IPRO 321

Fall 2007

ILLINOIS INSTITUTE OF TECHNOLOGY

Improving the Reliability and Efficiency of a Paper Shredder

THE MANHATTAN GROUP

ILLINOIS INSTITUTE OF TECHNOLOGY

The Team

Torque :

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  Information Technology & Management

- Vesna Pesik, Sr.

  Electrical Engineering

- Nil Valls, Sr.

  Physics, Aerospace Engineering

Gear Train:

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  Mechanical Engineering

- Tyler Inouye, Sr.

  Electrical Engineering

- Garrett Nielson, Sr.

  Electrical Engineering

- Brandee Toyama, Jr.

  Mechanical Engineering

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- 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.

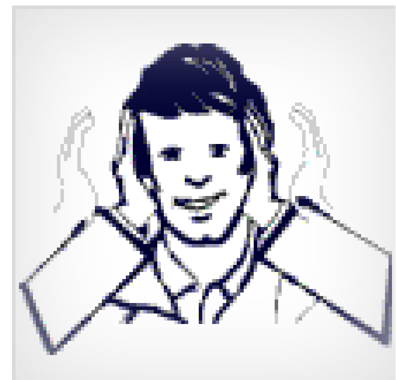
  Mechanical Engineering

Kyle Swaidner, Sr.

Aerospace Engineering

The Problem

Paper shredders are:

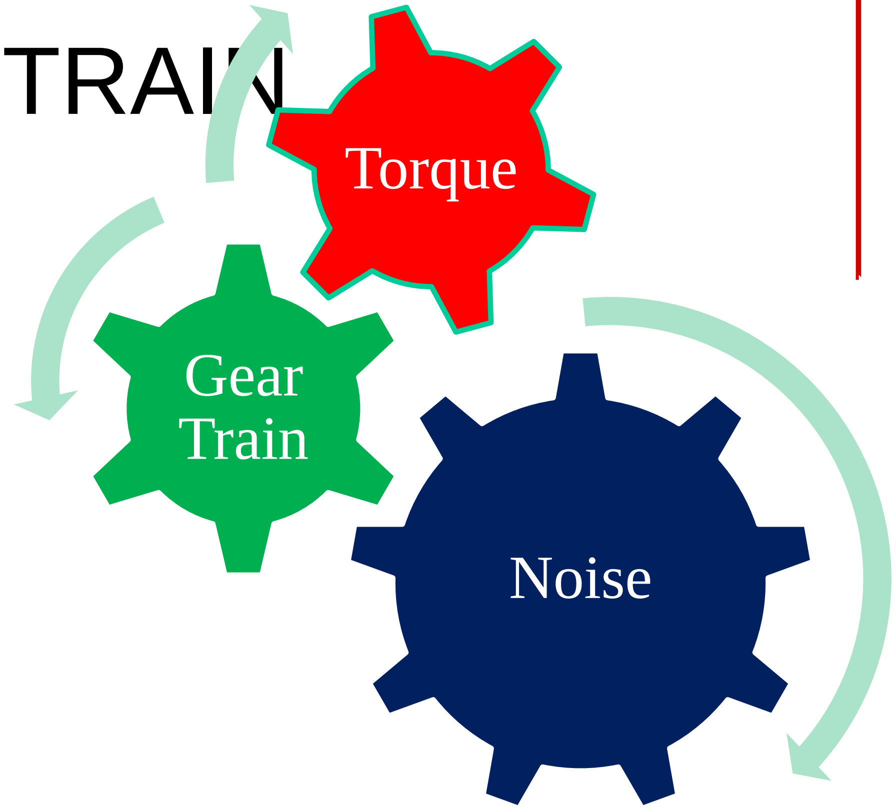


- Noisy

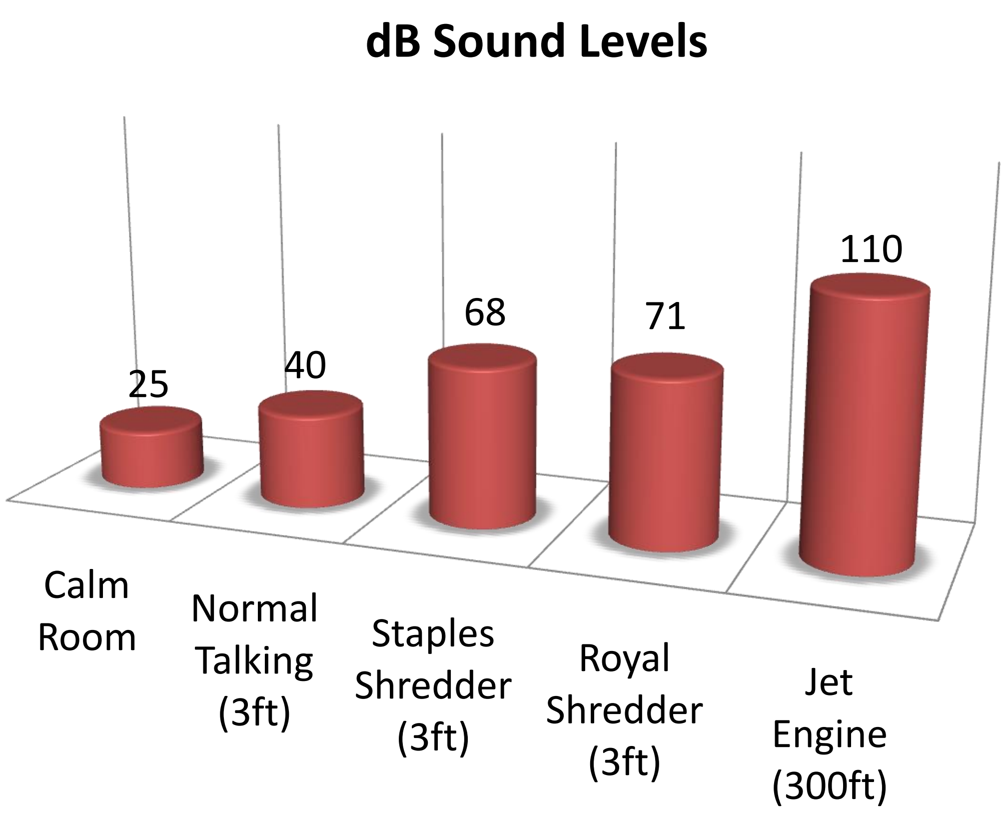
- Cost sensitive
- Unreliable

Objectives

- DETERMINE TORQUE
- OPTIMIZE GEAR TRAIN
- REDUCE NOISE



Noise Reduction

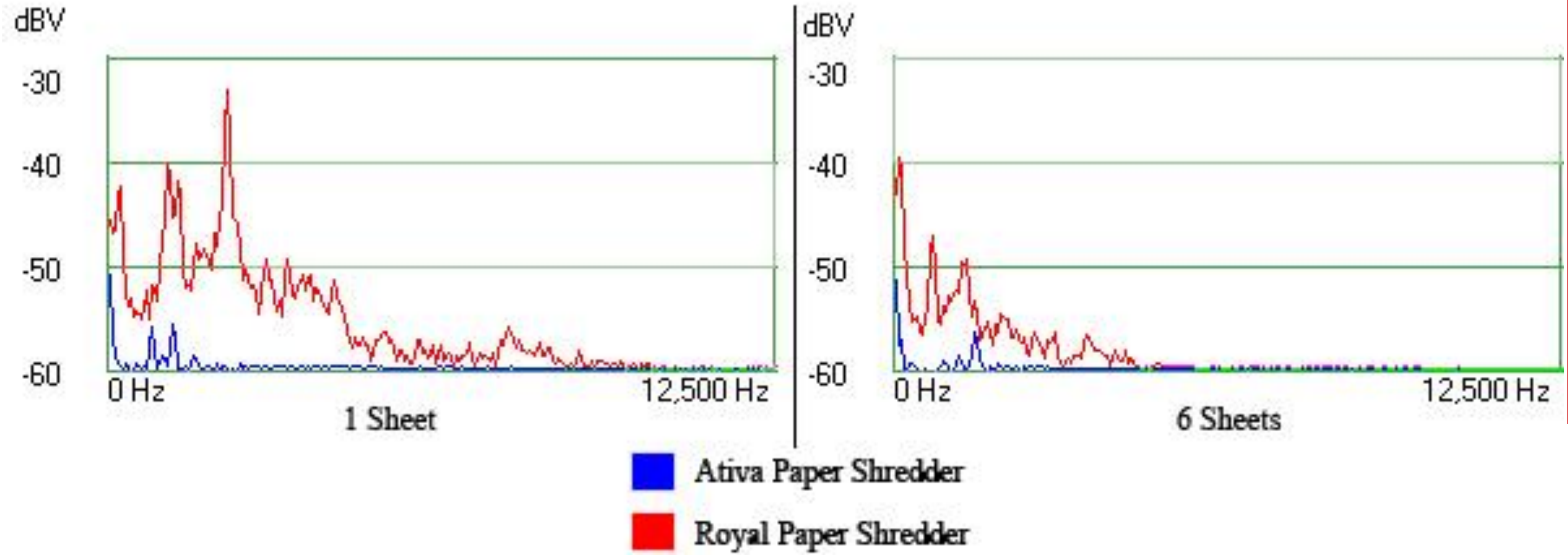


Two Paper Shredders

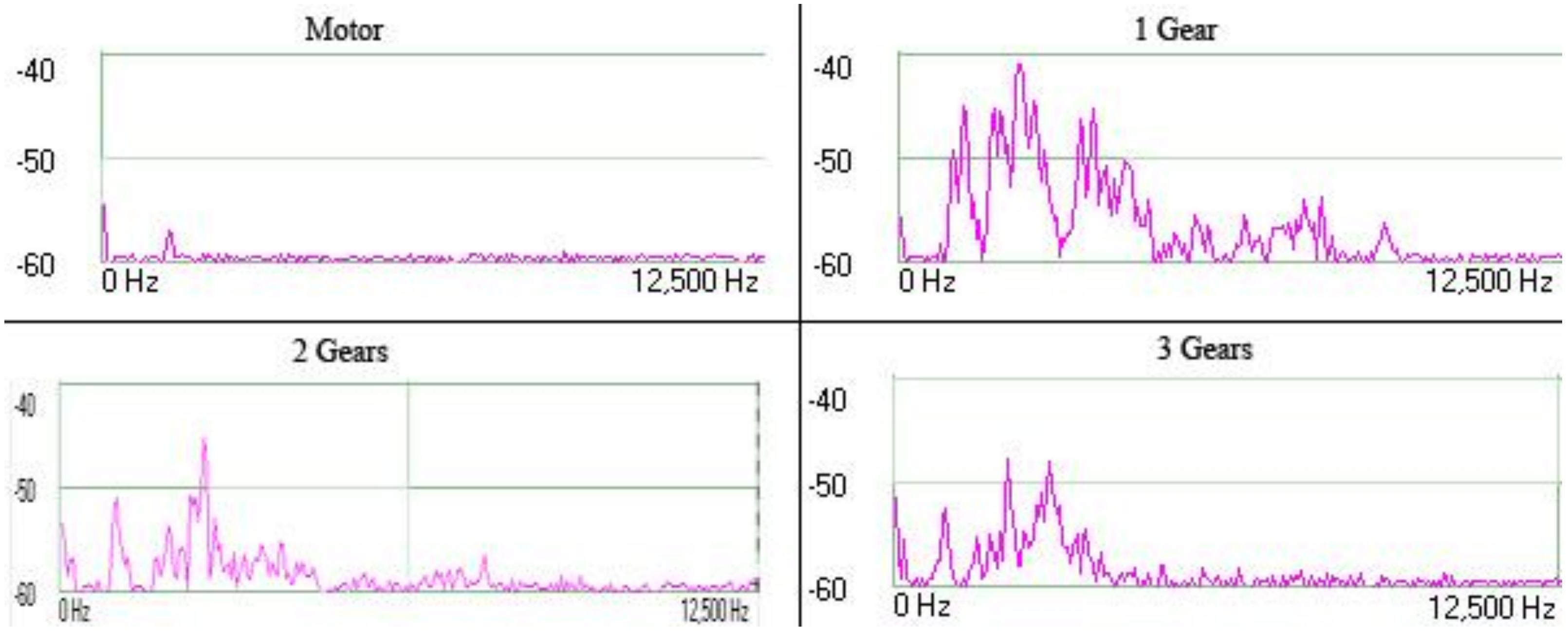
- Royal Paper Shredder ($30)
  - Cross Cut
  - AC Motor

- Ativa Paper Shredder ($70
  - Diamond Cut
  - DC Motor

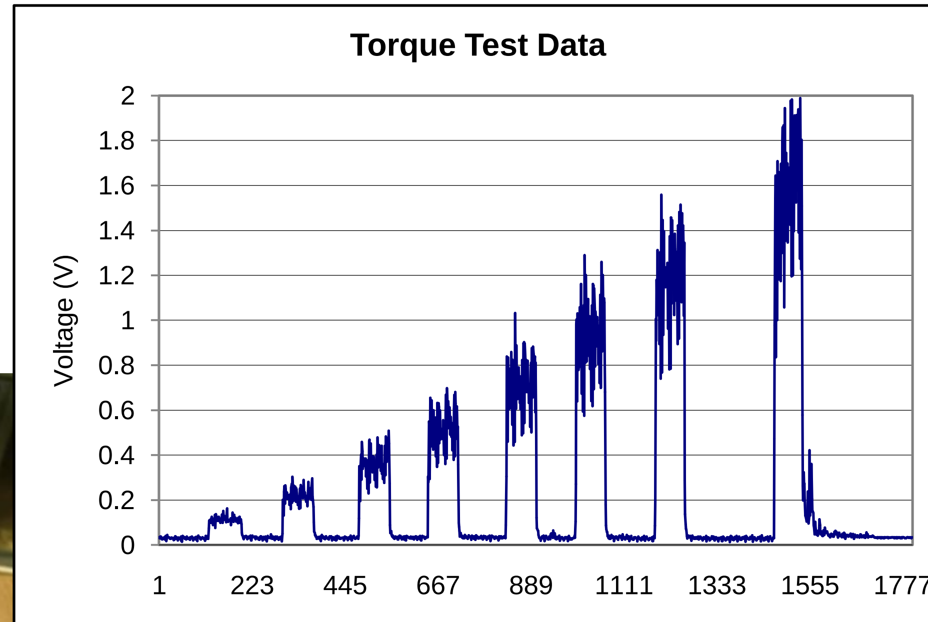
Noise levels of Shredders

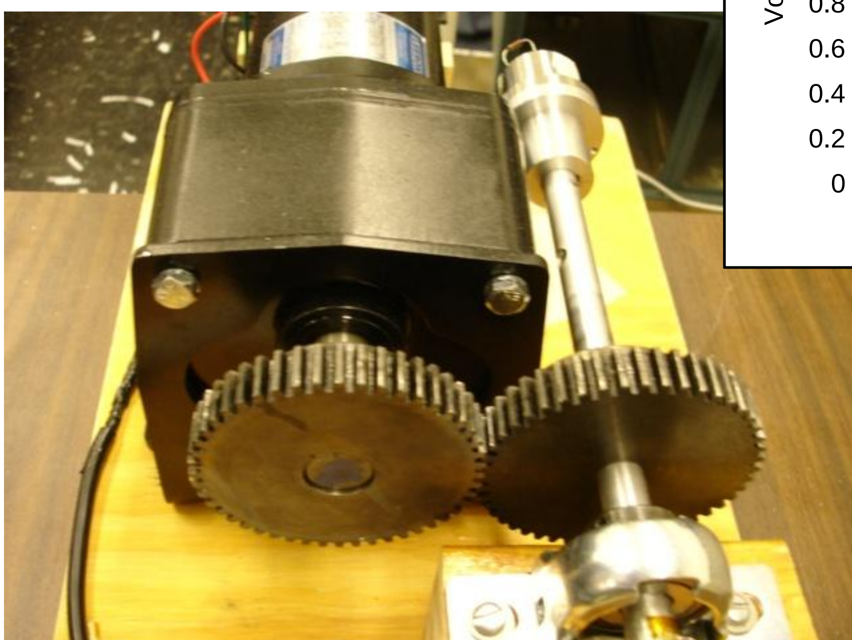


Noise level vs. No. of Gears



Torque


Torque Test Data
Voltage (V)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
223
445
667
889
1111
1333
1555
1777



Torque Testing

The torque necessary to shred paper was determined by:

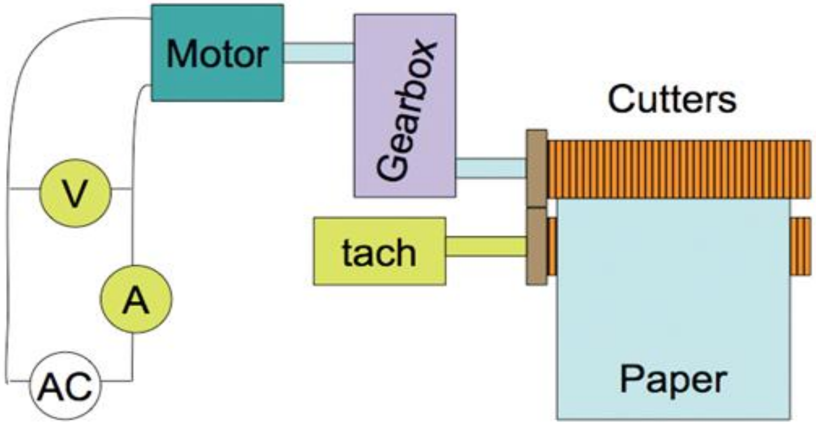
1. Electrical Method

2. Mechanical Method

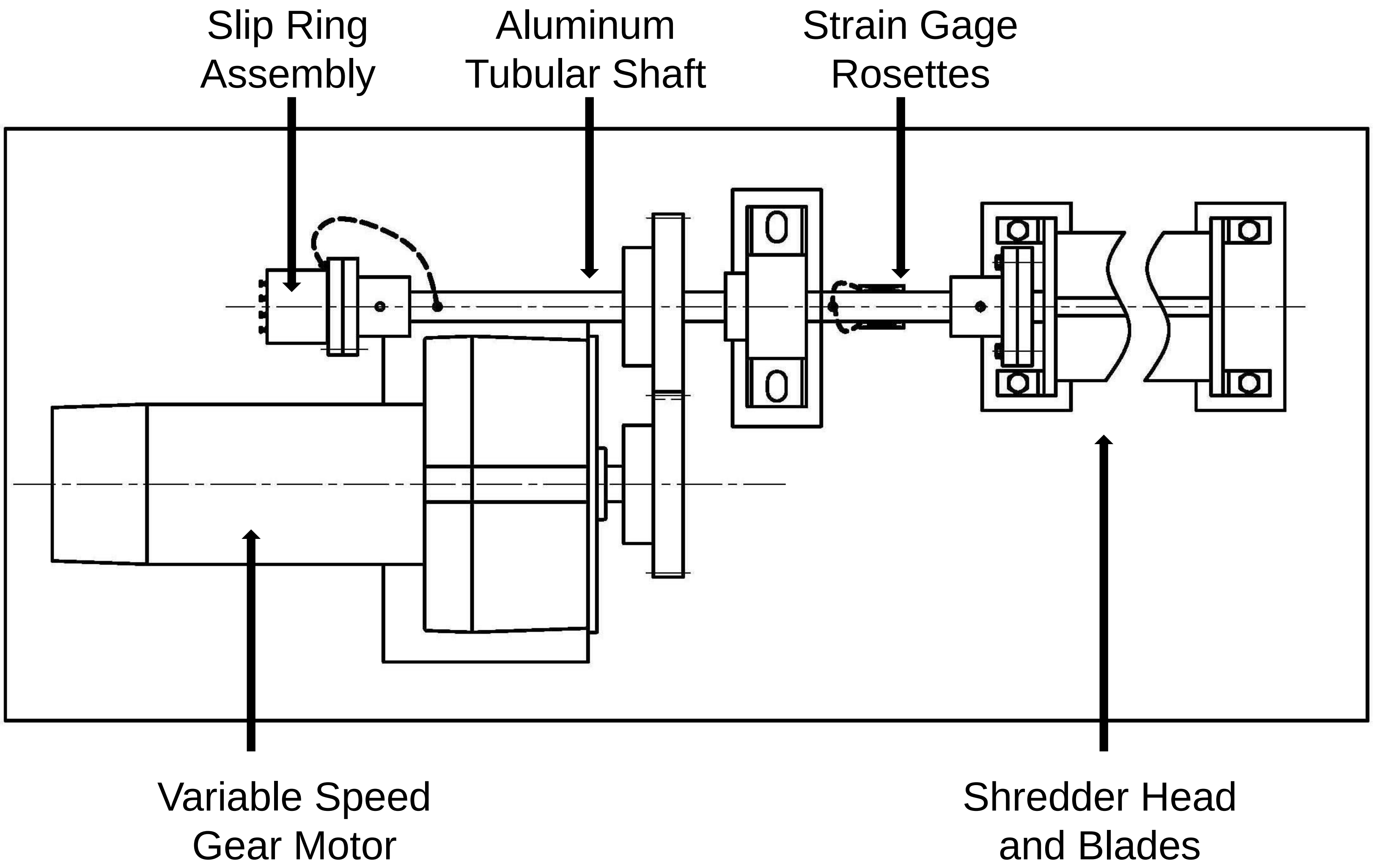
Electrical Method

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

$$Torque = \frac{V_{rms} \cdot I_{rms}}{\omega}$$



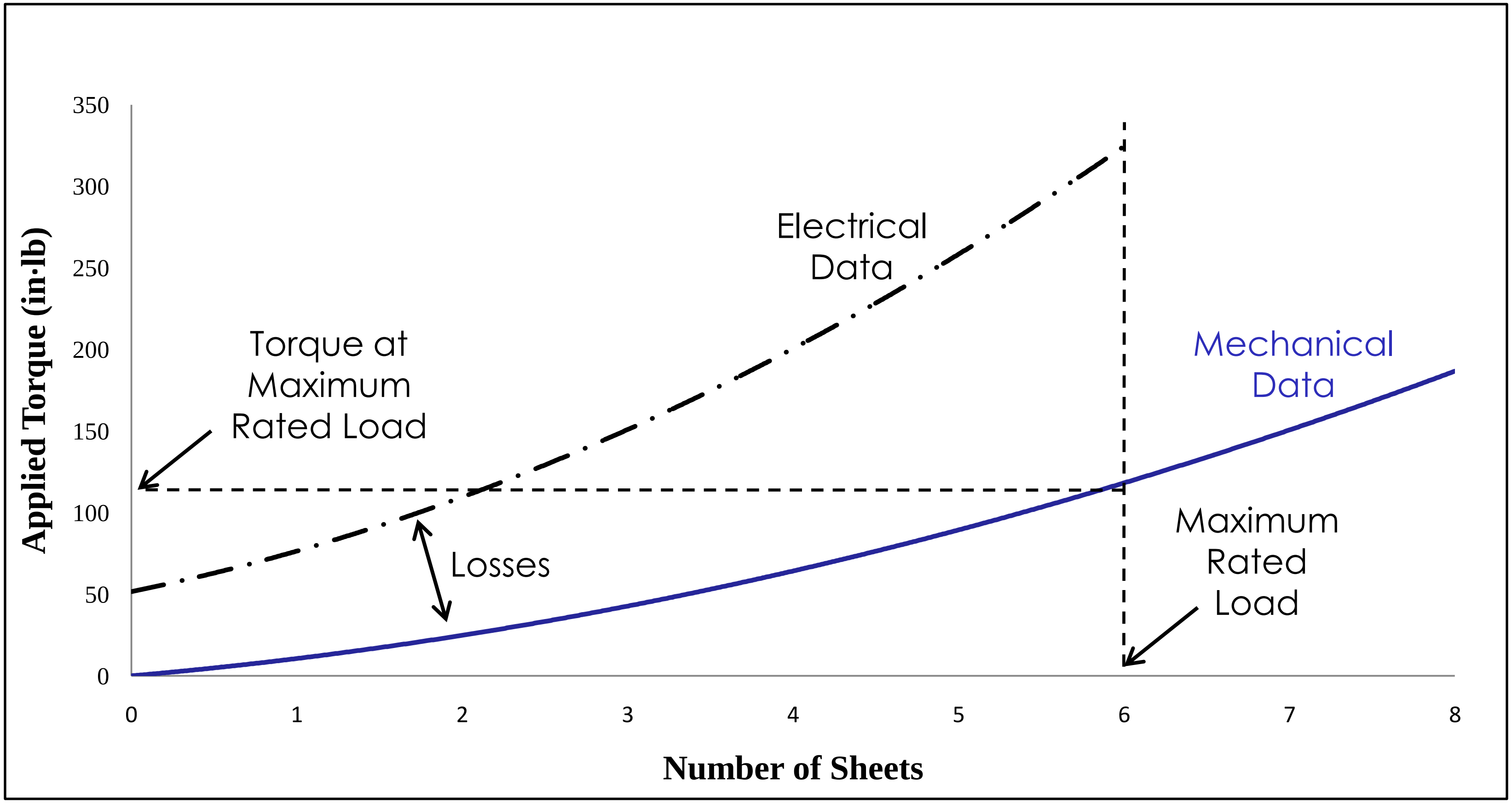
Mechanical Method



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

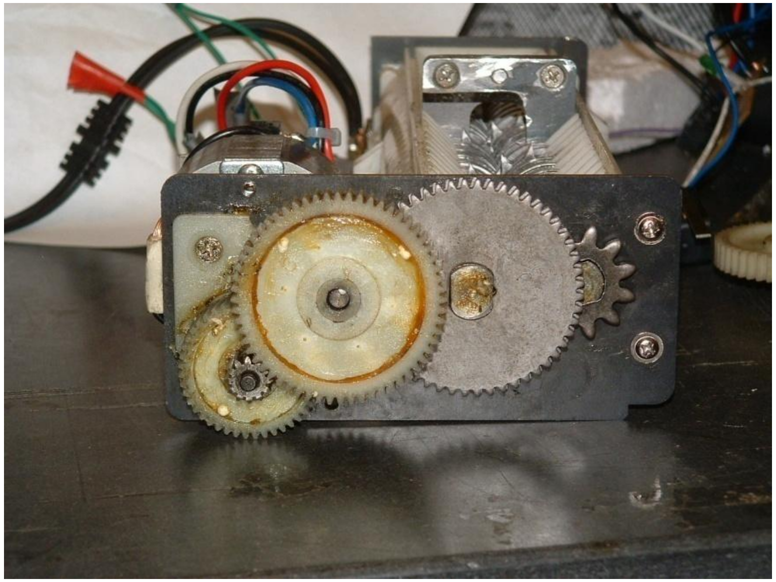
Power Curve for Shredding

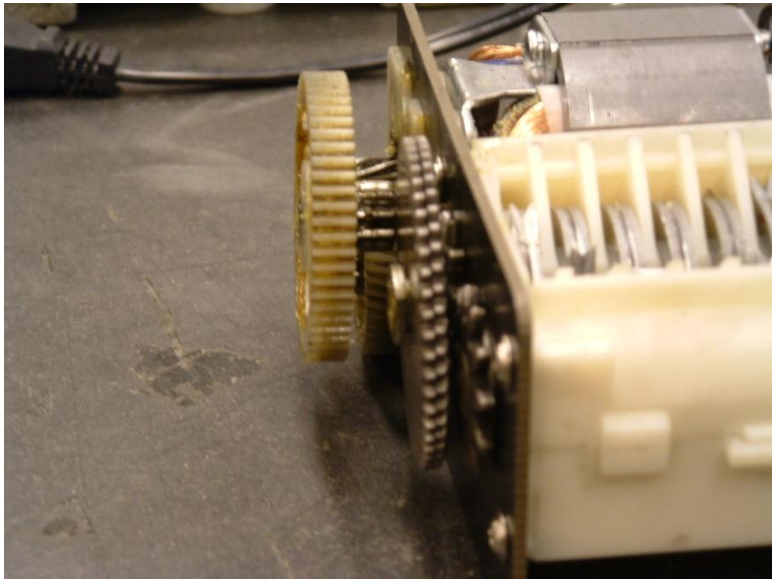


Application of Torque Data

- Motor and gear sizing
- Maximum load ratings
- Creation of new models
- Comparison with competing manufacturers

Gear Train

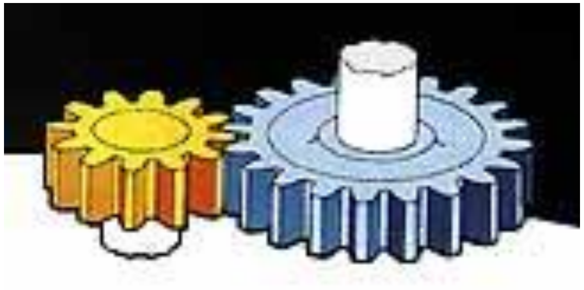




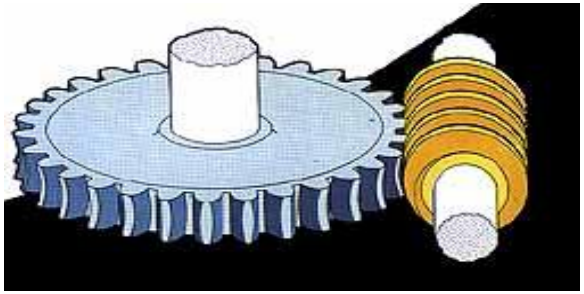
Research

- 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



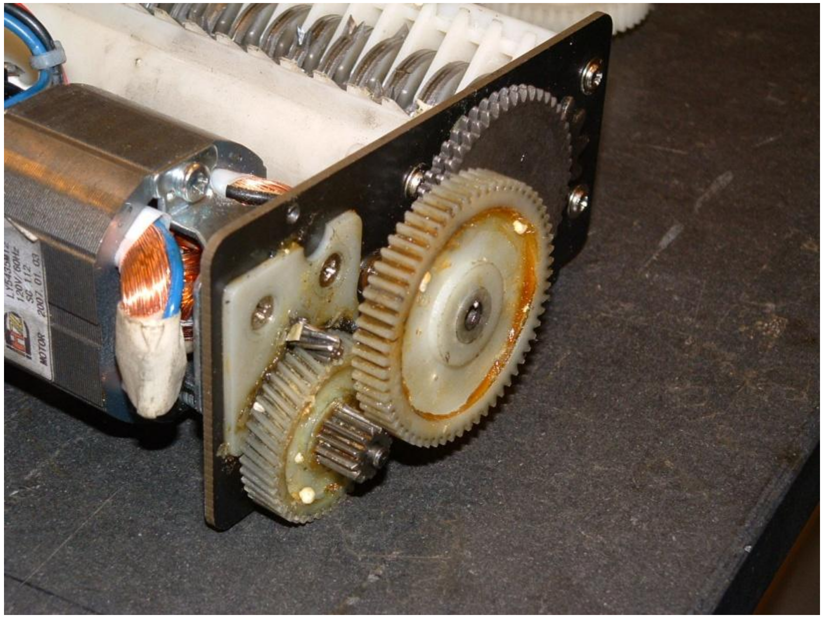
Spur Gear



Worm Gear

Helical Gear

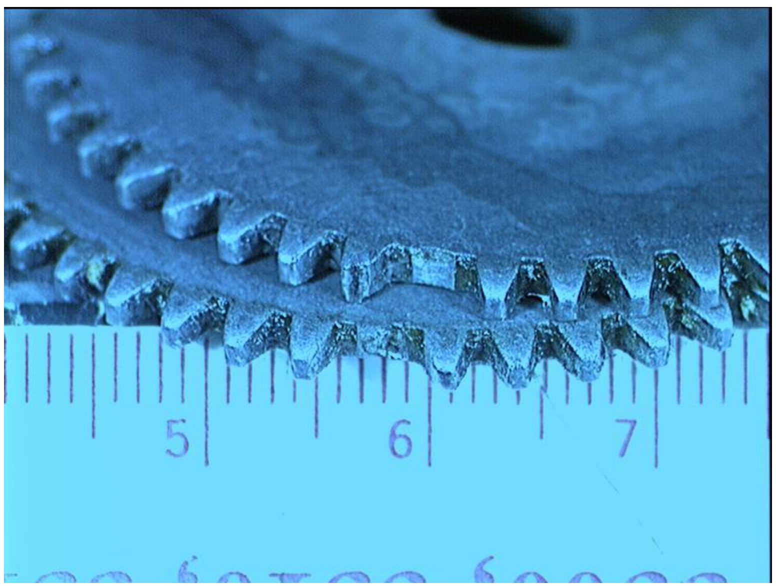
Double Helical Gear

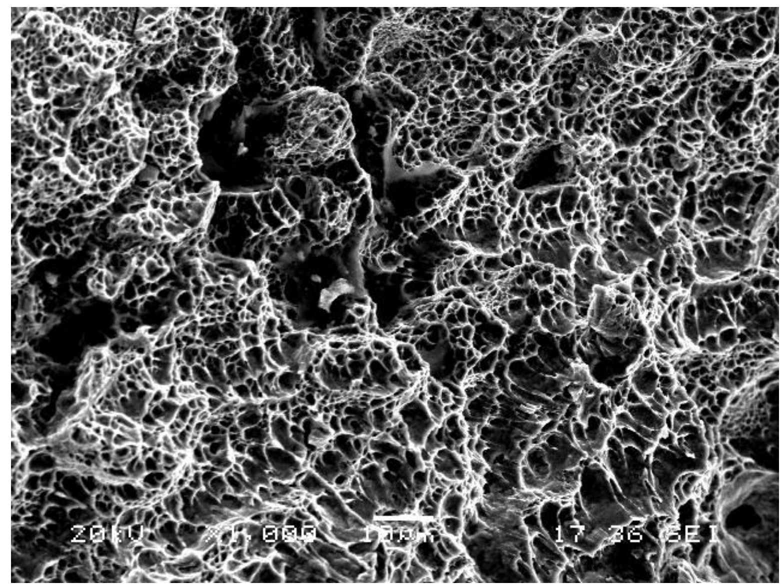


Shredder Gear Set

Work and Results

- Tested Gear Train to find maximum load before break





- Group compiled research into two excel files for calculations

Work and Results

gear 1		gear 2	
RPM	15000.00	RPM	1630.43
Torque(Nm)	0.16	Torque (Nm)	1.47
mesh 1			
Frequency (kHz)	75.00		
Normal	69.72		
Tangent	65.51		
Separation	23.84		
Stress at Root 1 (N/mm^2)	3.70		
Stress at Root 2 (N/mm^2)	3.60		

Forces Table Snapshot

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Work and Results

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

Gear Strength Table Snapshot

Recommendations/Results

- Gear train:
  - sufficient strength,
  - can be modified to reduce noise,
  - improve gear manufacturing process,
  - 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

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•Professor Sheldon Mostovoy

•Mr. Russell Janota, Director, MMAE Laboratories

•IIT Machine Shop

•Arrow Gear

Thank You