Dynamics of Machines

Prof. Amitabha Ghosh

Department of Mechanical Engineering

Indian Institute of Technology, Kanpur

Module No. # 14

Lecture No. # 02

Vibration Measurement: Types of Pickups

In the last presentation, we discussed about some commonly used pickups known as velocity pickups and accelerometers. In this presentation, we will discuss very briefly almost in the (()) manner of various types of transducers, which can be used in special circumstances. Some of them are contact types; some of them can be non contact types. We continue with our discussion on vibration measurement.

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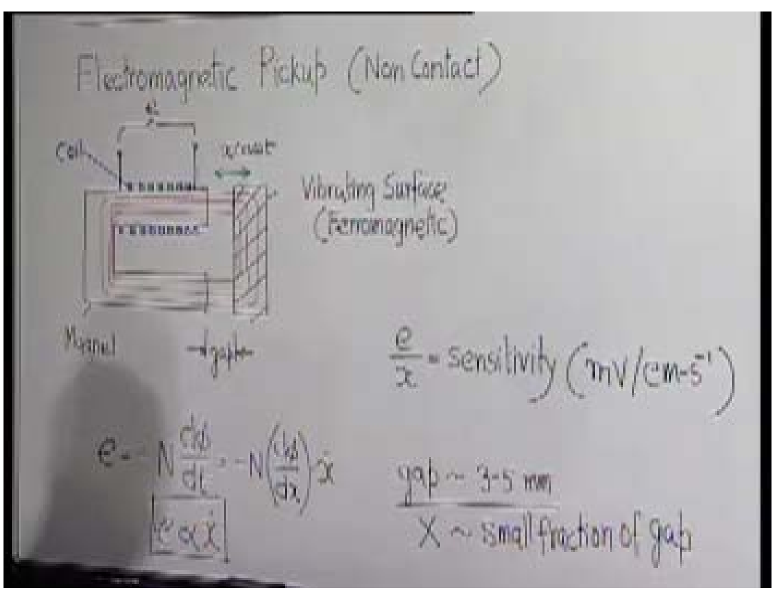

First, let us take a non contact type pickup based on electromagnetic induction. The basic scheme is shown. This is the coil; it is wound about one leg of this permanent magnet; this is the vibrating surface; it as to be ferromagnetic; this is the gap maintained and this is vibrating.

Now, let us see that the flux or magnet flux completes their path like this (Refer Slide Time: 04:10). If that be so, the intensity of this depends on what is the gap. So, as the gap fluctuates, the flux changes and since this coil is there, - we know from the basic theory of electromagnetic induction - that when the flux inside the coil fluctuates or changes with time, the voltage is developed. That means what we will get? We will get the voltage generated and this voltage is given by the number of turns. The flux, as you know is function of the gap and we may say as x cosine omega t. Therefore, we can write this as minus N into dphi by dx. That means the quantity, that means, the flux depending on this gap, which is given by this quantity, is a quantity dependant only on the configuration of the whole thing dimensions material and all those things and this obviously is dx dt; therefore which is x dot.

The voltage which you get is proportional to the velocity of the object, which is again a direct velocity pickup. What we will get? That means the sensitivity; that is, the voltage divided by the velocity is called as sensitivity. We may use some unit like mille volt or centimeter per second; centimeter per second is the velocity and voltage is the mille volt; these remains fairly constant. One thing we have to keep in mind is that, this is not going to remain a constant quantity, unless this vibration amplitude is small as compared to the gap. That means, the gap is not changing much and this gap is maintained in the range 3 to 5 millimeter and the amplitude of vibration X is a small fraction of the gap. In that case, this remains fairly constant and the voltage which we get e becomes proportional to x dot and the ratio is considered to be sensitivity of the pickup. Now to get some idea about the typical sensitivity, we plot as follows.

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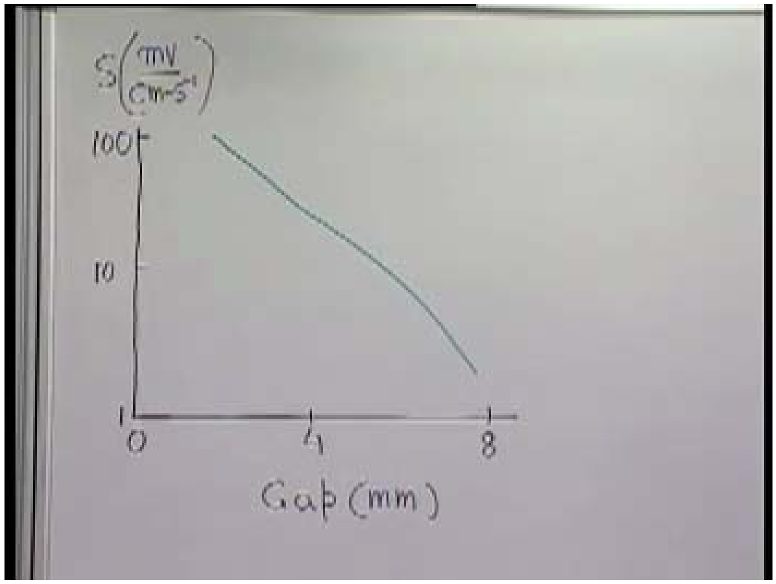

We plot the sensitivity in mille volt per centimeter per second, this is 0, 4, 8 and 1, 10,100. This will be sensitivity in mille volt per centimeter per second ((plot this)) what we will get is something like this, fairly a straight line but not exactly a straight line; but, this is the kind of characteristics for a pickup (Refer Slide Time: 09:14). One thing we can see is that, the change in gap; changes the sensitivity quite drastically. So, what we will get here is that unless the vibration is extremely small, but in normal case we will find that this is not exactly a constant. Therefore, we cannot say e will be proportional to x dot; that means what? It introduces certain amount of non-linearity because this by itself is a function of x, not a constant. So, e cannot be a linear function of x dot. So, the non-linearity will be introduced and there will be certain amount of distortion of the shape of the wave form; what we will get from here and the actual vibration, they will not match exactly.

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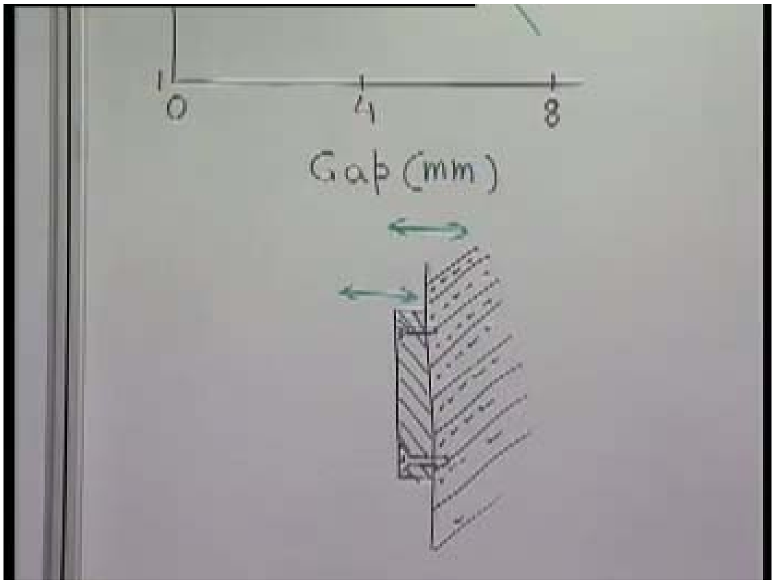

Now, another point we have to keep in mind when using ferromagnetic pickups is that this material will have to be a ferromagnetic material. There can be an object which is vibrating and we want to measure its vibration, but it is not made of ferromagnetic material. In such case, we try to solve the problem by this technique. If this is the material, which is not a ferromagnetic material but a plastic or a brass or something; not steel kind of things (Refer Slide Time: 11:04). Then what we do? We attach a ferromagnetic piece and the vibration of the original body is also the vibration of ferromagnetic plate, we have added. So, slight modification of the object has to be done by using this principle (Refer Slide Time: 11:49). So, when the system is not too small then it is possible to use this technique.

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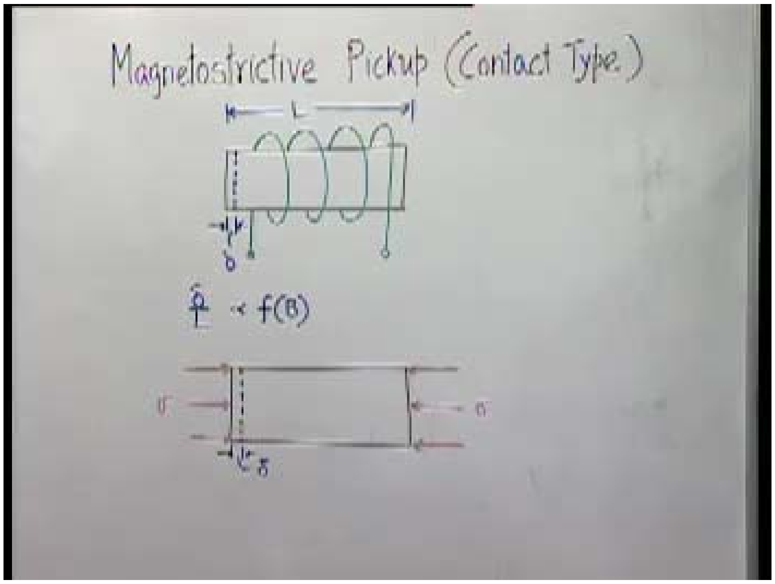

Next type of vibration pickup which we can use is based on phenomena, which we call magnetostriction and these pickups are of course, contact type pickup. What is magnetostriction? I hope it is all known to you; but I will give a very quick reference. When you enter some substation or such installations, where there are no moving parts, but there are only transformers which are again a stationary object, but still we get some humming sound; for example, when there is a motor and somehow the motor gets jammed and there is no rotation, but when alternating current is flown, we get humming sound, what is this? This is nothing but the result of magnetostriction.

Magnetostriction means, if we take a ferromagnetic object and it is subjected to some magnetic field, when a current is passed what happens? This will be magnetized and then what may happen? The length of object may undergo small change delta, now this delta by l, which is a coefficient of magnetostriction, where l being the length of the object is proportional to the function of the magnetic field (Refer Slide Time: 14:31). This is a property of the material, say for example; most ferromagnetic materials indicate certain degree of magnetostriction and this changes. When we supply an alternating current, the magnetic field in the object varies or fluctuates with time and the length of the object will also vary; though the amount is extremely small in micron range, but still when it is there, it can produce the sound. These phenomena, that means where a voltage is induced and it produces a strain is called magnetostriction. The other effect, where the reverse is also true that means, if we take a magnetostrictive object and try to apply some force or stress and change the length; the length changes. This will then generate some magnetic field. So, inducing a magnetic field in a ferromagnetic material changes its length. Similarly, changing the length by some trace, causing a strain generates a magnetic field reverse; this phenomenon is utilized in this type of pickup.

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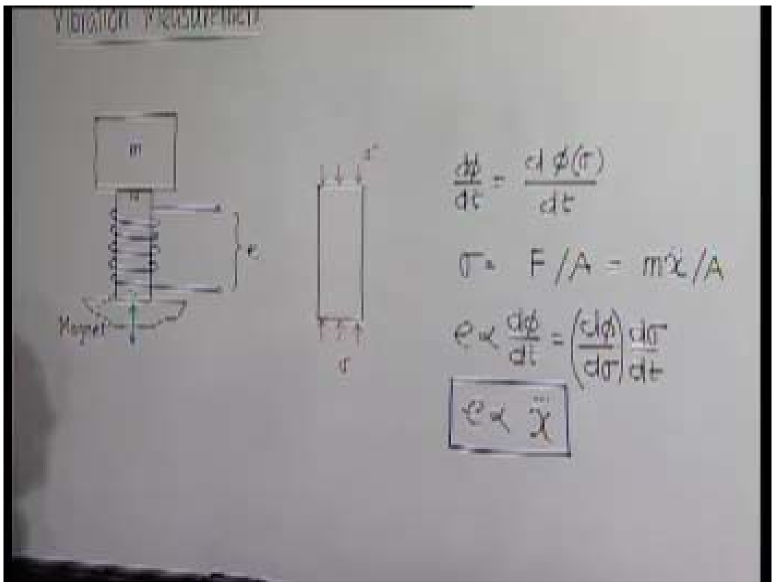

Basic principle of the pickup is like this as shown above, this end is subjected to vibration; this is the magnetostrictive material, where this is the South Pole; this is the North Pole; this is a magnet. What will happen now? We will find a voltage will be generated here. We consider this magnetostrictive material; a magnet and this is subjected to a load, what load? This side of course is connected to the original body and the other side is connected to this (( )) mass. So, this will be subjected to space ((it will be in loading)) of this mass.

If it is cyclic or periodic phenomena, then the flux here will fluctuate because this space will produce some extra flux due to magnetostrictive effect, as I mentioned. Therefore, dphi by dt, which is going to generate this voltage will be proportionally equal to dphi, which is function of sigma (Refer Slide Time: 19:28); how much is sigma? Sigma is equal to the force by area; how much is this force? Force is mass into x two dots divided by area.

Now, the voltage generated is proportional to dphi by dt or this dphi by dt can be written as dphi by dsigma into dsigma by dt. So, effectively e becomes proportional to x three dots. You see dphi by dsigma is quantity which depends on the configuration, dimension, material, and so on. That means, this system of the equipment property can be treated to be something constant for a particular experiment, but this dsigma by dt will be what? It will be proportional to x three dots. So, the voltage what we get here is proportional to the jerk or the rate of change of acceleration, which of course can be integrated electronically and output can be either acceleration, velocity, displacement or whatever you want. Basically in magnetostrictive transducer pickup, the voltage we get is originally dependant on the jerk or the rate of change of acceleration.

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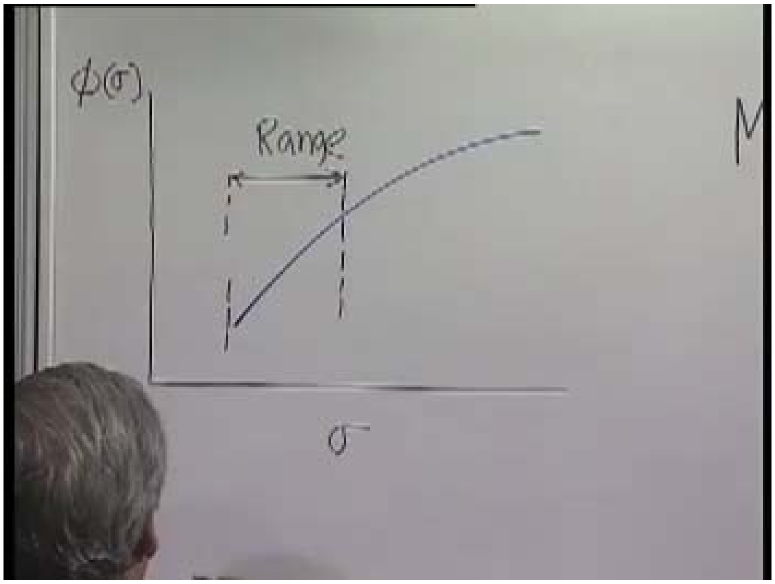

The dphi by dsigma, if you want to have some idea, let us plot the characteristic. The nature of the curve will be generally something like this, so only a small range where we may take it to be approximately lenient ((after that it can easily become non-linear)). As mentioned earlier, we should always try to get or achieve linear characteristics. In a particular case, if you want to do a general thing; this is sigma in kilogram per millimeter square, kilogram or force it is not an SI unit which has given in this. (Refer Slide Time: 22:44).

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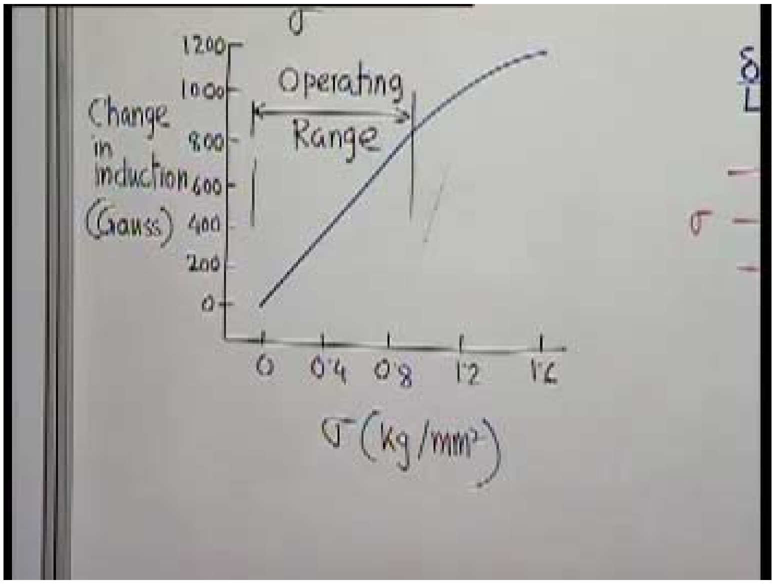

This is the change in induction in Gauss; it will be 0,200,400 like this. This is the realistic values for a particular case, so you can see that the operating range could be very easily found (Refer Slide Time: 24:09). This of course, you can really understand that if you have to attach it to the plane vibrating body, this becomes contact type.

Next, we take up another type of pickup which is again a non contact type pickup and are generally used for special purposes, they are based on the variation in capacitance due to the variation in gap, because any vibration - that is mechanical movement or displacement - can somehow be translated into the variation in the capacitance of the system and that can definitely produce some electric signal.

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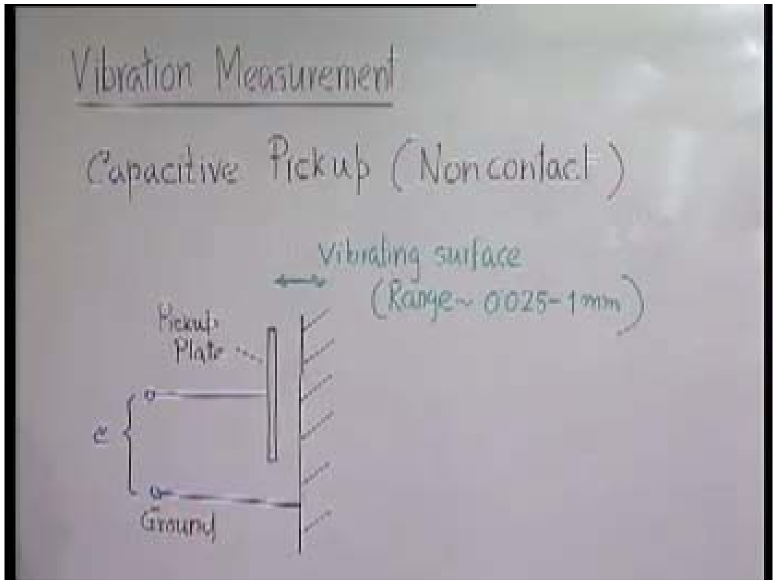

The basic principle, as you can see is very simple. If the surface of the object is vibrating, we place another plate parallel and very near to this (Refer Slide Time: 27:44). The capacitance of this system is produced by the two nearby surfaces, so they form a capacitance and that variation in the capacitance will be measured. One thing is very clear in this case that such type of devices cannot be a passive type. In the all other previous cases, where we generated some voltage which did not require outside source; the voltage was generated by the process itself. In this case, that is not going to be the case and we need to have an arrangement.

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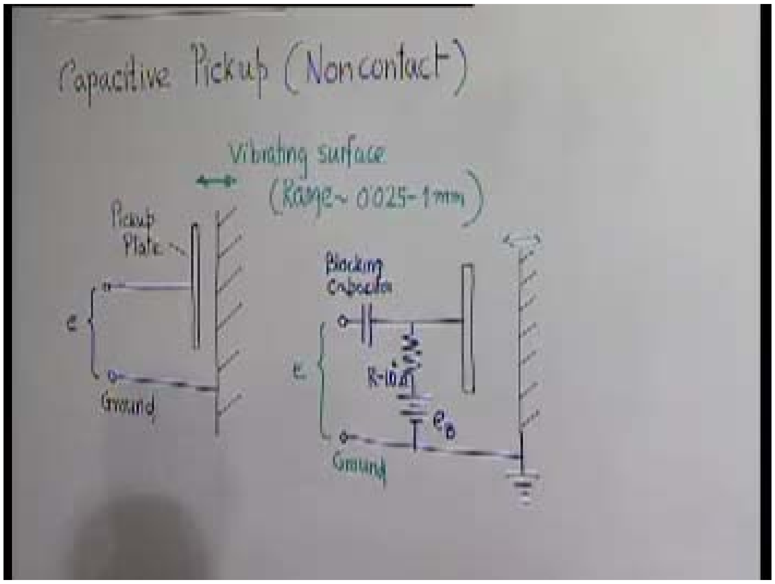

This circuitry which has to be used, its basic principle looks like this as shown above. We have to apply a bias voltage through DC force; it is connected across this gap with the help of very high resistance 10 to the power of 6. Since the whole process is a dynamic process and we cannot just attach it because then instrument itself this impedance will affect the current through this, so what is done? A blocking capacitor is given here, so the variation in capacitance here generates a fluctuating voltage. This particular device also will have non-linearity mainly because the capacitance is very sensitively dependent on the gap and that makes the situation non-linear and also the signal produced will have some distortion. One more thing to be kept in mind is that generally capacitance variation is used as special purpose cases, standard capacitance pickups are really used and they are available. So, when a particular situation is somewhat special and then this principle can be used in picking up the vibration.

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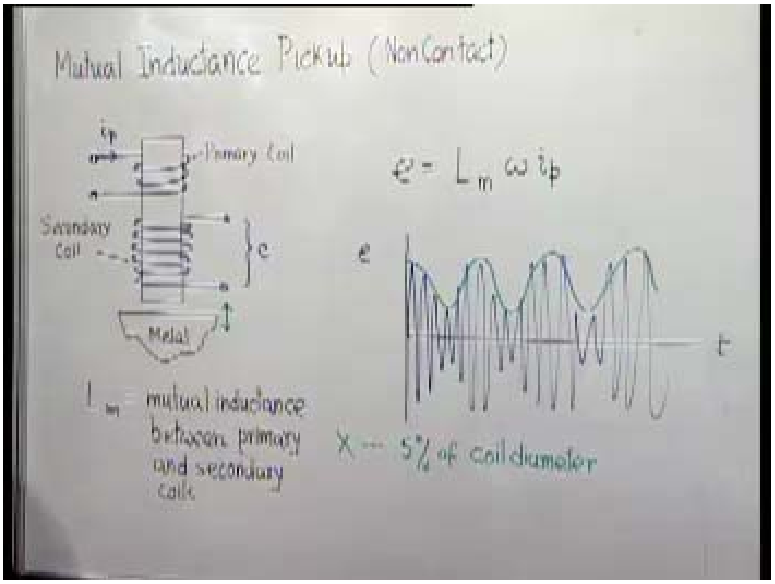

The next type of pickup is based on mutual inductance and which is also a non-contact pickup. There are two coils around same core; one is primary coil and other is secondary coil and we also pass a primary coil current i_p so that the field is established. Now, by any chance if we can change the mutual inductance; we can generate the voltage in the secondary coil and by changing this mutual inductance between the primary and secondary coils, let it be L_m; L_m be the mutual inductance, then the voltage which you will be able to generate will be equal to mutual inductance omega into $i_{p,}$ where i_p is a high frequency primary coil current, whose frequency is omega. So this is not a DC, actually it is a very high frequency current in the primary coil whose frequency is omega. In that case, if the mutual induction is $L_{m,}$ the voltage generated here will be e.

Now what happens, this gap which is a metal and due to the eddy current which has generated here; it produces an effect which changes the L_m. So, what would happen is interesting, if omega i_p is a very high frequency current; it will produce a voltage e something like this (Refer Slide Time: 36:05). Now, this fluctuation is because the mutual inductance is varying due to the variation of this. Therefore, the modulated output which you are getting, if it is demodulated, we will get fluctuation like this, which represents the vibration of the object which we are trying to measure.

The mutual inductance variation can be made almost linear over a displacement range approximately 5 percent of coil diameter. If the amplitude of vibration is kept within 5 percent of the coil diameter, then the mutual inductance variation can be made approximately linear or approximately proportional to the displacement or the gap. Therefore, the shape which will generate will not be much distorted and we will get reasonable degree of faithfulness of the result. This is also of course, you can see a non contact type pickup and just to get some idea about the magnitude of the effects, we can take a particular case.

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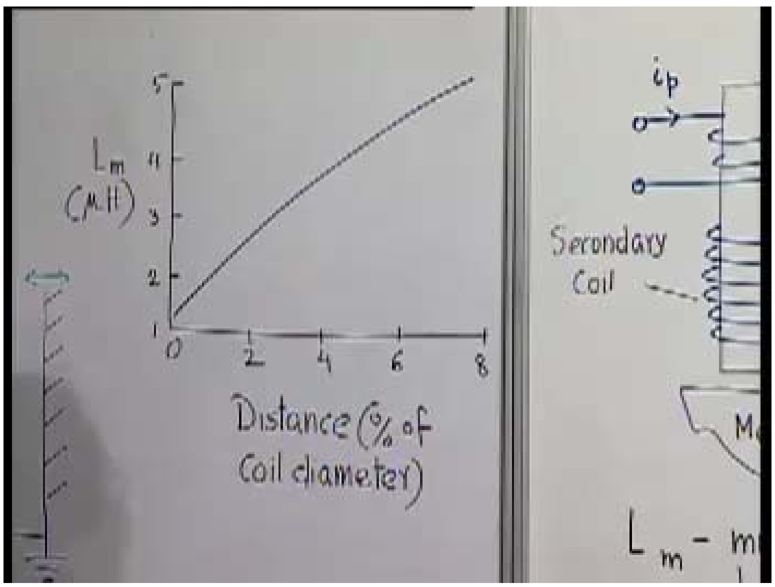

The distance or gap in percent of coil diameter and mutual inductance in micro henry, I will give in smaller scale 1, 2, 3, 4, 5 otherwise it will be too flat. This variation, we see will be almost something like not exactly linear, but almost a straight line; if you leave it or keep it within 5 percent of the coil diameter. So, this is the order of magnitude involved which can give better idea about the kind of quantity involved. There are many other types of pickups; I must say there are varieties of pickups in whole branch of Engineering, one may say by sensing vibration because it is used not only just to measure vibration, it is used for a condition monitoring, it is used for sensing the held of a particular machine or a system and so many large number of applications are here. There is another technique which is commonly used in any kind of vibration or dynamic measurement which I will just brief the function that is by using the strain gauge.

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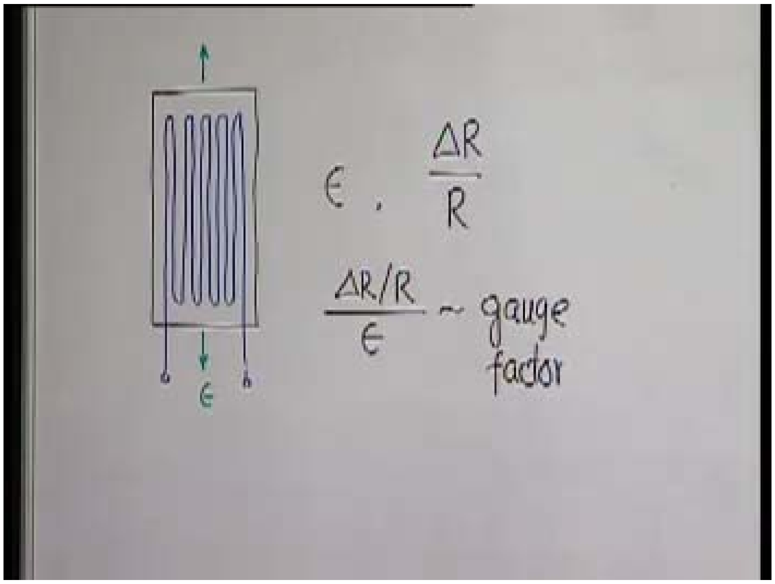

Now, I think again, what are strain gauges? It is known, but even then I will just give a very quick overview. The strain gauge is a very small, maybe one centimeter by fraction of a centimeter long, a (( )) kind of thing in which it is embedded to a very thin wire. Now to have a large length of the wire, we have to loop it like this, so the total length of the wire is very large and the resistance is measurable, but the overall dimension of this is small.

Now, what happens if we stick or grew it to a surface which undergoes extension or something? Suppose, if there is a strain or stress -whatever may be in this direction- then what will happen? The total length of the wire will increase by strain and as a result, it will cause change in the resistance. So, your strain and the fractional change in the resistance will be proportional.

Therefore, this quantity that means, change in resistance as a fraction of a resistance by strain, is something called gauge factor. In the ordinary strain gauges the gauge factor can be of the order of two or three, whereas in the semiconductor strain gauges it can be a couple of hundreds. Anyhow, this change, that means; it is very suitable for measuring strains. Let us see how you can use it, if we have to measure the vibration ((poor audio)) as an example.

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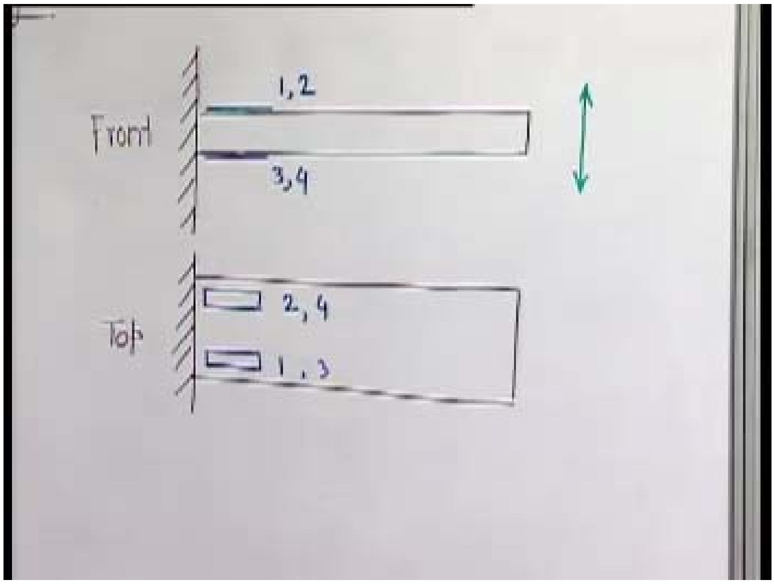

These are the two views: one top view, one front view. The top view and the front view at the same ((calculated beam)). Now when it vibrates; vibrating means it bends, what happens? It stretches like this when it goes down, so the outer surface will be extended and the lower surface will be compressed.

Similarly, in its upward half cycle, this will be subjected to tension and this will be subjected to compression. If we now apply strain gauges likewise, we put one strain gauge here, one here -on the top surface- and therefore, in top surface we have 1, 2 in this view, they will look like this. Similarly, in the bottom surface, we will have 3 and 4. So, during its bending 1and 2 are undergoing tension that means resistance will increase. Similarly in this side, it is under compression so resistance will decrease. Now this is used in the form of a bridge and the voltage is generated in this manner.

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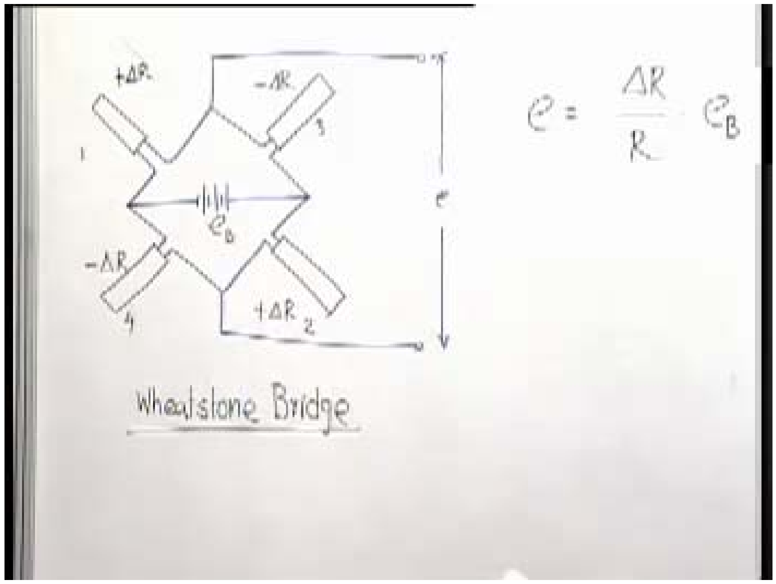

Now resistances or these strain gauges, I am representing like this, not that they are physically kept like this, but thus electrical circuit point of view am just keeping like this. If it is 1,2,3,4 and the circuit will have this kind of arrangement that means, which is called Wheatstone bridge. On principle, we could sense the resistance variation of only one strain gauge, but the sensitivity will be low.

The sensitivity can be improved or the electric signal generated can be made much more, if we use the concept of the Wheatstone bridge, where this is strain gauge 1, this is strain gauge 2. When it is going downward direction here, the change in resistance will be delta R; here also it will be delta R; here it will undergo compression; so this will be minus delta R, and this could be also minus delta R. So in the condition, when it is balanced that means all of them are deformed and resistance R, R, R, R. Then, if we apply a voltage here the output voltage will be 0.

Now, if it starts vibrating, what will happen? The unbalance will be created at any instant. You can see the ratio of this and this, a ratio of this and this will have maximum difference, because this resistance is increasing this decreasing and this is decreasing and this is increasing (Refer Slide Time: 47:55). Therefore, what happens is that effectively the voltage which is generated is four times and which is given by delta R by R into e_B and then this output can be taken to any record and can be studied and that means the vibration, the frequency, amplitude everything can be studied. Of course, we have to keep in mind that in all such instrumentation and measurement, it is essential to have proper calibration; that means; you have to give some known deformation and then find out the voltage, so that when you measure the voltage we know that how much deformation or strain has been created. So, this type of strain gauge used is very wide and in many cases, when a machine or a something is vibrating, where we cannot put any pickup or something it can always scrub the surface and we can attach a strain gauge and we can sense the strain it is subjected to or the surface is subjected to and that gives the idea about the vibration it is under gone.

This brings us to the end of out last module where we have studied measurement but as I mentioned it is a huge subject. Instrumentation we have to discuss, circuits we have not discussed and only some basic principles of some commonly used transducer we have discussed in this presentation.