Lobed Impeller Meters The lobed impeller meter is widely used in measuring and controlling of petroleum crudes and finished products. It consists of two lobed impellers which are geared to maintain a fixed relative position. These impellers rotate in opposite directions within the housing as shown in Fig. 11.25. A register is attached to one of the impellers through a gear train mechanism. The fluid to be measured is trapped in the space between the lobes and is passed from inlet to outlet.

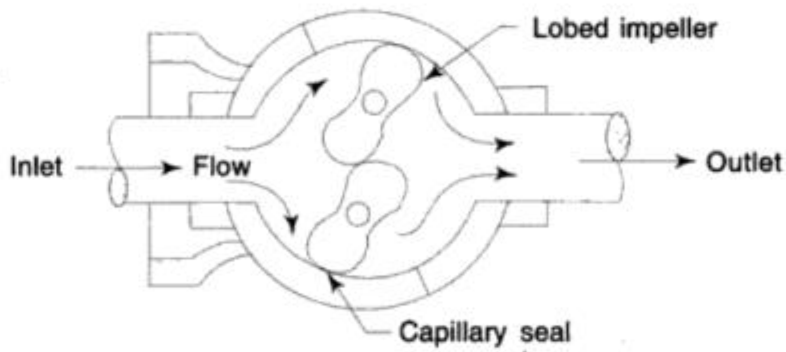

Fig. 11.25 *Lobed Impeller Meter*

A recent addition to this general type of meter is one using ovalgeared rotors in place of the lobed rotors. These meters may be used for either liquid or gases, and are normally built for service in pipe sizes from 50 to 610 mm, and their maximum capacities ranges from 1 to 17,500 gpm (or 3.8 to 66,500 litres/minute). The accuracy of these meters ranges from ±0.1 to ±0.5%.

Advantages The advantages of lobed impeller meter are:

(i) It is increasingly accurate at higher flows where leakage or slip is decreased.

(ii) It can be used for corrosive service.

(iii) It has a good capacity range.

Limitations The limitations of the lobed impeller meter are:

(i) Its cost is relatively high.

(ii) It requires frequent maintenance of rotating parts.

Rotating Vane Meters The rotating vane meter is most widely used in the petroleum industry and is used for such services as gasoline and crude oil metering. It consists of a cylindrical rotor that revolves on ball bearings around a central shaft and stationary cam, as shown in Fig. 11.23. As liquid flows against an extended blade, the resulting rotation of the rotor and the action of the cam cause the blades to act as cam followers, creating measuring chambers that accurately measure fluid through-put. Capillary action of the metered fluid effectively seals the blades to form the measuring cavities.

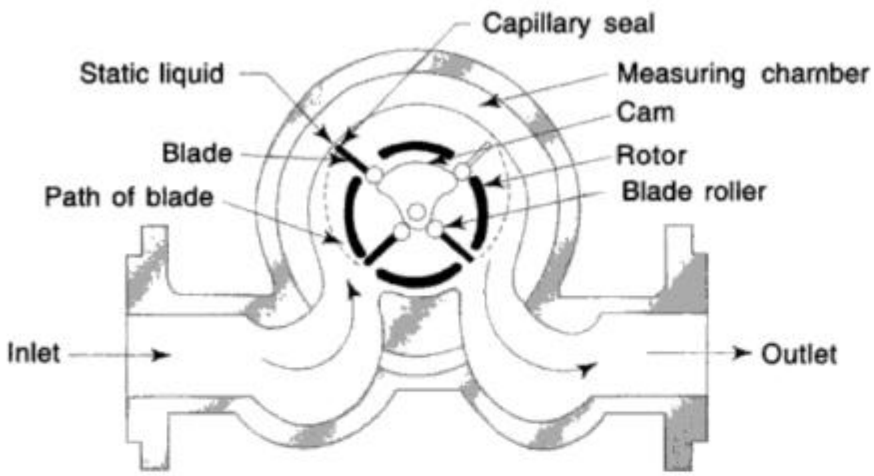

Fig. 11.23 *Rotating Vane Meter*

These types of meters are quite accurate and are available in sizes upto 400 mm. It has a normal accuracy of ±0.1%, an accuracy of ±0.05% has been achieved in the larger meters. These meters are built from a variety of materials of construction, and can be used for fairly high temperature and pressure services whose upper limits are approximately 177 °C and 1000 psig (6.9 MPa) respectively. These meters can be used to measure the flow ranges from a few gallons per minute of low viscosity clean liquids to 17,500 gallons per minute (66.5) litres/minute).

Advantages The advantages of rotating vane meter are:

(i) It allows low pressure loss.
(ii) It is applicable to a wide variety of gas and liquid fluids including viscous materials.
(iii) It has relatively high temperature and pressure ratings.
(iv) It is available in numerous construction materials.
(v) It has a good accuracy.

Limitations The limitations of rotating vane meter are:

(i) It tends to be bulky and heavy in larger sizes.
(ii) Its cost is relatively high.

11.3.8 Ultrasonic Flowmeters

In ultrasonic flowmeters, the measurement of flow rate is determined by the variation in parameters of ultrasonic oscillations. There are two types of ultrasonic flowmeters currently in use:

Time Difference Type These devices measure flow by measuring the time taken for ultrasonic wave to transverse a pipe section, both with and against the flow of liquid within the pipe. It consists of two transducers, A and B, inserted into a pipe line, and working both as transmitter and receiver, as shown in Fig. 11.20(a). The ultrasonic waves are transmitted from transducer A to transducer B and vice versa. An electronic oscillator is connected to supply ultrasonic waves alternately to A or B which is working as transmitter through a changeover switch, when the detector is connected simultaneously to B or A which is working as receiver. The detector measures the transit time from upstream to downstream transducers and vice versa.

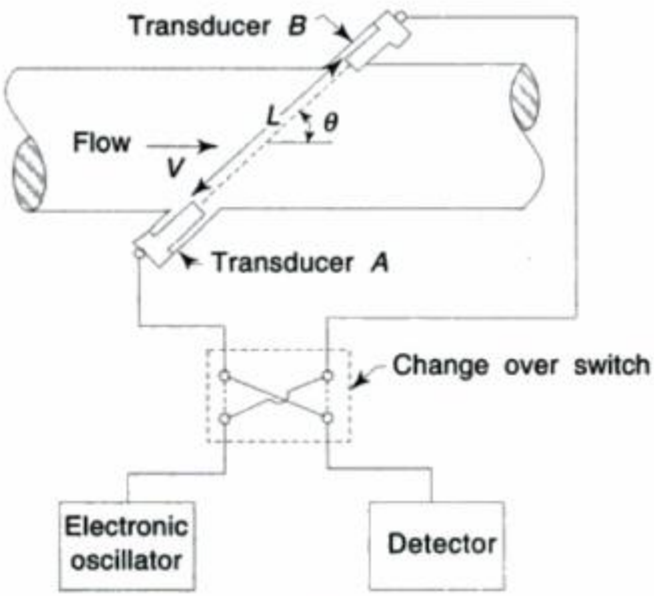

Fig. 11.20(a) *Time-difference Type Ultrasonic Flowmeter*

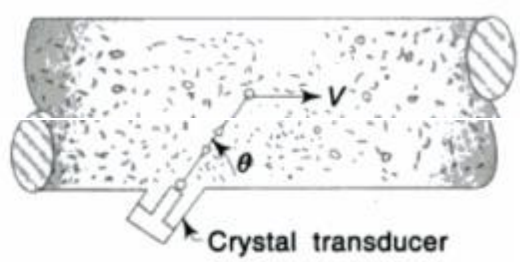

Fig. 11.20(b) *Doppler-type Ultrasonic Flowmeter*

The time T_{AB} for ultrasonic wave to travel from transducer A to transducer B is given by the expression:

$$T_{AB} = \frac{L}{(C + V\cos\theta)} \qquad (11.16)$$

and, the time (T_{BA}) to travel from B to A is given as,

$$T_{BA} = \frac{L}{(C - V\cos\theta)} \qquad (11.17)$$

where, L = the acoustic path length between A and B
C = velocity of sound in the fluid

θ = angle of path with respect to the pipe axis
V = velocity of fluid in pipe

The time difference between T_{AB} and T_{BA} can be calculated as,

$$\Delta T = T_{AB} - T_{BA} = \frac{2\,LV\cos\theta}{C} \tag{11.18}$$

or,

$$V = \frac{\Delta T\, C}{2\,L\cos\theta} \tag{11.19}$$

Since, this type of flowmeter relies upon an ultrasonic signal traversing across the pipe, the liquid must be relatively free of solids and air bubbles.

Doppler Flowmeters In doppler flowmeter, an ultrasonic wave is projected at an angle through the pipe wall into the liquid by a transmitting crystal in a transducer mounted outside the pipe, as shown in Fig. 11.20(b). Part of the ultrasonic wave is reflected by bubbles or particles in the liquid and is returned through the pipe wall to a receiving crystal. Since the reflectors (bubbles) are travelling at the fluid velocity, the frequency of the reflected wave is shifted according to the Dopple principle. The velocity of the fluid is given by the equation:

$$V = \frac{\Delta f\, C_t}{2 f_0 \cos\theta} = \Delta f K \tag{11.20}$$

where Δf = difference between transmitted and received frequency
C_t = velocity of sound in the transducer
f_0 = frequency of transmission
θ = angle of transmitter and receiver crystal with respect to the pipe axis.
K = constant

Advantages of Ultrasonic Flowmeters The advantages of ultrasoni flowmeters are:

(i) It does not impose additional resistance to the flow or disturb the flo pattern as the transducers are inserted in the wall of pipe.
(ii) Its velocity/output relationship is linear.
(iii) It has no moving parts.
(iv) Its repeatability is in the order of 0.01%.

11.3.4 Turbine Flowmeters

The turbine flowmeter is used for the measurement of liquid, gas and very low flow rates. It works on the basic principle of turbine. It consists of a multi-bladed rotor (turbine wheel) which is mounted at right angles to the axis of the flowing liquid, as shown in Fig. 11.13. The rotor is supported by ball or sleeve bearings on a shaft which is retained in the flowmeter housing by a shaft-support section. The rotor is free to rotate about its axis.

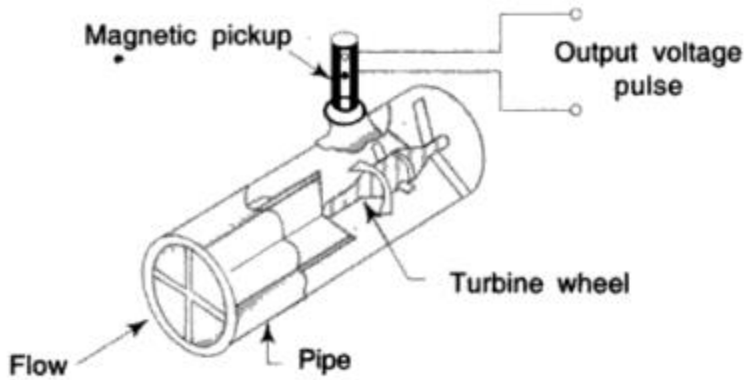

Fig. 11.13 *Turbine Flowmeter*

The flowing fluid impinges on the turbine blades (rotor), imparting a force to the blade surface which causes the rotation of the rotor. The speed of the rotor is directly proportional to the fluid velocity, and hence to volumetric flow rate when it is at a steady rotational speed. The speed of rotation is monitored in most of the meters by a magnetic-pickup coil, which is fitted to the outside of the meter housing. The magnetic-pickup coil consists of a permanent magnet with coil windings which is mounted in close proximity to the rotor but internal to the fluid channel. As each rotor blade passes the magnetic-pickup coil, it generates a voltage pulse which is a measure of the flow rate, and the total number of pulses give a measure of the total flow. The electrical voltage pulses can be totalled; subtracted and manipulated by digital techniques so that a zero error characteristic of digital handling is provided from the pulse generator to the final read out. The K factor (i.e. the number of pulses generated per gallon of flow) is given as,

$$K = \frac{T_K f}{Q} \tag{11.10}$$

where, K = pulses per volume unit
T_K = a time constant in min.
Q = a volumetric flow rate in gpm.
f = frequency in Hz

The turbine flow meters provide very accurate flow measurement over wide flow range. The accuracy range is from ±1/4 to ±1/2%, and the repeatability is excellent, ranging from ±0.25% to as good as ±0.02%. The rangeability of turbine meters are generally considered to be between 10 : 1 and 20 : 1, however, in low flow ranges, it is often less than 10 : 1. The military type turbine meters have achieved rangeabilities greater than 100 : 1. The turbine meters are available in sizes ranging from 6.35 to 60 mm and liquid flow ranges from 0.1 to over 50,000 gallons per minute.

The turbine meters are widely used for military applications. They are particularly useful in blending systems for the petroleum industry. They are effective in aerospace and airborne applications for energy-fuel and cryogenic (liquid oxygen and nitrogen) flow measurements.

Advantages The advantages of turbine flowmeter are:

(i) Its accuracy is good.
(ii) It provides excellent repeatability and rangeability.
(iii) It allows fairly low pressure drop.
(iv) It is easy to install and maintain.
(v) It gives good temperature and pressure ratings.
(vi) It can be compensated for viscosity variations.

Disadvantages The disadvantages of turbine flowmeter are:

(i) Its cost is high.
(ii) Its use is limited for slurry applications.
(iii) It faces problems caused by non-lubricating fluids.

11.3.3 Magnetic Flowmeters

Magnetic flowmeters are traditionally the first type of flowmeters to be considered for high corrosive applications and for applications involving measurement of erosive slurries. These meters utilize the principle of Faraday's Law of Electromagnetic Induction for making a flow measurement. It states that whenever a conductor moves through a magnetic field of given field strength, a voltage is induced in the conductor which is proportional to the relative velocity between the conductor and the magnetic field. This concept is used in electric generators. In the case of magnetic flowmeter, electrically conductive flowing liquid works as the conductor. The induced voltage is given by the equation,

$$E = CBLV \tag{11.5}$$

or $$V = \frac{E}{CBL} \tag{11.6}$$

where, E = induced voltage in volts
C = dimensional constant
B = magnetic field in weber/m^2
L = length of conductor (fluid) m
V = velocity of the conductor (fluid) in m/s

The equation of continuity to convert a velocity measurement to volumetric flow rate is given as

$$Q = VA \tag{11.7}$$

where, Q = volumetric flow rate
V = fluid velocity
A = cross-sectional area of the flowmeter

Now, putting the value of V from Eq. (11.7) the volumetric flow rate can be written as,

$$Q = \frac{EA}{CBL} \tag{11.8}$$

Since, for given size of flowmeter, A, C, B, and L become constants, the Q can be written as,

$$Q = KE \tag{11.9}$$

where, $K = \frac{A}{CBL} =$ a constant

Therefore, the induced voltage is directly proportional and linear with volumetric flow rate.

Construction and Working The magnetic flowmeter consists of an electrically insulated or non-conducting pipe such as fiber glass, with a pair of electrodes mounted opposite to each other and flush with the inside walls of its pipe and with magnetic coil mounted around the pipe so that a magnetic field is generated in a plane mutually perpendicular to the axis of the flowmeter body and to the plane of the electrodes. If a metal pipe is used, an electrically insulating liner is provided to the inside of the pipe. A cut way view of the magnetic flowmeter is shown in Fig. 11.12 (a).

Figure 11.12 (b) illustrates the basic operating principle of a magnetic flowmeter in which the flowing liquid acts as the conductor, the length L of which is the distance between the electrodes and equals the pipe diameter. As the liquid passes through the pipe section, it also passes through the magnetic field set up by the

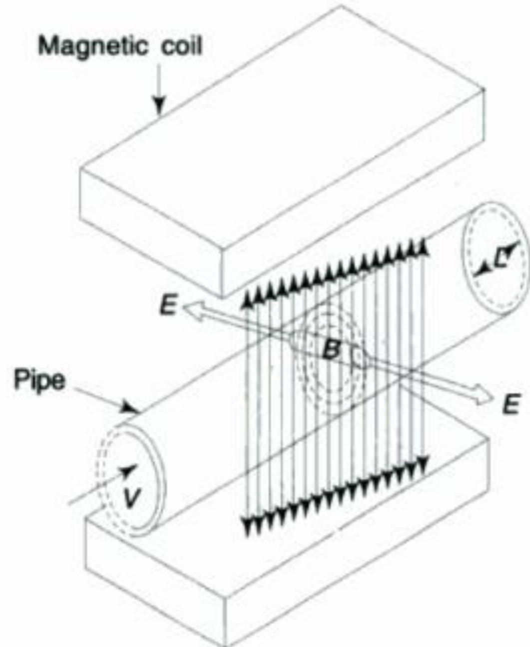

Fig. 11.12(b) *Working Principle of Magnetic Flowmeter*

magnet coils, thus inducing the voltage in the liquid which is detected by the pair of electrodes mounted in the pipe wall. The amplitude of the induced voltage is proportional to the velocity of the flowing liquid. The magnetic coils may energized either by AC or DC voltage, but the recent development is the pulsed DC-type in which the magnetic coils are periodically energized.

Advantages The advantages of a magnetic flowmeter are:

(i) It can handle slurries and greasy materials.
(ii) It can handle corrosive fluids.
(iii) It has very low pressure drop.
(iv) It is totally obstructionless.
(v) It is available in several construction materials.
(vi) It is available in large pipe sizes and capacities.
(vii) It is capable of handling extremely low flows (with minimum size, less than 3.175 mm inside diameter) and very high volume flow rate (with sizes as large as 3.04 meter offered).
(viii) It can be used as bi-directional meter.
(ix) Measurements are unaffected by viscosity, density, temperature and pressure.

Disadvantages and Limitations The disadvantages and limitations of magnetic flowmeter are:

(i) It is relatively expensive.

(ii) It works only with fluids which are adequate electrical conductors.

(iii) It is relatively heavy, especially in larger sizes.

(iv) It must be full at all times.

(v) It must be explosion proof when installed in hazardous electrical areas.