Chapter: three

MOVING COIL METERS

(Electromechanical Indicating Meters)

Classification and General Specifications of Moving Coil Meters:

These instruments consist of a gross(bulk) and motionless part and a small but rotatable part. In general, to the rotatable part an $m_d = m_d(x, y)$ torque (rotational momentum) which is function of the X quantity to be measured, in some instruments also the function of the observed quantity of y, is applied.

By the affect of this torque, movable part moves and rotates the pointer mounted on it and deflects the pointer in front of a scale. Mostly, observed quantity is the deflection amount of the pointer stopping in front of the scale after spme time back and forth movements.

Moving coil meters can be classified according to their using limits and summing under one group resembling with each other by their operational principles. These are;

1. Moving coil(permanent magnet) instruments and their different types(need galvanometer,titreşimli galvanometer, ballistic galvanometer, oscillography, fluxmeter, cross-coil instruments)
2. Thermos instruments(thermocouple and bimetallic thypes)
3. Rectifier and electronic amplifier type instruments.
4. Moving magnet instruments.
5. Moving ferrous(soft ferrous) instruments.
6. Electrodynamometers and wattmeters.
7. Electrostatic instruments.
8. Induction type instruments and watthour meters.

DYNAMİCS OF MOVİNG COİL METERS.

After the X quantity to be measured applied, in response to this value during the y deflection of the pointer is to be discussed.three momentums counter-balance the torque (m_d) which affect the movable part around the rotational axis, these are;

1. M_k : control momentum: forces the movable part to m_d= 0 position.
2. M_s : damping opposing the movement
3. M_e : inertia: necessary to accelerate the bodies(eylemsizlik momenti atalet momenti)

Dynamic balancing among these four momentus is

$$Me + Ms + Mk = Md$$

$$a.\frac{d^2y}{dt^2} + b.\frac{dy}{dt} + c.y = M_d[x(t), y]$$

a : rotational inertia $\frac{d^2y}{dt^2}$: angular acceleration of the rotational movement

b: damping coefficient $\frac{dy}{dt}$: rotational movement

c: spring constant y: amount of rotation

Md= Md[X(t)] if a,b,c are constants the equation is “a constant coefficient linear differential equation”

For now, we suppose that the X, quantity to be measured either does not change with time and is constant as changes much faster therefore movable part can not follow these changes or Md is constant.

For the time t=0 let be

X=0, Md=0 y=0 also $\frac{dy}{dt} = 0$ at t=0 x=x(t)=X constant quantity applied to the instrument, torque value of. Md=Md[x(t)]=Md[x]=Md

Before t=0, where dy/dt equalszero, immediately after t=0 can not an infinite acceleration therefore an infinite torque is necessary.

So, for t=0, y=0 and $\frac{dy}{dt} = 0$ by using these initial conditions if the equation is solved for Y deflection, the movement of the instrument can be defined

$$\frac{M_d[X]}{c} = \frac{M_d}{c} = Y \quad (balance\ position)$$

1) For $b^2>4ac$ as τ_1, τ_2 are time constants.

$\tau_1=\frac{-b-\sqrt{b^2-4ac}}{2c}$ $\tau_2=\frac{-b+\sqrt{b^2-4ac}}{2c}$

$$y = Y[1 + \frac{\tau_1}{\tau_2 - \tau_1} e^{-t/\tau} + \frac{\tau_2}{\tau_1 - \tau_2} e^{-t/\tau}]$$

2) For $b^2 <4ac$ $\tau = \frac{2a}{b}$ and $T = \frac{4\pi a}{\sqrt{4ac-b^2}}$ $T_0 = 2\pi\sqrt{\frac{a}{c}}$ for b=0, $T=T_0$

Period of underdamping period of overdamping

$$y = Y\left[1 - \frac{T}{T_0} e^{-\frac{t}{\tau}}\right] \sin(\frac{2\pi}{T} t + arctg\frac{2\pi\tau}{T})$$

3) For $b^2 = b_k^2 = 4ac$ ($\tau=\frac{2a}{b_k} = \sqrt{\frac{a}{c}} = \frac{T_0}{2\pi}$)

$$y = Y[1 - e^{\frac{-2\pi}{T_0}}(1 + \frac{2\pi}{T_0} t)]$$

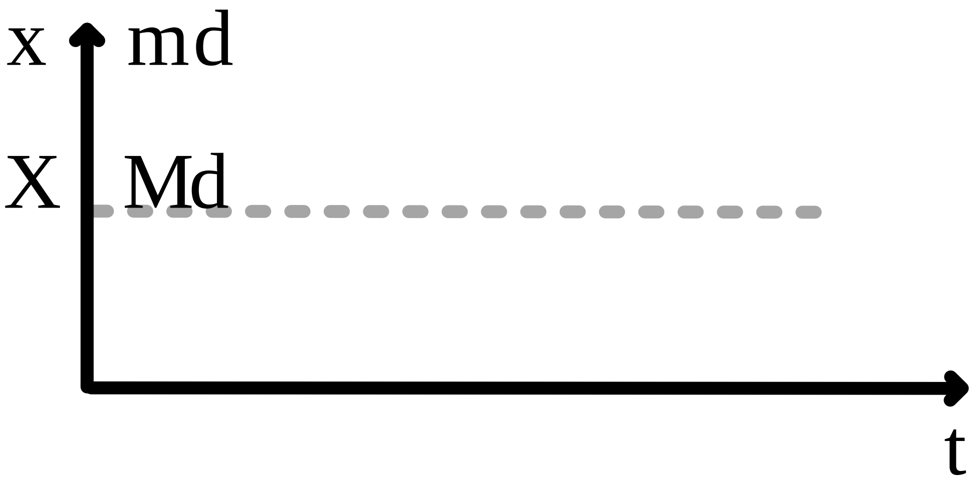
1st case: overdamping movement(delay is longer)

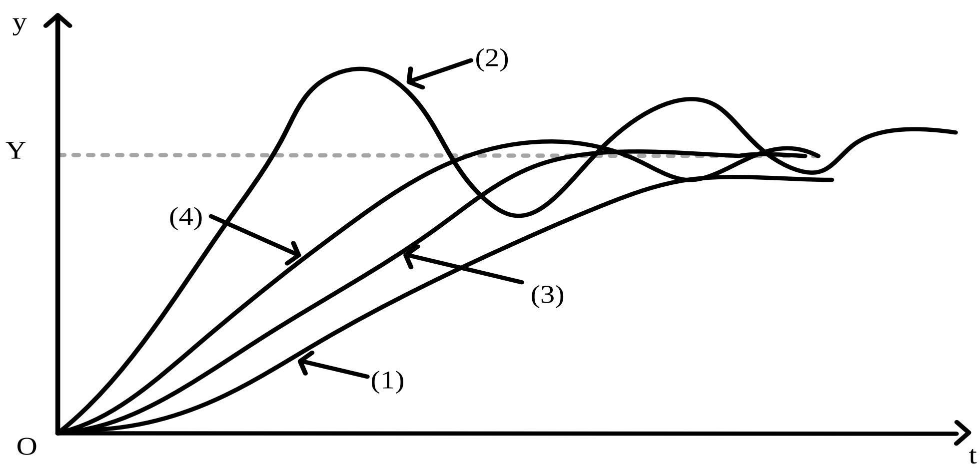
2nd case: underdamping movement case

3rd case: critical damping movement case

The case with the least delaying is $b^2 = b_k^2 = 4ac \quad b_k = 2\sqrt{ac}$ ➔ critical damping constant

In order to increase the reliability of the value shown, damping constant is made a bit less than the critical damping constant that by this way both damping and underdamping movement cases can be obtained.





(1): $b^2 > 4ac$: overdamping movement

(2): $b^2 < ac$: underdamping movement

(3): $b^2 = b_k^2 = 4ac$: *critical movement*

(4): $b^2 = 4ac - \mathcal{E}$: desired movement case

Accuracy and Sensitivity of Moving Coil Meters

Factors affecting the accuracy and sensitivity dye to the mechanical structure will be discussed. Effects related with the electrical structure differ according to the instrument types.

Let us $f(x, y, a, b, c) = 0$ a,b,c, parametric quantities.

Since the observation will be done when the pointer is stopped.

$\frac{dy}{dt} = 0$ $\frac{d^2y}{dt^2} = 0$ therefore c.y=m_d “static balance equation” is valid.

M_d torque depends on B(residual induction of the magnet) and R(coil resistance) are two more parameters

Let us $M_d(x, y, B, r) - cy = 0$

The difference between these two momentums is Δ_m

This is the result of the “Brownian movement” of air molecules which strike the moving part randomly and static frictions between non-moving and rotatable part. İn order to decrease indefinite value of this static friction momentum, the instrument must slightly be impulsed. By taking the full differentiation of the above function

$$\frac{\partial M_d}{\partial x} d_x + \left(\frac{\partial M_d}{\partial y} - c\right) d_y + \frac{\partial M_d}{\partial \beta} d_\beta + \frac{\partial M_d}{\partial R} d_R - ydc = d_m$$

Static friction momentm

Can be obtained.

1) By definition, the sensitivity is

$$D = \frac{dy}{dx} = \frac{\partial M_d}{\partial x} \Big/ c - \frac{\partial M_d}{\partial y} \cong \frac{\partial M_d}{\partial x} \Big/ c$$

In the most types of instruments $\frac{\partial M_d}{\partial y} = 0$

Therefore the senstivitiy is D= $\frac{\partial M_d}{\partial x} \Big/ c$

In order to increase the sensitivity $\frac{\partial M_d}{\partial x}$ partial differentiation must be increased and c must be decreased. Increasing $\frac{\partial M_d}{\partial x}$ also increases the accuracy. $\frac{\partial M_d}{\partial x}$ is upmostly limited by the materials used in the construction of the instruments. C might be decreased, but to decrease it extremely will make the momentums in the left and right side of the static friction equation very small. Therefore the movable part will be under the affect of Brownian movements of air molecules and the pointer randomly will move.

2) Factors Affecting The Accuracy

ΔB, ΔR, Δc, Δm are unidentities therefore limiting error in the measured quantity X is,

$$\Delta_x = \frac{\Delta_y}{D} + \frac{1}{\left| \partial M_d / \partial_x \right|}\Delta_m + \left| \frac{\partial Md / \partial B}{\partial Md / \partial x} \right| \Delta_B + \left| \frac{\partial Md / \partial R}{\partial Md / \partial x} \right| \Delta_R + \left| \frac{y}{\partial Md / \partial x} \right| \Delta_c$$

a) Δ_y limiting error can be eliminated by doing the pointer and scale marks thinner.
b) If ΔB, ΔR, Δc = are zero, $\Delta_{y=}0$ for a constant y deflection in X quantity, there will be a limiting error; $\Delta_x = \Delta_m / \left| \partial Md / \partial x \right|$ this is the effect of static friction momentums. When Δ_m decrease and $\left| \partial Md / \partial x \right|$ increases, Δ_x will decrease and the accuracy of the instrument will increase.

Results. To increase the accuracuy of the moving coil meters, static frictions and air molecule pulses should be small with respect to m_d, and also with respect to control momentum, because of control momentum is equal to Md.

To achieve this;

1) Moving part of the instrumental must be might weight its moving axis is in vertical position and the pivot on the crystal bearing decreases the static frictions. Moving part must have no longer surfaces.
2) Md(rotational momentum) and control momentum Cy are made greater.

After the best materials used in the construction if Md wanted to be greater, the power which the instrument receives from the circuit and the energy it dissipates must be increased. To equalize the control momentum to the rotational momentum c must be increased. This decreases the sensitivity. Therefore, instruments with high accuracy, have both receive greater power and lesser sensitivity.