet and long lasting paper shredders at the lowest possible price. For the fourth consecutive semester Mr. Seth Lewis requested that Professor Maurer and the students of IPRO 321 further seek potential methods of improving shredder performance and reliability.

The MMAE lab and machine lab will be used extensively for gear and materials testing. Software resources, sound measuring equipment, and equipment in the EE lab will be used as well.

Potential legal and/or ethical issues will involve patents and idea ownership. Since this is a sponsored IPRO, all discoveries will be property of Mr. Seth Lewis and the Manhattan group. There potentially could be a situation where this IPRO will be unable to provide necessary information to the IPRO office regard work and progress due to ethics.

Purpose

The purpose of this IPRO is to design a reliable and efficient paper shredder that is quiet, able to handle the amount of paper, and is available at a low cost. The Manhattan Group, a mass distributor of household shredders, provided specific goals that they would like the team to accomplish. The Manhattan Group asked the IPRO team to design a prototype paper shredder that would be quieter, more reliable and efficient. The shredder would have a feeder system as well as any other innovations that the team could come up with that would give their shredder an edge in the market. The sponsor also wanted the team to design a gear train system that would both make the shredder quieter and deliver more torque, requiring a less powerful and cheaper motor. All of these innovations and ideas were to be implemented in the most cost-effective way possible

The team used the research and work done by the previous semester IPRO to guide the project and use this information as a starting point for the research and work

done by this semester's team. One example of this was to follow the previous work that stated minimizing the gear train and optimizing it would reduce the noise and require a less powerful motor. To confirm this, the semester's IPRO team tested both the motor and shredder head to determine their torque output. This would help with the gear train by learning the torque needed to run the shredder head, and how much the motor puts into the system. With this information, the team could design a gear train that outputted the necessary torque with gears that would reduce the noise output. Also, previous semesters' work showed that plastic gears would be the quietest material and could hold up to the stresses placed on them. This semester's team used this information in designing the optimal gear train, using it to design the gear train to be cost-effective and able to handle the stress and torque requirements needed for the paper shredder.

Many constraints were faced throughout the execution of this semester's IPRO; the major constraints being time, resources, and difficulty with testing equipment. The team was constantly running into problems that required help in either repairing or in operating the torque testing machine and dyno-meter, which required time to fix and to understand how the machines work. The team ran into resource issues in dealing with the gears, as getting custom made gears would have been far too expensive, and acquiring other needed gears were expensive and difficult to locate, as well as a time issue in getting the needed parts in on time.

Assignments

The team broke into three sub teams to accomplish the goals set down by the sponsor. There was a sub team to work on the mechanical aspects, one for the electrical aspects, and one team for the innovation work.

Mechanical Team	Electrical Team	Innovation Team
Steven Flicek	Vesna Pesik	Michael Hatch
Aseem Pandey	Matthew Anderson	
Zachary Capps	Sebin Lee	
Patrick Bauer	Jason Howard	

The teams broke down this way based on major, interests in project, and abilities that would be needed for the project. For the mechanical team, Steve Flicek was named the team leader, for the electrical team the team leader was Vesna Pesik, and for the innovation team the team leader was Michael Hatch. The team scribe was Pat Bauer.

Each team member had their own specific tasks assigned to them to ensure that everyone did their part in the project and to split up large assignments to get all the necessary tasks completed.

Mechanical Team

Team Member	Tasks
Steve Flicek	1. Conduct research on paper shredder heads 2. Keep Mechanical team on schedule and updated on tasks
Aseem Pandey	1. Conduct research on paper shredder heads

	2. Purchase of paper shredders for research
Zachary Capps	1. Work out needed calculations for gear train 2. Conduct research on paper shredder heads
Patrick Bauer	1. Keep team informed of IPRO deliverables 2. Purchase gears for gear train 3. Conduct research on paper shredder heads

Electrical Team

Team Member	Tasks
Vesna Pesik	1. Keep Electrical team on schedule and updated on tasks 2. Electrical set up, data analyzing and calculations
Matthew Anderson	1. Conduct research on motor drives 2. DC rectifier design and testing 3. Data analyzing
Sebin Lee	1. Experimental measuring and data collecting 2. Data analyzing and calculations
Jason Lee	1. Conduct research of different motor types 2. Motor testing and analyzing

Innovation Team

Team Member	Tasks
Michael Hatch	1. Research patent laws associated with paper feeder 2. Design & build new "shredding" mechanism 3. Purchase various printing & shredding parts 4. Assemble discrete pieces into single unit

Research Methodology

The three teams approached their respective parts of the project in the follow ways.

Mechanical Team

The mechanical team worked on both the shredder head and gear train. The team used the torque measuring program developed by last semester's IPRO as well as the torque machine they designed to test the torque outputted by the three types of shredder heads the team had. The team put various amounts of paper through each shredder head, varying from one sheet up to six sheets, and measured the torque output of each shredder head at each of the amounts of paper. Following the data taking, for several amounts of sheets the data was fit to an appropriate function. Such a model is expected to estimate the behavior of the torque required to shred different amounts of paper sheets for a given paper shredder. This information is used in designing the gear train, as this determines how much torque is needed to drive the paper shredder. This information is also used to determine which paper shredder head would be the best for the Manhattan Group to use, seeing as they want a shredder that can shred the largest amount of paper for the least cost.

The second research work the mechanical team did was the work on the gear train. The research method for the gear train is based on the work done by this semester's and last semester's IPRO teams. Last semester's team set out to figure out how much torque the gears could take by adding paper to the shredder until it jammed, and then check to see if the gears broke or were stripped. This semester's team used the information gained from this process and used it to determine the optimal gear train. This semester's team used the amount of maximum torque that the gears could handle as a starting point to figure out how much torque could be put into the gear train to reduce the output needed from the motor. Once the amount of torque needed to run the paper shredder head was found, and the amount of torque the motor would output, the team then went about designing a gear train that would output that much torque with the least amount of gears designed with materials that could withstand the forces put on them. This was done using gear reduction calculations based on the motor speed and the shredder head speed.

Electrical Team

The problem presented to the electrical team was to find a motor that could output the necessary horsepower and torque to run the paper shredder while being cost-effective and able to be used in a paper shredder.

The first step the electrical team took to accomplish this goal was to obtain several different motors, some that were DC, some that were AC, and universal motors. The electrical team also reviewed the last IPRO team's research on the motor and see if it could be applied to their work. The team acquired motors from several different shredders as well as motors that could be found in the lab. The next step in the process was to obtain a dyno-meter to run the tests on the motors. The team hooked the motors up the dyno-meter and measured the horsepower that the motor outputted at different intervals. This data was used to help determine the motor's input into the gear train calculations

The other work the electrical team did with the motor was to determine the pitch of the gear coming out of the motor. This was needed to help determine the pitch that the gear train would run at. This was done by taking the diameter of the gear on the motor and using this with the motor speed to determine the pitch.

Innovation Team

The Innovation team's job was to find a way to implement a number of different possible design elements to improve the paper shredder. The main design implementation was an automatic feeder system. The research on this started with checking patents on automatic feeder systems and to see if similar systems have been designed for a paper shredder. The next step was to determine how a feeder system could be put onto a paper shredder and what types of systems could work for it.

The next step in the innovation research was to determine more efficient ways to shred the paper and yet still be cost-efficient. This was done by researching different shredding methods and seeing which ones required the least amount of torque and power. After the research was conducted, then the next step was to determine possible ways to implement these methods. Finally, after looking at all of the different factors, a prototype shredder would be drawn up from this research and then researched to see if the prototype would be possible.

Obstacles

There were many obstacles that faced all three sub teams as well as the team as a whole. The main problems that faced the entire team were time and resources. Each team had difficulty in acquiring either the necessary parts and testing equipment. Time was a major obstacle as the team was often trying to accomplish several tasks at once, while also keeping both the IPRO office up to date and turning in the deliverables. Another time issue was the amount of time it required to conduct the research for each team.

Mechanical Team

The first major obstacle the mechanical team ran into was dealing with the torque testing machine. The computer program that last semester's IPRO developed was not working properly, and this took the team a week until they could the program to work correctly. The next major issue was installing the paper shredder heads on to the torque machine. The shredder heads had to have different stands and bearings built into the stand for the torque testing machine so the different shredder heads could be installed on to it. After this, when the first shredder head was installed, the gages on the torque testing machine started giving incorrect readings, so the team had to have new gages installed, and this slowed the team down. Finally, the team had many issues in obtaining the needed gears. One company never responded to the team, and another company's prices were far to expensive to obtain the gears as well. Also, the team could not install its original gears with the chosen shredder head, so the team had to order a second set of gears and find an alternative method setting up the gear train

Electrical Team

One major obstacle the electrical team ran into was in conducting their testing using the dyno-meter. The team had difficulty in operating the machine, as it was difficult to work and to get the machine to produce readings that made sense. Another issue with the dyno-meter was installing and switching out the motors. The team had difficulty getting the motors to connect to the machine as well as then getting the results to make sense.

Innovation Team

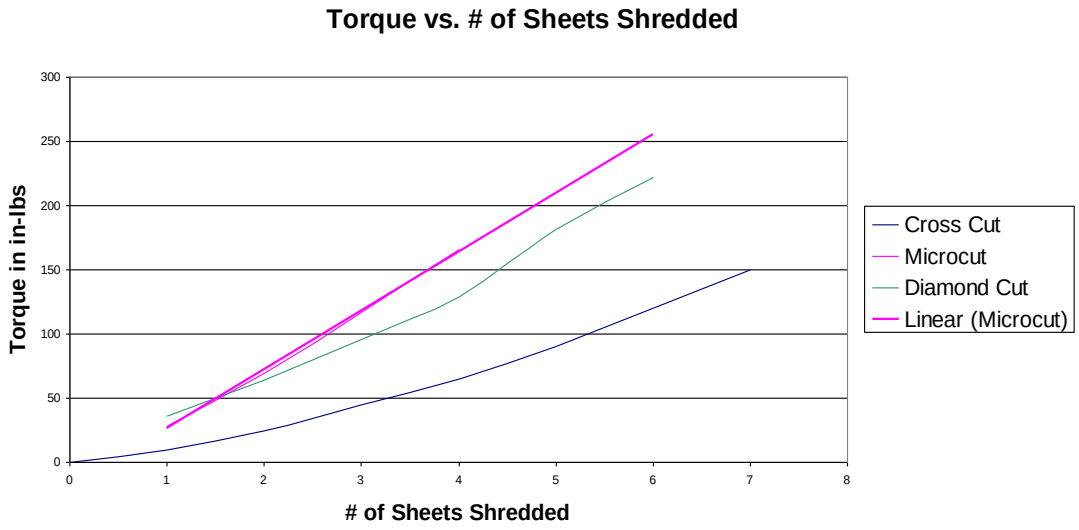
The innovation team ran into difficulty coming up with new designs as well as implementing these new designs. Many of the initially proposed designs were too difficult to be manufactured from scratch by the facilities offered by IIT. Finding a way to design a feeder slowed the team down tremendously, and then finding a way to add the feeder to a paper shredder also caused many issues. Additionally, brainstorming different ways to shred paper proved difficult, as each newly conceived method resulted in several difficulties (i.e. sufficient power or strength to ensure a working and efficient device). Furthermore, seeking a feasible solution that, ultimately, did *not* infringe upon previously filed patents, was another unforeseen ethical and legal setback.

Results

The team needed to collaborate with their research in order to build a prototype that would meet the sponsor's requirements.

Mechanical Team

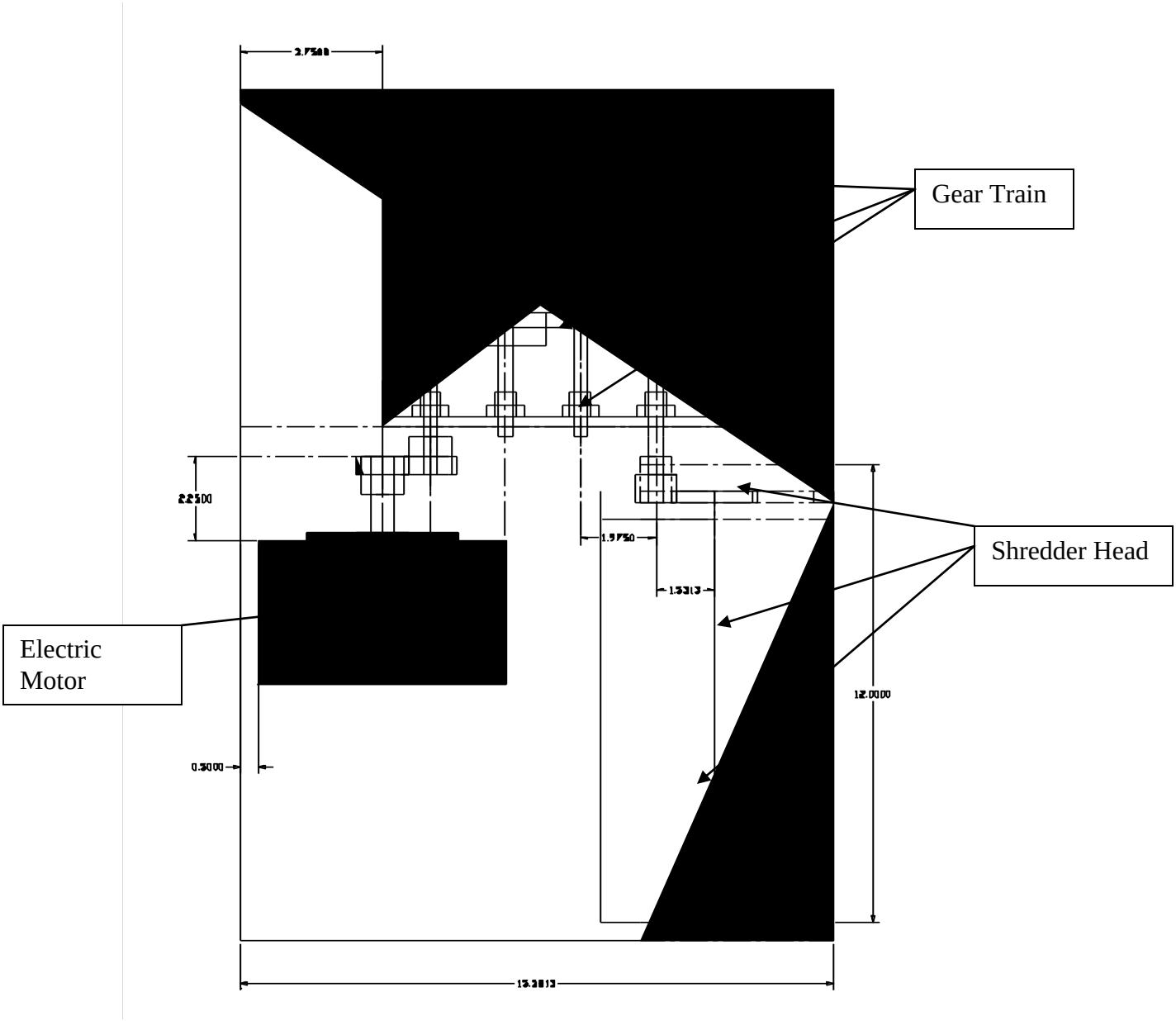
The first task the mechanical team accomplished was to determine the torque required various amounts of paper on different shredder heads obtained. This was done through the use of the torque testing machine that the previous semester's IPRO had constructed. The data obtained from the torque testing can be seen below.



From the data above, diamond cut offered the best balance between security and torque required. Also, diamond cut and Microcut are rated at level 3 security while cross-cut is rated at level 2.

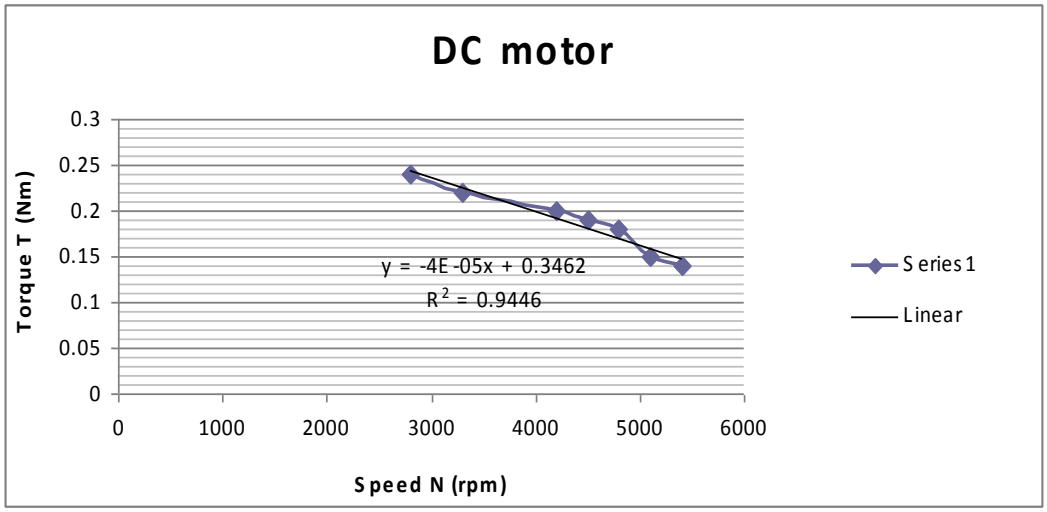
The second task of the mechanical team was to develop a gear train: the gear train transfers the torque from the motor to the shredder. The gear train uses speed reduction to increase torque at the shredder head. Knowing the torque required at the shredder head and given by the motor which is shown in the electrical results below, a gear ratio was developed to drive the shredder. The gear ratio obtained was 165:1. The gear ratio was

made into a gear train. Having the gear train, electric motor, and shredder head, a prototype was developed and can be seen below.

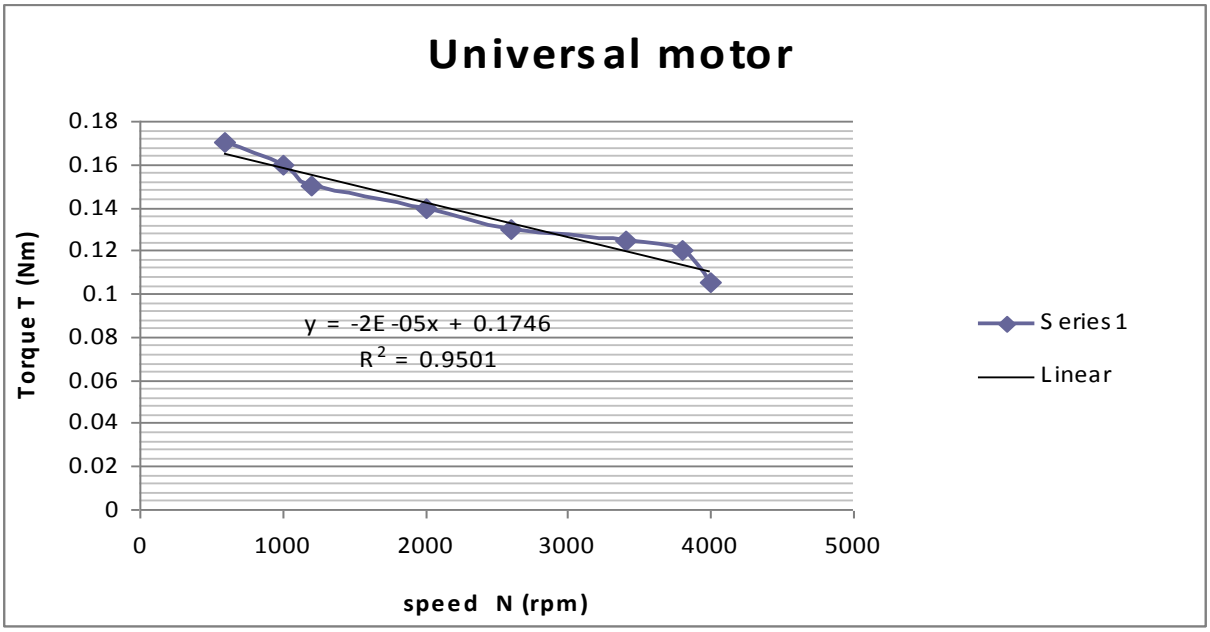


Electrical Team

The electrical team determined that DC motors provide substantially more torque and speed versus the universal motor. The DC motor also lasts longer than the universal motor. Furthermore, if a universal motor is chosen, DC power should be used. DC power will provide more power and longevity at a lower voltage versus the full AC line voltage as is usually used in shredders with universal motors. The graphs showing this data are displayed here, first the data for the DC motor.



Here is the data for the universal motor



The electrical team used this data to determine which motor would work best for the shredder, which is the DC motor.

Innovation Team

Adhering a paper feeding apparatus to a shredding unit is relatively uncomplicated. However, paper feeding precision requires utmost care, as the goal of feeding a single sheet at a time to a unit is not a trivial one.

Upon proper assembly of a paper feeding apparatus, shredding the actual paper may be easily implemented thereafter in a number of forms, namely:

1. Continuing with tradition strip-cut methodologies to shred paper after being fed
2. Nontraditional self-propelled slicing of paper, wherein the force of the paper being expelled from the frontend of the feeder to the back along a series of sharpened blades will constitute the actual shredding of the paper itself.

3. Nontraditional method of incorporating a rotating hole-punching device that will pierce automatically fed sheets of paper into particularly chosen fragments.

Recommendations

Based on the research, the team came up with the following recommendations for Mr. Seth Lewis and the Manhattan Group

- The prototype paper shredder can be used to interchange different motors and shredder heads to test different designs
- The gear train can be changed to non-metallic to decrease noise
- DC motors are less noisy then the Universal, but they are more costly based on the results obtained from the tests the universal motor provides better horse power when is driven on DC power, also the coefficient of efficiency is higher
- Implementing an automatic paper feeder coupled with non-rotating shredding blades could improve paper shredding efficiency and customer satisfaction

The team also came up with a list of recommendations for future teams that work on this IPRO in order to continue progress on the work that has been started.

- Obtain more competing shredder models. Pull the shredding heads out and place them in the new torque measurement device. This will find the torque curve for each shredder. The machine was created to be able to do this so different shredders can be compared.
- Obtain more motors. Take these motors and run them through both the dyno-meter and then run them through the prototype as well
- Obtain a different set of gears. Put these gears into the prototype and see how well they work. Also try gears of different materials and see if they can handle the stresses and torques needed
- Test the prototype more thoroughly. Because of time constraints, the team was not able to test the prototype thoroughly, leaving many questions unanswered about the machine
- Investigate a manner in which a hole-puncher may be made in such a way that is spherical in shape, pierces paper in squares, and can rotate along an axis.

References

- Mr. Seth Lewis –*President of Manhattan Group*
- Professor Maurer – *Faculty advisor for IPRO 321*
- Professor Sheldon Mostovoy –*MMAE Professor at Illinois Institute of Technology*
- Motion Industries – *Gear distributor and place where team purchased gears*
- Boston Gears – *Gear producer and maker of the gears the team used*

Acknowledgements

Mr. Seth Lewis

President of The Manhattan Group

The team was very grateful that Mr. Lewis brought this opportunity to IIT for students to work on. Mr. Lewis took time to come and visit with us and check our progress and assist

us in working towards his objectives. He also provided the team with the necessary shredders and parts to perform tests.

Professor Sheldon Mostovoy
Faculty Advisor for IPRO 321
Professor Mostovoy made himself readily available to answer the teams questions and provide us with his expertise. He played a huge role in the design of the gear train and helped the team in working through issues with the torque machine .

Professor William Maurer
Faculty Advisor for IPRO 321
Professor Maurer guided the team through the entire semester. He answered all necessary questions to get us started on the project and to ensure that the team stayed on schedule. He also worked with Mr. Lewis to ensure that he stayed updated on the progress and worked to get the shredders needed for the project.

Machine Shop
Illinois Institute of Technology
The team would like to acknowledge the machine shop for all the work that they put into the torque measurement device. The team designed and created schematics of the machine and the machine shop took time to ensure that it was built to the correct specifications.

IPRO Department
Illinois Institute of Technology
We would like to thank the IPRO office for working to give us this wonderful opportunity. It was good experience to work as a team on a specific problem in order to please the sponsor.

Motion Industries
Gear Distributor and Store
We would like to thank Motion Industries for their help in obtaining the necessary gears to run the prototype as well as providing necessary information on the gears needed

Boston Gears
Gear Maker and Distributor
The team would also like to thank Boston Gears for producing the gears used in the prototype shredder and for being helpful by answering all necessary questions involving the gears and bearings