Mechanical Measurement Systems
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Lecture-26
Transducers-2

Hello, I welcome you all in this course on Mechanical Measurement Systems. Today, will continue our discussions with transducers and today, we will discuss the selection of transducers and the type of transducers so to begin with; the selection of transducers.

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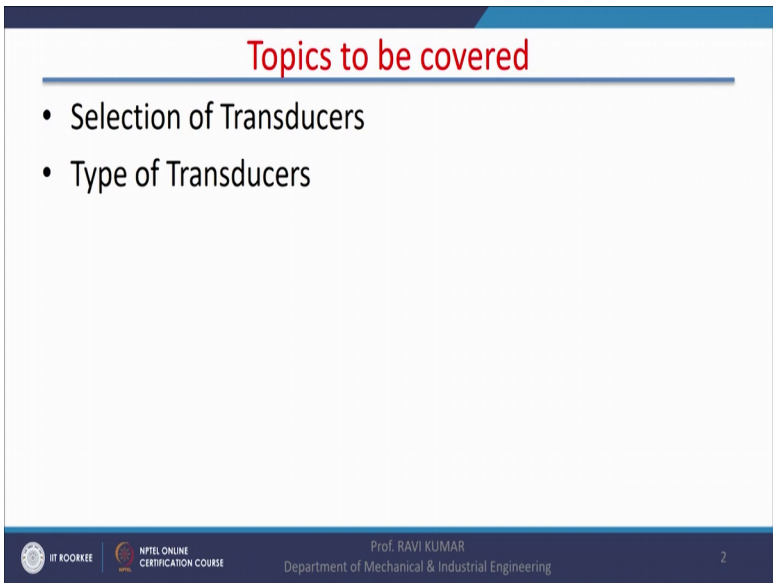

So, we have to look for many aspects of the transducers before selecting a particular transducer, first of all, we should know, first of all first and the foremost thing we should see; what is the range of the measurement and what is the range of the output expected range of the output.

Suppose, pressure transducer pressure transducers output is range of the output is let us say 2 to 3 bar or 200 to 300 Kilo Pascal and we are applying a transducer of 0 to 25 bar in a range of 0 to 25 bar 0 to twenty bar because these type of transducers in a range of 0 to 25 or 0 to 20 bar are very easily, I mean they are in abundance in the market.

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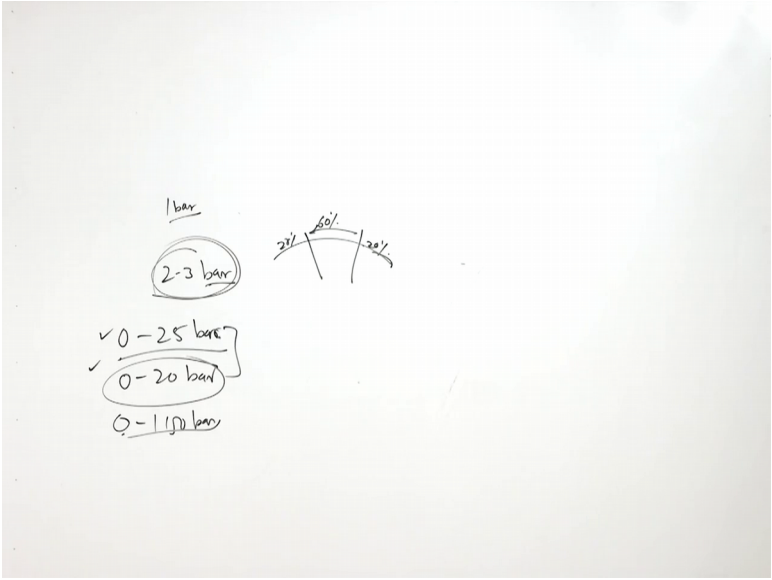

So, they are easily available. So, but if you put 0 to 20 to 20 to 3 bar or 1 bar pressure, it may encore many errors, I mean it is not appropriate to go for such type of transducers as I told you earlier this for the skill range the entire skill range your reading should fall in middle 60 percent, 20 percent this side and 20 percent on this side, you should avoid this, sometimes it is unavoidable, but while choosing a trans transducers, we can always ensure that the expected output falls in this range, right.

So, 0 to 5 bar will be ok, for this 0 to 5 bar will be ok, for such type of measurements not 0 to 20 or 0 to 100 bar second thing is the commercially available transducers or pressure gauges, they give gauge pressure. Gauge pressure is the above the atmospheric pressure which is above the atmospheric. So, one should not forget one should not forget to add atmospheric pressure in pressure indicated by the pressure gauge or transducers absolute pressure transducers are also available.

So, why when we are going for the selection of the transducers we should ensure or when we are applying using the transducers for pressure measurement, we should ensure whether it is a absolute pressure type of transducers or pressure gauge type of transducers or the gauge pressure type of transducers and range is also important. Now, the first thing second thing is the transducers should have high impedance input impedance.

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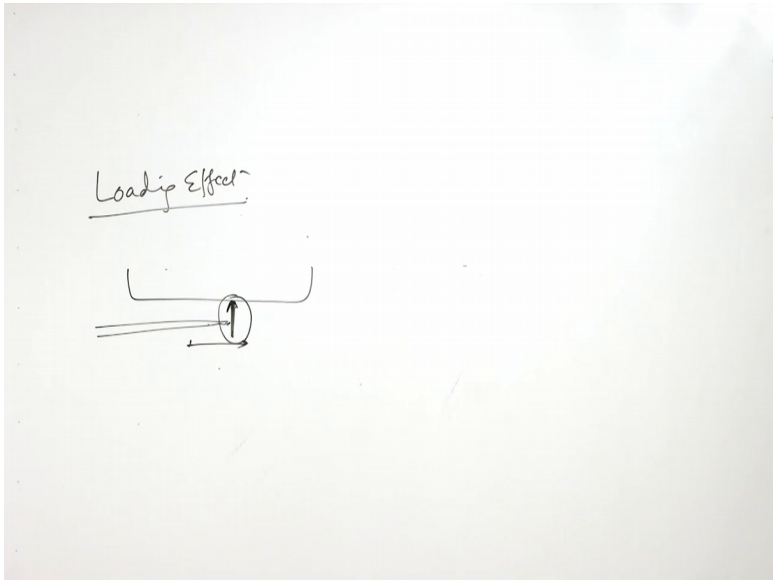

Loading effect; loading effect as I stated earlier, it is some energy is used, part of the input energy is used for actuation of the transducer and this part of energy is results in the loading effect. For example, we are using potentiometer for the displacement, there is a potentiometer and there is a attachment to the potentiometer and there is a stylus and we are using this potentiometer for displacement measure measurement.

So, due to inertia of this indicator, I mean where the this stylus is attached the actual displacement will be less than the real, I mean the displacement we get out of this device will be little less than the displacement, we should have got without because this is an output section in the displacement and due to inertia and effect of this the actual displacement will be less than the ideal displacement. So, the loading effect should be avoided same as in case in the thermocouples in the process of temperature measurements or thermometer energy is drawn from the measuring right.

So, that also cause the loading error and a transducers should have very good resolving resolution, I mean measuring device should have very good resolution throughout the entire region of measurement. So, that is another selection criteria and the system should be highly sensitive to the desired input.

It should not be sensitive or it should it should be insensitive to the any interfering and the modifying input and the systems should be very highly sensitive to the desired input that is eh selection criteria for the transducer and it should be preferably very small,

small is easy to manipulate size of the transducers has to be small as small as possible it should be able to work in the hostile environment may be in the oxidizing environment or the corrosive environment specially in the corrosive environment because in those places specially the near the seacoast the environment is very corrosive.

So, the transducer should be able to perform in that environment, it should be able to witness pressure shock and vibration extra. So, this the pressure shock and vibration should not act as a interfering input to the transducer right high degree of accuracy high degree of it is always desired that the measurement of the transducer have to be high, it should have high degree of accuracy, high degree of repeatability, it should be error free and the most important thing is every transducers specially electrical transducer should have some overload production in mechanical transducers, we can design we can take some factor of safety, but in electrical transducers, right.

So, they should have some overload protection. So, the transducer is not damaged, if there is the dynam input of or a pulse, there is a pulse in the transducers. So, you should not get damaged. So, this is the selection this is about the selection of transducers. Now type of this is important type of transducers.

So, type of transducers means what is the basic principle of measurement basic principle of measurement means when I will write, you will understand the that first is resistance type of transducers.

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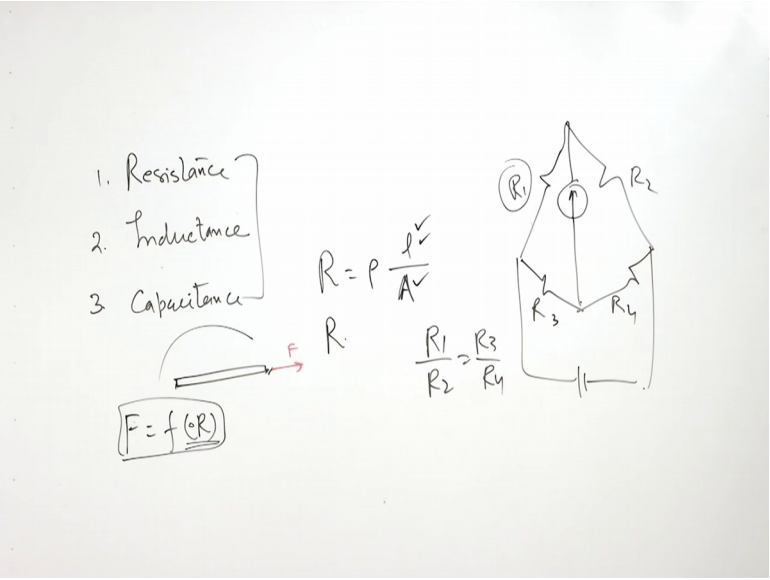

Second is inductive transducers; inducted type or inductive, third is capacitance, first of all, we will discuss all this three, right and if you look at the governing equation and how it is I mean not very high physics or mathematics involved for this simple resistance transducers. Now, resistance of any wire resistance of any wire R is specific resistance specific resistance length of the wire cross section area of the wire, right.

If I change because specific resistance of a wire is constant, but if I change length of the wire or cross section area of the wire the resistance will change, right and for example, I change cross section area of wire a wire, electrical wire is put under tension, the force is applied on electrical wire; when the wire is put in tension its length will increase, right because it is a metallic wire, the length will increase and at the same time, its cross section area will reduce and this will alter the resistance of the wire for different type of loading.

We can have different type of resistance of wire, right and then we can have force is a function of resistance of wire. Now, the issue is how to measure the resistance of wire ok, resistance of wire has changed. Now, we have to measure resistance of wire as well. So, normally it is made an arm of a wheat stone bridge if you remember a wheat stone bridge, R 1, R 2, R 3, R 4, then this is R 1, R 2, R 3 and R 4 and it is balanced, if it is a balanced wheat stone bridge galvanometer is here. So, R 1 by R 2 is equal to R 3 by R 4, so, balancing is done and when the wheat stone and R 1, R 2, R 3 and R 4.

So, just R 3 and R 4; this two is known to us just by manipulating the R 2 and when we manipulate R 2 and we see there is no deflection here, right, then we get value of ah; obviously, we get the value of R 1. So, wheat stone bridge is used a wheat stone bridge is used for finding out the value of R 1 or change in r one. In fact, the value of R 1, once we find the change in R 1 delta R, this is change in R 1, once we know the change in resistance, we can always find the force because this relationship is already with us.

So, we can find the force applied on the wire, right and the second way of doing it is change in the resistance by temperature, one way this is the one way of changing the resistance, another way is changing the resistance by temperature and this change in resistance also can be done in by another way like as in the case of potentiometer in potentiometer, we do not put wire in the tension in potentiometer, there is a particular length of the wire.

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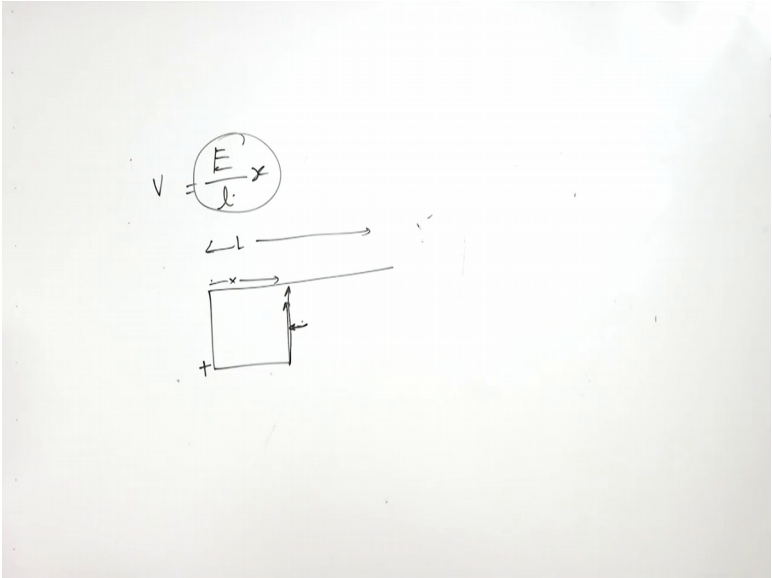

There is a particular length of the wire, right and this is plus and this is minus. So, this l by sorry V by E by x is the potential rate again E by l is the potential gradient, if we are taking only this is l, if you are taking output only x from x length of the wire the potential is going to be E by l multiplied by x.

So, now, this potential can be related with the movement of this indicator or yolk on the wire itself how much part of the wire is active, that will decide the displacement in the in displacement of this is related with output of the potentiometer and there is the another way by varying resistance.

So, one way of arranging the resistance is just to simply stretch the wire as in the case of strain gauges in the strain gauges strain is developed in the wire in the strain is measured. Now here, in this case that is the case of potentiometer, how the displacement is measured with the help of a potentiometer, another case is change in the resistance with temperature.

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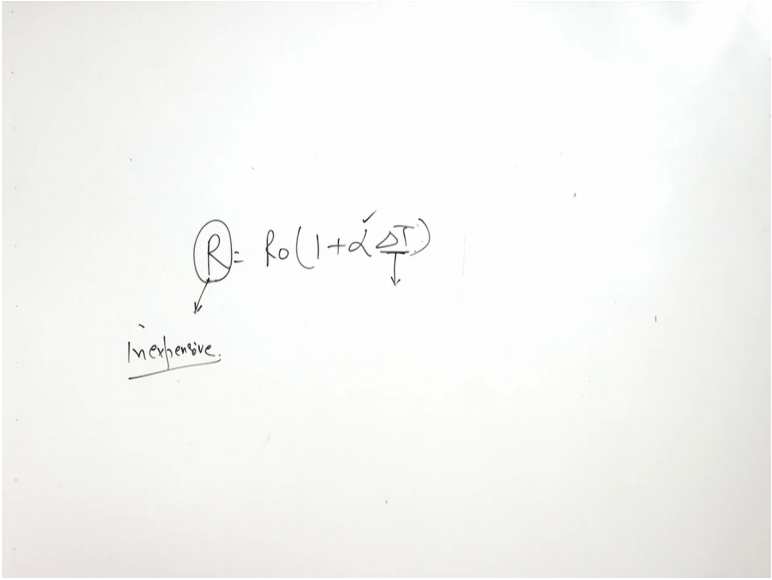

R is equal to Ro 1 plus alpha delta T. Now this principle is used for change in the resistance is used for temperature measurement, right. So, in this case, alpha for every wire or metal is known for every metal is known. Once we have the value of delta T, we can measure the change in the resistance, right and this change in the resistance or we just we measure the change in the resistance, this change in resistance would reflect change in the temperature all these devices will be discussing in details when I will particularly discuss some of the temperatures pressure at that time I will discuss in details all these issues will be discussed, right.

So, the resistance the best part of the resistance transducer is that it is inexpensive, if you go for inductive type or capacitance type of transducers, they are comparatively they are more expensive and these transducers are resistive transducers are simple to operate operation was not is not very typical and for large amplitude I mean if you are using potentiometer.

You can measure the displacement of the order of 1 meter, but if you take induct transducers like lvdt for a displacement measurement of 1 meter the size will be very huge and will be difficult to manage linearity will not be maintained, but for resistive transducers, right.

So, large amplitude of the input can be measured with these transducers electrical efficiency is high for this transducers, but the problem with this is for example, in the

case of potentiometer the considerable force is required to move the slide right and that causes the loading effect second thing is we are using a metal and properties of metal are with us for the pure metal which is 100 percent for example, copper we are using copper wire. So, we have the properties of copper when the copper is 100 percent pure.

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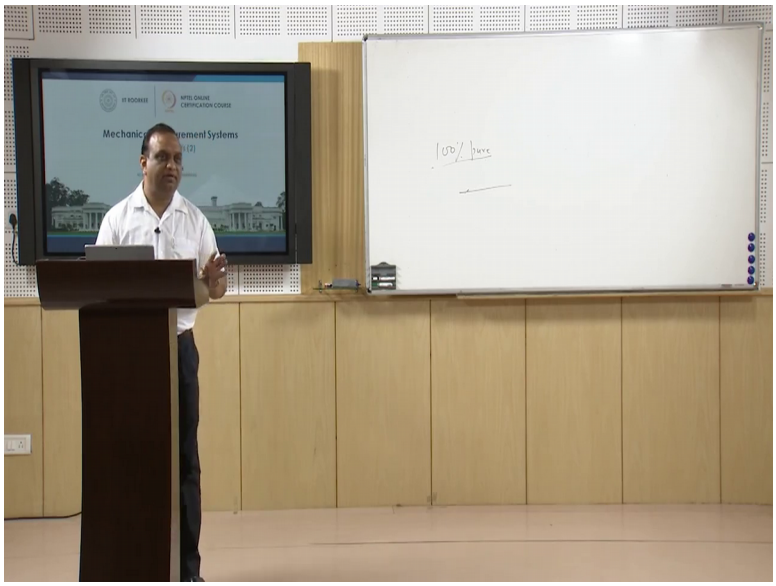

But normally we do not get copper at 99.9 percent of 99.5 percent copper right and still some continuation may be there that is one thing, second thing we are using a wire for some for resistance measurement, cross section area may not remain constant. They are some fabrication limitations cross section area may not remain constant when the slide is moving over the wire wearing of wire may takes place. The cross section area may reduce, there may be cut on the wires, some places; the connectivity is there, but some cuts are here that will alter the output for the system so.

So, these are certain drawbacks, but they are cheap, but on the one side, they are cheap on the other side, there are certain limitations also for resistive type of transducers will take one by one resistive transducers, for example, resistance strain gauge.

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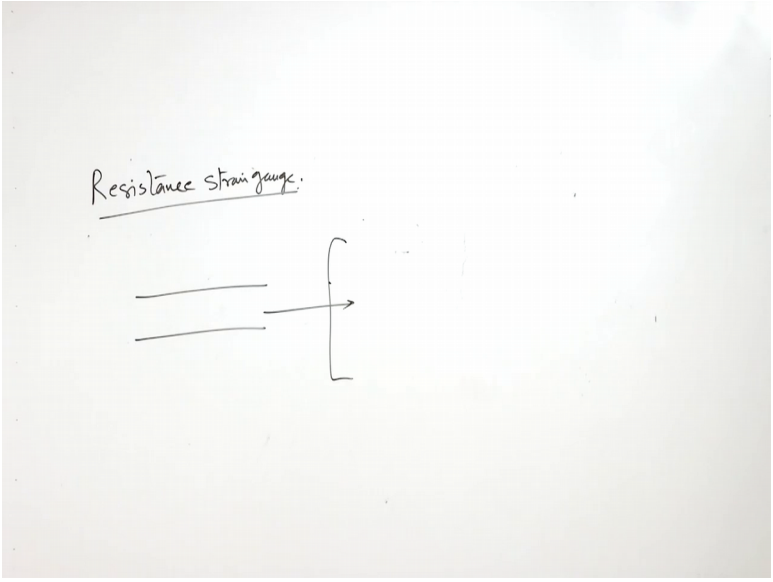

Resistance strain gauge; the principle of working of strain gage is when the strain is developed resistance is changed, right and these strain gauge are these are used for measuring the pressure for torque measurement also, they are used because if you are putting a strain gauge here it is a thin foil.

So, when the torque takes place the strain gauge will be strained and then you can measure the change in resistance and the torque applied on the shaft, the theta of the shaft you can measure and subsequently torque can be measured displacement also can be measured with the help of resistance type of a strain gauges resistance thermometers are here as I explained I mean with temperature resistance of the wire will change right or so, resistance of the substance will change, right and this will also cause resistance, this is how we can measure the change in temperature, we can relate change in resistance with change in temperature.

So, they are known as resistance thermometer resistance hydrometer also there hydrometer is used for moisture content. So, if there is a moisture content in the in the there is a porous resistor. So, porous resistor when the high humidity air comes the to the Porus resistor; its alters the resistance of the porous resistor.

So, this is how the humidity can be or moisture content can be checked moisture content in any mixture can be checked with the help of resistors hydrometer, there is hot wire meter; hot wire endo meter is also there to find the velocity and the and the and principle

is when a hot wire when the air is blown higher, the velocity of air more the heat is carried away by the air, right.

And if I want to maintain constant temperature on the surface, more energy has to be pumped in to the wire. So, this energy can related with the velocity or we are giving constant energy to the wire, then fall in temperature of wire that can be related with the velocity. So, this is also one of the application of resistance transducer photoconductive cells are there their cells when the light flux falls on the cell the resistance changes. So, this change in resistance with the light flux can further be related and we can get we can find the corresponding light intensity which is falling on the sensor.

So, that is another application thermistor is there, it is the semiconductor thermistor and it is a; it has negative temperature coefficient it means when we increase the temperature, the resistance of the thermistor reduces; thermistor is also used as a controlled device in many of the electrical applications and the relationship between temperature and the resistance is not linear, but it does not mean they are very accurate any measuring instrument which does not have I mean linear relationship linearity is required, but input output relationship if it is not linear.

It does not mean that is poor in accuracy the instrument can be non-linear at the same time, it can be very highly accurate and nowadays ICs are available. Now, the circuit are available where non-linear relationship can easily convert can be easily converted into the linear relationship. So, thermistor they are it has very non-linear input output relationship, but it is very good for temperature measurement potentiometer type of systems I have already move you expected you when there is a slide we slides moves on the on a wire and more is movement towards the earth more higher is the output from the potentiometer right.

So, there are certain devices which are used for which use the principle of change in resistance with the input signal. Now after this; there is a principle inductance.

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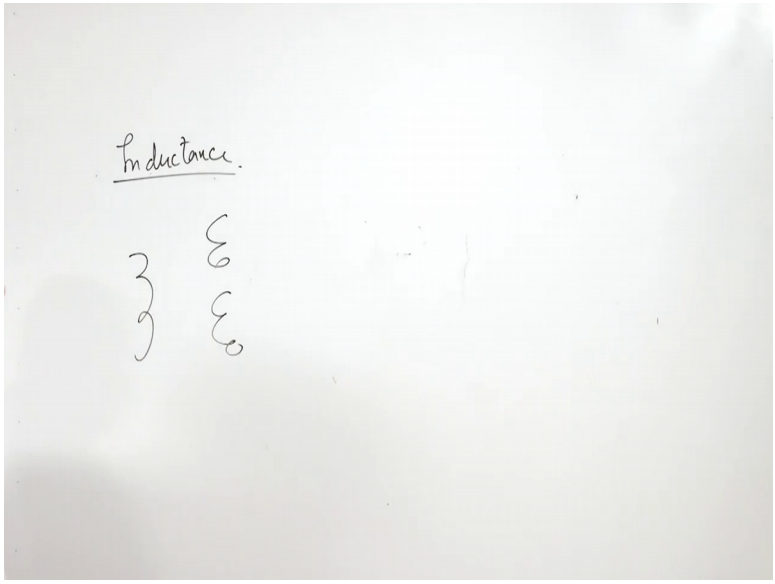

Inductive transducers; where the principle of inductance is used right these transducers either, they operate on mutual inductance or self inductance, right and when there is a change in the flux. So, necessarily they have to operate on AC, they do not have to operate on DC. So, when there is a change in flux EMF is generated, right, the work on this principle self inductance means there is there is change in the flux in the primary coil in EMF will be generated mutual inductance is if two coils are placed near to each other change in the flux in this coil will cause induction EMF in this coil, right and these transducers.

They operate in a in a limited range not like resistance transducers; they can operate in higher range. So, in compare with them they all rate in a in a limited range and lvdt; lvdt is one of the very popular transducer for displacement measurement E will be discussing in details in the subsequent lectures about lvdt and these transducers because they are working on an induction principles of electrical induction they have to be properly shield especially at the point of application.

If there is a lot of change in the flux at the point of application proper shielding of the transducer is required, otherwise, the transducers will responsive to the furious input and that will cause ultimately cause error in the measurement and third thing is core iron core is used normally inductive transducers, I will explain lvdt; lvdt also iron core is used iron

core works as a as a production for flux when the flux enters the iron core, it is it is to greater extent protected by the external influence.

So, iron core is not only used in many of inductive type of transducers. Now, they are differential transformers also which are used in because principle of transformers is also used in inductive transducers and differential transformer type of system is also, there is a one primary and two secondary this is used in lvdts, they are certain eddy current because eddy current also are induced. So, eddy current types of gauges are also used for the measurements; they also use the principle of inductance. Now the third one is capacitance type of transducers.

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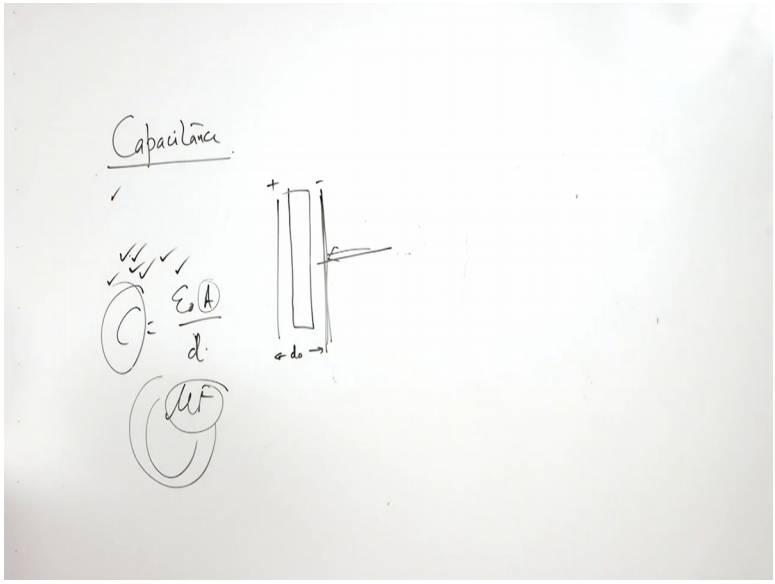

Capacitance; now if two; there are two plates; if they are charge plus and minus is a normal simple arrangement of capacitance and if even if it not filled, it is there air also right, then because capacitance is epsilon naught A by d.

So, distance between the plates right and if we change the value of d, either, we change the value of d, right, the C will change and then when we measure the C, we can correlate always correlate with C, with the change in resistance with the plates, if we change the area that is also possible suppose they are 2 disc, they are not complete disc, they are they are partially cut.

So, when we rotate one disc core the other then overlapping will change that will also change the C or we hence insert some; let us say iron core or some material dielectric ,material. So, dielectric strength will also change right that will also change this is the basic; I mean this is the physics kind this measurement by capacitance transducer.

So, it works upon it depends the output the capacitance depends upon the plate area the distant between plate and di-electrical strength of the material between these two plates and this C is again when we are able to measure C; we can connect these change in C with certain physical phenomena, right and, but issue here is because capacitance is always in microfarad or Pico Farads.

So, output signal is weak in case of capacitance or it is range is very small, if you farads change will takes place for a substantial input. So, that has to be unfired. So, that is one of the basic requirement in a capacitance transducers that output signal of the transducers has to be amplified because for a substantial change in input there is only small change in the output and so, magnification in this is a very important part in this type of transducers, right and rest of the thing, suppose, you connect a stylus of an output is displacement to this plate, then the this plate will move to this plate, then definitely C will change or force or friction is exerted on this plate that the plate will come into this direction in that case also C will change.

So, I mean they are many ways we can use this property of or these phenomena of capacitance for the purpose of measurement. So, we can have in we can have variable capacitance pressure gauges capacitor microphones are also there, I mean on microphone also I mean there is a pneumatic pressure or I mean the sound will they also cause pressure on this on one plate and the when the plate moves with the with the sound is and c will also change according to sound waves. So, we can have capacitor microphone also dielectric gauge magneto-strict gauge.

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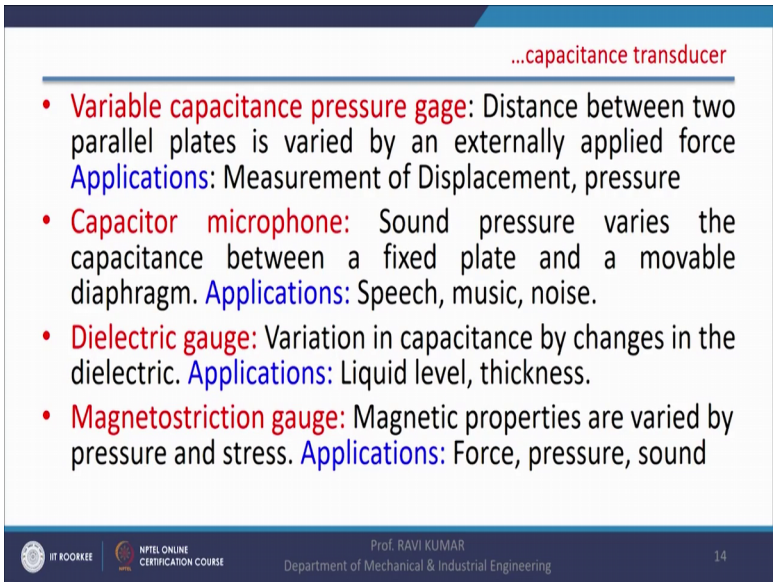

So, these types of gauges are having the working principle of a capacitive transducers. Now, a very interesting type of transform, we have already covered resistance induct principle of resistance and change in resistance change in inductance and change in capacitance. Now, in addition to this, there are transducers which are known as piezoelectric transducers now piezoelectric phenomena.

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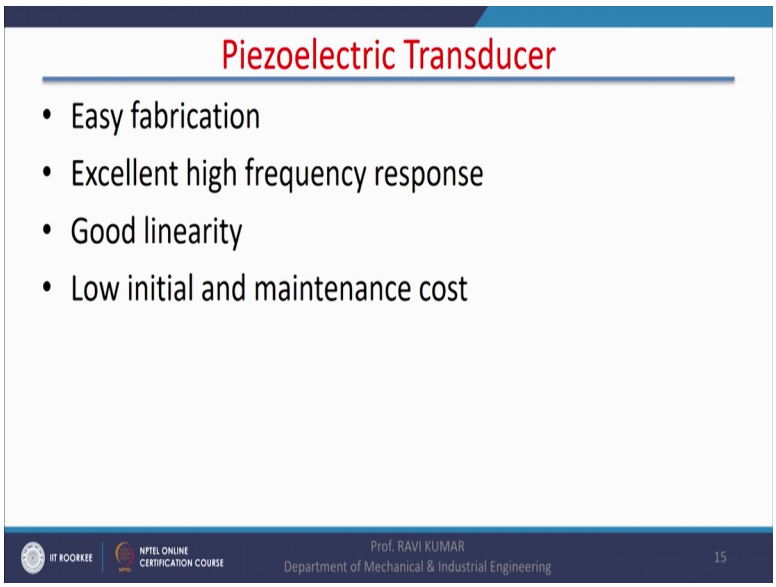

First of all, there are certain benefits of piezoelectric transducers, they are easy to fabricate.

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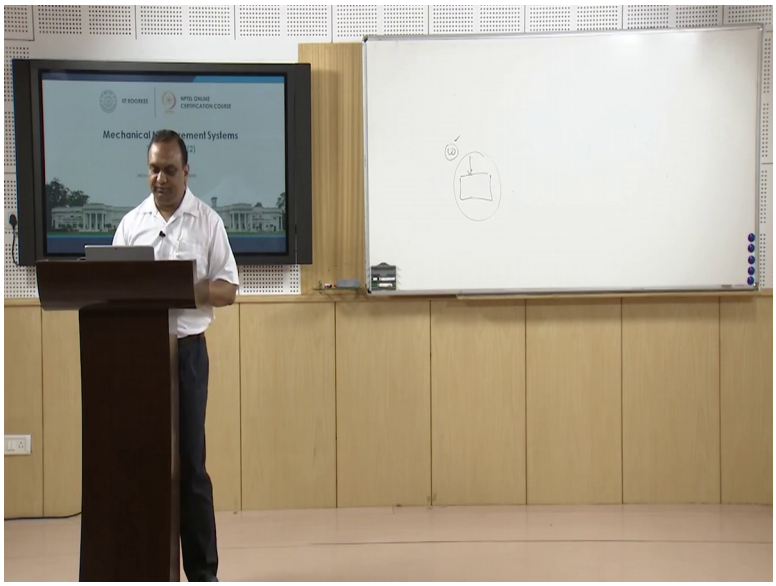

Fabrication is easy frequency response is very good for piezoelectric transducers where there is a frequency input for highly accurate transducers, this piezoelectric crystals are used, even they are used for the pressure measurement; pressure me measurement normally in pressure transducers, either strain gauges are used for pressure measurement or this piezoelectric crystals are used.

Now, the property of piezoelectricity is because there is a piezoelectric crystal, if you apply force or the pressure compress or try to compress the crystal EMF will be generated and this EMF is proportional to the applied force response of piezoelectric crystal is very good I mean it is mille seconds.

So, that is why for frequency input for frequency input that the best primary sensing element. In fact, they are very good primary sensing element their linearity is very good, then piezoelectric crystals, they are very good linearity there is no maintenance cost is very low. So, there are many points which are in favor of piezoelectric transducers, but piezoelectric sensors are costlier, if you compare with cost of the strain gauge processes piezoelectric type of sensors are quite costlier, if you compare the cost the piezoelectric material or it falls in three groups.

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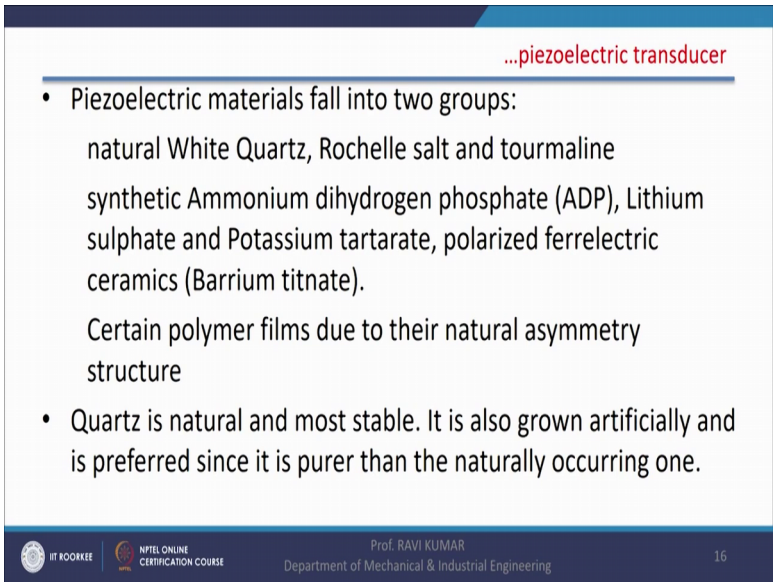

So, these three groups are natural the piezoelectric material which is found in natural nature.

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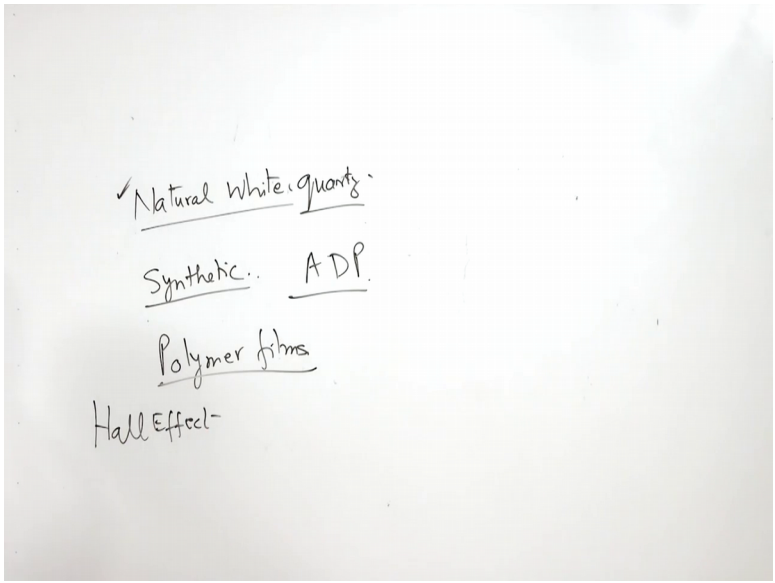

So, natural white quartz, it is an another material is Rochelle-salt that is also natural piezoelectric material tourmaline that is also natural piezoelectric material and some are synthetic piezoelectric crystals. So, synthetic piezoelectric crystals is first of all is ADP ammonia dehydrate phosphate ADP, it is a synthetic Piez piezoelectric crystal lithium sulphate and then many just giving one some example polymer certain polymer films

also work as a piezoelectric transducer polymer films they also work as a they also have property of Piezo electricity, but the natural quartz is most stable, this natural qua quartz is most stable and it is also grown artificially and is preferred since it is pure than naturally occurred ones.

So, natural quartz natural quartz is most stable type of piezoelectric transducers. So, they have certain relative merits and demerits the will discuss when will discuss in details about the piezoelectric transducers certain transducers work on the Hall Effect. Now, Hall Effect is for example, there is a conductor there is a conductor.

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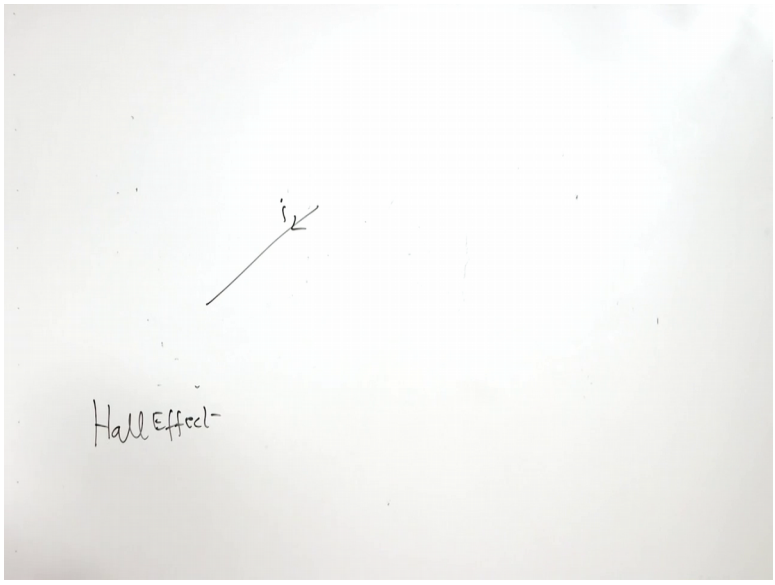

Right, suppose this is a conductor right vertically if I am I magnetic field is applied across these two edges EMF will be generated repeating suppose current is in going in this direction the kinetic field is vert; there is the vertical magnetic field or downwards critical field EMF will be generated between these two phases depending upon the direction of magnetic field and direction of current flow, right and this effect is also used in number of measuring devices the certain bio sensors also.

So, bio sensors they are biological substance which are sensitive to certain type of input. So, in subsequent lectures, I will I will cover the bio sensors also because nowadays there is lot of stress on bio sensors, right. So, this is all for today.

Thank you very much.