Experimental Physics - III
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture - 20
Measurement of Magnetization of Ferromagnetic Material (continued)

now I will demonstrate the Vibrating Sample Magnetometer. How we use vibrating sample magnetometer for measuring the magnetization, as a function of magnetic field, as a function of temperature alone can do the experiment. But, here we do not have option for temperature variation. we will do the experiment measuring the magnetization as a function of magnetic field.

as I told that I need magnetic field, this is the electromagnet.

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I can show this is the electromagnet and this pole piece these two are pole pieces. These two are pole pieces electromagnet that, we have power supply here.

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Electromagnet for power supply here; power supply here. we are applying current to the coil of the electromagnet from this power supply. This DC power supply. and this is the gauss meters This is the Hall probe; this is the Hall probe; Hall probe.

first we have to calibrate the electromagnet How to calibrate the electromagnetic, many times I have discussed. first using the Hall probe, we have to calibrate the electromagnet applying different magnetic field. from that calibration, we can find out the magnetic field for different coil current.

now, that is why I have kept this Hall probe just outside from this from the center of the electromagnet. but you can change; when you want to calibrate, you can just put this Hall probe inside the at the center of the pole pieces.

then after calibration just we will take out from here, we will take out from here (Refer Time: 03:06) there. next you see as I told that is in VSM setup. there is a rod and this rod, this at this end of this rod this is a cylindrical coil kind of things this cylindrical things we can see. there we have put sample we have put sample in this at the end of this rod, here this at this end. this is the sample holder, there we have put sample and that holder is attached with this rod; this holder is attached with this rod and it is other end of the rod is connected with this the loudspeaker head. This is the loud speaker head.

Now, loudspeaker head; rod is connected with the loudspeaker head and other end we have used for putting the sample here. Now, you see this two we can see this two wire is coming. this two wire is coming from the pickup coil Here, you see here there is a wooden these two wooden pieces to hold the coil to hold the coil, coil is here, coil is here you can see coil is here.

We have put on the surface of this wooden pieces, on this both side of the and this wooden piece, we have attached with the pole of the electromagnet pole of this electromagnet. these two wires, this one and this one, these two wires are coming from the pickup coil from both side, pickup coils are there.

Now, these two wire; this wire and this wire, this wire, this wire; this both this here you can see two wire.

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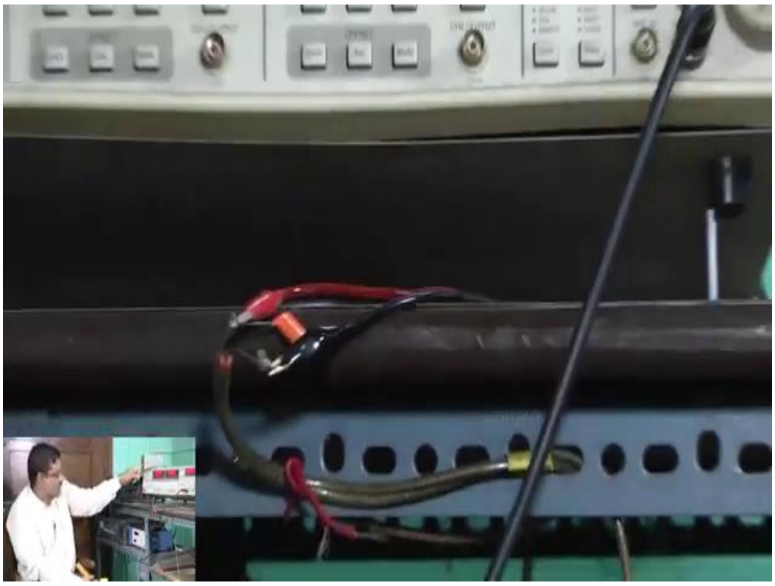

these two wire is from pickup coil. this is this will give us the signal vs, sample signal vs equal to v 0 sin omega t plus phi s as I told you. these signals are we are putting this is the signal, we are putting on this.

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This one is amplifier; lock-in amplifier. this signal whatever we are getting from the sample, we are getting from the pickup coil, that signal we have giving to the input of the input of the lock-in amplifier.

lock-in amplifier is used to measure the very weak AC signal. in this case, the due to weak due to weak magnetization; magnetic flux also will be weak and the induced EMF also will be weak. to make the detection sensitive people use lock-in amplifier.

in this experiment, it may happen that the signal is very small compared to the knowledge. to pick up to take out this signal from this knowledge lock-in amplifier is the is called lock-in technique is very powerful technique, lock-in technique is very powerful technique to pick up the to get out the signal from the noise.

here whatever from this coil whatever a coming that is input signal we are giving, in that signal this signal this our not only signal of our interest is not there, with that lot of electrical noise is there. some noise or maybe these higher amplitude, than the then our signal of interest. now, you put them in an ordinary amplifier before measurement, then what will happen?

Then, it will amplify all. It will amplify all Noise as well as this signal. that will not be effective for measuring the weak signal of our interest that is why lock-in technique is used. lock-in technique will give me the will give me the signal of our interest; signal of our interest. how lock-in will know that that which signal you want. that from frequency.

If I know the frequency of my signal, I want to measure the amplitude of the signal basically; if I know the frequency of the signal, that then we can we can get this signal from the signal out from the noise. that that I have to tell the lock-in, I have to tell the lock-in to lock a particular signal of which frequency is known to me and that I have to tell to the lock-in amplifier. that we tell reference signal.

we use the reference signal; the frequency of reference signal is same as the frequency of the of our signal of interest. reference signal internally you can generate there is oscillator inside this lock-in amplifier, you can generate from this lock-in amplifier or externally you can give. There is option reference in externally I can give, externally here you see here this reference signal. externally I can give to this to the lock-in.

in us in this present case, we have used the internal reference signal. So, what we have done? internal reference signals that frequency of that signal we can hear you see these references retail, here reference is retail reference. from this we can set the frequency of the signal reference signal, amplitude of the reference signal. here you see this frequency, where visited frequency.

the signal we have used that the frequencies 80 hertz 80 hertz frequency signal we are using amplitude is these 0.01 volt and its phase angle is this minus 1 to 9.27 degree, these phase angle of this reference signal; that signal out. that same signal we are taking out and putting to the putting to the amplifier; putting to the amplifier of the loudspeaker

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that I have put to the amplifier of the loudspeaker. loud speaker will vibrate with this same frequency of the signal of the signal and the, what about amplitude we have given that amplitude I can amplify here. 80 hertz signal sinusoidal signal here you can see these which type of signal. It is a v 10 anyway.

sinusoidal signal is given to the amplifier of the loud speaker and there from the backside of this loud speaker, this amplifier that is that through this wire, here you can see this wire that power is given to the loudspeaker that means, loud speaker that rod is vibrating that rod will vibrate with these with the frequency of 80 hertz.

now, what we saw, this we have this arrangement that where this loudspeaker will vibrate with will vibrate with the frequency 80 hertz. now, that signal we will get the signal that we will get, that we are giving to the lock-in amplifier. the frequency of the signal will be 80 hertz this 80 Hertz that our signal of interest along with lot of noise of all sorts of frequencies.

And amplitudes will come through this wire and putting in the lock-in amplifier. Lock-in amplifier principle as I mentioned you earlier I have discussed about the lock-in amplifier. Lock-in amplifier will lock the signal of that frequency 80 hertz and other will be eliminated. Only that signal of 80 hertz will be detected by the lock-in amplifier and corresponding the voltage will see here.

lock-in amplifier if you adjust the phase angle properly as I mentioned that you will get only these amplitude part, these DC part. This is the amplitude cos phi. if you if you adjust this phi cos phi; phi is the phase difference between initial phase difference of reference and our signal. if you change, if you change the, if you change the phase of the reference 1 to make this phase difference 0, then what will happen? This cos phi as I told; this that will be 1. you will get only amplitude this value we are telling x value.

similar, the system inside this there are similar another system, where this amplitude and sin phi term will produce that we tell, y; two displace are here; one is this and another is this. this for cos phi amplitude, cos phi term and this is amplitude sin phi term. that means, we will adjust the phase of the reference to make when we will make it maximum x, then y will be 0 and vice versa.

If you just add the 90-degree phase additional phase, then just opposite scenario, we will see here, x will be 0 and y will be maximum. x or y, that is showing the amplitude part right; amplitude into cos phi term. amplitude we are interested about the amplitude or r. one is x another y. r square equal to x square plus y square; r theta x y and r theta. relation is r equal to square root of the x square plus y square and theta will be tan theta equal to or tan phi equal to y by x.

either if you can adjust this x and y and then you can find out this also will it will calculate your itself and it can there are option to show the r and theta also. either you we are interested about the amplitude. either you can just put at the r, display here you can see, if I can put at r if I r square root of x square plus y square and if you can adjust (Refer Time: 17:39) to make x maximum y 0 or y maximum x 0, in that arrangement if you make. then only you can note down x or y.

that is amplitude of this amplitude of this signal of 80 hertz signal. I have 80 hertz reference signal this is phase. I have adjusted. Now, I will switch on I will switch on.

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I will, I have to. experiment now, what I have to do? I will start this 0; from 0 coil current electromagnetic coil current I will go to the maximum value. I will start the experiment for maximum value then from there I will change and go to the negative current and maximum and then, come back to this. This way I will complete the work complete the loop.

here it is it is not bipolar; it is not bipolar. just one side that we will do and then, one should reverse the quality and do the other side this is the this is the power supply for the electromagnet. here I can give current let me give maximum current say I will go to the 8.73 ampere. for that current what is the magnetic field for calibration, I will know. Now, for this here my sample is (Refer Time: 19:31), it can vibrate slightly it is in almost middle. I put in middle

Now, at this magnetic field there is a magnetization I want to measure that magnetization, now I will have to vibrate the sample. for vibration of the sample, I have to change the. I it is switch on. here amplifier. this loud speaker amplifier, I am changing the I cannot change the frequency, but I can change the amplitude to make this vibration I set this amplitude like this around 5 here.

Now there are some small sound but if I switch off this magnetic field, then one can. this vibration amplitude is not much it is difficult to see, but it is vibrating you know.

from loudspeakers with this 18 hertz, it is vibrating. Now, what I will do? now, I should get signal here This is adjusted. let me check it that now, we have to see whether my system is or not. each time what you can do? (Refer Time: 21:13). I can go I can change the phase I can change the phase to get maximum, here you can see I have changed I am making y 0, I am making y 0, I am making y 0, changing the phase initial phase of the reference signal. This is more or less 0. This side it is a 0.1809 millivolt, that signal amplitude other side is the 0.0054 it is fluctuating. But I can make it I think yes, I am trying to make it 0 more or less it is this is the value.

Now, you see here I have option to just add 90 degrees, with the reference. phase difference whatever, now, it is 0 phase difference. If I put this on you see that these become almost 0 and this other one becoming maximum, this similar value. it is a minus 90 means I can come back original one.

this the one has to do this exercise because, then you will be sure that your setting up this lock-in is perfect and you can go ahead for experiment. what I will do here? I will put at x, since these values completing its not 0, but then if I put at r, then I will get r value, then I will get r reading here, whatever displaying here. this is r value. This r value will be because y is almost 0. r value will be equal to almost nearly equal to the x value.

Anyway, you note down for this magnetic field, current is this a corresponding magnetic field for this. this maximum magnetic field I have given, this. Now, I will decrease the magnetic field and go to 0; decrease the magnetic field and go to 0. next, if I am just decreasing you see this should. magnetization will decrease. is this type of curve you will see? I will decrease and note down this reading.

now point 7.80, this is the magnet electromagnet current corresponding magnetic field; field from the calibration and the signal voltage I am getting 0.1715. Now, these voltage corresponds to the what magnetization that I as I told that from calibration we will get. this calibration is made and then we supply to the student

using the nickel sample, we know what is the, but that is that will not be valid actually because that will depend on what is the amplitude here setting of the vibration of this one and this other factors calibration may not be varied. one can take nickel sample and put there and find out the lock-in voltage for that for the same frequency and if you have to use that calibration because nickel sample saturation magnetization will be supplied and corresponding lock-in voltage, you will get from here.

calibration factor that factor you have to multiply for your unknown sample, you have to multiply or divide with this lock-in voltage to get the magnetization; for that magnetic field. for different magnetic field, I am decreasing the magnetic field. It should decrease and it is happening you see, now it is 7.22. it is very sensitive. Now, it is 6.89 ampere current. you may decrease it.

now, you see now I am going now, it is 4.92 ampere current. It is the 0.1, 0.09. current is 4.12 ampere. it is 0.074 6 inch Now, I am at 0; I am at 0 Sorry, I am at 0. 0 current means 0 magnetic field. this 0.245 is the amplitude.

corresponding there will be magnetization. these will be the remnant magnetization because I have 0 magnetic field what is the. to then, I should change the polarity; I should change the polarity and, but there is option to change the polarity. No, I have to just reverse the current direction and from 0, I will continue negative current opposite direction current. I will get the next part.

generally, we use bipolar power supply, but it is very costly. in teaching laboratory generally, we use this and you have to put three times, you have to change the polarity here and take this is one loop, this is one first half, then second one quarter, then next quarter, then third quarter, then fourth quarter.

you have to change the direction of the current just changing the polarity here since it is not bipolar. this way one can find out the hysteresis loop, but it is a time consuming. For teaching lab, it is difficult to complete this experiment four-four year. that is why we student we tell students to take this one half. just after that, they change the polarity here and continue the experiment go to the result.

just one part we asked them to do and this is a very nice experiment or in teaching lab how to use lock-in amplifier; how to use lock-in amplifier for detecting a very weak signal from the noise. here this VSM that signal is not very strong If magnetic material has weak magnetization, in that case it is very signal will be very weak. lock-in technique will help us to measure even very weak magnetization.

this is the base in arrangement and I showed you how to measure the signal voltage using the lock-in amplifier and from calibration, I have not shown you, but just using the known sample, we use nickel sample, this saturation magnetization of nickel sample is known, for that sample, we will apply maximum magnetic field and at that field, it is saturated that we that we know and for that, what is the lock-in after setting up what is this lock-in voltage. this lock-in this that magnetization divide by this lock-in voltage that will give me this factor.

Now, for unknown voltage, I will multiply or unknown sample this whatever voltage at different magnetic field will get that will be multiplied with this factor all the time, then it will be converted to the magnetization from lock-in voltage to magnetization and magnetic field versus magnetization, the data we can get and if we plot it, you will get this; you will get the variation of vibration as a function of magnetic field.

here we have used the ferromagnetic material. we expect the hysteresis loop. if you take one half even one half, then what is the saturation magnetization; what is the remnant magnetization and what is the quartz field that we can find out.

I think I will stop here.

Thank you for your attention.