A Pulsed Field Hysteresigraph for Characterization of NdFeB magnet blocks

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Abstract:

A pulsed field hysteresisgraph ($\mu_0 H_{max} \sim 6$ T) has been developed for characterization of NdFeB magnet blocks. The system is now in use for magnetization of NdFeB magnet blocks which are used in development of magnetically coupled drives for gas Lasers at CAT.

A system consists of a magnetizing fixture, Charger unit & PM blocks.

Introduction:

The need for magnetically coupled drives often arise, whenever rotational motion has to be transmitted in an experimental enviornment, which is under vacuum or which has to handle corrosive substances. In such circumstances, the integrity of the exptal enclosure can not be compromised. We required such drives for our Excimer laser dev Programme. To operate these lasers at high rep. rate, blowers are used for gas circulation. The gas mixture contains corrosive gases like flourine or hydrogen chloride.

The impeller of blower has to be driven by motor & no leaks are tolerated. Dynamic seals have short operating lives, and always danger of a leak developing. A magnetic drive totally avoids this problem

High energy NdFeB magnet blocks have been used for magnetic drives.

Static fields available with Fe.yokes up to about 2T are not sufficient.

Higher fields are produced by SC magnets (10-15T).

Therefore, We taken up development of magnetic hyst eqpt to characterize NdFeB magnet blocks.

Types of characterization:

1. To magnetize the magnet up to saturation
2. Calibrate - using Ni samples
3. J(H) curve of magnet

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A System Description

Magnetizer system is a capacitor discharge type

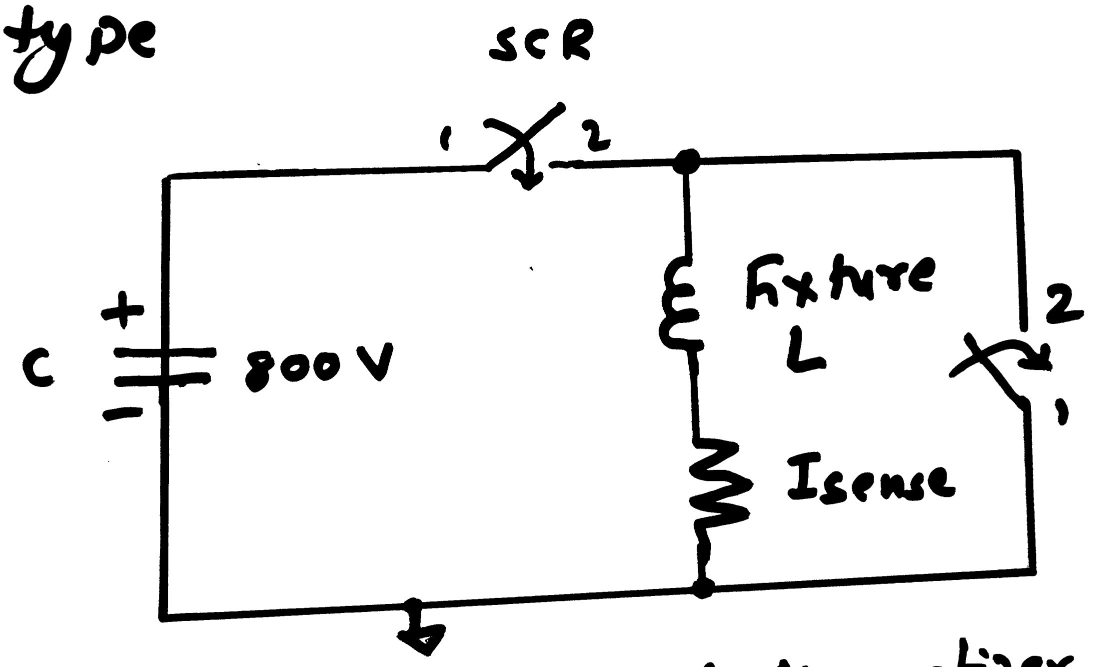


Fig : Schematic of Magnetizer System

Capacitor is charged to a desired voltage V then discharges into fixture, so high current pulse is generated in the fixture. As a result of this, A pulsed field of 6T, has, however produced in the fixture. Pulse duration depends on capacitance & inductance of magnetizing fixture.

The frequency of oscillation is given by

$$\omega = \sqrt{\frac{1}{LC} - \left[\frac{R}{2L}\right]^2} \quad \text{rad/sec}$$

where R : equivalent resist. of discharge circuit

L : Inductance of magnetizing fixture

C : Charging capacitance

Current thru the inductance of fixture is given by

$$I(t) = \frac{V}{L\omega} e^{\overset{-tR/2L}{\overbrace{-t/R}/2L}} \sin \omega t$$

v : charging voltage

$$I_{peak} \text{ at } t = \frac{1}{\omega} \tan^{-1}\left(\frac{2\omega L}{R}\right)$$

At this peak current B_{pk} at centre of fixture

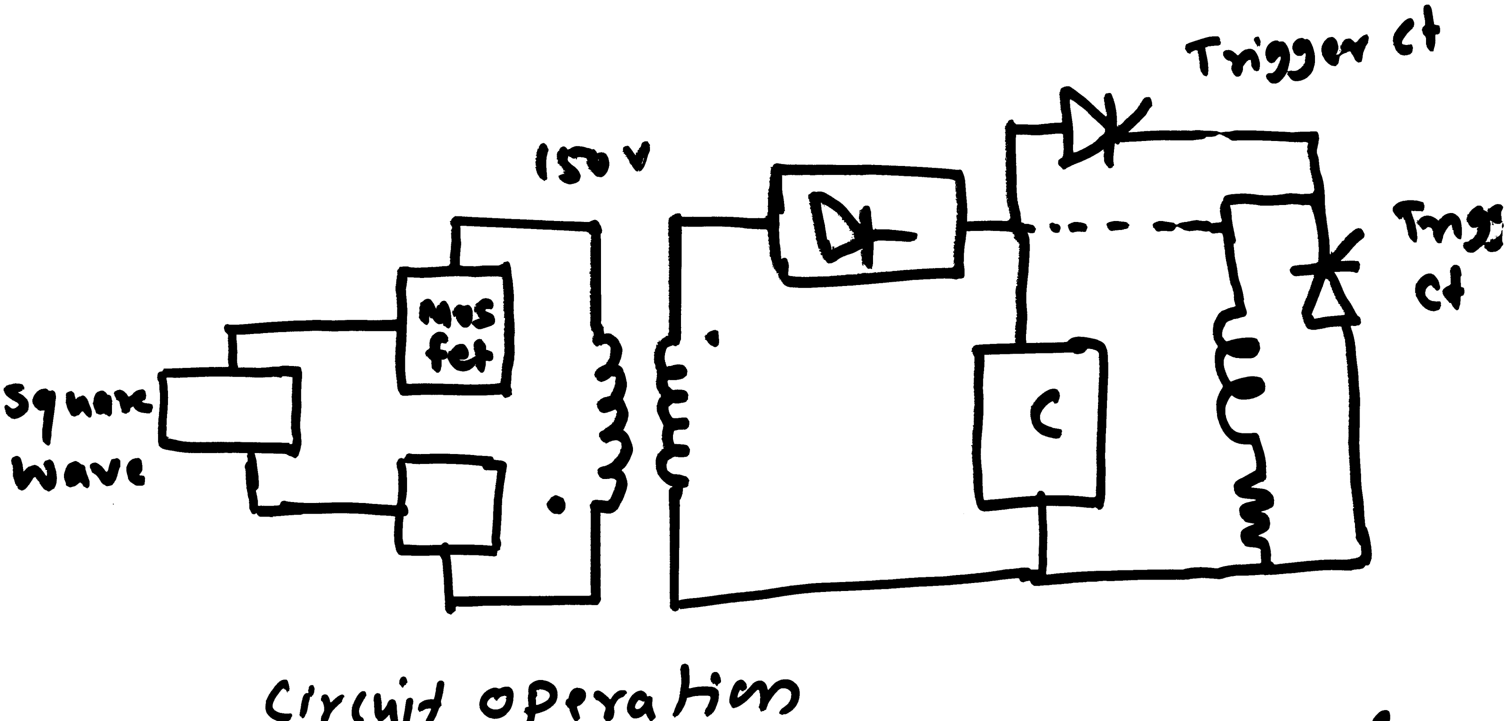
$$B_{pk} = \frac{\mu_0 N I_{pk}}{L_{eff}}$$

$$L_{eff} = \sqrt{l_e^2 + D_e^2} = 80.72 \text{ mm}$$

$$L = \frac{3.14 \mu_0 N^2 D_{eff}^2}{} = 1.72 \text{ mH}$$

Capacitor charging Scheme:

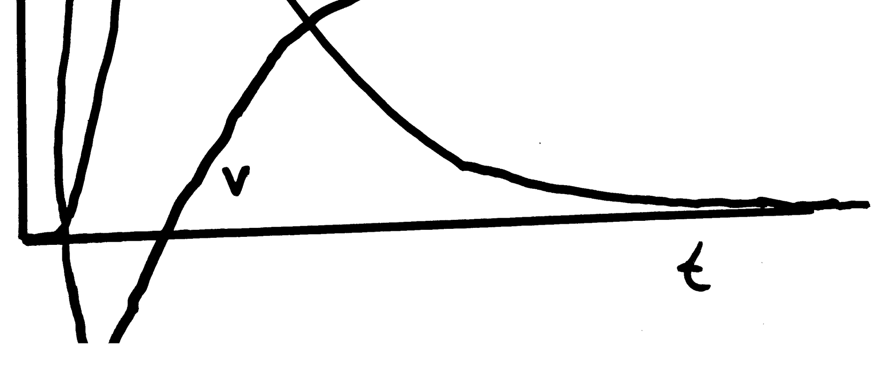
Pulse by pulse charge method. In this method first energy stored in primary inductance of transformer, then transformed to Capacitor. In a few pulses capacitor reaches at desired value of voltage.



Circuit operation

First capacitor is charged slowly by transformer method. Initially Both Mosfets on simultaneously, Diodes in secondary are reverse biased so secondary is open.

During on period current in primary rises up. As MOSFETS goes off at the end of Pulses, diodes in secondary are forward biased & Primary current is transformed to secondary according to turn ratio & capacitor starts charging. After a few pulses capacitor is charged to desired voltage. At this time charging stops & SCR X1 is fired. Current in Inductance of fixture starts building up (sinusoidal) at pk current SCR X2 is fired to prevent negative charging of Capacitor, now current decays exponentially.



Experimental time Variation of I of Solenoid fixt

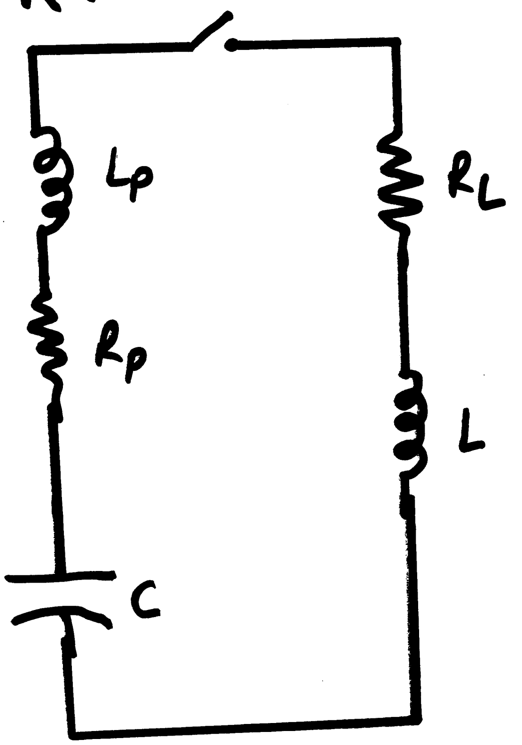
Magnetizing Fixture :

Test fixture is a simple air-core solenoi

L: 1.72 mH

C: 5.1 mF

R: 0.4 Ω



Electrical Circuit diagram for magnetizer & load.

The dynamic behavior of this equiv circuit is described by

$$\frac{d^2 i}{dt^2} + \frac{R_t}{L_t}\frac{di}{dt} + \frac{i}{L_t C} = 0$$

with initial condns

$$i(0) = 0$$

$$\frac{di}{dt}(0) = \frac{V_o}{L_t}$$

where

i = current (A)

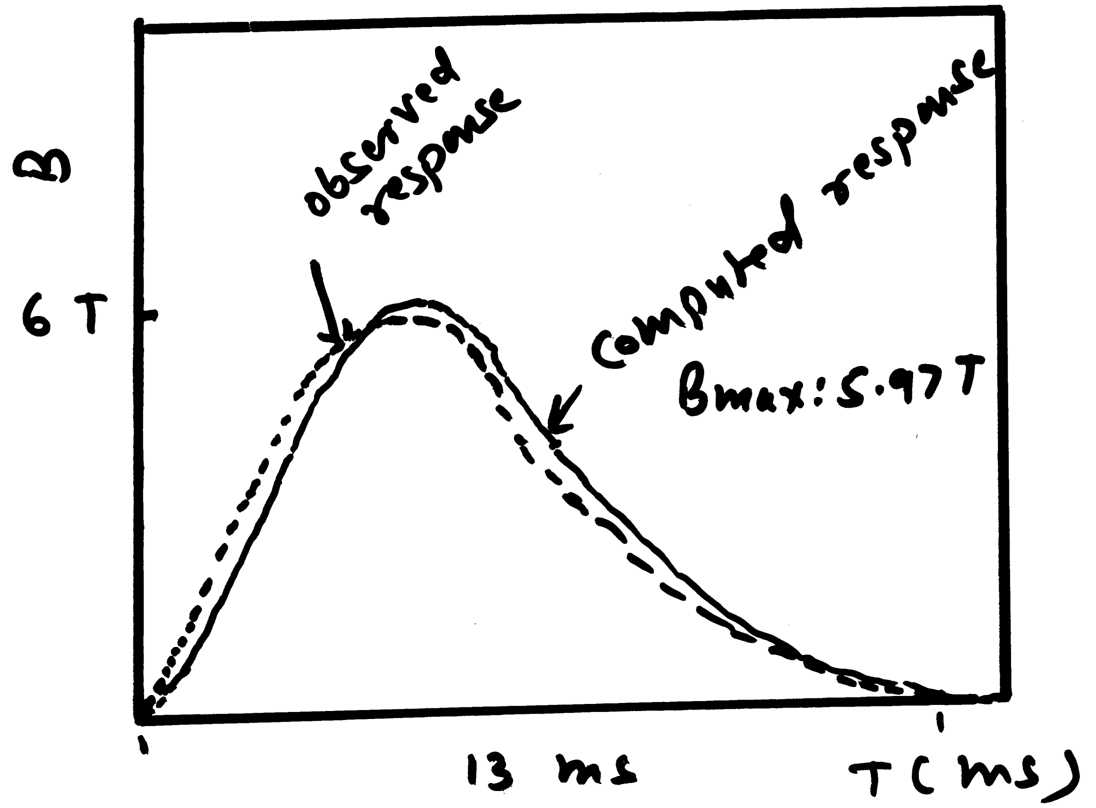
$R_t = R_p + R_1$ Ω

$L_t = L_p + L$ (H)

V_o = Initial voltag on the capacito

Pspice simulation is carried out

Computed transient response of the test coil is shown below:



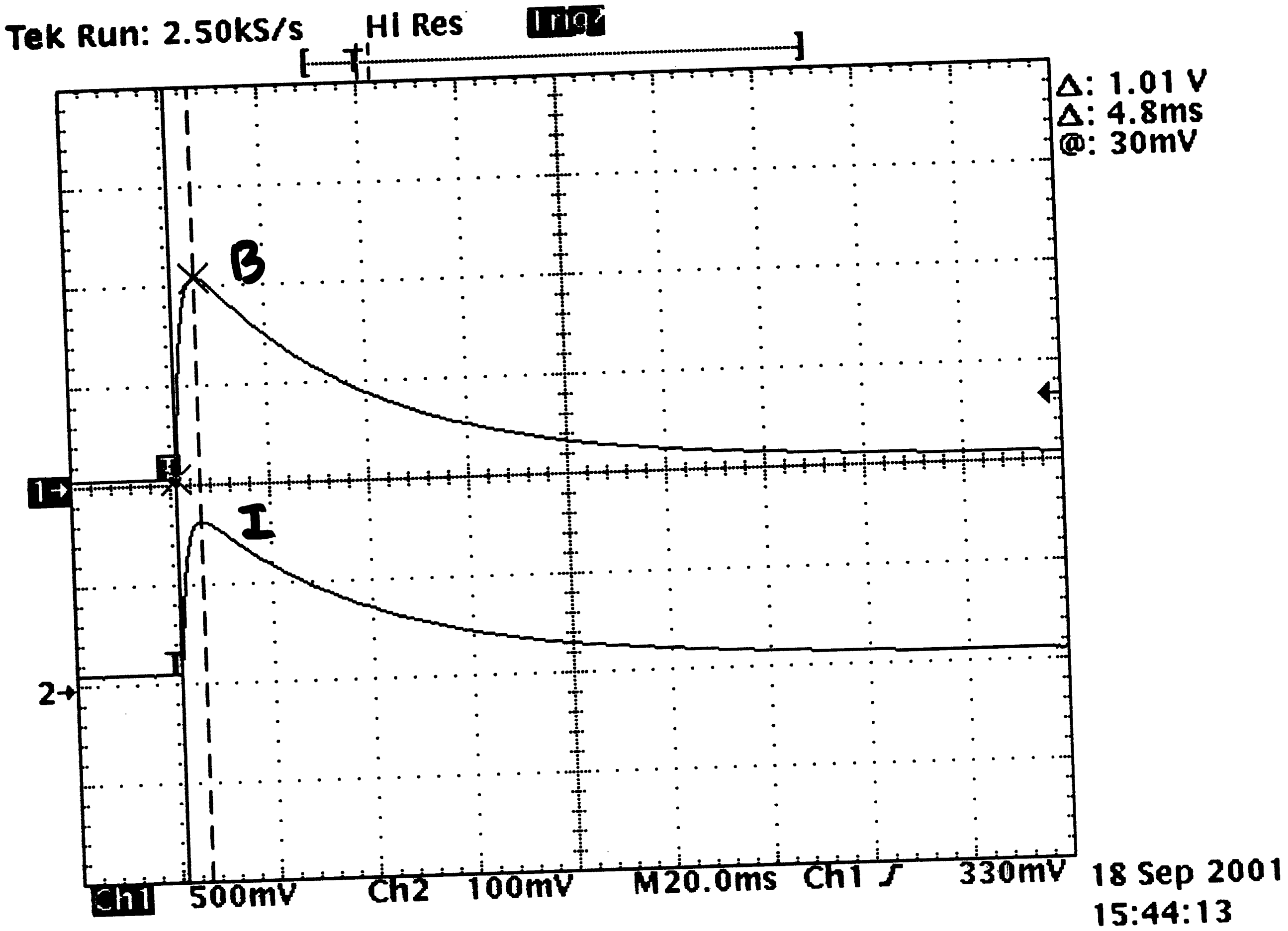
Test data transient to the computed transie

: Lp : Parasitic inductance, Rp : parasitic capacitance also determined.

Experimental data closly matches with computed data.

Lp ~ 10 μH
Rp ~ 0.08 Ω

	observed	simulatio
T(ms)	13.2 ms	13 m
Bpk	5.97 T	6.0 T



Observed Response: Digitizer traces

J-H Curve of a Ni Standard Sample:

Std Samples: Ni rod (5 mm dia x 5 mm long)
purity 99.99 %
Princeton App Research Co.

Saturation magnetization, J_s : 0.62 T
@ 9.360 Oe

We measured Ni rod J-H curve using this set up.

Observed values, J_s : 0.618 – 0.624 T
@ 9.350 Oe

In the present work, the coercivities larger than 1.1 Oe is observed. This is due to eddy current effect.
This has been explained by classical model, assuming uniform magnetization of sample.

Classical model for eddy currents

$$P = (r_0^2/8\rho)(dJ/dt)^2$$

Area of hyst loop $\oint J \cdot dH \simeq 4 f J_r H_c$

where r_0 : radius of Ni rod
ρ = Resistivity
f = frequency

Therefore, using the experimental time variation of magnetization, dJ/dt, that is measured

$$H_c = \frac{(r_0)^2 \, (dJ/dt)^2}{32 f J_r \rho}$$

$$\simeq 1.120 \ \mathrm{Oe}$$

For Ni, Rod : 5 mm ϕ × 5 mm long

$$\frac{dJ}{dt} = \frac{0.62\,T}{13\ \mathrm{ms}} = 0.0476\ T/\mathrm{ms}$$

$$= 47.6\ T/\mathrm{sec}$$

$f \sim 20/\mathrm{sec}$

This is smaller than value measured by 10 Oe.

⇒ Increase of H_c of Ni rod is due to the eddy currents induced during the AC measurements.

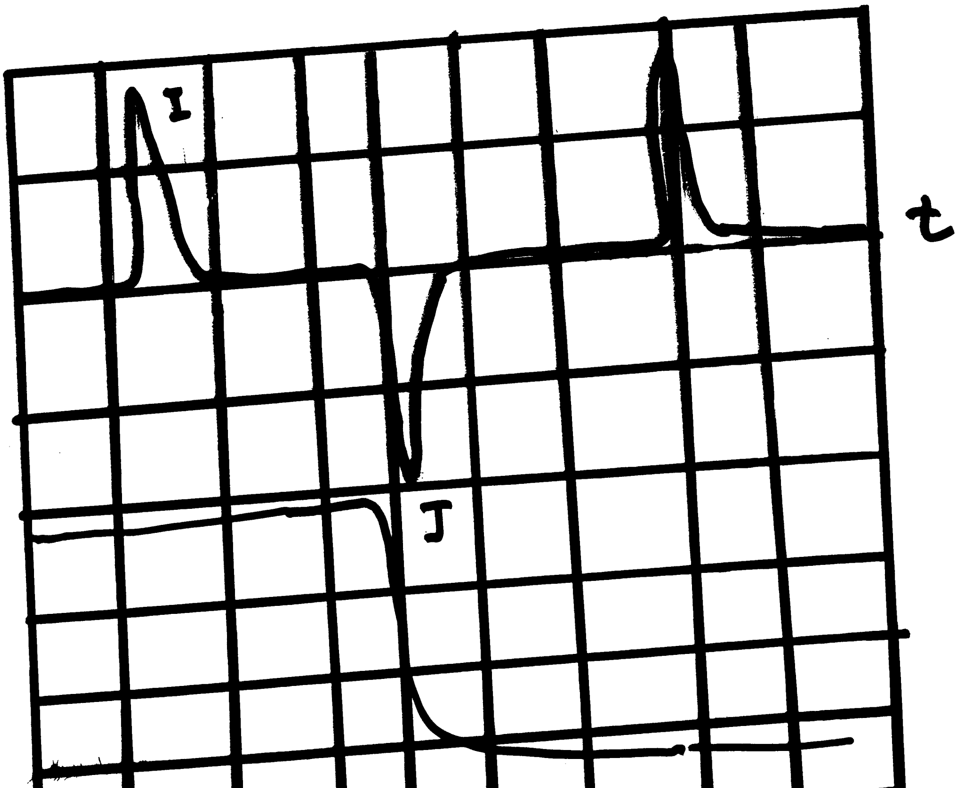
J-H Curves of NdFeB magnet:

Magnet sizes: 5 mm dia × 5 mm long

Source: Pulsed symmetrical bipolar magnetic field generator

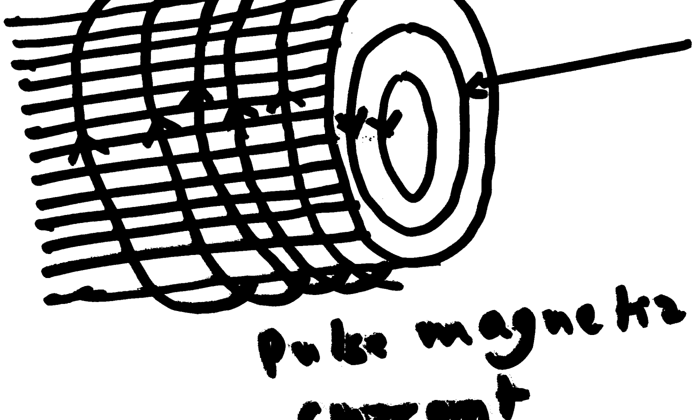
scheme consisting of capacitors C_1 C_2 & C_3 & dc P/s

Air solenoid magnet is excited at first +vely, then -vely with other switch on.



Pulse Magnetization!

- * Magnetic field penetrates less deep into the magnet the greater its conductivity & cross section are.
- * Ferrite magnet - $\rho \sim 10^4$ ohm-cm, its conductivity is less, therefore pulses of short duration can be chosen
- * Metal magnets - conductivity is larg greater cross sectional area & lange pulses must be chosen.
- * Eddy currents produce a field wh acts against the magnetizing field



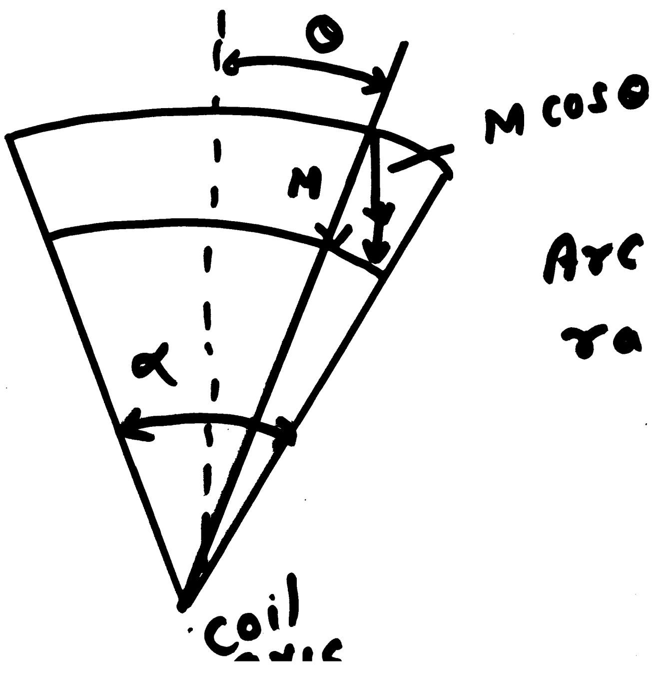
- * To keep less effect of eddy curents, W selected 13 ms pulse length with smal section of magnet.

SCOPE :

1. Magnetic moment measurements of NdFeB magnet blocks Using Helmholtz coil system is under construction
2. Use of Helmholtz coils to measure Arc magnets - A system is being developed

Arc magnets :→ magnetization is
not completely llel to the coil Axis.
then H. coil reading is lower than
true magnetization of the sample.

A correction for arc magnet - true
radial orientation is under dev



Arc magnet with
radial orientation

Conclusions

- Economical hyst loop tracer is developed, that is able to measure J-H loops of RE magnet

- Accuracy of pulsed field J.H loop measurements is nearly comparable with conventional hyst meas.

- A pulsed magnetic field up to 6T, however, developed

- J_s, saturation magnetization is calibrated by using std Ni Rod sample, and showed close agreement with reported values.

- Increase in H_c due to pulsed hyst is calculated

- Computed results & experimentally observed results are in close agreement.