Analysis of linear resistance potential meter

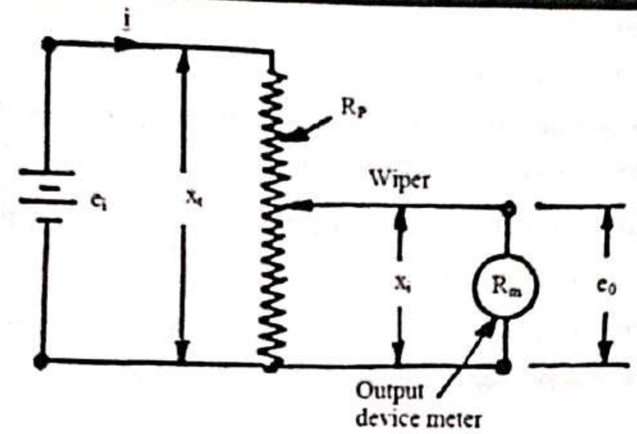

Fig. Loaded potentiometer

Let e_i and e_0 = input and output voltages respectively ; V.

x_t = total length of translational pot ; m

x_i = displacement of wiper from its zero position ; m,

R_p = total resistance of the potentiometer ; Ω

If the distribution of the resistance with respect to translational movement is linear, the resistance per unit length is R_p/x_t.

The output voltage under ideal conditions is :

$$e_0 = \left(\frac{\text{resistance at the output terminals}}{\text{resistance at the input terminals}}\right) \times \text{input voltage}$$

$$= \left[\frac{R_p(x_i/x_t)}{R_p}\right] e_i = \frac{x_i}{x_t} \times e_i$$

The under ideal circumstances, the output voltage varies linearly with displacement as shown in Fig. (a)

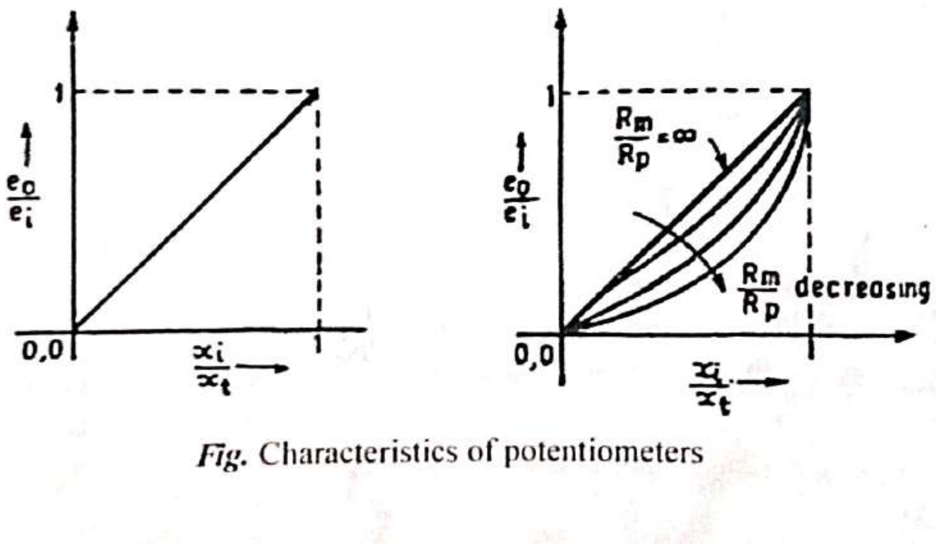

Fig. Characteristics of potentiometers

Sensitivity $S = \frac{output}{input} = \frac{e_0}{x_i} = \frac{e_t}{x_t}$

The under ideal conditions the sensitivity is constant and the output is faithfully reproduced and relationship with input. The same is true of rotational motion.

Let θ_i = input angular displacement in degrees, and θ_t = total travel of the wiper in degrees.

∴ Output voltage $e_0 = e_t \cdot (\theta_i/\theta_t)$

This is true of single turn potentiometer only.

The error, which is referred to as a ***loading error*** is caused by the input resistance of the output dev

Loading Effect

The resistance of the parallel combination of load resistance and the portion of the resist potentiometer is :

$$\frac{(x_i/x_t)}{(x_i/x_t)R_p + R_m} = \frac{KR_pR_m}{KR_p + R_m}$$

The total resistance seen by the source is :

$$R = R_P(1-K) + \frac{KR_pR_m}{KR_p + R_m} = \frac{KR_p^2(1-K) + R_pR_m}{KR_p + R_m}$$

∴ Current $$i = \frac{e_i}{R} = \frac{e_i(KR_p + R_m)}{KR_p^2(1-K) + R_pR_m}$$

The output voltage under load conditions is :

$$e_0 = i\frac{KR_pR_m}{KR_p + R_m} = \frac{e_i(KR_p + R_m)}{KR_p^2(1-K) + R_pR_m}\frac{KR_pR_m}{(KR_p + R_m)}$$

$$= \frac{e_iK}{K(1-K)(R_p/R_m) + 1}$$

The ratio of output voltage to input voltage under load conditions is :

$$\frac{e_0}{e_i} = \frac{K}{K(1-K)(R_p/R_m) + 1}$$

NOTE

Thus, in order to keep linearity, the value of R_m/R_p, should be as large as Possible. However, when we measure the output voltage with a given meter, the resistance of the Potentiometer, R_p, should be as possible.

∴ Error = output voltage under load – output voltage under no load

$$= \frac{e_i K}{[K(1-K)(R_p/R_m)+1]} - e_i K = -e_i \left[\frac{K^2(K-1)}{K(1-K)+R_m/R_p} \right]$$

Based upon full–scale output, this relationship may be written as:

$$\%\varepsilon = -\left[\frac{K^2(K-1)}{K(1-K)+(R_m/R_p)} \right] \times 100$$

Except upon for the two end points where K = 0 i.e. $x_i = 0$ and K = 1 where $x_i = x_t$ the error is always negative Fig. shows a plot of the variation in error with the slider position for different ratios of the load (output device or meter) resistance to the potentiometer resistance.

Power Rating of Potentiometers

The potentiometers are designed with a definite power rating which is related directly to their heat dissipating capacity. The manufacturer normally designs a series of potentiometers of single turn with a diameter of 50 mm with a wide range of ohmic values ranging from 100 Ω to 10 kΩ in steps of 100 Ω. These potentiometers are essentially of the same size and of the same mechanical configuration. They have the same heat transfer capabilities. Their rating is typically 5 W at an ambient temperature of 21°C. This limits their input excitation voltage. Since power $P = e_i^2 / R_p$, the maximum input excitation voltage that can be used is:

$$(e_i)_{max} = \sqrt{PR_p} \text{ volt}$$

Linearity and Sensitivity

It has been explained earlier that in order to achieve a good linearity, the resistance of potentiometer R_p, should he as low as possible when using a meter for reading the output voltage which has a fixed value of input resistance R_m.

Advantages and Disadvantages of Resistance Potentiometers

Resistance potentiometers have the f owing major *advantages* :

(i) They are inexpensive.

(ii) They are simple to operate and very useful for applications where the requirements are not particularly severe.

(iii) They are very useful for measurement of large amplitudes of displacement.

(iv) Their electrical efficiency is very high and they provide sufficient output to permit control operations without further amplification.

(v) It should be understood that while the frequency response of wire wound potentiometers is limited, the other types of potentiometers are free from this problems.

(vi) In wire wound potentiometers the resolution is limited while in Cermet and metal film potentiometers, the resolution is infinite.

Strain Gauges

If a metal conductor is stretched or compressed, its resistance changes on account of the fact that length and diameter of conductor change. Also there is a change in the value of resistivity of the conductor when strained and this property is called piezoresistive effect. Therefore, resistance strain gauges are also called piezoresistive gauges.

Let us consider a strain gauge made of circular wire. The wire has the dimensions: length = L, diameter = D before being strained. The material of the wire has a resistivity ρ.

$\therefore$ Resistance of unstrained gauge $R = \rho L/A$.

Let a tensile stress s be applied to the wire. This produces a positive strain causing the length to increase and area to decrease as shown in Fig. Thus when the wire is strained there are changes in its dimensions: ΔL = change in length, ΔA = change in area, ΔD = change in diameter and ΔR = change in resistance.

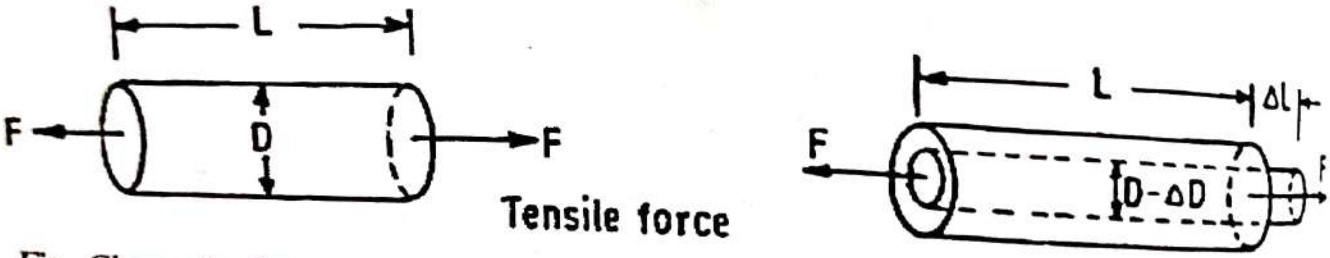

Fig. Change in dimensions of a strain gauge element when subjected to a tensile force.

In order to find how ΔR depends upon the material physical quantities, the expression for R is differentiated with respect to stress s. Thus we get:

$$\frac{dR}{ds} = \frac{\rho}{A}\frac{\partial L}{\partial s} - \frac{\rho L}{A^2}\frac{\partial A}{\partial s} + \frac{L}{A}\frac{\partial \rho}{\partial s}$$

Dividing Eq^n. throughout by resistance $R = \rho L/A$, we have

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{1}{A}\frac{\partial A}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s}$$

It is evident from Eqn., that the per unit change in resistance is due to

(i) per unit change in length $= \Delta L/L$,

(ii) per unit change in area $= \Delta A/A$. and

(iii) per unit change in resistivity $= \Delta\rho/\rho$

Area $\quad A = \frac{\pi}{4}D^2 \quad \therefore \frac{\partial A}{\partial s} = 2.\frac{\pi}{4}D.\frac{\partial D}{ds}$