Experimental Stress Analysis
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Lecture - 32
Temperature Compensation, 2-wire and 3-wire Circuits

The advantage of a strain gauge technique is after I paste the strain gauge and connect it to the strain meter, it is possible for you to read the strain directly from the strain meter. On the other hand, if you look at optical methods you need to know how to interpret the fringe patterns, so that makes the difference. That makes strain gauge technique is very popular and I said though it is very popular, I have said it is a very well used and abuse technique.

Mainly because we have seen so many subtle things have an influence on the final measurement. We have seen choice of the alloy material, choice of the carrier, choice of the adhesive and also on which specimen material we have to make measurement, they have all have influence in different ways. So if you do not take care of these subtle issues, the measurement you make from strain gauges could be erroneous could be way off.

We saw if you do not take care of the stability issues, a zero drift can be of the order of 270 microstrain. Then we brought it down to 30 microstrain by the selection of appropriate alloy material, appropriate carrier and also the bonding. Though on one hand you say strain gauge technology has very well developed, you can measure even 0.5 microstrain.

If you do not adopt the various procedures mentioned in selecting a strain gauge and also in installing the strain gauge your measurement could be way off. This you have to keep in mind and we have been looking at various lectures how do you handle the thermal influence because one of the most disturbing aspect in strain gauge instrumentation is how do you take care of the temperature changes. We will have a formal look at it in this class.

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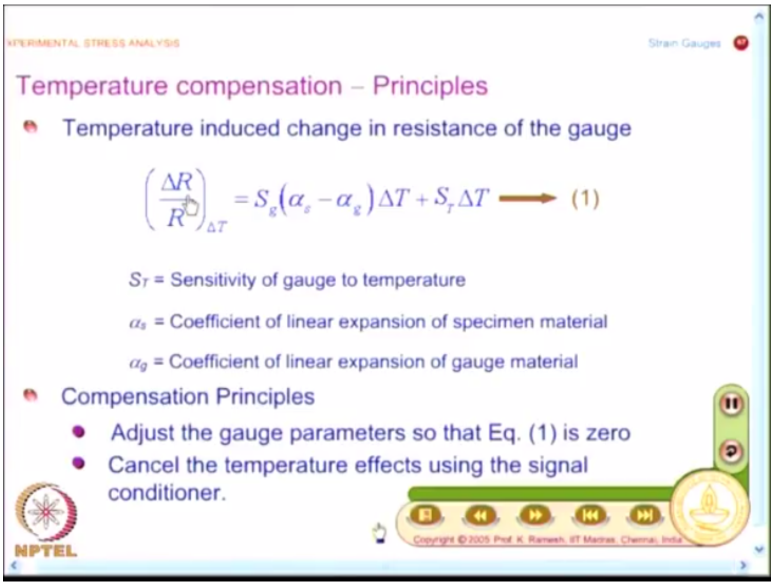

And what we have is we have to compensate for any effect due to temperature and what we have is what is temperature compensation, what kind of methodologies that I can employ to compensate for change in temperature and when I look at what happens to the strain gauge for a change in temperature, the delta R/R as a function of temperature change, delta T is related to Sg*alpha s-alpha g*delta T.

So the first term comes from differential thermal expansion of the specimen and the gauge, so this causes the strain to be introduced that is why I have Sg here and whatever the strain introduce is a function of change in temperature and you also have another term which is purely a function of temperature because of change in temperature the resistance of the strain gauge changes and that is given by another factor called ST.

So a change in temperature causes change in resistance, has 2 terms one because of thermally introduced strain and another one where the resistance changes as a function of temperature. When I go for compensating for temperature effects, I have 2 broad approaches. One approach is adjust the gauge parameters so that equation 1 is 0.

So whatever the equation that you have here if I have a method to change what is alpha g I have a way of handling this so that whatever the term 1 and term 2, they compensate for each other and I get what are known as self-temperature compensated gauges. See in strain gauge instrumentation, if I say you paste one strain gauge, you paste another strain gauge on ordinary material, keep it at the same temperature, connect it as a half brush and cancel it, this is one methodology.

On the other hand, I take a strain gauge and then paste it and forget about usual temperature change, which occur in simple experiment then that is good enough but in this case what will happen is whatever the methodology I adopt, whatever the strain gauge that I develop, it is tailor made for the specific base material. So from an instrumentation point of view it makes your life simple,

You just paste the strain gauge automatically the temperature effects are cancelled. So that you get by adjusting the parameters of the foil so that you have appropriate modification in alpha g and ST so that equation goes to 0. The other effect which I have mentioned at several classes, cancel the temperature effects using the signal condition and this comes in very handy when you are using a Wheatstone bridge.

You have the adjacent arms, cancel each other, so that is the way that we will use the signal conditioner for canceling the effect due to temperature.

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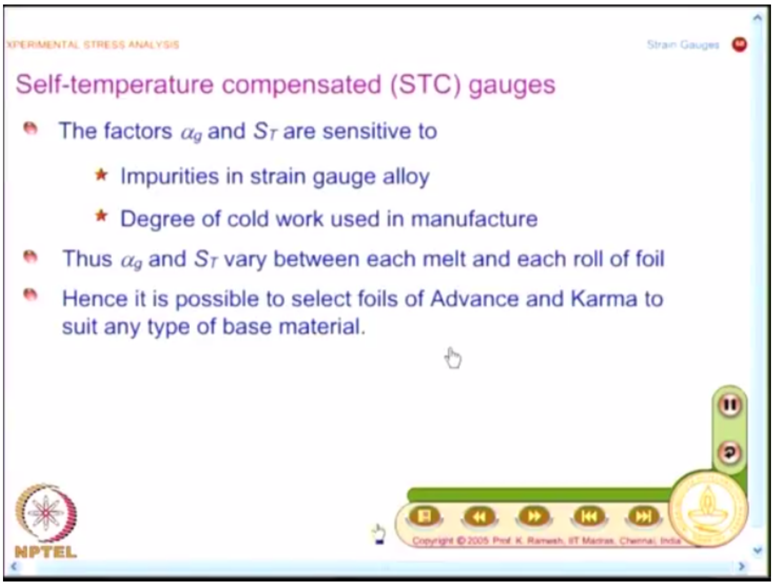

First, we will take up how do we get self-temperature compensated gauges and you know in the literature it will be abbreviated as STC and fortunately you find the factors alpha g that is coefficient of expansion of the gauge material and sensitivity of the strain gauge material for temperature change or sensitive to impurities in strain gauge alloy. See normally you do not want to have any impurities.

When you are making an alloy, you want that to be free of impurities so that it gives you the desirable material properties that you look for, but in this case, you find impurities play a role. So by modifying the impurities, it is possible for you to control alpha g and ST and another aspect is while making a strain gauge foil, you also do a cold work and degree of cold work used in manufacture.

So in essence what happens the values of alpha g and ST vary between each melt and each roll of foil. So what you do is you go through the metallurgical process, create the foil, then estimate what is the value of alpha g and ST for that particular batch and use it for making strain gauges for a particular base material. This is the physics behind it. So in essence it is possible to select foils of Advance and Karma to suit any type of base material.

We have excluded Isoelastic. We have seen Isoelastic is hypersensitive to temperature change. So you do not even talk of self-temperature compensated gauges made of Isoelastic alloy. You talk only when you use the Advance or Karma alloy and there also we saw a subtle difference, Karma alloy comes for larger temperature change whereas in the case of Advance alloy the temperature limit is slightly less than what you can do in Karma alloy.

So what you will have to do is when you are going for self-temperature compensated gauges you look at from the metallurgy point of view and look at what is the property of each melt and each roll of foil.

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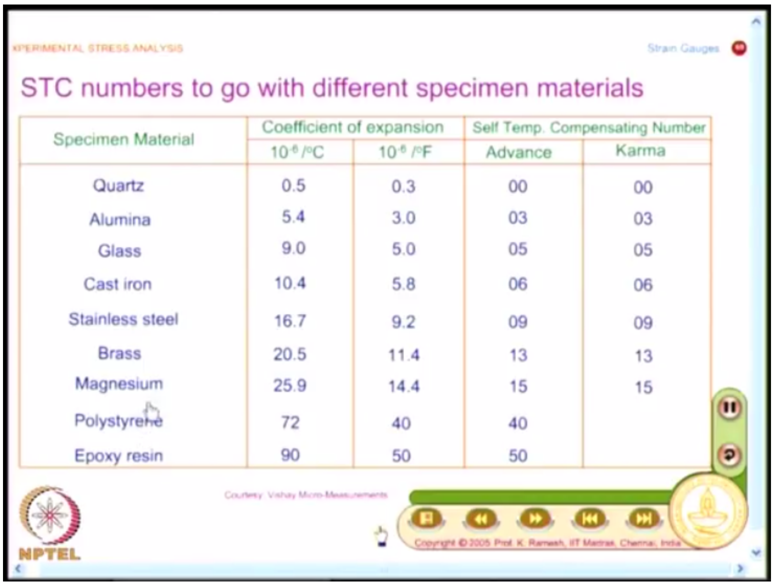

Specimen Material	Coefficient of expansion		Self Temp. Compensating Number	
	10^{-6}/°C	10^{-6}/°F	Advance	Karma
Quartz	0.5	0.3	00	00
Alumina	5.4	3.0	03	03
Glass	9.0	5.0	05	05
Cast iron	10.4	5.8	06	06
Stainless steel	16.7	9.2	09	09
Brass	20.5	11.4	13	13
Magnesium	25.9	14.4	15	15
Polystyrene	72	40	40	
Epoxy resin	90	50	50	

And they also have numbers associated with the gauges. I said when I say self-temperature compensated gauges, they are selected for a given specimen material. The coefficient of expansion is given in terms of per degree centigrade and per degree Fahrenheit for various base materials and if you look at the self-temperature compensating number, it is given for Advance alloy as well as Karma alloy.

And if you look at this, this matches with the coefficient of expansion in terms of per degree Fahrenheit. For Alumina it is 3*10 power -6 per degree Fahrenheit, you have the number associated as 03 and when it is 5 you have this as 05, 5.8 you make it as 6 here, 9, 13, 15, 40, 50 and whatever the STC number for a particular specimen material, it is given the same number when you make it out of Advance alloy or Karma alloy.

So what you will have to keep in mind is when you say self-temperature compensated gauge, it is meant for a particular specimen material. If there is a normal temperature change, whatever the changes on the temperature, it will get compensated because of the specific property of the metal foil. Suppose I have a self-temperature compensated gauge meant for steel, I should not use it on aluminium.

Then, I will have no control on how to interpret the signal at all, but later in special applications there is also a recommendation to use this kind of gauges. See when you bring in a new feature, it is advantageous as well as disadvantageous. So you will have to know for which application how to use it and another aspect is can the self-temperature compensated gauges be used for a range of temperatures.

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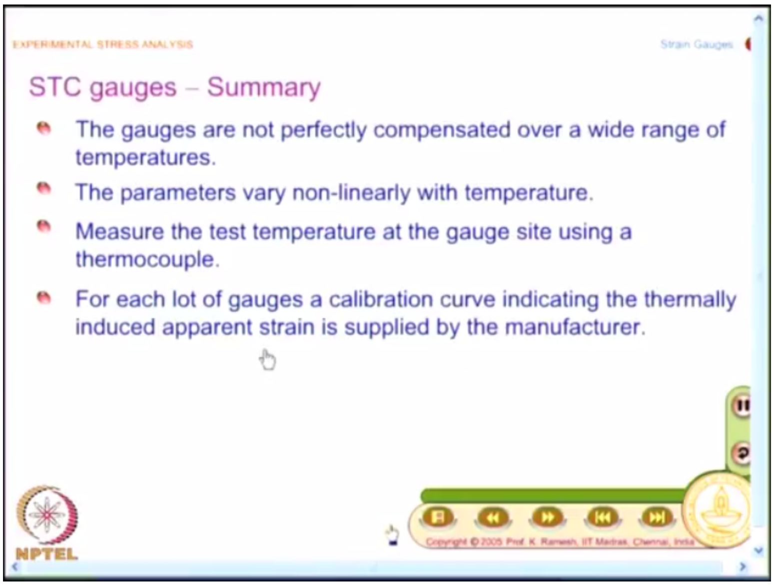

That is another question, but the answer is no. So they are not perfectly compensated over a wide range of temperatures. For small temperature variation, self-temperature compensation is alright and that is good enough for most of the applications we want only like this. We have already seen because when current passes through the conductor you have I squared R loss.

At least, the heat generated because of that can be compensated by a self-temperature compensation and this is not meant for a wide range of temperature. So that you will have to keep in mind. So when you are doing a strain gauge instrumentation, it is not that you go pick out some strain gauge, paste it on the specimen material and connect it and find out what is the strain reading.

The strain meter will still give you some numbers but those numbers could be way off that is what you have to keep in mind and what you find is these parameters vary nonlinearly with temperature. That is the reason why we are unable to handle a wide range of temperatures. One of the remedy is measure the test temperature at the gauge side using a thermocouple. If I am unable to use a self-temperature compensated gauges for a particular application, measure the temperature by using a thermocouple.

Once you find out the temperature, what you do is the manufacturer supplies for each lot of gauges a calibration curve indicating the thermally induced apparent strain. That we have already seen in the earlier classes. We will again have a look at it.

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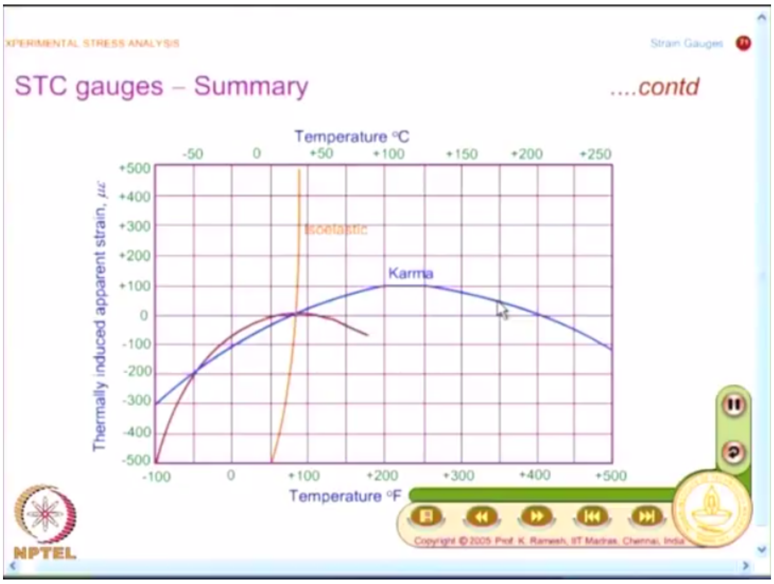

And the suggestion is I have temperature and I have thermally induced apparent strain. So I measure from this graph for a given temperature what is a thermally induced apparent strain and subtract it from my measurement. Whatever the measurement I make, I subtract it, but this is cumbersome.

See what you will have to look at is if I have a single gauge which is self-temperature compensated I can directly reach from the strain meter the job is handled very comfortably from measurement point of view. On the other hand, if I have to do any of this, you have to look at the graph, subtract it and with modern computerization you have such database available along with the software that the manufacturer supplies.

So all this also now easy to handle with system 5000, system 7000 and so on, but the methodology is this. You should not take a wrong view that STC gauges can be used for a wide range of temperature, it is not so but if you work beyond the range of temperature possible the via media is measure the temperature, use the graphs available and subtract the information. So that makes your life lot more simpler.

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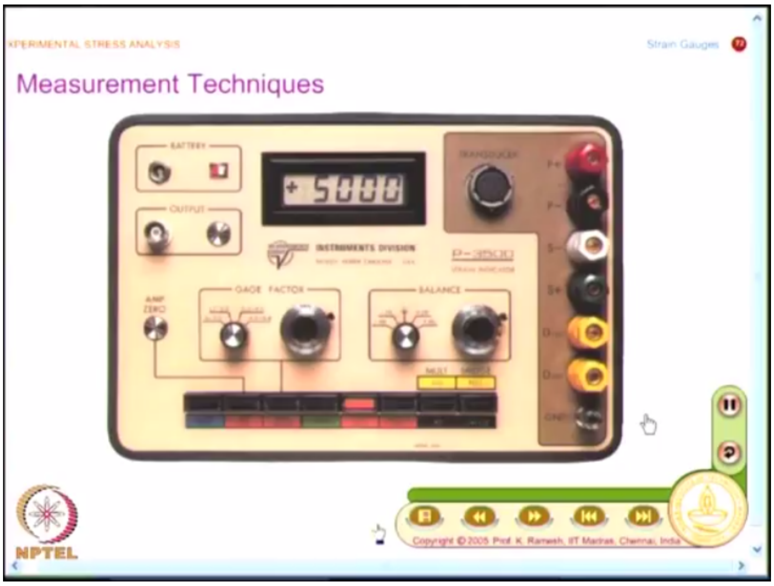

Now we go and look at what are the measurement techniques. I am showing a typical strain gauge meter and I would like you to draw your attention to few finer aspects. First issue is if you look at very carefully, this is for 120 ohms and this is for 350 ohms. It may not be clear on the screen but you know there are provisions available for selecting internal resistors of 120 ohms or 350 ohms.

See in one of the earlier classes, we have looked at when you are using a Wheatstone bridge, if I have to maximize the signal from the Wheatstone bridge, I should use R1, R2, R3, R4 having same values and we have seen strain gauges are available at 120 ohms and 350 ohms very commonly and you can use 120 or 350 or various applications and depending on the strain gauge that you select you must also have the other resistor selected in the Wheatstone bridge.

It is not that you take a strain gauge, connect it to the strain meter, you measure the strain. It is not as simple as that. You have to make certain settings. So one of the first step that you will have to do is have you selected the correct completion resistors of the Wheatstone bridge. The second aspect is you have a knob available for setting the gauge factor and you all know the delta R/R=Sg*epsilon.

And Sg is like a multiplication factor and I said Sg is determined experimentally and supplied by the manufacturer. It is available with the percentage value of error, so from batch to batch the Sg can change. So you have to put in the appropriate value of Sg, not only this later we will take up certain discussion on how to account for transfer sensitivity effects. Some of these effects also can be easily canceled by modifying your gauge factor appropriately.

So you have a knob specifically available in the strain gauge meter to set the gauge factor and you also have another set of knobs for you to adjust the initial balance. See when you start with the bridge has to be balanced and you will have some provision in the strain gauge meter to account for this imbalance. Beyond a point, it cannot balance. If the imbalance is more, we will see how the imbalance can be more.

You cannot adjust it then the only way you have to take a recourse is measure the initial value and also find out the final value then final-initial that kind of subtraction you may have to do and what you see here is you see this as 5000 microstrain and you know periodically you need to keep calibrating the equipment. So what you have is you have a standard shunt resistance available in the equipment itself that can be connected and that is rated for 5000 microstrain.

So that is how you keep calibrating the equipment. You also have a provision to select the gauge factor and you also have a provision to adjust for initial balance and particularly you have to ensure that you have selected the correct set of completion resistors and these are all very simple steps, which you should not forget.

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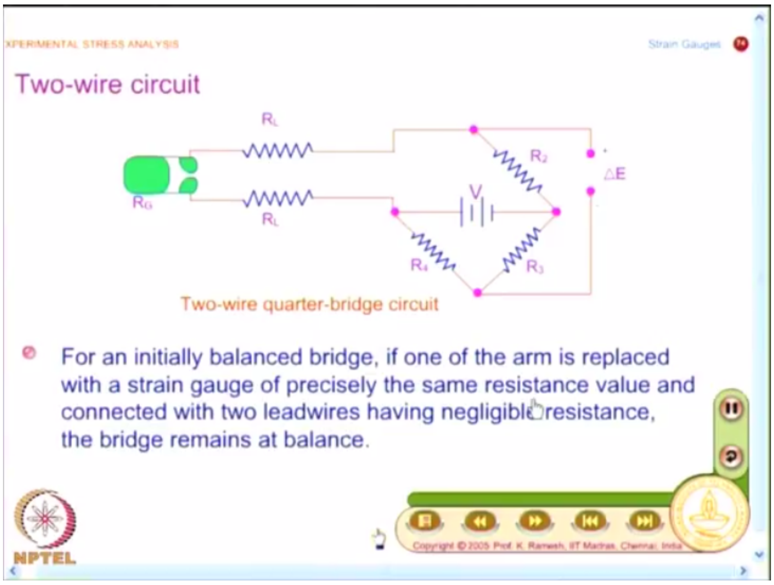

And suppose somebody gives you a strain gauge what will you do? You just connect the strain gauge to the Wheatstone bridge. I have 2 points and I take a wire and then connect it to whichever arm that I want to do it, I connect it appropriately and that is how you would normally connect a strain gauge by connecting 2 wires. What is influence of the lead wire? See the lead wire is not a superconducting material, it has some resistance. If the resistance is low what you find? For an initially balanced bridge, if one of the arm is replaced with a strain gauge of precisely the same resistance, we have already seen the reason for it.

If I want to have high bridge sensitivity, each of the resistance connected in each of the arms should have the same value. When you connect with 2 leadwires having negligible resistance the bridge remains at balance. You need to make a neat sketch of this. We will first look at what is the kind of problem that this can pose and once we see what is the kind of problem we will also look at what is the remedy.

See before we look at the remedy, we should know what is the problem it creates and in most of the strain gauge applications, it is convenient to use only a quarter bridge because you need to paste only one strain gauge, soldering also you have to do for only one strain gauge and connect it to the quarter bridge. Only when you are working on transducer applications, you look for having a full bridge configuration.

Otherwise to make your life simple in terms of instrumentation, a quarter bridge is convenient but this has certain inherent problems. These inherent problems can be solved in a very simple manner by going in for what is known as a 3-wire circuit but even with that if your problems are not sorted out, it is desirable that you go for a half bridge where you are able to take care of all these influences of temperature.

And then leadwire resistance and so on and so forth. So what you will have to look at is when somebody gives you a strain gauge, you will naturally connect it like this. You may normally ignore what is the role of this leadwire resistance. We will look at what is its role.

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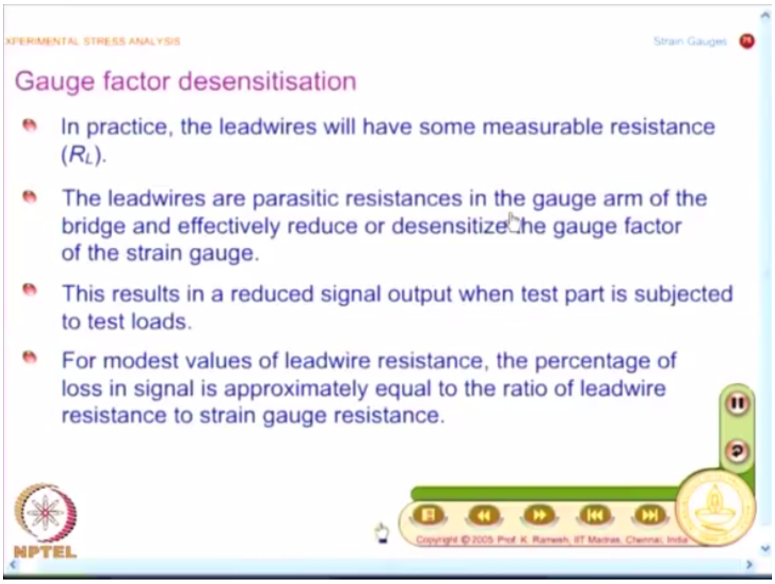

And what way it modifies your measurement of strain. You will have to note that leadwires are parasitic resistances in the gauge arm. You do not want them, you want to have a magic material which has no resistance and strain gauge is connected. See I also said if you have a magic material, a single spec of it can have 120 ohms or 350 ohms, I paste it at the point of interest and connect it and make measurement, then I have no problem about strain variation or gauge length influence etc.

And we saw it is just not possible, you need to have only a wire and you need to have a minimum of 36 millimeter we saw and you need to make it as a loop. It forms a grid, the moment you forms a grid, it is sensitive to axial strain as well as transfer strain, so far we have not looked at the transfer strain effect.

We will take that up later but we had a specific alloy which would give you very high resistance in a small length of wire that is what we use it as a strain gauge foil alloy but the leadwire resistance we will take a high quality copper wire, which has the least resistance. Ideally, I want to have no resistance for the leadwire, but in practice you will have some resistance for the leadwire.

And leadwire resistance is considered as a parasitic resistance and what happens, it effectively reduces or desensitize the gauge factor of the strain gauge. Because of this leadwire resistance, the total resistance in that arm goes to strain gauge+leadwire resistance. So the balance of the bridge is also affected. Not only this, you will have a reduced signal output when the test part is subjected to test loads.

And there is also a sort of an estimation people do. For modest values of leadwire resistance, the percentage of loss in signal is approximately equal to the ratio of leadwire resistance to strain gauge resistance. You know these are all subtle issues. You know you have to bond a strain gauge and from the place where you have bonded the strain gauge, you need to take a leadwire and then connect it to your strain gauge meter.

You cannot avoid that but the issue is it has a very important influence and we will have to look what way it can modify and how to reduce its influence. You know that is very important.

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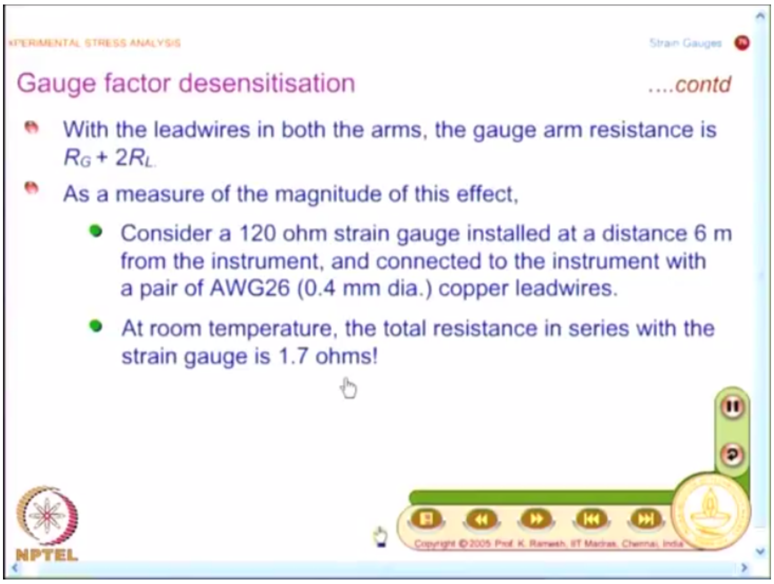

And as I mentioned earlier the resistance in that arm increases to RG+2RL and let us look at a simple practical example. Suppose I take an installation which is at a distance of 6 meter from the instrument and you have to connect this strain gauge to the instrument and you take a good set of copper leadwires, the specifications also given, this is AWG26 of 0.4 millimeter dia.

For a 6-meter length, the total resistance in series with the strain gauge is 1.7 ohms. This is at room temperature. So what you find is when I connect a strain gauge by a leadwire, you cannot ignore the resistance of the leadwire and what it appears, it is reasonable to think when I have a 6-meter length, I have used a good quality copper leadwire, which has given me only 1.7 ohms extra.

If you have not been introduced to strain gauge technology, you will consider 1.7 ohms as small. I have a 120 ohms gauge, I only modified it slightly with a leadwire resistance of 1.7 ohms what way this affects the balance of the bridge we will look at. See small or big is a relative term and you have to look at the context in which you are looking at this.

We have already looked at in the case of a strain gauge meter, there are knobs available for adjusting the initial balance and we have also seen all the 4 arms should have identical resistors. Because of the leadwire, I have some extra resistance. So this needs to be balanced. Because what I want to do is I want to measure change in resistance because of load applied. The leadwire has to be accommodated in an initial balance.

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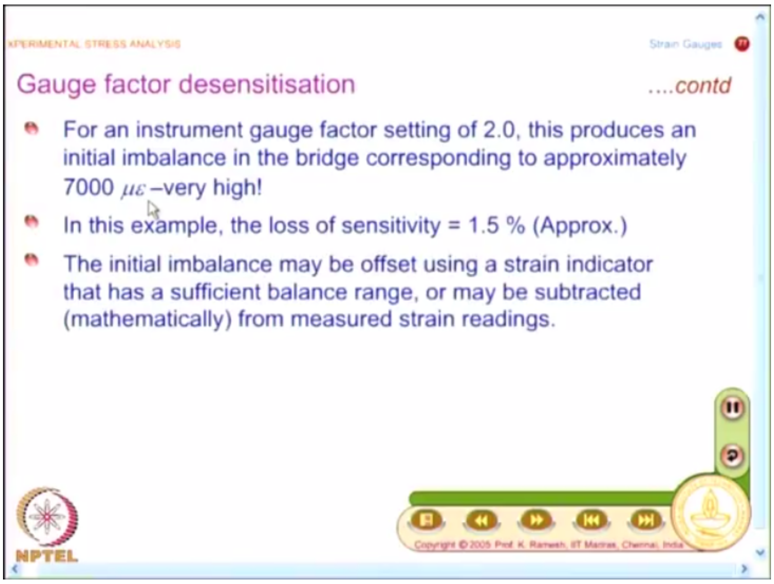

When I have 1.7 ohms, I find the equivalence in terms of strain is 7000 microstrain and we have already seen in the case of most engineering materials 0.2% strain the material yields, 0.2% is 2000 microstrain so we will never go to 7000 microstrain unless I am looking at some plastic deformation and so on. So my measurement range will be much smaller, so this is what you have to keep in mind.

In strain gauge instrumentation, you are measuring quantities of the order of 10 power -6 though 1.7 ohms looks much smaller in comparison to 120 ohms, this is very significant from strain gauge instrumentation point of view and when I have this we have already seen what is the loss of sensitivity, it is given as ratio of the leadwire resistance to the strain gauge resistance, which is something like 1.5% approximately.

And what you will find is because it is 7000 microstrain, initial imbalance is difficult to offset. See you may be able to offset if the strain gauge meter is capable of accommodating 7000 microstrain. If you are unable to do it, you have to note down the initial value and then final value and find out what is the strain. There is no other go. So the point here is see if we have taken a 6-meter length, 6 meter length means I have at the end of this room the measurement application and I have strain gauge meter here.

And if you look at a real life structure like an aircraft, you may have length of leadwire of the order of even 100 meters. It is not a simple length and you need to have a via media to correct for this kind of problems. We have just looked at by connecting a long leadwire what is the problem. Now we will bring in. In all strain gauge instrumentation, we always bring in change in temperature.

And I also noted change in temperature is not necessarily change in temperature of the specimen just because current is flowing through the strain gauge, the strain gauge gets heated. When strain gauge can get heated, the leadwire also can get heated. So we will also have to look a temperature change. We will see how the temperature change influences.

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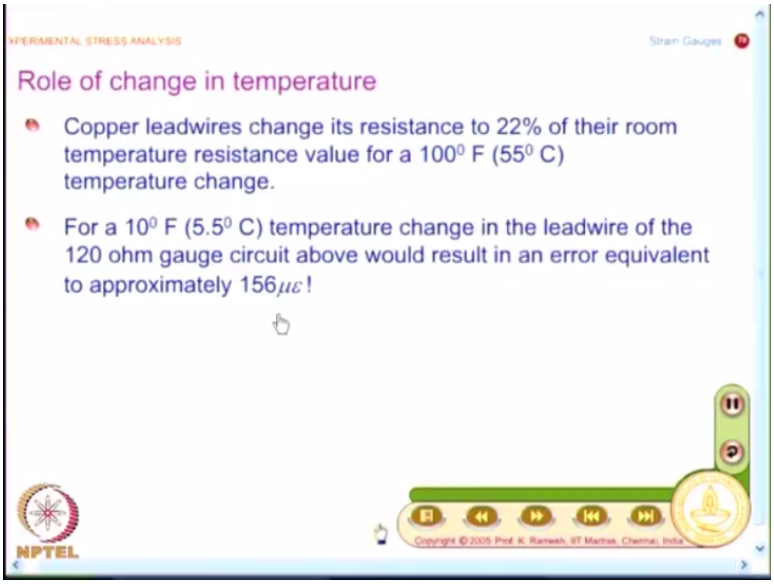

And it is noted that copper leadwire change its resistance to 22% of the room temperature resistance for a 55 degree centigrade temperature change. So if there is a change of 55 degree centigrade, the resistance will change by 22%. We will not look at a change of 55 degree centigrade. We will just look at a change of 5.5 degree centigrade change in temperature. If I consider it for a leadwire connected to a 120 ohm gauge circuit, a 5.5 degree centigrade change would result in an error equivalent to approximately 156 microstrain.

It is not small, I had mentioned earlier, depending on the specimen material and configuration, even simple changes if you do not consider error could be of order of 20% and what we are looking at is a small temperature change on the lead wire can cause a strain value of 156 microstrain. It is very significant; see on the one hand we said technology is well developed to measure 0.5 microstrain.

And I also gave a thumb rule when you are designing an experiment, you design your experiment in such a manner that you have at least 100 microstrain developed at the point of interest for the given loading so that you can have certain reliability on the strain measurement and you cannot make any measurement without connecting a leadwire. If leadwire itself poses this kind of problem, you have to address it.

You know this is not a problem from somewhere. It is not that you have done a faulty design. What you will have to look at is even a routine strain gauge connection introduces these kind of errors, 156 microstrain is not insignificant. You have to account for it.

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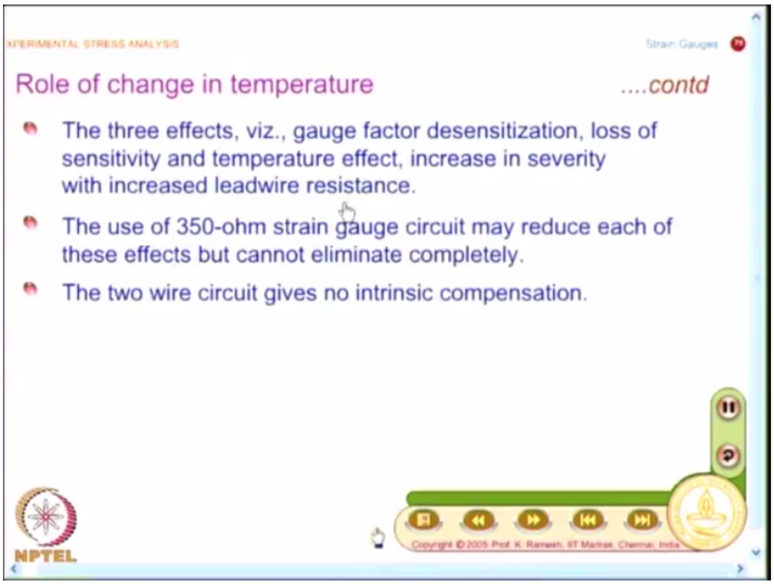

So what you find is the gauge factor desensitization or loss of sensitivity and temperature effect increase in severity with increased leadwire resistance. So you have to account for it in practical applications. So one way of looking at this is going for a 350 ohm strain gauge. This can reduce each of these effects but cannot eliminate any of them completely. See we had already looked at a remedy.

If I have to work on plastics, heat dissipation is very poor, the recommendation is do not use the 120 ohms strain gauge, use a high resistance strain gauge. You going for a 500 ohms or 1000 ohms for composites and indirectly if you take a higher resistance of the strain gauge, it also helps in issues related to desensitization caused by the leadwire and what you find finally is the 2-wire circuit gives no intrinsic compensation.

So before we find out a remedy, we should understand what is the problem. Now we have understood reasonably well what is the problem caused by a 2-wire circuit.

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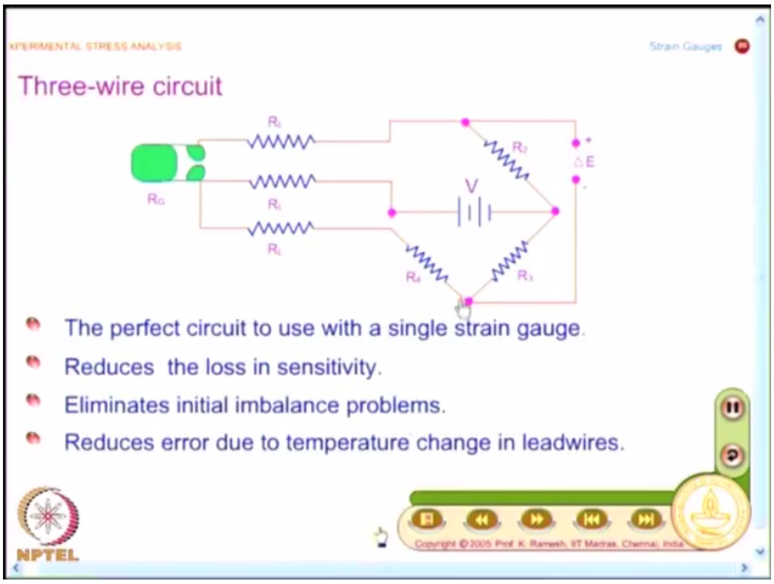

The via media to overcome this is a 3-wire circuit. I want you to make a decent sketch of it and instead of 2 wires coming from the strain gauge from one of the tab ends I take 2 wires and intelligently connect them to the Wheatstone bridge. This portion does not change but how do you connect the strain gauge to the strain meter in forming the bridge is slightly modified and shown here.

And what is recommended is this is the perfect circuit to use with a single strain gauge. When I am using a quarter bridge, this is the best arrangement and this reduces the loss in sensitivity and what are the other features? It eliminates initial imbalance problems. You have to intelligently look at you know I have adjacent arms, the adjacent arms cancel each other, so that is done here is for this arm I have one resistance RL and for this arm I have another resistance RL.

So when I have 3 leadwires, you have one leadwire attached to one of the arms, you have another leadwire attached to another arm. Thus it eliminates initial imbalance and also reduces error due to temperature change in leadwires because adjacent arms cancel each other. You need to have a decent sketch of it, you need to know what is a 2-wire circuit, that is very simple and straightforward.

You should know how to connect the 3 wires intelligently to form the Wheatstone bridge and whatever the third wire that I use, this is essentially used to connect the voltage that does not take part in your initial imbalance problems.

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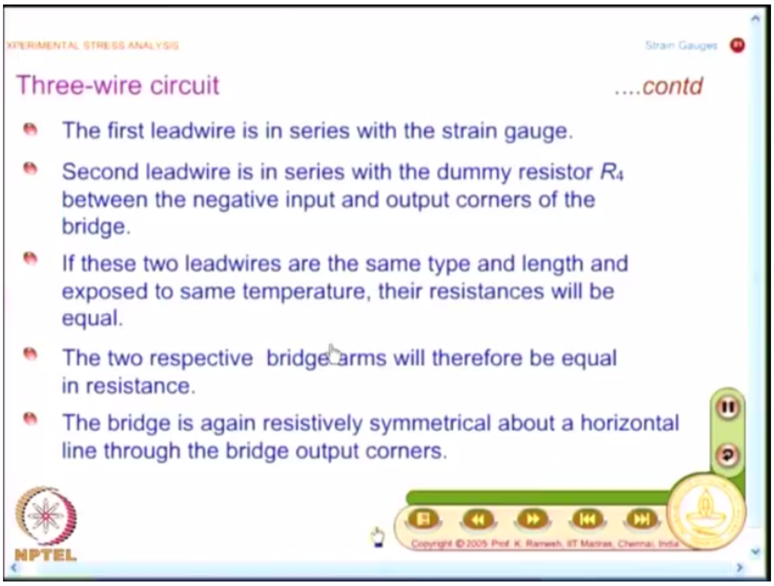

And whatever I have said earlier is now summarized as points. The first leadwire is in series with the strain gauge. The second leadwire is in series with the dummy resistor R4 between the negative input and output corners of the bridge. So I have leadwire on 2 different arms and obviously you are going to have these 2 leadwires of the same type and length and exposed to same temperature, the resistance will be equal.

Because I have leadwire connected to 2 arms, the 2 respective bridge arms will therefore be equal in resistance. There is no imbalance and if you look at the bridge it is again resistively symmetrical about a horizontal line throughout the bridge output corners. So what we have achieved is by connecting one more leadwire, we have intelligently reduced the desensitization of the gauge factor.

Because I have leadwires on 2 adjacent arms, even the temperature change will be canceled. Whatever the temperature change happens in one leadwire, it is canceled by the temperature change in the other leadwire. The only requirement is I need 3 wires to be connected. That is very simple, considering the kind of errors that you get in 2 leadwire system, a 3 leadwire system has better performance.

So whenever you go for a quarter bridge and that is the most common usage when you are measuring strain at a point. You will only use a quarter bridge, even if you use a strain rosette each strain gauge need to be connected to every stone bridge. So that means each one will be a quarter bridge. So quarter bridge configuration is most common in many of the strain gauge measurement scenario.

So in such scenario what we find is a 3 leadwire system eliminates the problems that you come across in a 2 leadwire system. Mind you, this is not because of temperature compensation in the usual sense. You may still use a self-temperature compensated gauge but if you use a 2 leadwire system, the leadwire resistance change because of temperature can be damaging.

We saw that is 156 microstrain so that you have to compensate for, whereas a 3 leadwire system definitely helps.

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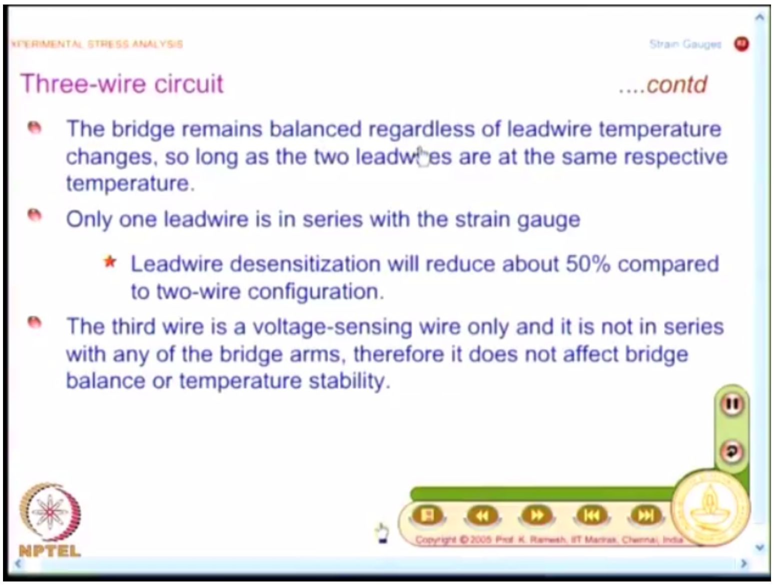

But you know you will also have to look at whatever the modification that you bring in, it is not sufficient that you can always use this in any application. There is definite improvement by a 3 leadwire system. The bridge remains balanced regardless of leadwire temperature changes and leadwire desensitization will reduce about 50% compared to 2 wire configuration.

The third wire is a voltage sensing wire therefore it does not affect bridge balance or temperature stability. We are just summarizing the advantages of a 3-wire circuit. The bridge remains balanced that is the first advantage. Leadwire desensitization is reduced by 50%. The temperature stability is unaffected.

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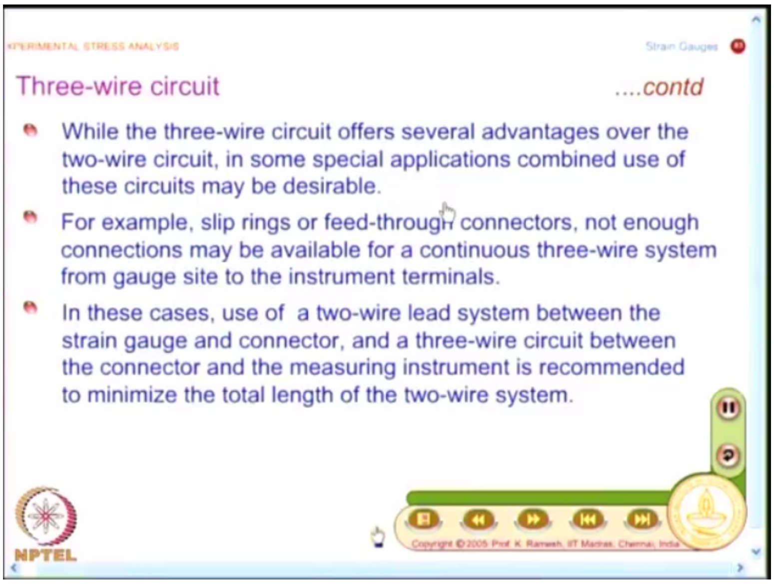

See a 3-wire circuit definitely offers several advantages but you cannot use this always. There are reasons why we are unable to use it. The recommendation is in some special applications, combined use of these circuits may be desirable. See you can take one example, in the case of rotating components, if I have to make strain measurement I have to attach a slip ring.

The slip ring prevents twisting of the wires and you have carbon bushes in this but these slip rings comes with certain limited number of channels. You cannot increase the number of channels easily and it will also have certain number of tapings that you can do. 2-wire system then I need only 2 points. If I use a 3-wire system, I need 3 points, which luxury may not be possible.

So what is recommended is use of a 2-wire lead system between the strain gauge and connecter and a 3-wire circuit between the connector and the measuring instrument is recommended by that you minimize the total length of the 2-wire system. So one example is given. The idea is if you are unable to eliminate 2 leadwire system at least reduce its length wherever possible use a 3 lead wire system to the extent you can go.

And the example given is in a rotating component, if I have to make strain measurement, go up to the slip ring as a 3 leadwire system, from the slip ring to the actual strain gauge, you go for a 2 leadwire system. That way you have a break even in employing combination of 2 wire and 3 leadwire system so you can bring down the influence of 2-wire system in the final measurement.

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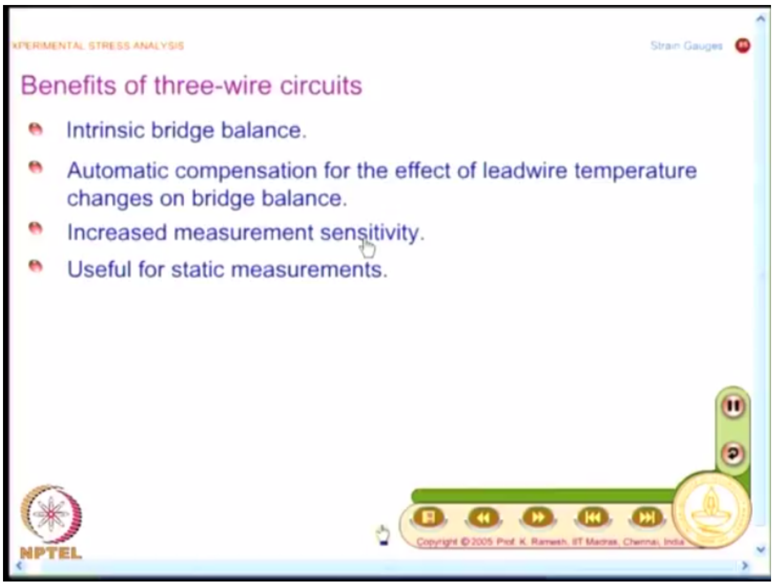

And what are the benefits of 3-wire circuits? A 3-wire circuit has intrinsic bridge balance. It has an automatic compensation for the effect of leadwire temperature changes on bridge balance and it also has increased measurement sensitivity and definitely recommended for static measurements because temperature effects are significant when you are measuring over a period of time.

So you need to compensate for temperature change and for static measurements when you are using a quarter bridge, go for a 3 leadwire system and also in applications where you are unable to use a 3 leadwire system for the entire length at least use it to the length that is possible. See when you say 3 leadwire systems is advantageous, 2 leadwire system also has a role to play.

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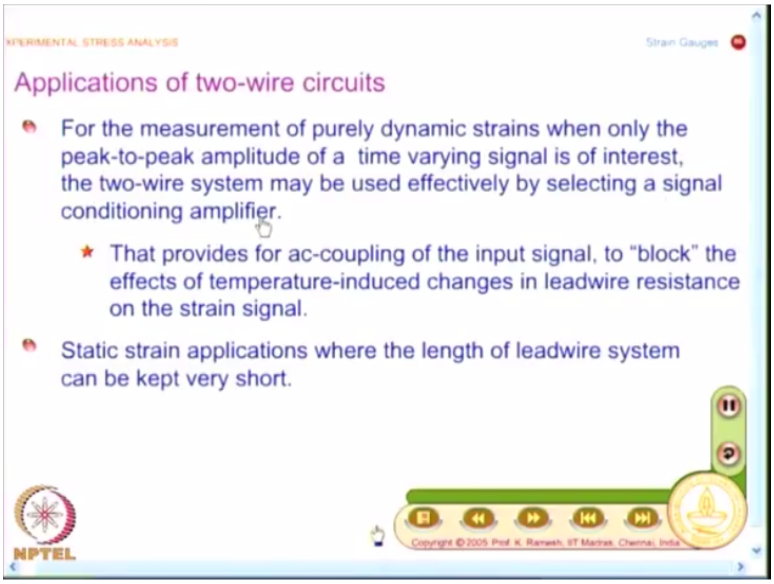

We will see in which class of problems the 2-wire circuits are applicable. Suppose I am working only on dynamic strains when only the peak-to-peak amplitude of a time varying signal is of interest and in such applications, the 2-wire system may be used effectively by selecting a signal conditioning amplifier. The conditioning amplifier need to provide for ac-coupling of the input signal, to block the effect of temperature induced changes in leadwire resistance on the strain signal.

And you know you have also done experiment in the laboratory class using the strain gauge where you had a specimen very close to the strain meter. You must have hardly use half a meter of length of leadwire. So when the length of leadwire is very small and also use a high quality copper wire conductor which has very less resistance, 2 leadwire is alright. 2 leadwire is convenient, you know from rooting the leadwire, soldering, you make less effort.

But it has its own problems and it can also be used in certain specific applications comfortably and mind you, you go back and verify your strain gauge measurement. In most instances, people are not aware that there is something called a 3 leadwire system. Many are not aware of it that is why I have cautioned I have always mentioned strain gauge technology is widely used unabused technique.

Because if you know the nuances, you will definitely recommend a 3 leadwire system from the point of view of confidence in the measurements. If you are not trained in strain gauge instrumentation, it is very common place to see people use a 2 leadwire for measurement even for very long distances of the specimen away from the instrumentation. So I would at least request the students not to use the 2 leadwire system when the leadwire length is very long.

It is very simple. You will only ask if I connect a strain gauge, naturally one will use only 2 wires why should I use 3 wires, it is very unconventional and the way you connect it to the Wheatstone bridge you are able to eliminate some of this nuisance of a 2 leadwire system that you will know only when you go through a course on strain gauges. There are nuances in instrumentation.

So in this class what we looked at was what is temperature compensation, what are the philosophies that you can think of. We also introduced the concept of self-temperature compensated gauges. I cautioned when you said self-temperature compensation, it is not that temperature compensation is available for a wide range of temperature, for normal changes in temperature they are good enough.

And you should also be very careful that you use the correct strain gauge for the specimen material. When I have a STC number for a different material, I use it on a different material. Then I will end up with a mess of strain gauge instrumentation. So in normal applications, you should use the STC number suitable for the paste specimen material. Why I say all this is you know we will also have to look at selection of the strain gauge.

When I have to go for a selection of a strain gauge, one of the parameter in the selection is the STC number. We will also look at a strain gauge designation system and we will find out how to select a strain gauge for a given application. For that I am preparing all the background, what is the property of the alloy, what is the characteristics of the carrier, what is the characteristics of the adhesive, now we looked at what are the measurement options.

We have looked at you can go for a 2 leadwire circuit or a 3 leadwire circuit and finally we have seen 3 leadwire system has many advantages in comparison to a 2 leadwire system. Not only this, implementation is very simple. It does not really call for any great difficulty in implementation, you need one more leadwire and it takes your pressure on monitoring the accuracy of the strain gauge instrumentation system because otherwise we saw the errors are quite high.

A temperature changes in a 6-meter wire can give 156 microstrain, it is very high and we saw for the same distance, the initial imbalance could be 7000 microstrain. These are not small quantities. So it is prudent to go for a 3 leadwire system when you are using a quarter bridge configuration. Thank you.