Experimental Physics I
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Lecture – 40
Expt. To study linear expansion

So, today we will demonstrate the measurement of thermal expansion coefficient of a metal rod.

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So, this is the experimental setup for measuring the thermal expansion of a metal rod ok.

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So, now you see here this one setup, where this one is called micrometer and this rod when rod will be expanded. So, this arrangement is done in such a way the how much it is expanded. So, this from this reading we can tell that is the expansion of the rod and now why rod will expand. So, if we increase the temperature of the rod, then it will expand. How much it is expanded, so that reading we have to take that will be taken using this micrometer.

And with temperature that expansion, we will increase or decrease depending on whether temperature is increasing or decreasing, so that reading so this reading of the temperature also we have to take. So, this here we will get basically this reading of the temperature. So, now, let us say where is the sample then, this we will measure the expansion coefficient of a rod. Where is the rod? Rod is basically I have to first I can open it, just I can open it ok.

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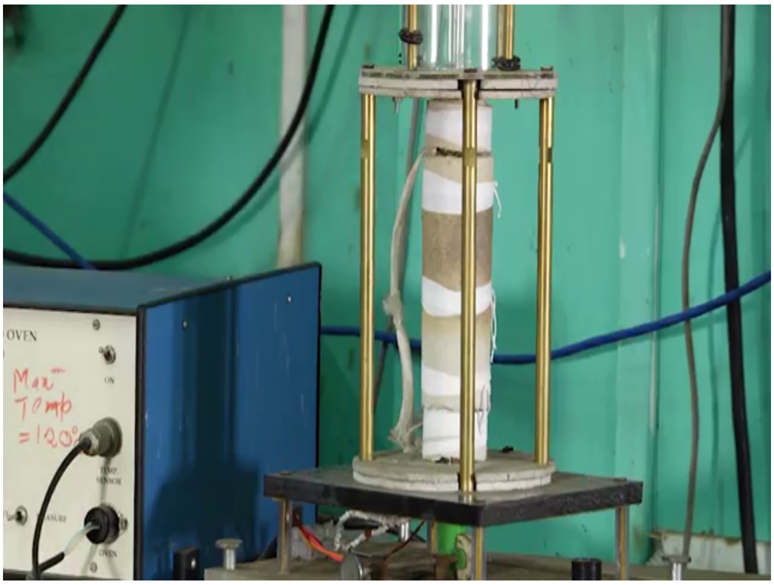

Then actually here this thermal insulators asbestos it is called I think a ceramic kind of things is used. So, this rod is basically inside of this ceramic cylinder. So, now surrounding the rod, there is a coil where there is a coil heating coil basically.

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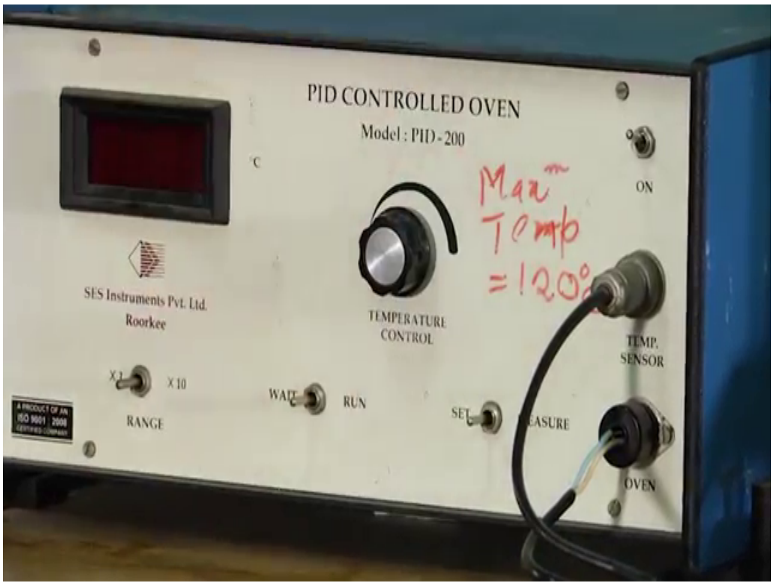

So, this current here, you can see from here it is written oven, here it is written oven ok.

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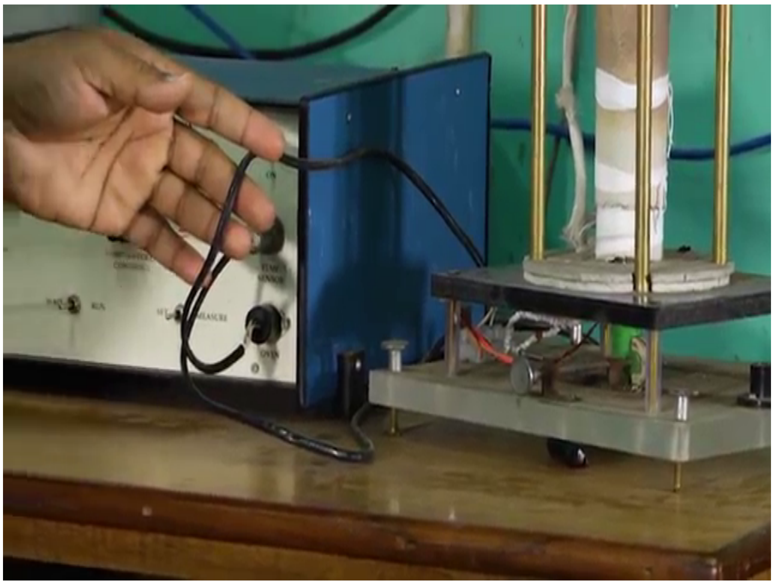

So, this, that means, from here basically we are passing current through yeah passing current to the coil surrounded this rod, metal rod. So, this, so that metal rod we cannot see as I told you so but this current is given to the rod not rod to the coil, so that is basically oven.

Now, this power if power is higher, then this temperature of the oven will be higher, so this temperature of the rod will be higher, right so, now I have to measure the temperature also. So, there is a temperature sensor actually here you can write see that it is a written temperature sensor, this is basically a thermocouple, here this is the temperature sensor this, this is the thermocouple.

So, this one end of the thermocouple is basically near the near the rod ok, where the temperature of the rod can be, can be measured ok, can be detected. So, temperature sensor will tell this meter, what is the temperature at the sample point, so that will be displayed here so that is the face this temperature measurement is based on the thermocouple principle ok. So, this is one part.

Second part is, is just here this control of the power, this oven power ok, this basically current in the coil, we can control the current in the coil, so that we can control the temperature of the sample. So, here you can see set and measure, here wait and run ok, wait and run. So, temperature control, basically this is the temperature controller temperature controller, and it is called PID controlled oven ok, PID controller oven.

What is PID? PID this full name is Proportional Integration a Integral and Differential, Proportional Integral and Differential controlled oven ok. So, I think I will describe what is the how it how it works.

So, here you can see this wait and run, and the set and measure. So, I now rod is in a oven, power is given from here to the oven. And what is the temperature of that rod that will be noted down, that sensor thermocouple will tell to this meter ok. So, here there is a scope to set the temperature. Say I want temperature say 150, 150 degree centigrade. So, then I have to put knob here, then I can switch on this where it is I think, it is back side switch or front side switch.

Student: turn left

Turn left, this one? This one on and off ok.

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So, it is on and off here ok. So, it is on. So, whatever here you are seeing this it is basically it is showing temperature, so already.

Student: (Refer Time: 07:20) set setting.

This is set temperature. Here you see this knob is at set means, I have put this temperate set, I think here, I can rotate to change the set temperature say I will say that 150 degrees, 150 degree ok. So, this set. Now, if I put here measure, so what is the actual temperature now of this rod of this oven placed? So that is the actual temperature ok. So, 19.3 that is the temperature at right now.

Now, wait means here I am not, I am telling this instrument that you do not send power to the coil oven wait. Now, if I so at this condition, so rod placed that temperature is this ok, so I have to note down this temperature. And at this temperature, what is this, what is the reading of this that I have to note down. So, here this micrometer, so here you can see this is retaining 1 micrometer. So, this each, this least count of this micrometer is basically 1 micrometer ok.

So, here initially I have to noted down the reading of this micrometer, it is 0. So, at 19.4 or 3 degree centigrade, the micrometer reading is this. So, this is this I can take the original length of the rod at this temperature. Now, I will increase temperature, and then rod will expand at different temperature, and that the how much it is expanded, so that we will get from this reading. So, here I have set at 150 degree then, now if I just put a run, if I just put a run, so at this temperature will increase here, you can see this temperature reading will change. So, it is better so, if you want this faster change of the temperature, so we should put you should set at that set temperature at higher value.

Anyway, so this see, this temperature is changing 19.7, now 19.8 now ok. So, this reading is coming from the temperature sensor. And I have set at 150 degree centigrade that means, this change of temperature will continue as long as this it reach to the 150 degree centigrade. So, this PID control means, it will automatically, it will set at 150 degree, but you know this to change that the for changing the temperature, this system is getting, is a there is a feedback loop you know, it is a just every time it is what is the set temperature and what is the present temperature ok.

So, it is taking this temperature difference. If temperature difference is higher, so it is giving power to the coil proportionally, the temperature difference is higher a set temperature and present temperature, so this power so power is given, power is given to the oven that is proportional ok.

And then it is when you will go to close to the 150 degree, but it cannot just suddenly cannot just go to 150 and stop. So, what it will do, it will go beyond 150, say 155, then it will said no this temperature this is higher now. So, it will come so then here basically integration and proportional. So, because slight change. Here this it is not this higher, now from 150 there change is within plus minus 5 degree ok. So, then it is basically do the integration is feedback, it is a power is given through the integration circuit. And then if it is very close to that 150 plus minus 1 ok, so then it is basically, you know the slope differential slope basically at a particular point so that the slope at a particular point ok. So, it is the slope is nothing but differential ok. So, there is a differential circuit also.

So, when it is very close to 150 plus minus 1 degree. So, there it use this differential circuit for applying current to the power to the oven ok. So, this is the reading, this is the method, this power supply this controller is used, so that is why it is called the PID controller. So, now we see this temperature is increasing ok, initially our is a 19.3. What was the reading? Now you see reading is changed, what is the reading you can find out. So, at 30 I will note down this one is I can see 123.5134, it is between 3 and 4. So, I will note down the reading.

So, at every 10 degree, so initial say it was 19.3 around 20. So, then I took reading at 30, then I will take reading at 40 or you can take reading at each 5 degree change of the temperature ok. So, I am noting down the temperature initially 19.3, then this reading was micrometer reading was 0 ok. Now, 30 degree, micrometer reading is 3 or 3.51 one can write approximately micrometer ok, just you can guess between these 2 division 2 line. So, it was around in middle. So, at 35 we want to take reading. So, you see now it is 14 now I can see it is 14 ok.

So, at 35, it is 14, 30 so, exactly you have to take. So, you have to be ready for taking readings ok. So, then 40, 50 so up to maximum I think how if will go, because this meter works up to 200 degree centigrade ok. So, its limit is 200 degree centigrade. So, I think we will take 10 reading up to 150 degree centigrade, each show I will get it 10 degree difference if I take reading I will get 15, the sets of reading.

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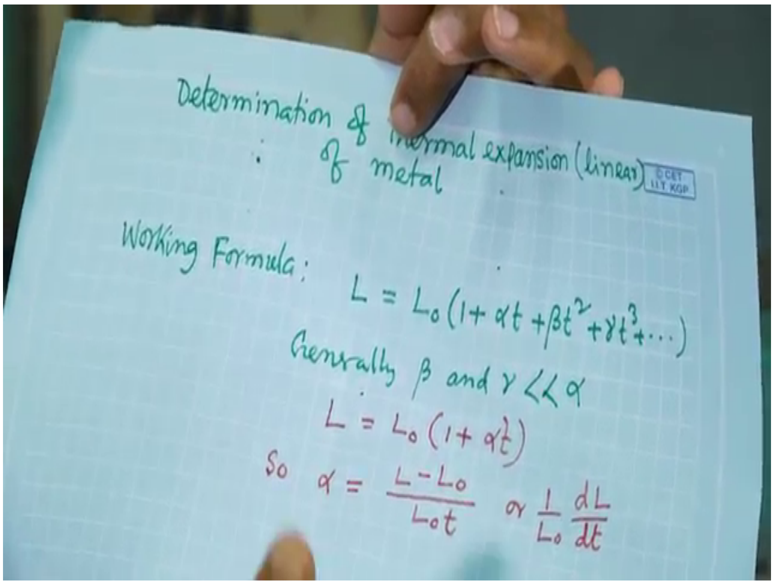

And now that working formula is very, very simple you know working formula is very, very simple right. So, this you know this linear expansion expression L equal to L 0 1 plus alpha t plus beta t square plus gamma t cube etcetera. So, generally beta, and as so all are thermal expansion coefficient, this is the first order, the second order, third order. So, this beta first, second or a third order this coefficient are very, very small compared to this first order, so that is why then we keep up to this first order ok.

So, at temperature t, at temperature t, so I will not tell temperature actually temperature difference what about original temperature, it was 20 degree in our case. So, at 30 degree, so this t is basically t minus t 0 ok. So, it is a 10. So, it is a delta t basically ok. So, this L means length of the rod which was L 0, so that is now L. So, L equal to L 0 1 plus alpha t.

Now, alpha equal to L minus L 0 by L 0 t; so, this is basically this t as I told delta t and this are delta L ok. So, one can write del L by del t 1 by L 0. So, here, here we are getting basically, this due to the temperature difference from the original one, of course, L 0 corresponding that temperature t 0 ok. So, this for temperature difference from the original what are the increment of the length that we are noting down ok.

Now if you plot, so you have data for temperature as well as for this expansion delta t and delta L ok. So, you can plot a graph, you have 15 sets of data. So, basically you will get a more or less linear curve, initially it is the linear, then because of this other parameter it is a higher temperature, it will be, curve, it will curved right.

So, here actually our measurement L 0 is given, in our case it is I think 5, 50 5 centimeter in the in our case this is rod metal rod is a 5 centimeter ok. And now del L by del t we will find out from the graph and then easily you can you will find out this alpha. So, I think, I will so now, you see this is the 55, it is increasing and every time you have to note down. So, experiment is very simple.

Here actually, this is the thermocouple is used for measuring the temperature. And also this thermocouple is helping for feedback for this PID controller, because set temperature and that actual temperature depending on the difference between these two as I told this proportional integration and differential that circuits are there which one will be in which circuit will give power to the oven. So, that will be decided by this controller ok.

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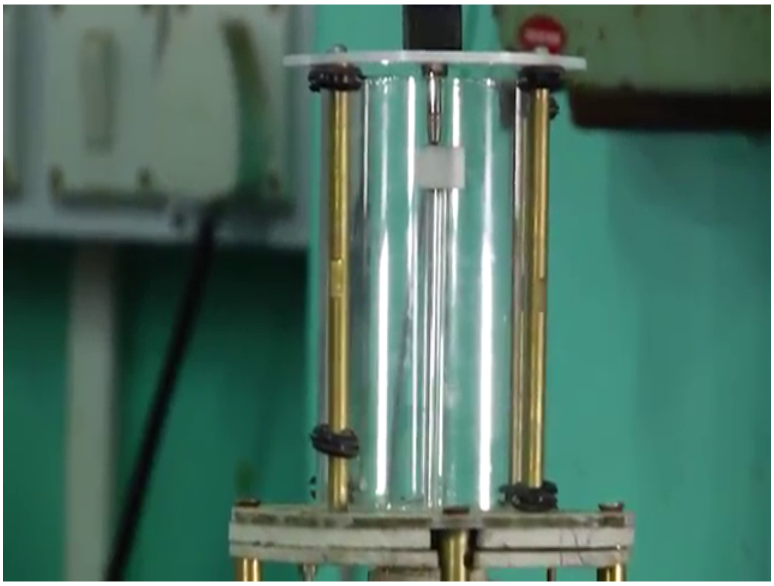

So, and here you see this, this micrometer it has if you just push it, then it rotates, so this has scaled. So, how much push, so depending on this rotation will be there so that is the basically micrometer. So, this rod it is here metal rod. And then on top of it, this some glass rod is there. And just this some Teflon kind of things here, just it should be to make it, just plain surface on glass you cannot put this one it may break. So, this just to be Teflon cap, we have used ok. And on top of it, this micrometer this yeah what I should tell this is the pointer is there, this pointer is connected with this what I think this push rod at the bottom.

So, if it is push, how much it is push so that is the reading is given accordingly. So, why it is pushed? Because of expansion of the rod, so that is why the expansion of the rod is directly related with this reading and temperature from thermocouple we are getting from here. So, temperature versus this expansion the data only we have to take. And as I told from working graph, you can find out del L by del t and you will get this linear expansion coefficient. So, I think in next class I will discuss about the data analysis and error calculation. So, I will stop here.

Thank you.