Magnetic Damping

By Ammar Farooq, Muhammad Qasim and Ahmed Tilal

OBJECTIVES AND PLAN

- To determine how damping varies with the magnetic field
- To determine effects of air damping
- Obtain graphs to show how damping constant varies

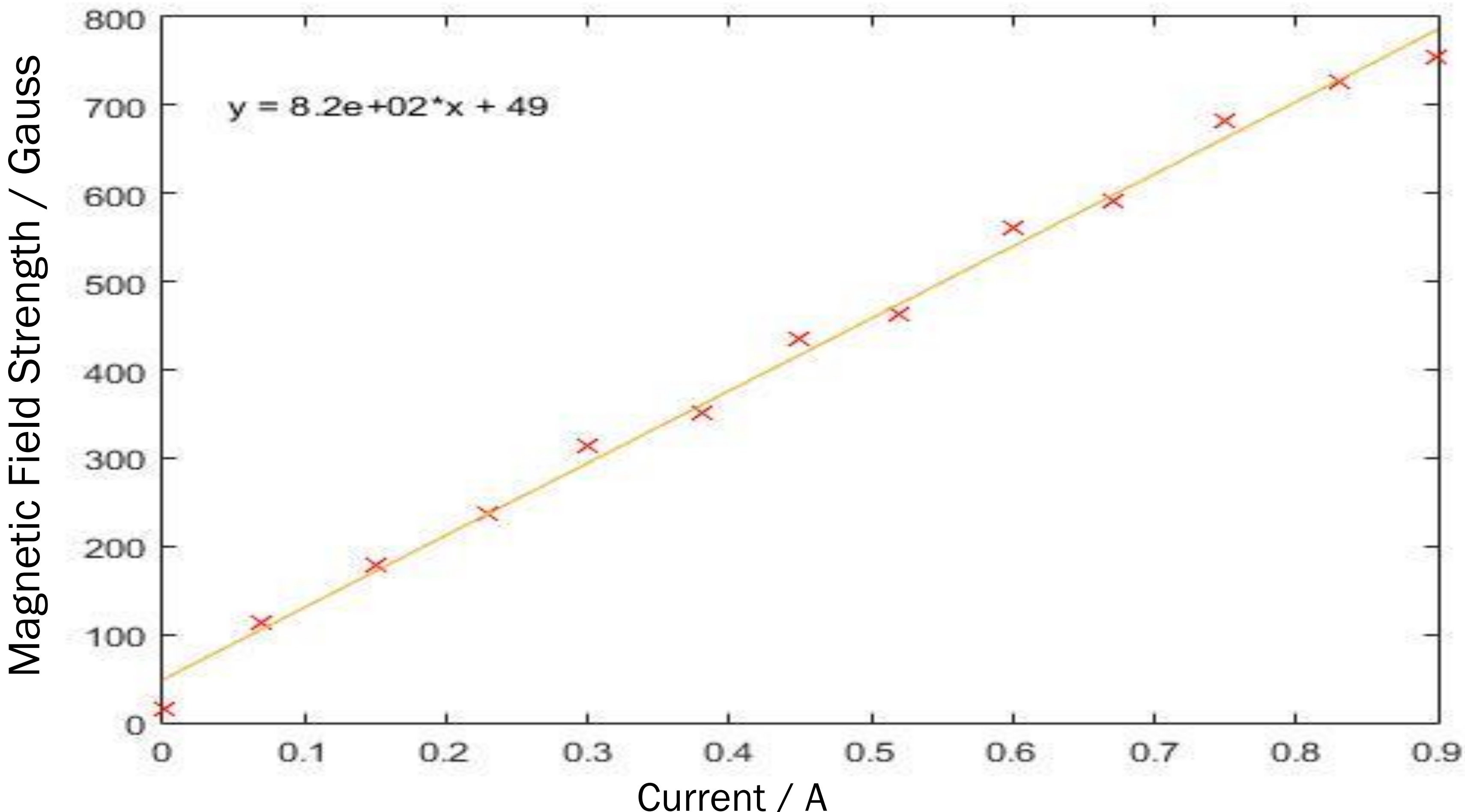
STAGE 1

1. Set up apparatus
2. Find Initial time periods for pendulum and get a general idea of the nature of the resistive torques.
3. Finding dimensions of the pendulum & calibrating the magnetic field.

INITIAL APPARATUS

- Retort Stand
- Metal disc (compound pendulum)
- Electromagnet (BUCKLEY SYSTEMS LTD. Sr. No. 64899)
- Vernier calipers
- Multimeter (GW INSTEK GDM-451)
- Hall Probe (Non Calibrated, Linear, A1323EUA-T)
- Power Supply (BK PRECISION 1665)

FIELD CALIBRATION



DRAWING MODEL

$$\textit{The resistive torque will be dependent on the induced eddy currents.}$$

$$I = \frac{d\emptyset}{dt}$$

Assuming a resistive Force F $\propto -\dot{x}$

$$F = -k\dot{x}$$

$$\tau = -k(L + R)\dot{\theta}$$

$$\tau = -\alpha\dot{\theta}$$

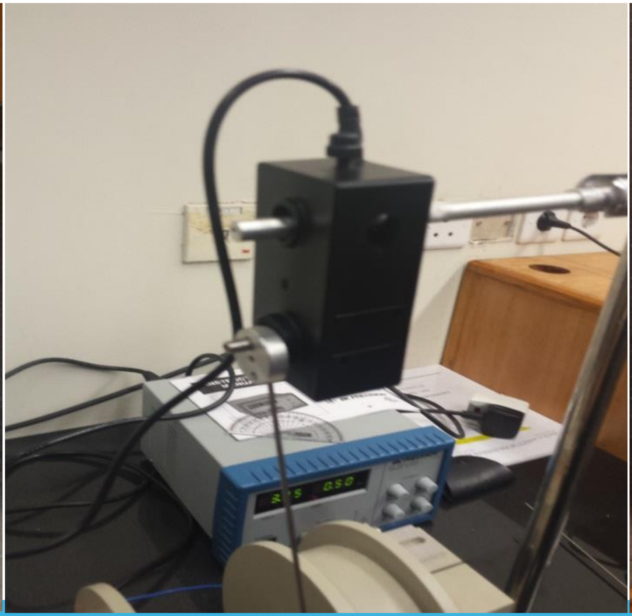
$$I\ddot{\theta} = -a_0\theta - \alpha\dot{\theta}$$

$$\ddot{\theta} + 2\beta\dot{\theta} + \omega_0^2\theta = 0$$

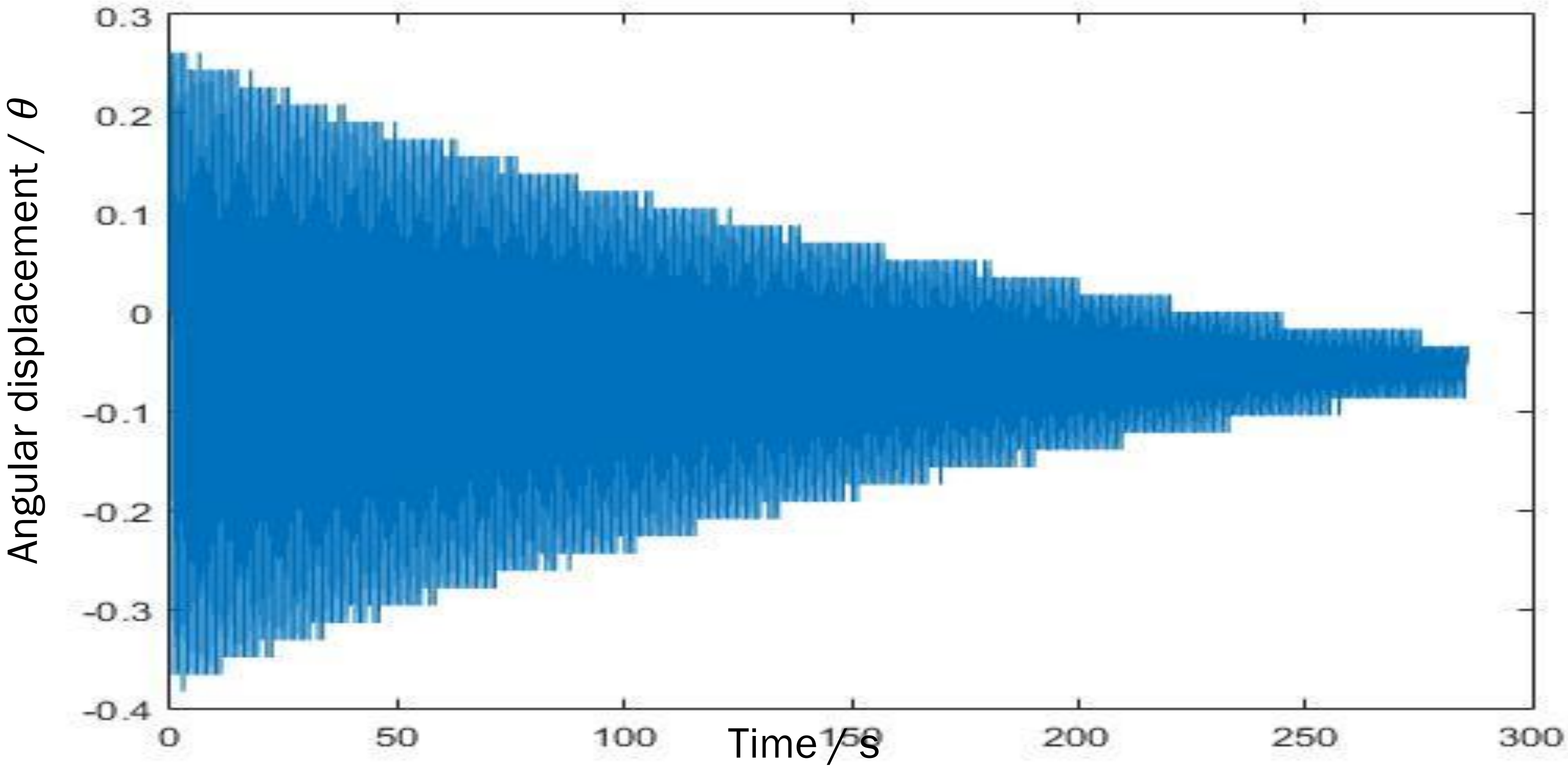
where $2\beta = \frac{\alpha}{I}$

NEW APPARATUS ADDED

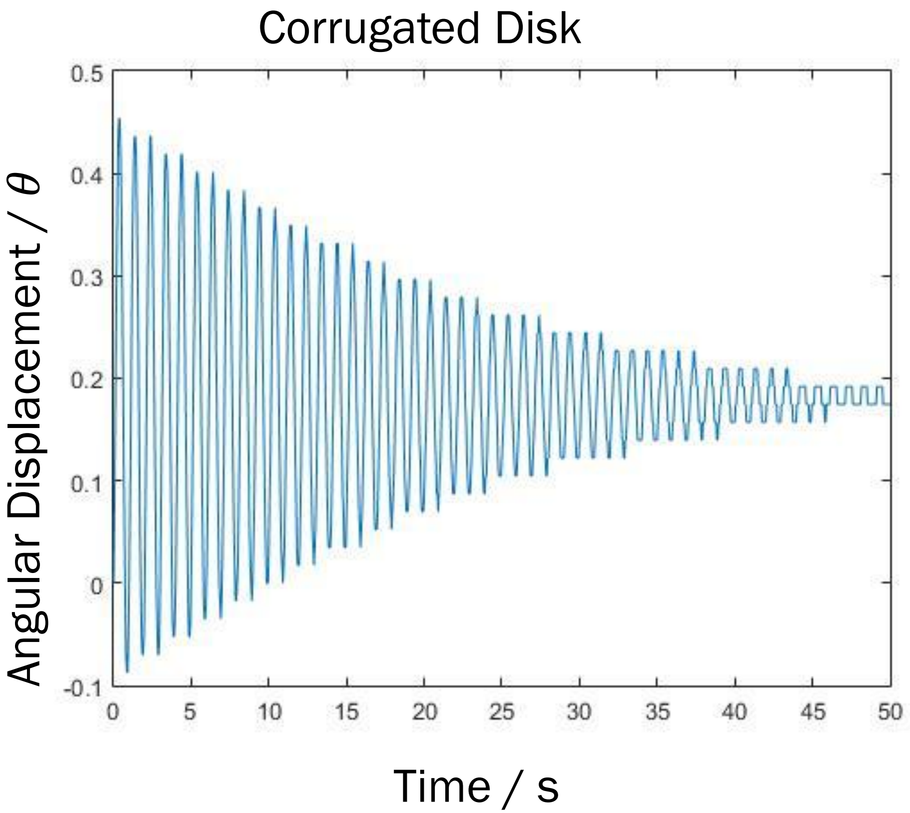
- Angle Sensor with accessories (Vernier Rotary Motion Sensor with Lab Quest Mini)
- Variable sized metal discs

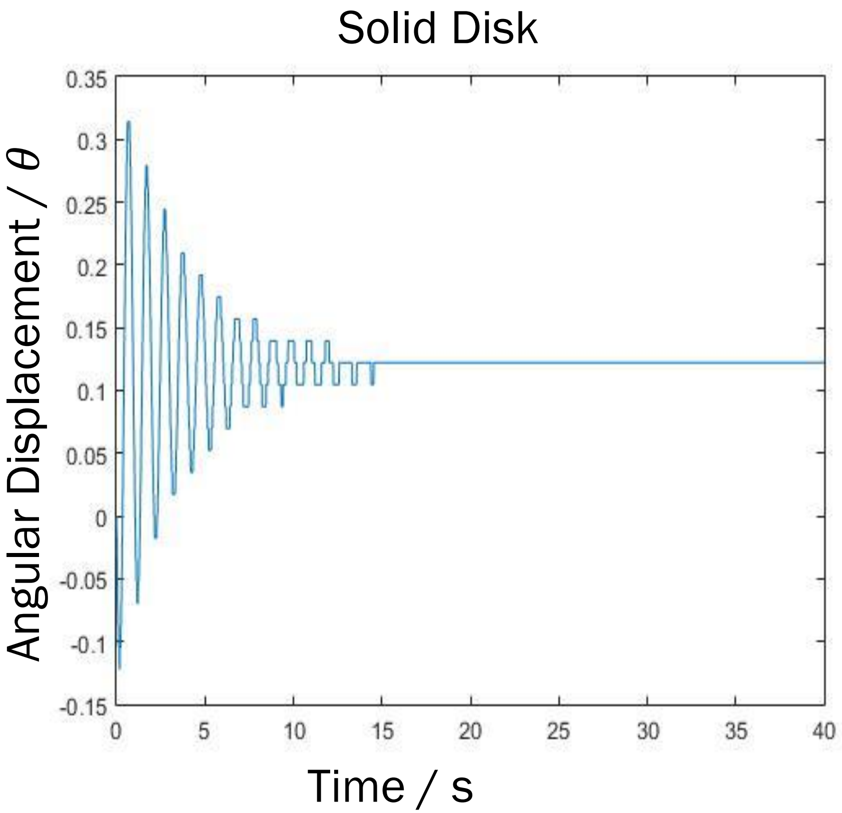


OSCILLATIONS IN AIR



AT 0.5A COMPARISON B/W CORRUGATED AND SOLID DISK





NEW MODEL

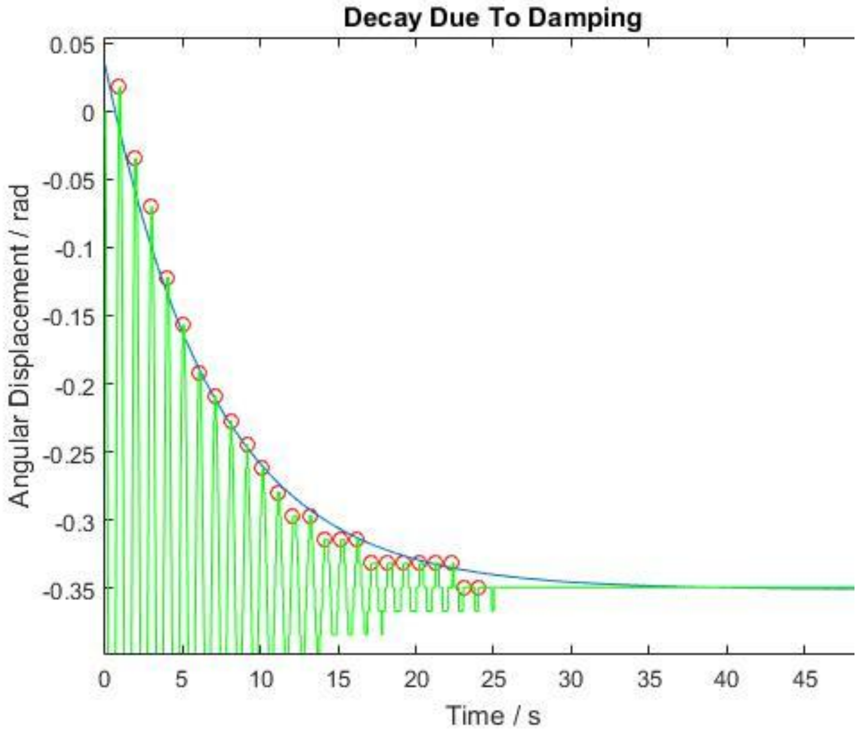
Solution to the proposed equation:

$$\boldsymbol{\theta} = \boldsymbol{\theta_0 e^{-\beta t}} \cos(\boldsymbol{\gamma t} + \boldsymbol{\varphi}) + \boldsymbol{c}$$

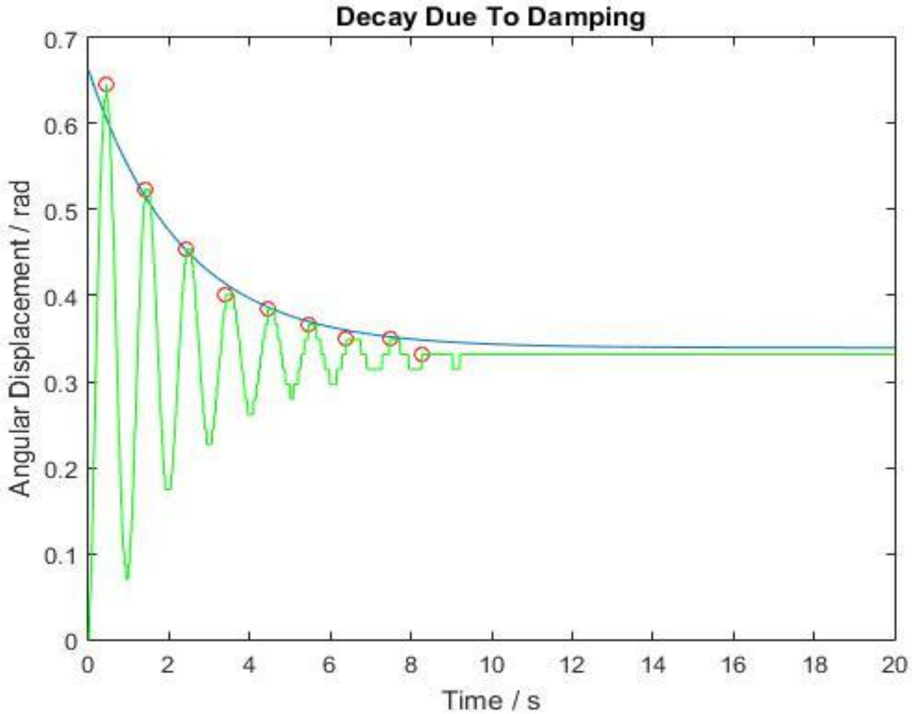
To extract envelopes:

$$\boldsymbol{\theta_{envelope}} = \boldsymbol{\theta_0 e^{-\beta t}} + \boldsymbol{c}$$

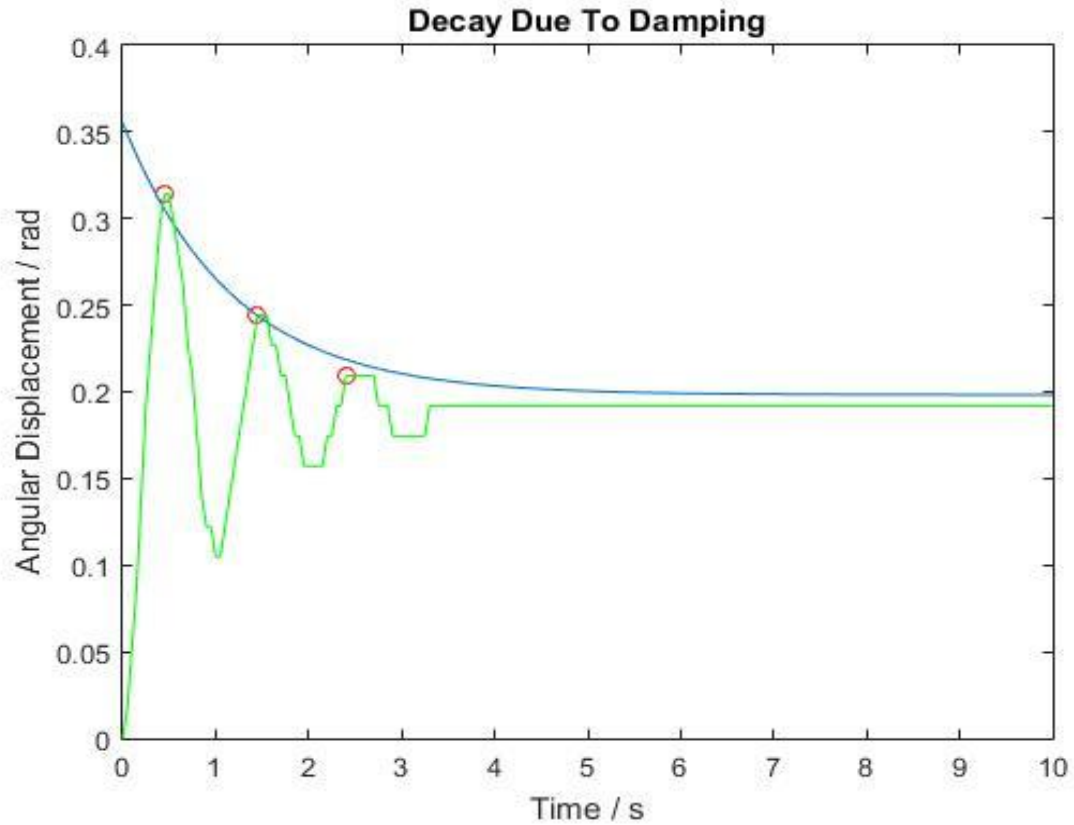
GRAPHS



B = 377 Gauss



B = 623 Gauss



Decay Due To Damping
Angular Displacement / rad
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
8
9
10
Time / s

B = 869 Gauss

VARIATION OF DAMPING CONSTANT WITH THE MAGNETIC FIELD

$$\boldsymbol{F} = \int \boldsymbol{dV}(\boldsymbol{j} \times \boldsymbol{B})$$

$$\boldsymbol{j} = \boldsymbol{\sigma q}(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B})$$

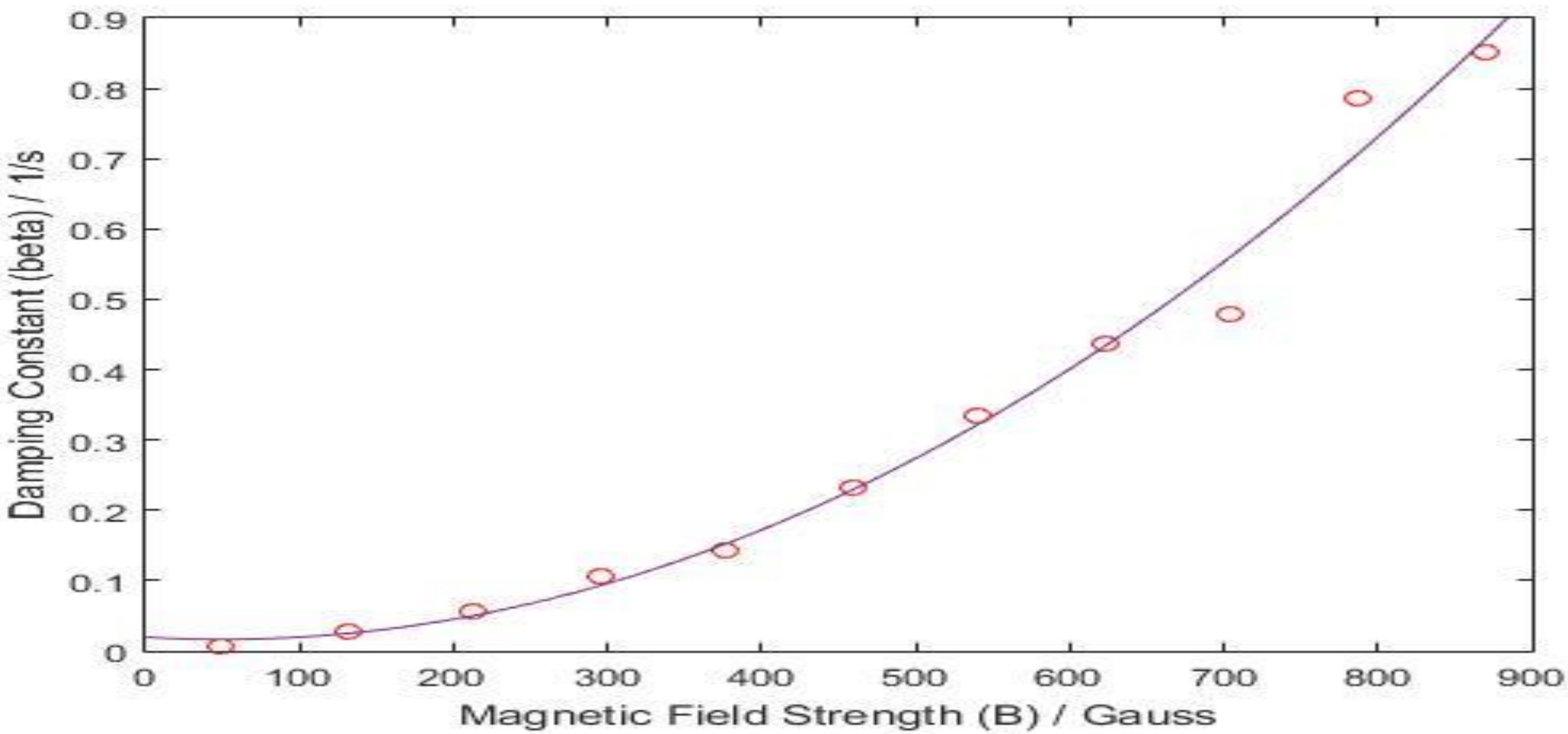
$$\boldsymbol{F} \sim -\boldsymbol{B}^2\ \boldsymbol{\sigma \pi R}^2 \boldsymbol{tv}$$

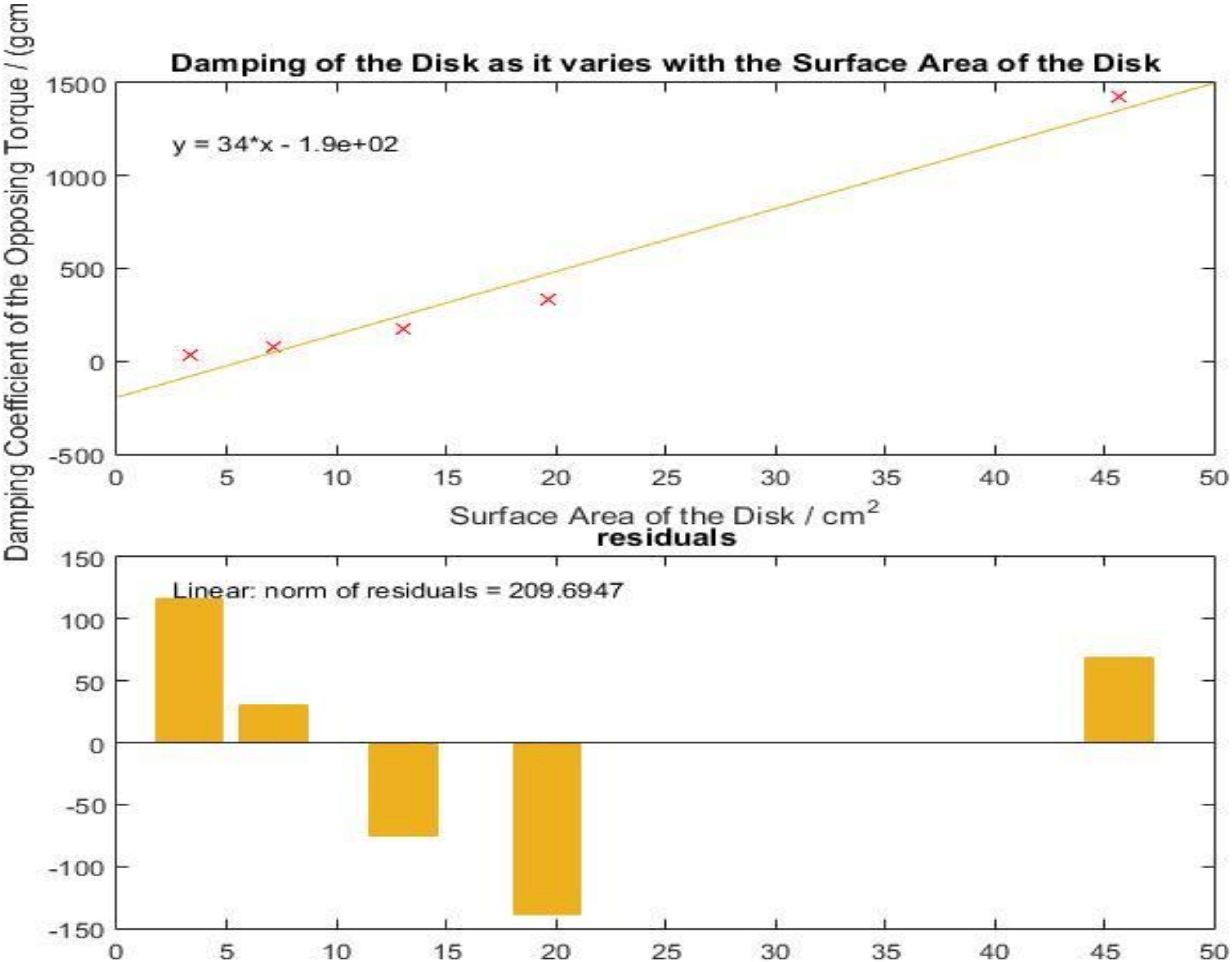
(From Modern Electrodynamics by Zangwill)

B **=** Magnetic field vector ***σ*** **=** Conductivity of the metal ***t*** **=** Thickness
R **=** Radius of the Disk

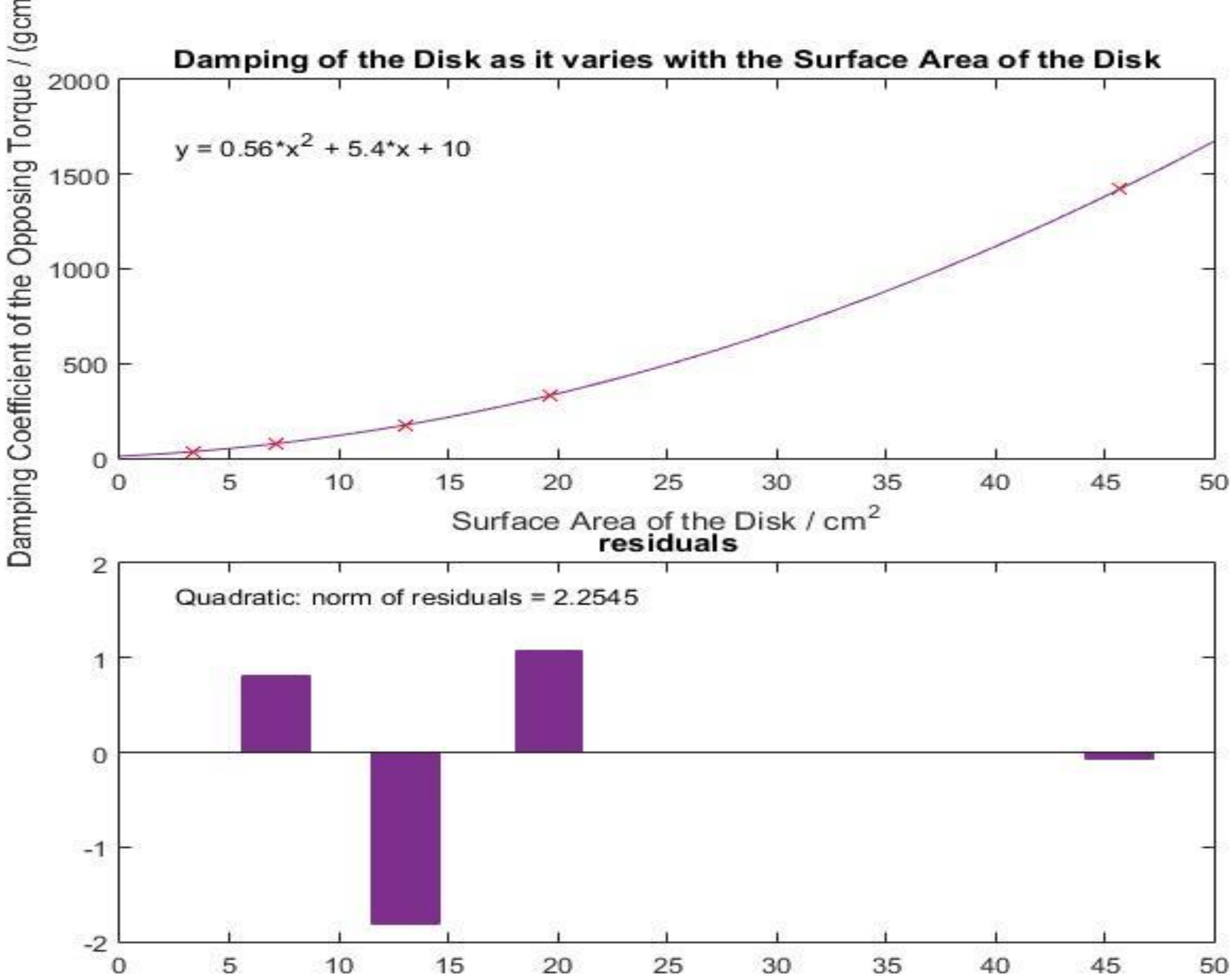
By the suggested model	$\boldsymbol{k} \propto \boldsymbol{B}^2$
And by extension	$\boldsymbol{\beta} \propto \boldsymbol{B}^2$
Also	$\boldsymbol{k} \propto \boldsymbol{\pi R}^2$

Damping constant as it varies with the magnetic field

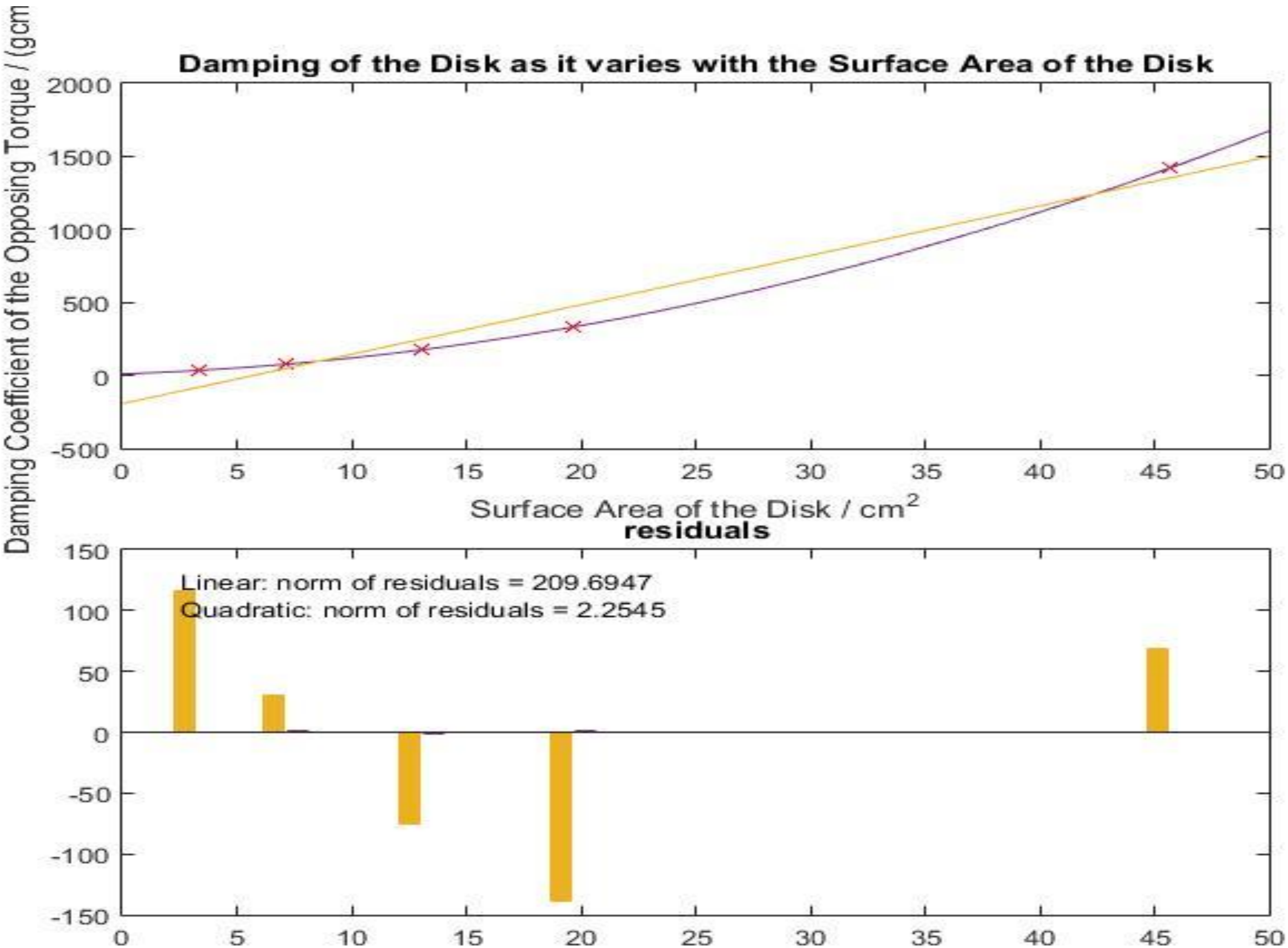




Damping of the Disk as it varies with the Surface Area of the Disk
y = 34*x - 1.9e+02
Damping Coefficient of the Opposing Torque / (gcm
1500
1000
500
0
-500
0
5
10
15
20
25
30
35
40
45
50
Surface Area of the Disk / cm2
residuals
Linear: norm of residuals = 209.6947
150
100
50
0
-50
-100
-150


Damping of the Disk as it varies with the Surface Area of the Disk
Damping Coefficient of the Opposing Torque / (gcm
y = 0.56*x^2 + 5.4*x + 10
2000
1500
1000
500
0
0 5 10 15 20 25 30 35 40 45 50
Surface Area of the Disk / cm^2
residuals
Quadratic: norm of residuals = 2.2545
2
1
0
-1
-2
0 5 10 15 20 25 30 35 40 45 50

COMPARISON & IMPROVEMENT



CONCLUSION

Magnetic damping is dependent on multiple factors.

Most important of these that can be manipulated to give the desired results are:

- The magnetic field strength
- The surface area of the disc perpendicular to the magnetic field.

Damping force F is such that:

$$\boldsymbol{F} \propto \boldsymbol{B}^2$$

$$\boldsymbol{F} \propto (\boldsymbol{SA})^2$$

$$\boldsymbol{F} \approx -(\boldsymbol{SA})^2 \boldsymbol{B}^2 \boldsymbol{\sigma t v}$$