Improving the Reliability and Efficiency of a Paper Shredder
# The Team

## Torque:
- Yuxiong Huang, Grad.  
  *Information Technology & Management*
- Vesna Pesik, Sr.  
  *Electrical Engineering*
- Nil Valls, Sr.  
  *Physics, Aerospace Engineering*

## Gear Train:
- Justin Choriki, Jr.  
  *Mechanical Engineering*
- Tyler Inouye, Sr.  
  *Electrical Engineering*
- Garrett Nielson, Sr.  
  *Electrical Engineering*
- Brandee Toyama, Jr.  
  *Mechanical Engineering*

## Sound:
- Stephen Flicek, Sr.  
  *Mechanical Engineering*
- Richard King, Sr.  
  *Computer Engineering*
- Angad Nagwan, Sr.  
  *Mechanical Engineering*
- Leslie Obst, Sr.  
  *Mechanical Engineering*

## Torque Apparatus:
- Plamen Marinov, Sr.  
  *Mechanical Engineering*

## Kyle Swaidner, Sr.

*Aerospace Engineering*
The Problem

Paper shredders are:

• Noisy

• Cost sensitive

• Unreliable
Objectives

- DETERMINE TORQUE
- OPTIMIZE GEAR TRAIN
- REDUCE NOISE
Noise Reduction

dB Sound Levels

Calm Room: 25
Normal Talking (3ft): 40
Staples Shredder (3ft): 68
Royal Shredder (3ft): 71
Jet Engine (300ft): 110
Two Paper Shredders

- Royal Paper Shredder ($30)
  - Cross Cut
  - AC Motor

- Ativa Paper Shredder ($70)
  - Diamond Cut
  - DC Motor
Noise levels of Shredders

[Graph showing noise levels for Ativa Paper Shredder and Royal Paper Shredder for 1 Sheet and 6 Sheets.]
Noise level vs. No. of Gears

- Motor
- 1 Gear
- 2 Gears
- 3 Gears
Torque Test Data

Voltage (V)

Torque

![Motor and gears with a graph showing voltage changes](image-url)
Torque Testing

The torque necessary to shred paper was determined by:

1. Electrical Method

2. Mechanical Method
Electrical Method

- Input power \((V_{rms} \cdot I_{rms})\) was measured with a voltmeter and ammeter.
- Rotational speed \((\omega)\) was measured with a tachometer.

\[
Torque = \frac{V_{rms} \cdot I_{rms}}{\omega}
\]
Mechanical Method

- Slip Ring Assembly
- Aluminum Tubular Shaft
- Strain Gage Rosettes
- Variable Speed Gear Motor
- Shredder Head and Blades
Key Features

• Gear reduced DC motor
  – Adjustable speed

• Strain gage rosettes
  – Allow torque measurements by computer software

• Calibrated with known weights and a measured moment arm
  – Ensures high accuracy

• Allows the mounting of other shredding heads
Power Curve for Shredding

- Applied Torque (in-lb)
- Number of Sheets

- Torque at Maximum Rated Load
- Electrical Data
- Mechanical Data
- Losses
- Maximum Rated Load
Application of Torque Data

• Motor and gear sizing

• Maximum load ratings

• Creation of new models

• Comparison with competing manufacturers
Gear Train
Research

• Group research on basics of gear types and uses

• Leveraged previous IPRO work where possible

• Contacted and collaborated with gear companies for gear train analysis
Research

Spur Gear

Helical Gear

Double Helical Gear

Worm Gear

Shredder Gear Set
Work and Results

- Tested Gear Train to find maximum load before break

- Group compiled research into two excel files for calculations
# Work and Results

<table>
<thead>
<tr>
<th>gear 1</th>
<th></th>
<th>gear 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RPM</td>
<td>15000.00</td>
<td>RPM</td>
<td>1630.43</td>
</tr>
<tr>
<td>Torque (Nm)</td>
<td>0.16</td>
<td>Torque (Nm)</td>
<td>1.47</td>
</tr>
<tr>
<td>mesh 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency (kHz)</td>
<td></td>
<td>75.00</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td>69.72</td>
<td></td>
</tr>
<tr>
<td>Tangent</td>
<td></td>
<td>65.51</td>
<td></td>
</tr>
<tr>
<td>Separation</td>
<td></td>
<td>23.84</td>
<td></td>
</tr>
<tr>
<td>Stress at Root 1 (N/mm(^2))</td>
<td></td>
<td>3.70</td>
<td></td>
</tr>
<tr>
<td>Stress at Root 2 (N/mm(^2))</td>
<td></td>
<td>3.60</td>
<td></td>
</tr>
</tbody>
</table>

Forces Table Snapshot
Work and Results

<table>
<thead>
<tr>
<th>Material</th>
<th>Specification</th>
<th>Ultimate Tensile Strength</th>
<th>Yield Tensile Strength</th>
<th>Tooth Hardness - Core</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rm</td>
<td>Rp(0.2)</td>
<td>VPN</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------------</td>
<td>---------------------------</td>
<td>------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td></td>
<td>MPa</td>
<td>MPa</td>
<td>HV</td>
<td></td>
</tr>
<tr>
<td>1 Grey Cast Iron</td>
<td>BS EN 1561:1997</td>
<td>200</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>EN-GJL-200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Grey Cast Iron</td>
<td>BS EN 1561:1997</td>
<td>250</td>
<td>125</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>EN-GJL-250</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Grey Cast Iron</td>
<td>BS EN 1561:1997</td>
<td>300</td>
<td>150</td>
<td>240</td>
</tr>
<tr>
<td></td>
<td>EN-GJL-300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Ductile Cast Iron</td>
<td>BS EN 1563:1997</td>
<td>600</td>
<td>370</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>EN-GJS 600-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Ductile Cast Iron</td>
<td>BS EN 1563:1997</td>
<td>700</td>
<td>420</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>EN-GJS 700-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Ductile Cast Iron</td>
<td>BS EN 1563:1997</td>
<td>800</td>
<td>480</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>ENGJS 800-2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Carbon Cast Steel Normalized</td>
<td>BS 3100:1991</td>
<td>500</td>
<td>260</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>A3, A5 **</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Gear Strength Table Snapshot
Recommendations/Results

• Gear train:
  o sufficient strength,
  o can be modified to reduce noise,
  o improve gear manufacturing process,
  o install bearing on first gear.

• Maximum shredding capacity should not be increased: (2 Extra sheets  60% increase in Torque)

• Slower, higher torque motor to reduce noise, & provide more consistent operating speeds.
Acknowledgements

• Mr. Seth Lewis, President, The Manhattan Group

• Professor Sheldon Mostovoy

• Mr. Russell Janota, Director, MMAE Laboratories

• IIT Machine Shop

• Arrow Gear
Thank You