Maratha Vidya Prasarak Samaj's

Rajarshi Shahu Maharaj Polytechnic, Nashik

Udoji Maratha Boarding Campus, Near Pumping Station, Gangapur Road, Nashik-13.

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MECHANICAL ENGINEERING MEASUREMENTS

UNIT 6 : MISCELLANEOUS MEASUREMENT SOUND, SPEED AND HUMIDITY MEASUREMENTS

Prof. M. S. Gaidhani

Mechanical Engineering Department

Tel.:0253 2311018 www.rsmpoly.org mangesh.gaidhani@rsmpoly.org

Measurement of speed

Tachometer, What's That?

- Tachometer is used for measuring rotationalspeed
- Can be used to measure speed of a rotating shaft
- Can also be used to measure flow of liquid by attaching a wheel with inclinedvanes

What Are the Different Types of Tachometers?

- Classification of tachometers:
  - Mechanical Tachometers
    - Revolution counter
    - Hand speed indicator
    - Tachoscope
    - Centrifugal tachometer
    - Resonance (vibrating read) tachometer
  - Electrical Tachometers
    - Eddy current or drag cup tachometer
    - Tachogenerator (DC and AC)
  - Contactless electrical Tachometers
    - Magnetic pickup tachometer
    - Photo-electric tachometer
    - Stroboscope

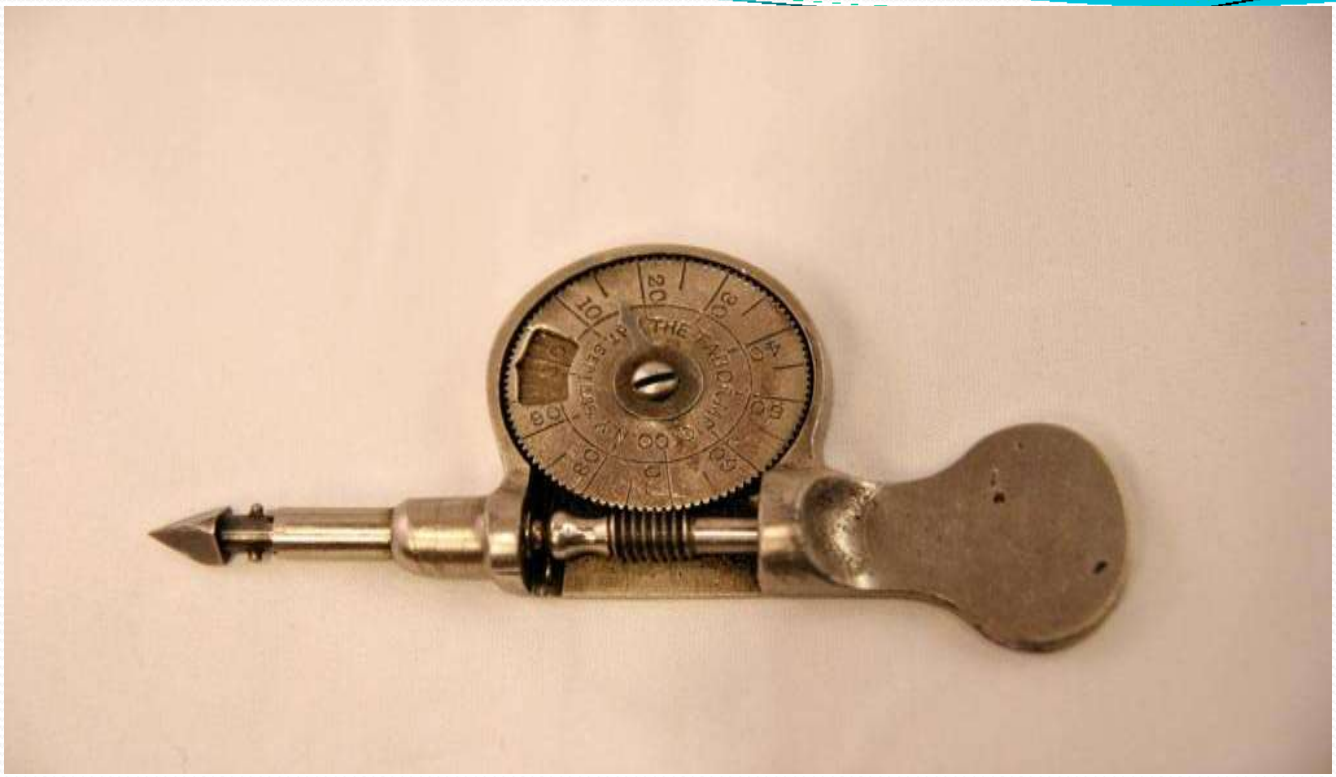
- Tachometers can also be classified on the basis of data acquisition – contact or non contact types
- They can also be classified on the basis of the measurement technique – time based orfrequency based technique of measurement
- They can also be classified as analog or digital type

Mechanical Tachometers

Revolution counter

- Revolution counter is used to measure an average of rational speed instead of instantaneous rotational speed.
- It consists of a worm gear that is usually attached to a spindle. It has two dials, an inner one and an outer one.
- The inner dials represent one revolution of the outer dials and the outer dials represent on revolution of the spindle.
- The tachometer has a stopwatch attached to the revolution counter and is used to indicated time.
- These are limited to low speed engines and measure satisfactory upto 2000-3000r.p.m.

1. Revolution counter



- Speed measure upto 2000-3000 rpm.

2. Hand speed indicator

- Hand Speed Indicator has an integral stopwatchand counter with automaticdisconnect.
- The spindle operates when brought in contact with shaft.
- Counter does not function until start and wind button is pressrd to start watch and engage the clutch.
- The instrument indicates average speed over short interval in r.p.m .
- Accuracy about 1% of the full scale.
- Measure speed within range 20,000 to 30,000 rpm

Hand speed indicator

3. Tachoscope

- Tachoscope consists of revolution counter for timing device.
- The two components are integrally mounted and start simultaneously when contact point is pressed against rotating shaft.
- The rotational speed is computed from readingof counter and timer.
- Tachometer can be used to measure speeds up to 5000r.p.m.

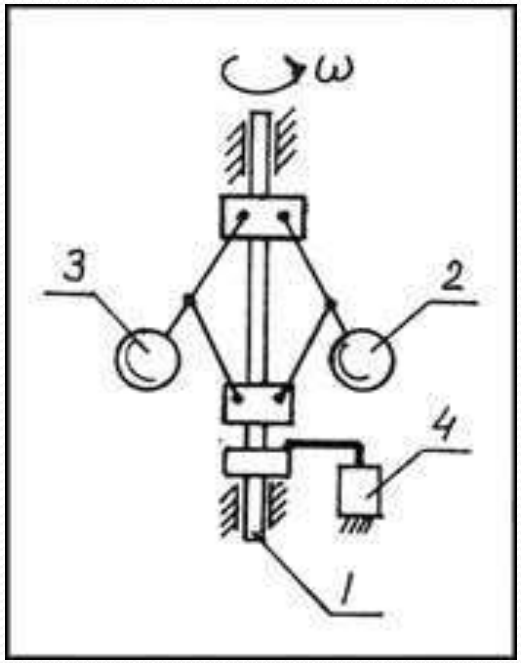
Tachoscope

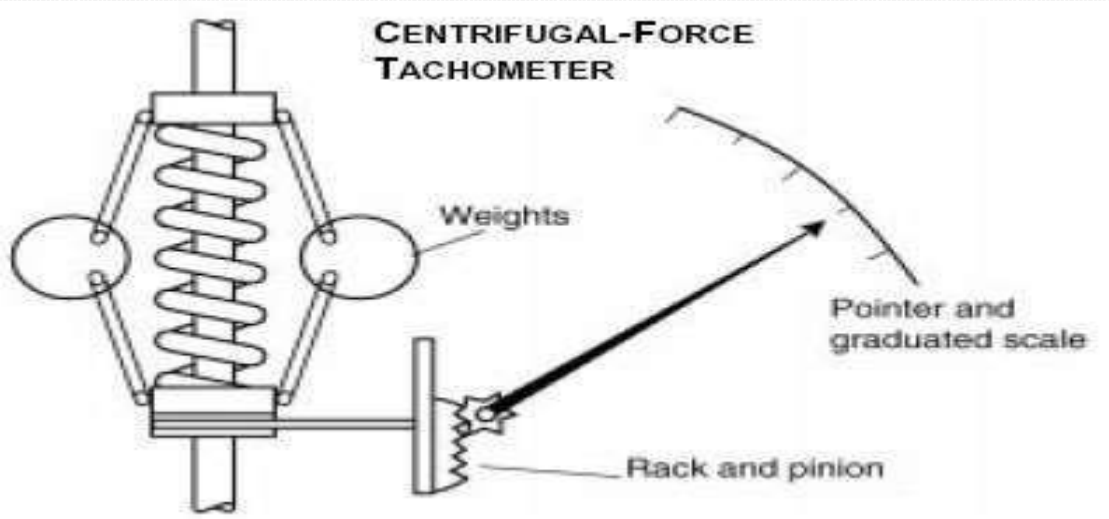
Tachoscope

4. Centrifugal force tachometer

- Centrifugal Tachometer operates on principle that centrifugal force is proportional to speed ofrotation.
- It consists two balls arranged about spindle. Centrifugal force developed by these ballscompress spring as function of speed positionspointer.
- They are suitable for40,000r.p.m. with an accuracy of about ±1 %.

Centrifugal force tachometer





w = angular speed, 1 = shaft,
2 and 3 = masses, 4 = displacement-sensitive element.

5. Resonance (vibrating reed) tachometer

- In Vibrating Read Tachometers a series of consecutively timed steel rods are used to determine speed on basis of vibrations created bymachine.
- One end of rod is fixed to a base which is kept in contact with any non-moving part of machine and other is attached to calibratedscale.
- These can be used in speed range of 600-10000 rpm with an accuracy of ±0.5 %.

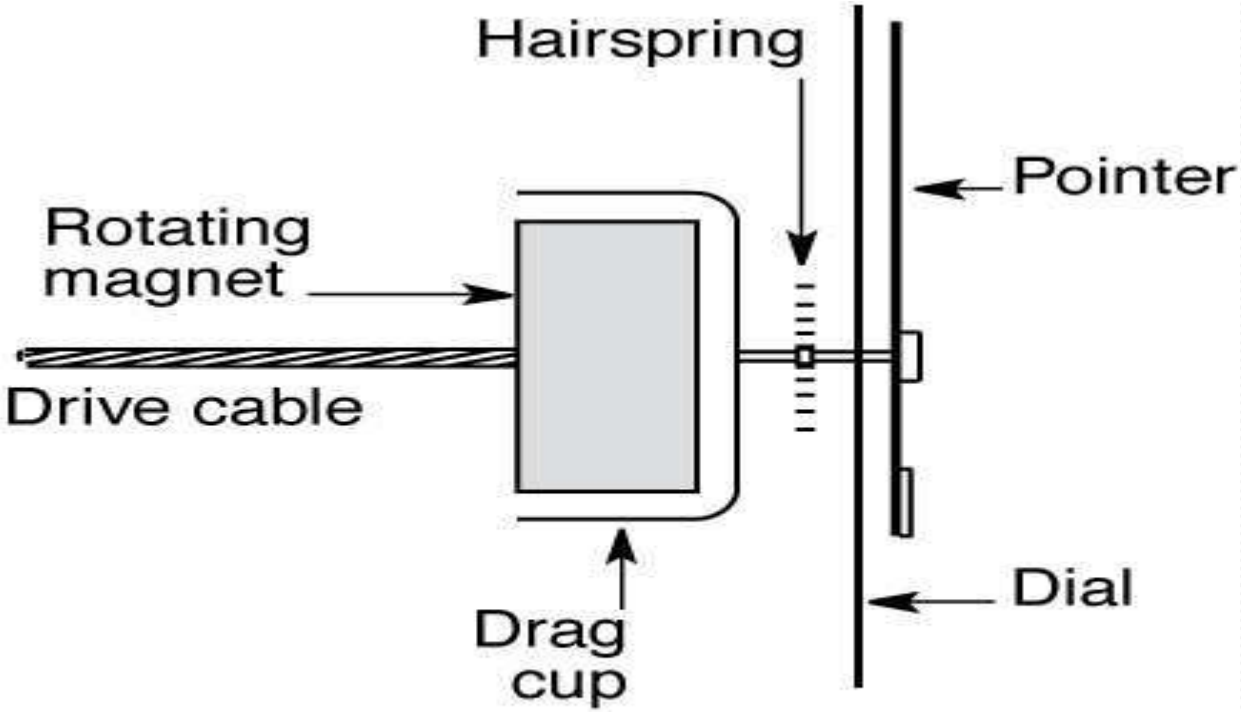
Resonance (vibrating reed) tachometer

Electrical Tachometers

1. Eddy current or drag cup tachometer

- An eddy-current tachometer uses the interaction of the magnetic fields generated by a permanent magnet and a rotor, whose speed of rotation is proportional to the eddy currentsgenerated.
- The currents tend to deflect a disk, which is mounted on the shaft and restrained by a spring, through a certain angle.
- The deflection of the disk, which is rigidly connected to a pointer, is indicated on a dial.
- Used for measuring rotational speeds upto 12,000rpm with an accuracy of ± 3%.

Eddy current or drag cup tachometer



magnetic-drag tachometer

Tachogenerators

•Employ small magnet type dc or ac generators which translate the rotational speeds into dc or ac voltage signal.

•Relative perpendicular motion between a magnetic field and conductor results in voltage generation in the conductor.

• Magnitude of this voltage is a direct function of the strength f the magnetic field and the speed with which the conductor moves perpendicular to it.

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D.C. Tachogenerator

- In a D.C. generator the e.m.f generated depends upon the following two factors:
  (i) Field excitation
  (ii) Speed
- If for the field system permanent magnet pole pieces are used, then the generated voltage depends only on the speed. Hence the **speed can be computed by measuring the generated e.m.f.**
- The shaft whose speed is to be measured is coupled to the armature.
- A moving coil voltmeter is connected across the brushes to measure the generated voltage. The variable resistance R is incorporated to limit the current through the voltmeter.
- Since voltage is proportional to speed, the voltmeter may be calibrated in terms of speed (r.p.m.).

D.C. Tachogenerator

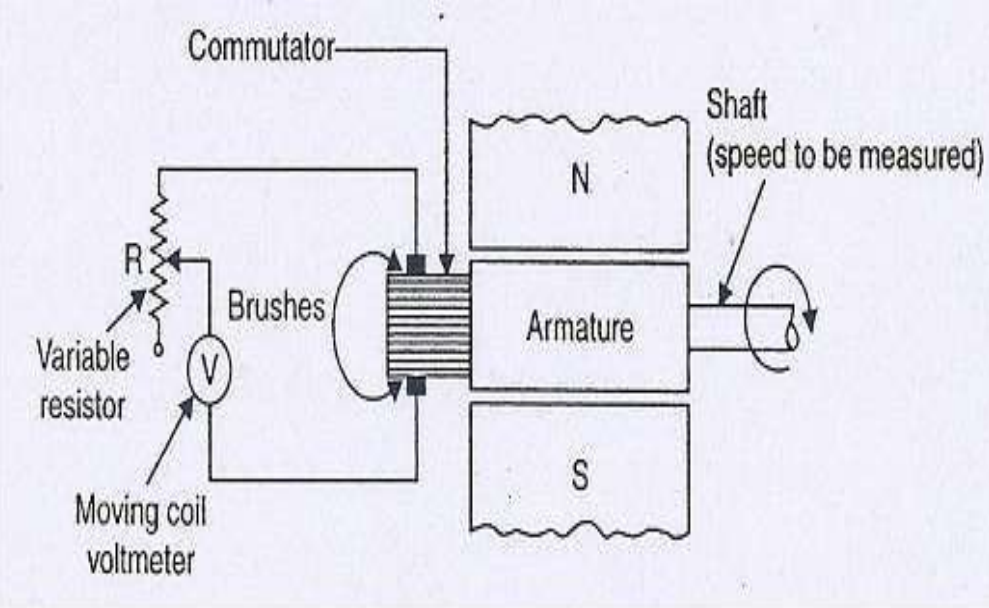
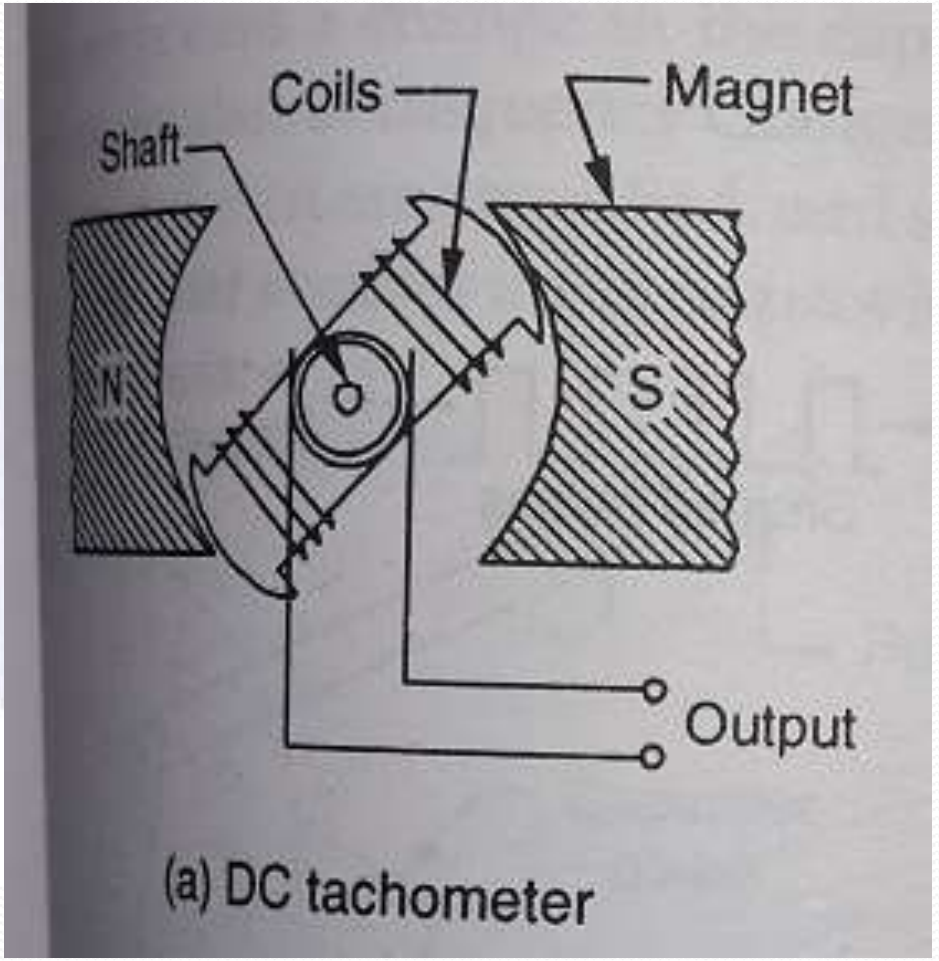


Fig. 32. D.C. tachometer generator.



A.C. Tachogenerator

- The inherent demerits associated with D.C. tachometer generator, due to the provision of commuter and brushes, are eliminated in A.C. tachometergenerator.
- It consists of, like an alternator, a stationary armature (stator) and a rotating field system (rotor). Owing to the generation of e.m.f in a stationary coil on a stator, commutation problems no longerexist.
- The alternating e.m.f. induced in the stationary coil is rectified, and the output D.C. voltage is measured with the help of a moving coil voltmeter(V).
- The ripple content of the rectified voltage is smoothened by the capacitor filter(C).

A.C. Tachogenerator

- As the speed depends on both the amplitude of the voltage and frequency, anyone of them can be used as a measure of the speed. In an A.C. tachometer, it is the induced voltage that is considered as the required parameter.

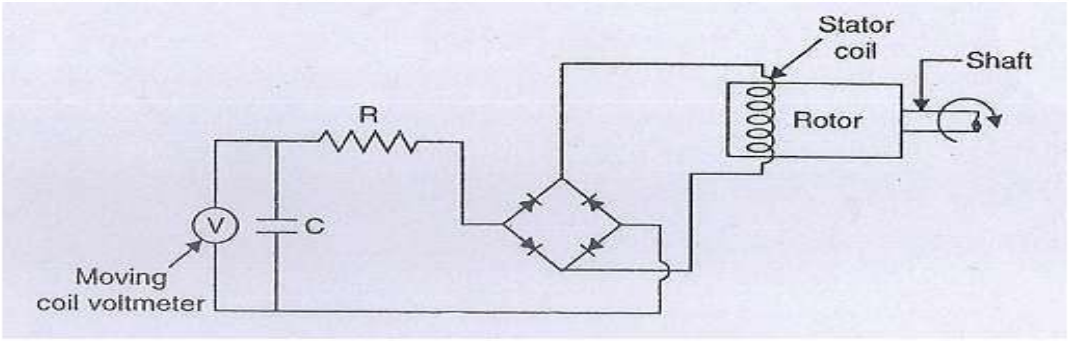
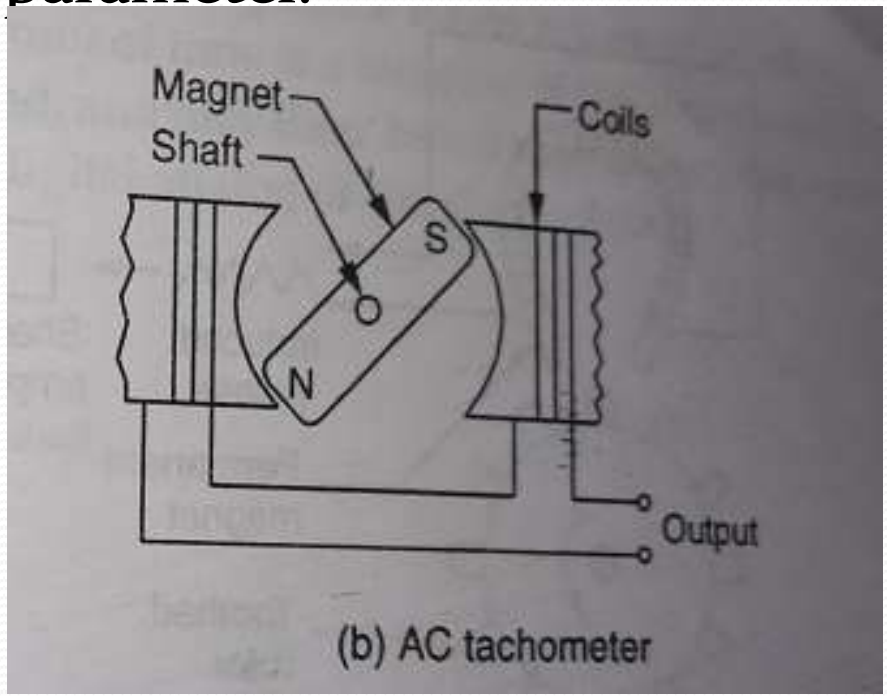


Fig. 33. A.C. tachometer generator.

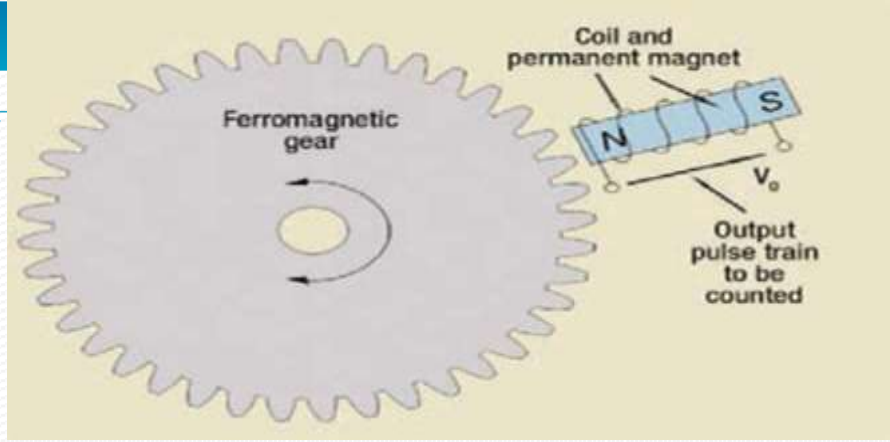


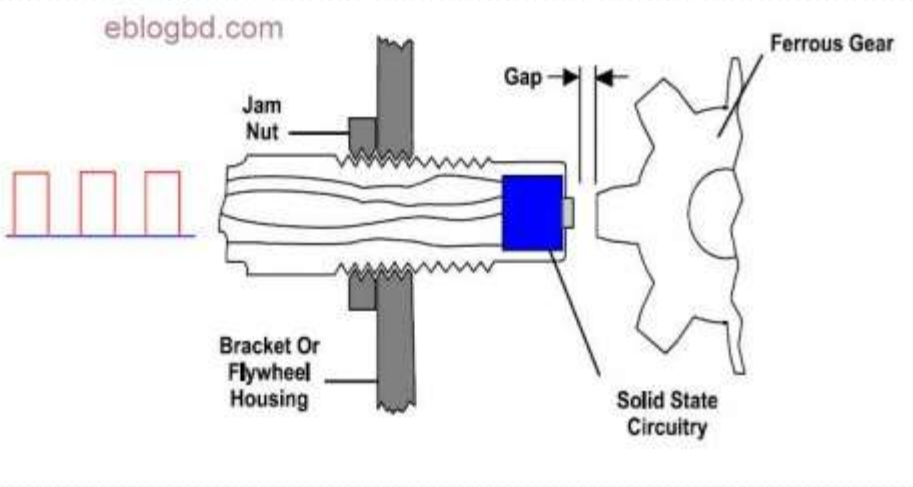
AC tachogenerator	DC tachogenerator
The AC tachogenerator is use to measure speed only in one direction only.	The DC tachogenerator is use to measure speed in both direction.
It consists of a stator and a rotor arrangement or a squirrel cage setup.	It consists of horse shoe type permanent magnet.
Need of rectifier to convert AC output into DC.	Output is in DC form therefore no need of rectifier.
No problem of brush friction and brush bounce.	Problem of wear and tear brushes at high speed.
Ripples are reduced.	Small ripples are appearing at output.
Maintenance is difficult.	Easy to maintenance.
AC tachogenerator  AC tachogenerator	DC tachogenerator  DC tachogenerator

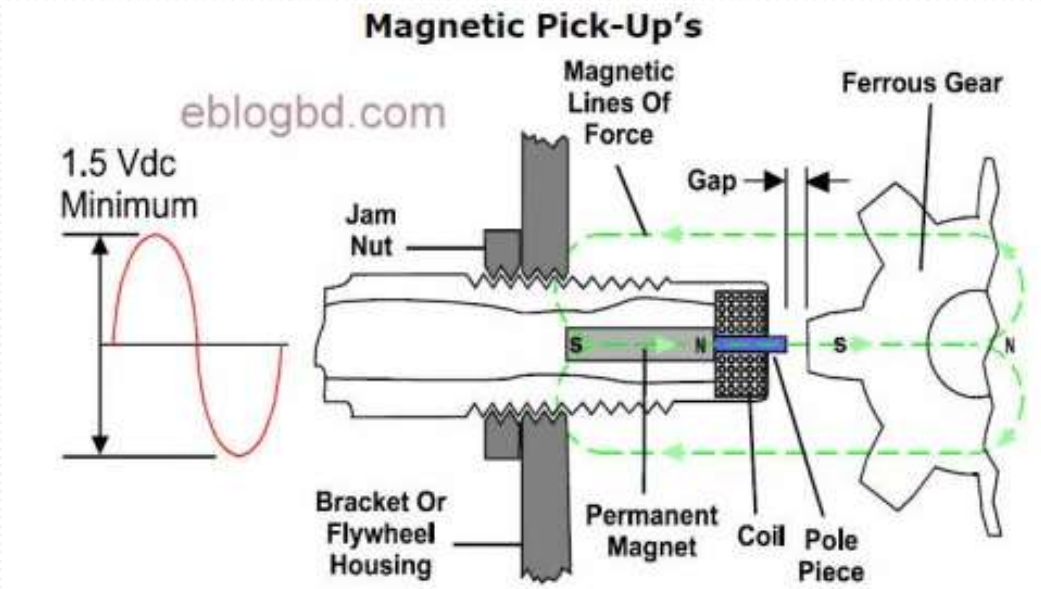
Contactless electrical Tachometers

1.Inductive type pickup tachometer

- A coil wounded on permanent magnet not on iron core, this configuration enable us to measure rotational speed of the systems.
- In the construction of variable reluctance sensor, we use ferromagnetic gearwheel. As the gearwheel rotates, change in magnetic flux take place in the pickup coil which further induces voltage. This change in magnitude is proportional to the voltage induced in the sensor.


Coil and
permanent magnet
Ferromagnetic
gear
N
S
V_o
Output
pulse train
to be
counted


eblogbd.com
Jam
Nut
Gap
Ferrous Gear
Bracket Or
Flywheel
Housing
Solid State
Circuitry


Magnetic Pick-Up's
eblogbd.com
1.5 Vdc
Minimum
Magnetic
Lines Of
Force
Ferrous Gear
Gap
Jam
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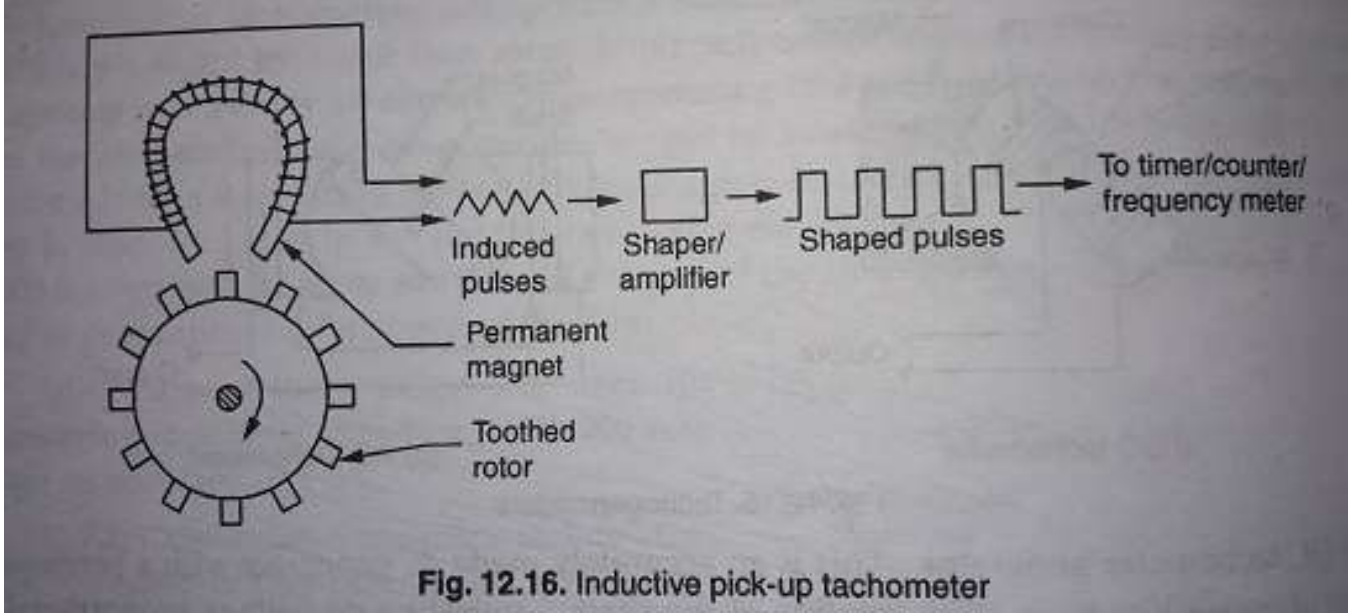


Fig. 12.16. Inductive pick-up tachometer

Let, T-> No. of teeth on rotor

N-> Revolutions per second

P -> Number of pulses per second

Speed,N = pulses per second / Number of teeth

$$N = P/T$$

$$= P/T * 60 \text{ rpm}$$

•If rotor has 60 teeth, and if the counter counts the pulses in one second, then the counter will directly display the speed in revolutions per minute.

2. Capacitive type Pickup tachometer

- Various pick-up devices can be used in conjunction with a digital counter to give a direct reading of speed.
- An inductive pick-up tachometer is shown in Figure (a).
- As the individual teeth pass the coil they induce an e.m.f. pulse which is appropriately modified and then fed to a digital counter.
- A capacitive pick-up tachometer is shown in Figure (b). As the rotating vane passes between the plates a capacitance change occurs in the form of a pulse.
- This is modified and then fed to the digital counter.

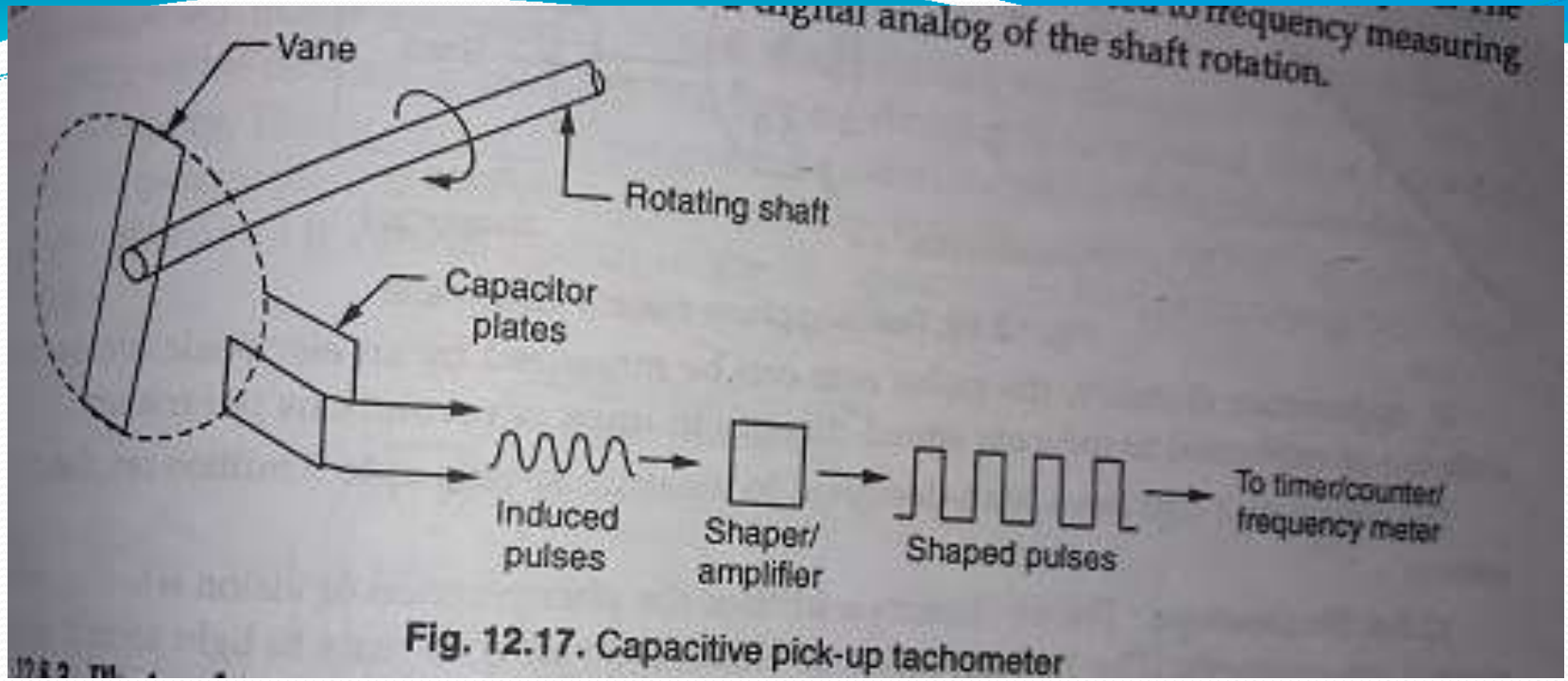
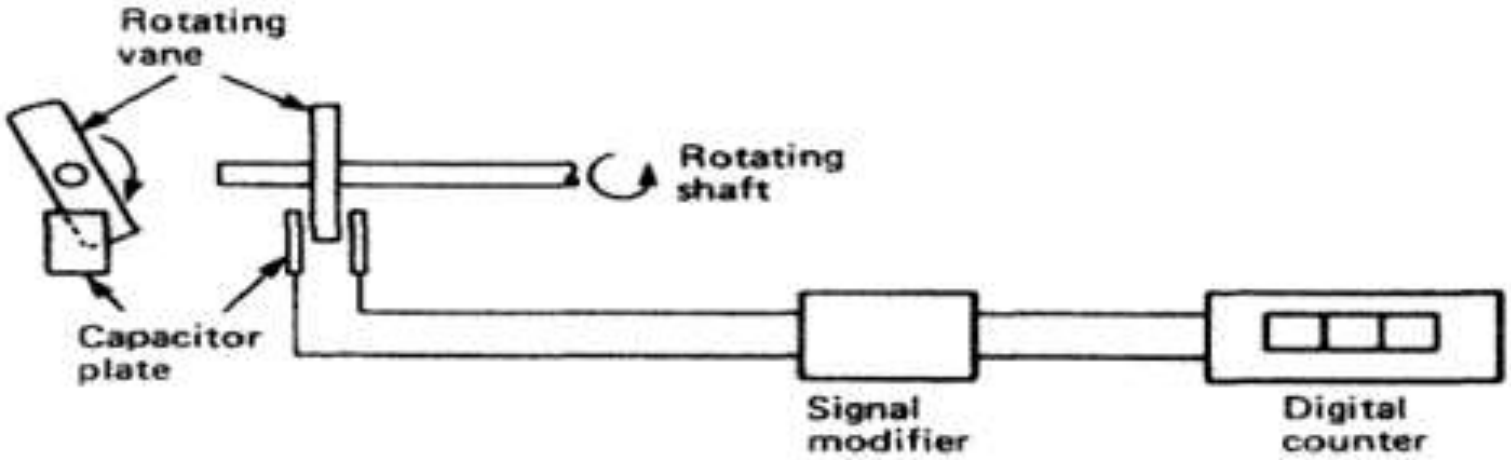


Fig. 12.17. Capacitive pick-up tachometer



(b) Capacitive

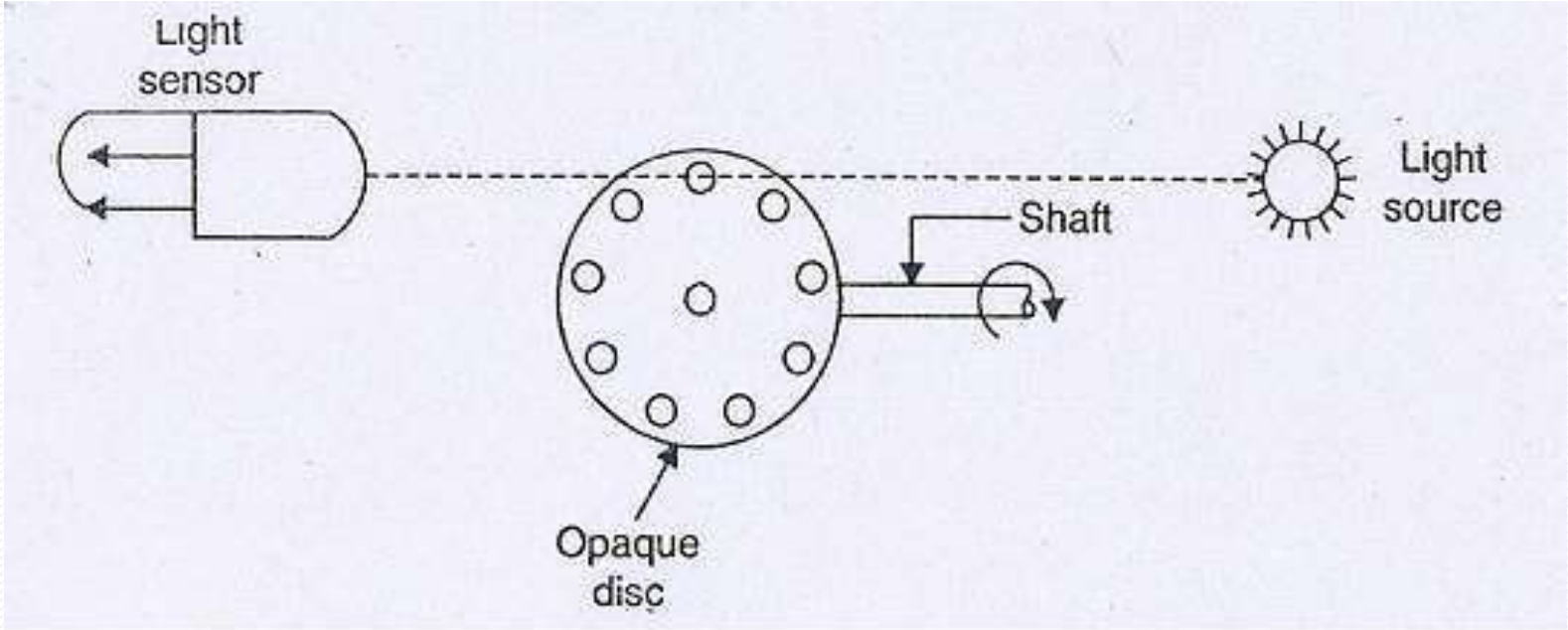
Photo-electric tachometer

- It consists of a opaque disc mounted on the shaft whose speed is to be measured. The disc has a number of equivalent holes around the periphery. On one side of the disc there is a source of light (L) while on the other side there is a light sensor (may be a photosensitive device or photo-tube) in line with it (light-source).

- On the rotation of the disc, holes and opaque portions of the disc come alternatory in between the light source and the light sensor. When a hole comes in between the two, light passes through the holes and falls on the light sensor, with the result that an output pulse is generated. But when the opaque portion of the disc comes in between, the light from the source is blocked and hence there is no pulse output.
- Thus whenever a hole comes in line with the light source and sensor, a pulse is generated. These pulses are counted/measured through an electronic counter.

Photo-electric tachometer

- The number of pulses generated depends upon the foliowing factors:
  i. The number of holes in thedisc;
  ii. The shaft speed.
- Since the number of holes are fixed, therefore, the number of pulses generated depends on thespeed of the shaft only. The electronic counter may therefore be calibrated in terms of speed (r.p.m.)



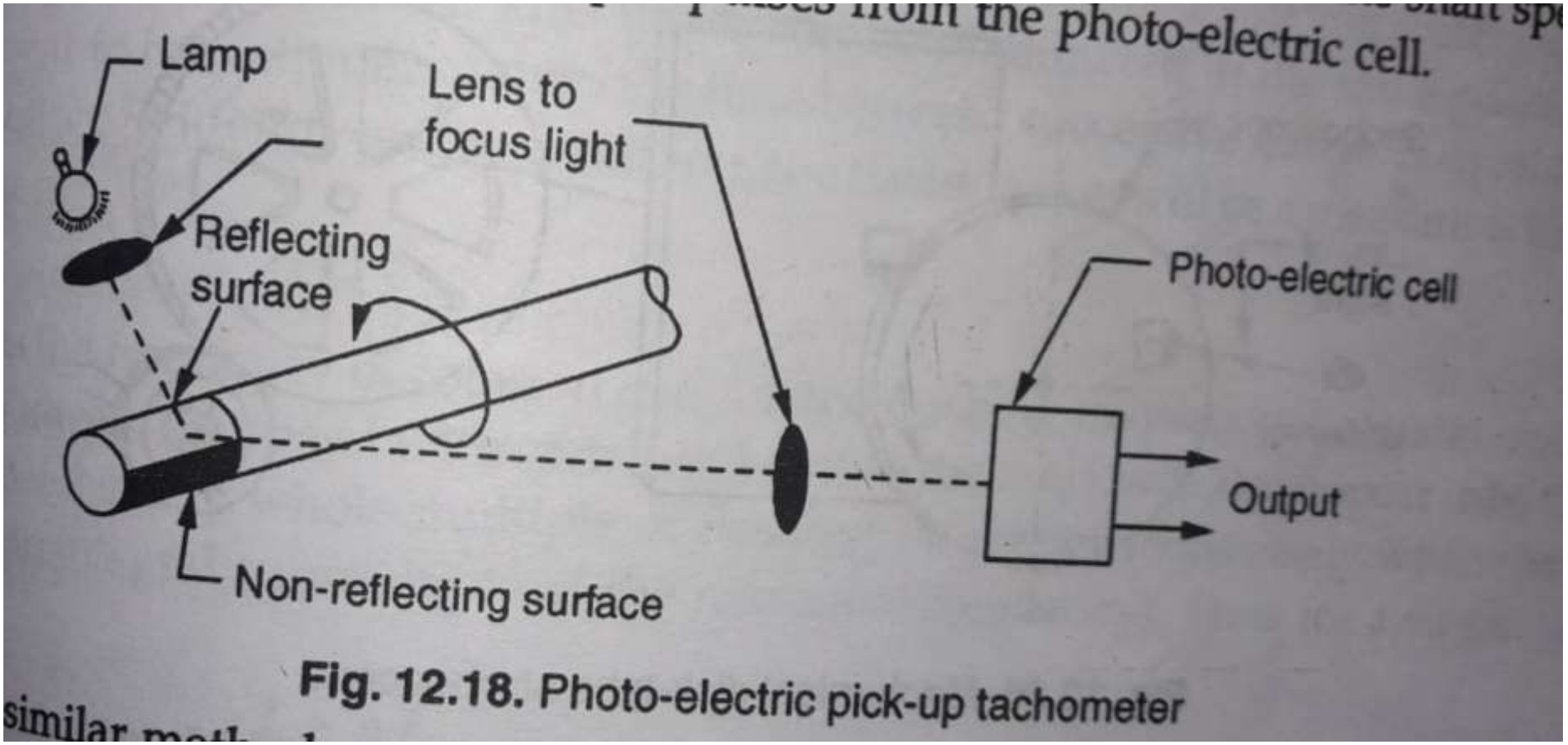
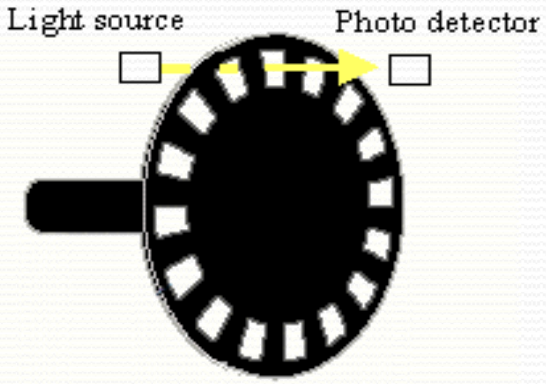
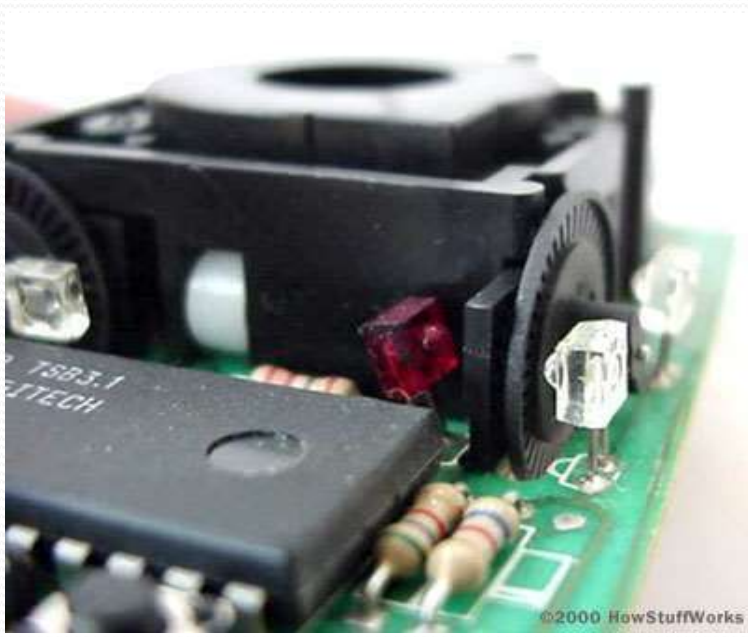


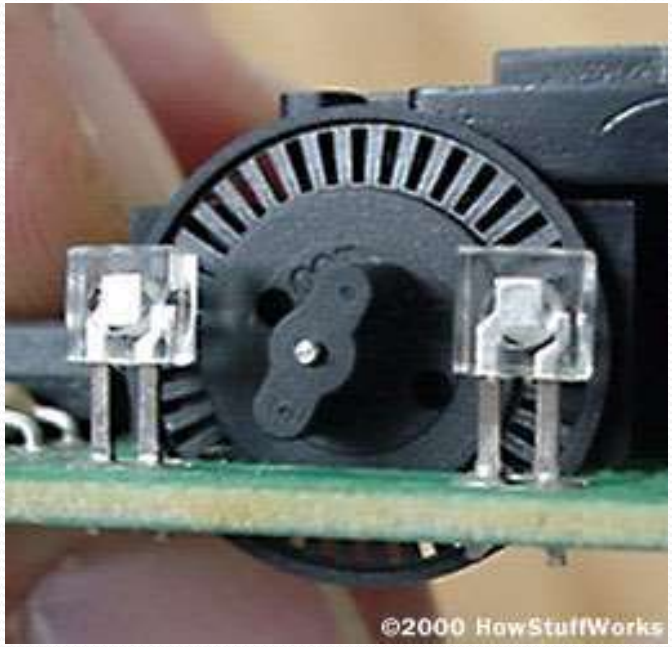
Fig. 12.18. Photo-electric pick-up tachometer

Photo-electric tachometer

- Computer mouse with a ball







Stroboscope

- The instrument operates on the principle that if a repeating event is only viewed when at one particular point in it's cycle it appears to be stationary. A mark is made on rotating shaft, and a flashing light is subjected on the shaft. The frequency of the flashing is one very short flash per revolution.
- To determine the shaft speed we increases the frequency of flashing gradually from small value until the rotating shaft appears to be stationary, then note the frequency. The frequency then doubled, if there is still one apparent stationary image, the frequency is again doubled. This continued until two images appear 180 degrees apart. When first appear for these two images the flash frequency is twice the speed of rotation.

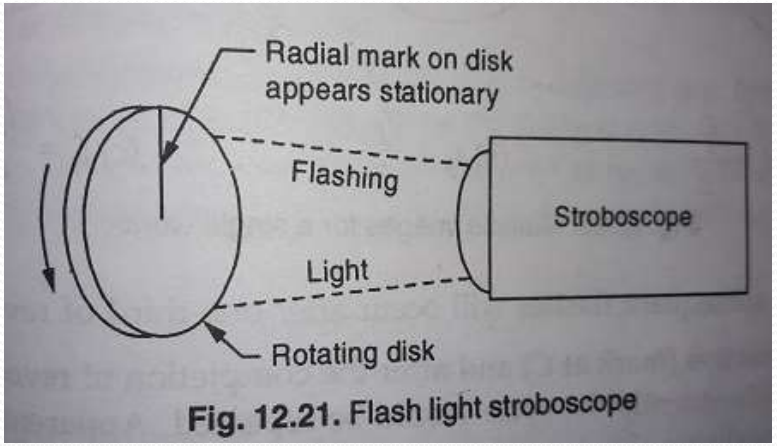
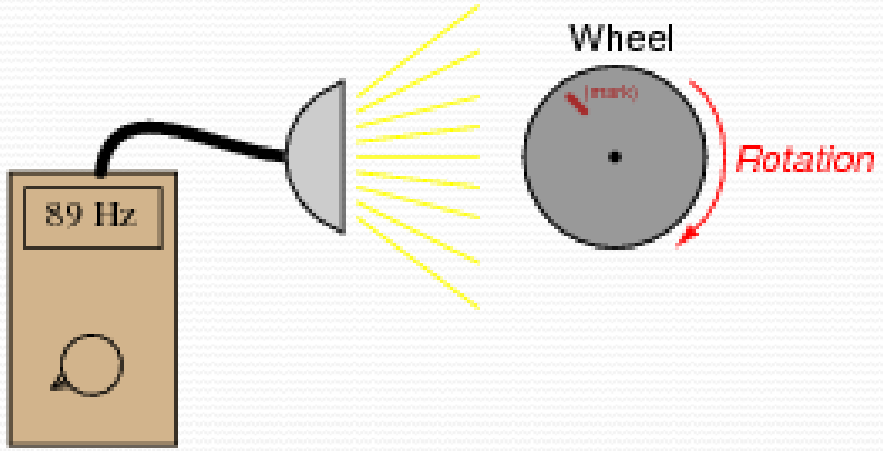


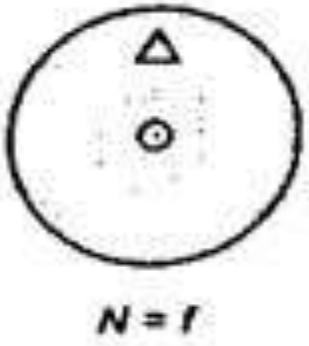
Fig. 12.21. Flash light stroboscope



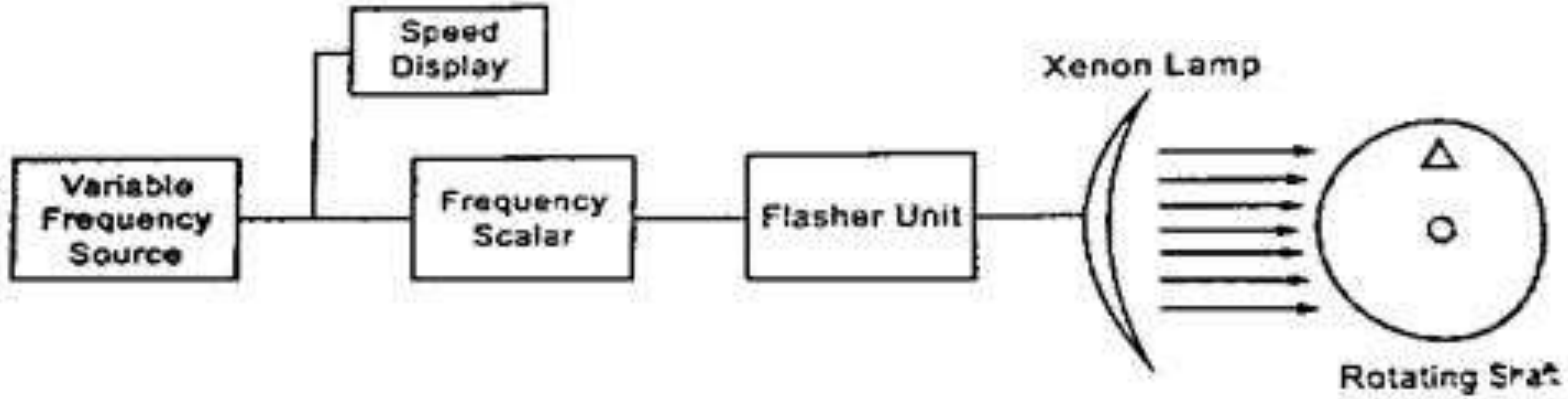
i) Single mark on the shaft

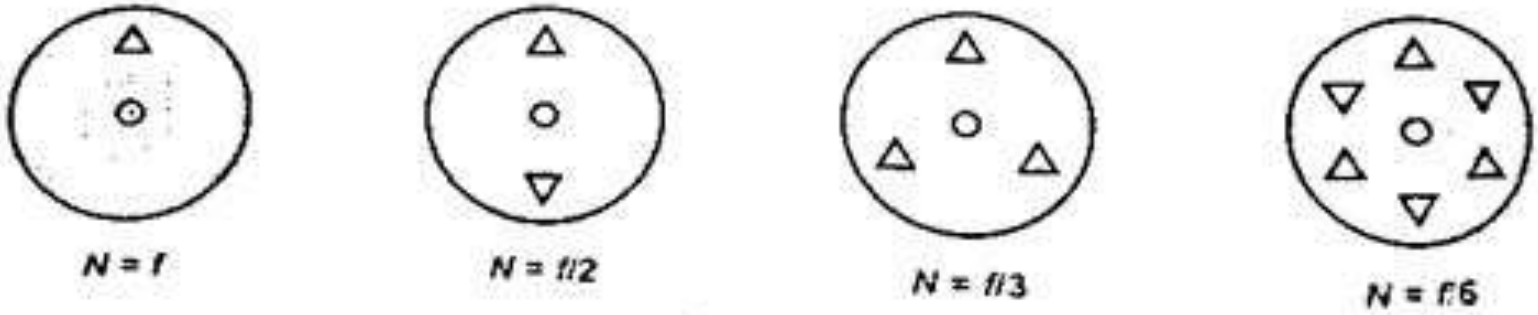
$f_r = f_f$

$f_r = nf_f$



Where, n=1,2,3,4 …etc.





(a) $f_r = f_f/2$ (b) $f_r = f_f/3$ (c) $f_r = f_f/4$

2) Multiple marks on the shaft

- For getting stationary pattern when,

$f_r = f_f /4, f_f /5$ ……etc.

- For certain values of f_r which is smaller than f_f namely,

$f_r = f_f /N, 2f_f /N, 3f_f /N$…….

Where N represents the number of distinguishing made on shaft.

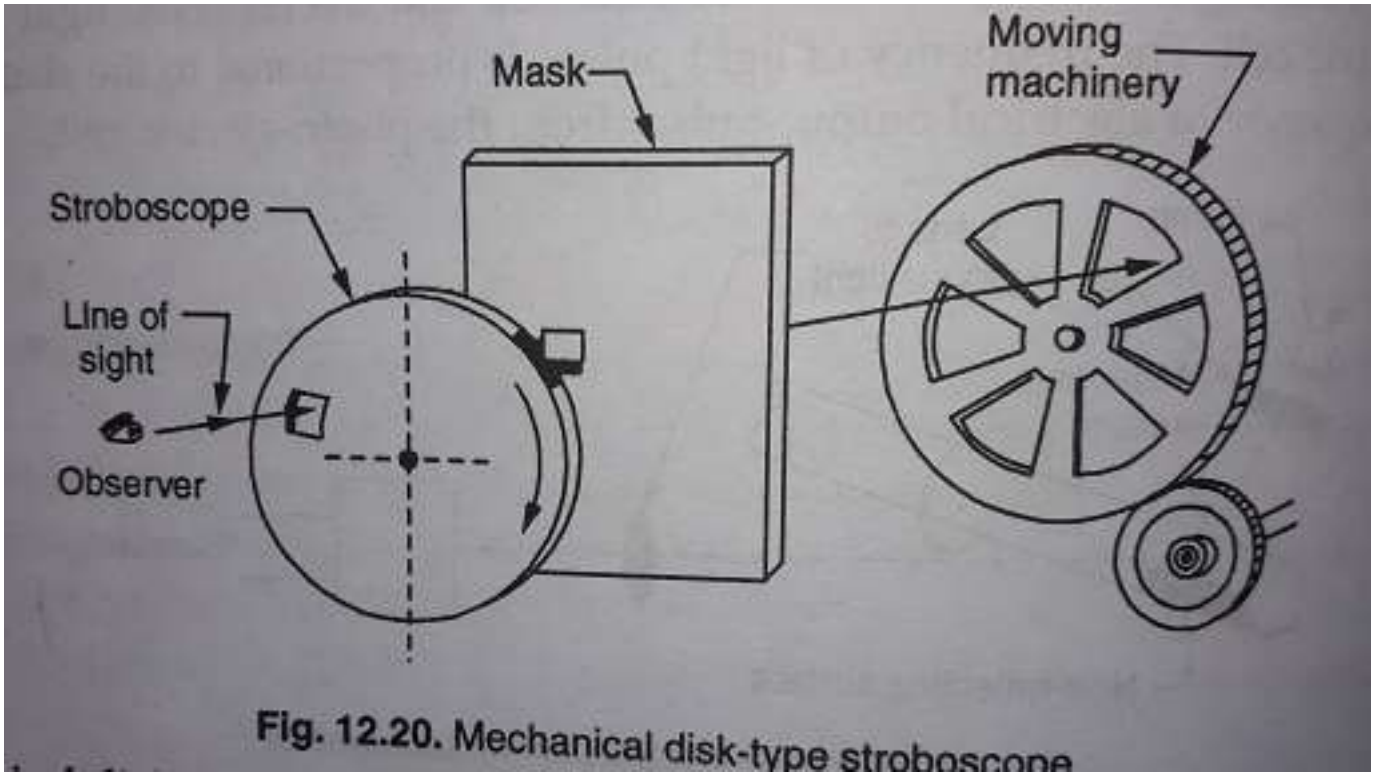
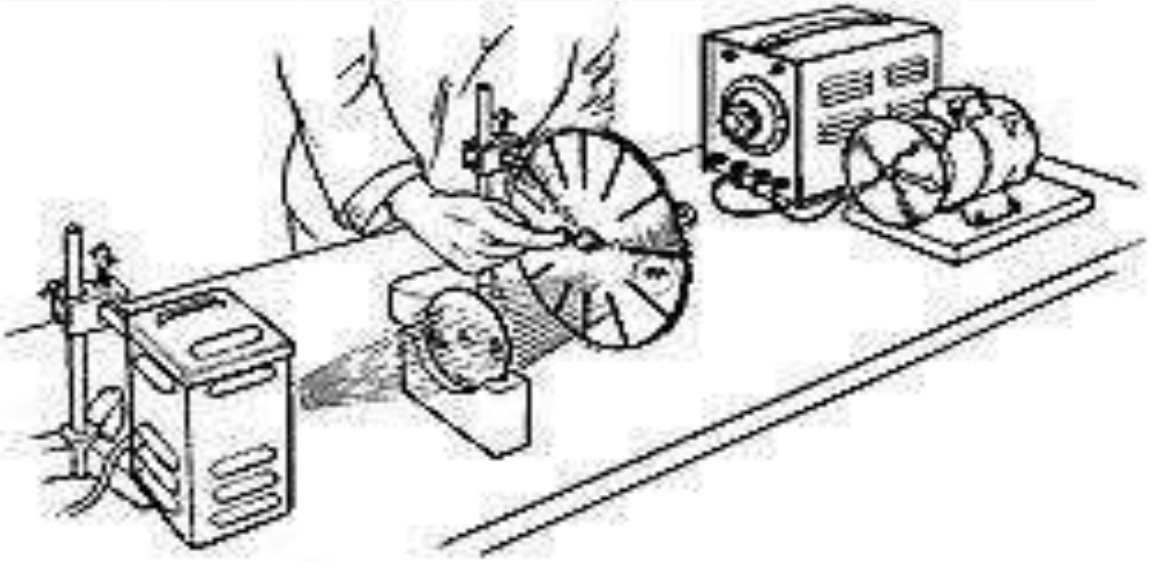


Fig. 12.20. Mechanical disk-type stroboscope

Shaft speed = (disk speed) x (no. of opening in the disk)/ no. of images

Stroboscope

- Stroboscopes are used to measure angular speed between 600 to 20,000 rpm .
- It's advantage is that it doesn't need to make contact with the rotating shaft.



- For exact speed measurement, the flashing rate is adjusted and synchronism is attained (appearance of a single line stationary image) for the highest rate of flashing.
- If synchronism occurs at n different flashing rates f1,f2,….fn, then the actual shaft speed is calculated from the relation;

$$f_r = \frac{f_1 - f_n(n-1)}{f_1 - f_n}$$