Industrial Safety Engineering
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Lecture – 48
Control Chart Analysis

Hello everybody. Let us start Control Chart Analysis. If you recall my last class in last class I have shown you that, how time series data exhibit different kind of patterns and in control chart analysis you also want to identify the patterns. Here, the basic issue is that the control chart ultimately identify the assignable causes means; if there are any specific reasons for the behavior of the system in terms of accident occurrences so that can be identified through control charts.

So, there are the varieties of control charts, but we will be discussing a few which are relevant to us, for primarily from safety analysis point of view. And second is that that suite that type of particular distributions.

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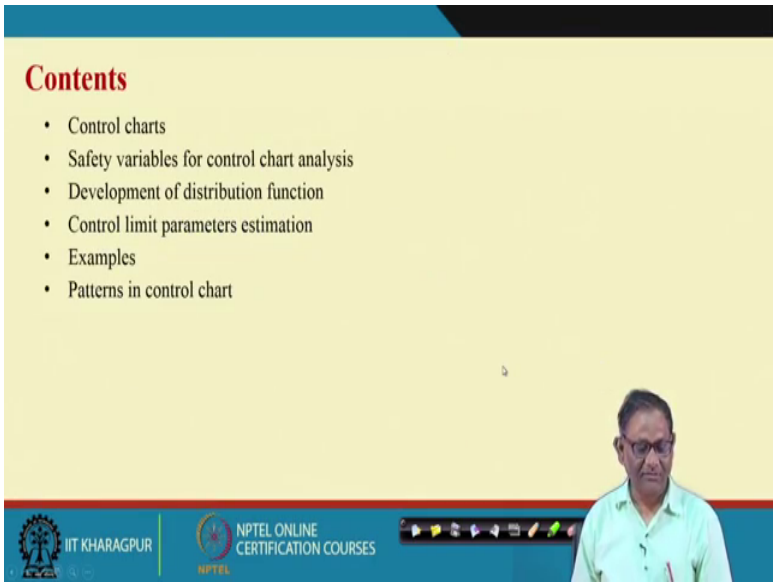

So, let us see that what are the contents today. We will first describe what do you mean by control chart, and then we will see that safety variables what can be used for control charts. Then we will see that how the safety variables ultimately lead to different distribution functions.

And then we will find out that how the control chart parameters can be estimated. And then with certain examples we will revisit the things, and finally I will show you that different patterns which basically usually appear in the control chart and most of them are applicable to quality related issues, but many of them are applicable to safety related problems. And I can say that may be most of all of them may be applicable to safety related problems, but it all depends on how do you encounter the situation if you have proper particular kind of data.

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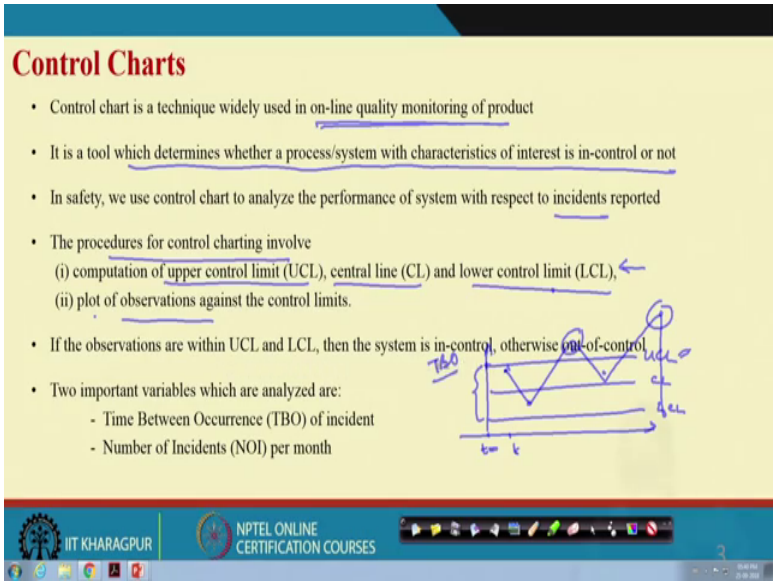

So, Control Chart is a technique that is widely used in online quality monitoring system. Please keep in mind online quality monitoring ok. So, what is the need of doing this? So, which determines whether a process of system with characteristics of interest is in control or not: for example, if your department is performing at certain level depending on the design, depending on the procedure, depending on the process involved depending on the people involved, so it safety; inherent safety is at certain level.

So, now what happened? If you maintain all those component of the system with effectively, so the safety performance basically will be within that particular level, what is inherent to the system. Now from the entropy principle you know that the component of the system will deteriorate an as we result what happen the safety performance also deteriorate. Now if the deterioration is due to some factors like process or procedures or the technology or the other way I can say the human or the software what you are using.

So, then what happened the deterioration can be attributed to a particular type of deterioration, which should not have happened. And that particular feature whether it is a human related, process related, procedure related, environment related, that feature or features are responsible for the deterioration or I can say the deterioration can be assigned to that particular feature.

And this is known as assignable cause. So, if there is any assignable cause so that cause ultimately lead to system improvement or deterioration. But from safety point of view we are basically interesting in the deterioration part, but the improvement part was equally important because if any time we find out improvement then we can also look into it. And then I will see you why I am; how has that improvement taken place and there then that can be followed ok. So, essentially then mean control chart; actually talks about the capability within which a process or a system will perform and beyond that if any situation arises then that can be attributed to assignable causes. That is what we will see.

So, the procedure of control chart involve finding out the upper control limit, central limit and lower control limit, that we will discuss. And then what happened, once these control parameters are identified you will be have the control chart on hand. And then whenever any observation you found so that you plot on that chart and ultimately you will see the position of the observation with reference to upper and lower control limit. And that is why it is used online. So, mean that first the; suppose this is my chart, this is my upper control limit, this is my lower control limit, this is my central limit; now chart is ready with certain previous data you have made it.

Now suppose t equal to 0 you start t equal to 1 and observation for example, suppose if I say this is in a time between accident or occurrences, so then when the first incident takes place you see that what is the time taken time taken maybe this much. So, then or second like this or third like this, fourth like this, fifth like this, sixth like this. So, if you plot these you may find out this is one and this is another one; these are out of control above UCL.

So, whatever within this upper and lower control limit they are basically talking about the process, that performance. Anything beyond this or below these talks about some; that is some assignable issues or causes responsible for this to happen.

So, that is why when anything or when you plot the particular variable in a control chart online it can be monitored that is the purpose ok. If the observations are within UCL, then the system is in control otherwise out of control; two important variables which we will be looking into time between occurrence and number of incident per month, because we are talking about in terms of safety ok.

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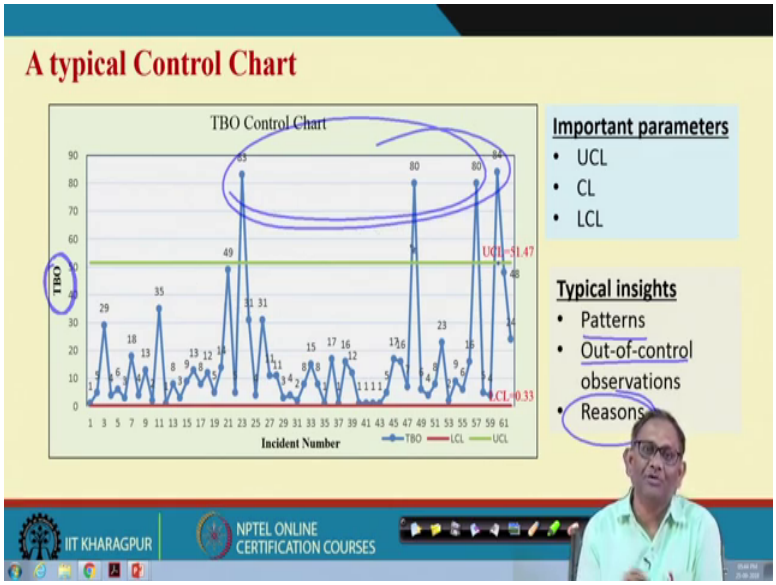

So, this is a Typical Control Chart where the time between occurrence we are plotted. So, these are the incident number and this is time between occurrence this axis.

So, we have created upper control limit that is 51.47 lower control limit it should be it is 0.33 ok. And then every incident observations in terms of time between occurrence they are plotted and you found out that this is one which is out of control out of control, out of control, out of control, but at the lower side nothing is there ok.

So, a control chart will be looking like this. And then important parameter is upper control limit this one you do identify lower control limit this is you have to identify and there will be some central limit ok. Then what are the typical inside that you will observe from this control chart pattern, whether this when you are plotting the observations connecting through line is any pattern you are observing. What are those pattern? Pattern means whether it is basically random or whether it is systematic there is a trained and other things are not so, that pattern.

So, either the things will be the; if any point is out of control in beyond LCL and UCL that is out of control. If there is any pattern that also related to out of control situations, then either out of control observations or patterns once observed you have to find out the reasons for those out of control situations. So, that is what is the purpose of control chart.

So now, when you talk about control chart; control chart over that; that means, here we are basically what time here plotting from incident point of view: incident 1, incident 2 like the incident N and here we have considered time between incident. And then in order to first you have to design this control chart in the design you have to find out UCL you have to find out LCL and you have to find out CL and what for the particular variable of interest like here time between occurrences.

Then you have to read this control chart. In the control chart you have to read out of control observations like this or the pattern or and also you have to find out the reasons and then those reason should be properly address so, that this out of control situation will not occur. Interestingly as safety is a one sided variable means either if it is a safety this higher the better or if it is a incident it is lower the better, if it is a TBO time between occurrence it is higher the better.

So, now anything beyond UCL here these are higher the better. These many cases we found out that the incident free period is more than what is actual what should have been actually happened from the process (Refer Time: 01:36) point of view at the system that testing point of view, but it is more than the UCL and the better now. So, then you what you do you will find out why during this period (Refer Time: 10:45) has do not taken place or (Refer Time: 10:47) taken place; that means, some good practices was adopted that time.

So, then why in other time those good practices where not adopted so, you have to adopt those good practices ok. Now I will show you how UCL, LCL, CL will be estimated depending on the variable and its distribution.

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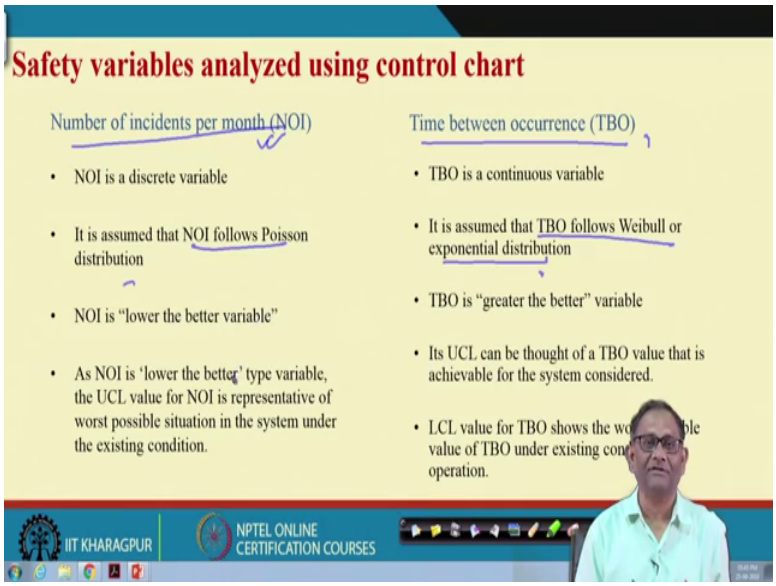

So, first one: first variable we will consider I think this is time between occurrences, second one is number of incident per month. So, this is a continuous variable this is a discrete variable. So now, what happen we have seen earlier from our study that TBO follows Weibull or Exponential distribution, whereas NOI follows Poisson distribution.

Now so that means, we have to find out upper control limit, lower control limit related to either Weibull or Exponential distribution depending on which distribution the TBO follows. And here we have to find out the upper and lower control limit for the Poisson distribution ok. So, let us see that How UCL and LCL are computed?

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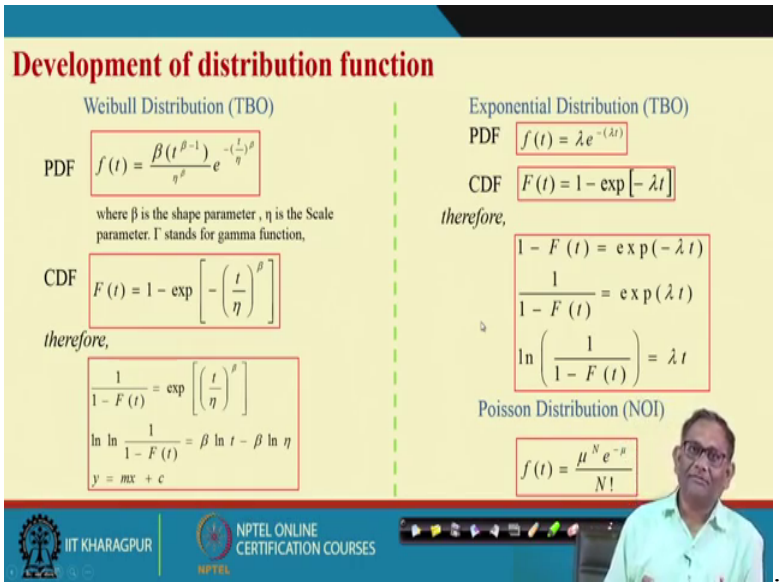

So, all of you know the Weibull distribution and Exponential distribution we have seen this while quantifying the basic events. So, this is the PDF for Weibull distribution, this is the CDF for Weibull distribution. And then this kind of plotting also you have given to you. Similarly for Exponential distribution you have seen this kind of this plotting and also Poisson distribution is basically the PDF is this.

So, if you consider number of occurrences or in an incident per month, then you use Poisson distribution. If you use time between occurrences then you see which TBO exponentially distributed or Weibull distributed that you find out ok.

So, that mean What is the your job? First you find out the characteristics, for which control chart is to be prepared. Is it time between occurrence or number of incident these two variable we are considered you can find out other safety variables also. For the time being we are considering these two variable need not required to say that you can take other kind of safety variable if it is continuous find out the continuous (Refer Time: 13:18) distribution if it is descrete find out the discrete distribution ok.

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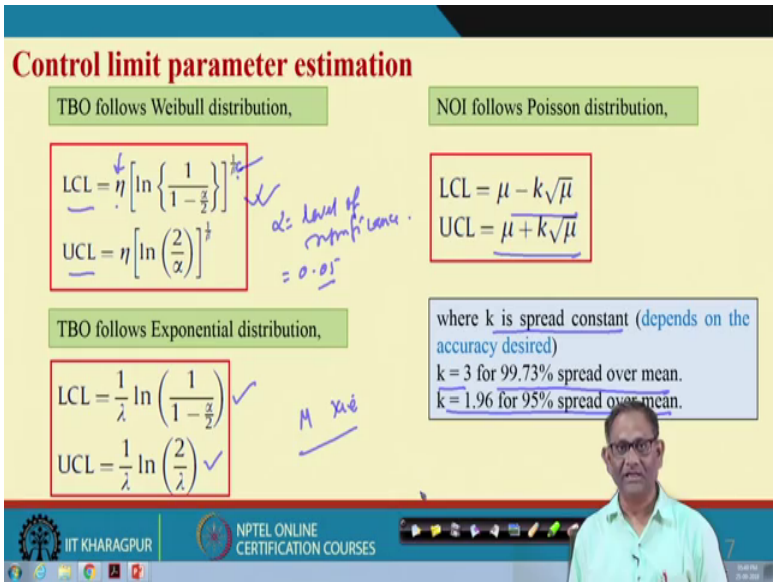

So, then these you LCL and UCL values these are obtained. I am not going to the mathematics of these because it is a complicated one, but there are paper available where from where you can find out this LCL and UCL. So, if it is a Weibull distribution then eta log 1 by 1 minus alpha by 2 1 by beta. You know beta is a safe parameter eta is a scale parameter and alpha is level of significance; then mean is usually it is related to the amount of error you are accepting. So, alpha usually we take 0.05.

So, here also if it is exponentially distributed then this is the LCL this is UCL. If it is Poisson distributed than mu minus k mu plus k root mu; where k is the spread constant and k is 3 for 97.73 spread over mean 1.96 for 95 percent case over mean ok.

So, that control chart with Weibull distribution expansion distribution there paper in reliability engineering in system safety. Some paper I think x i e M M x i e m e m g paper I have seen. And using their paper we have also developed some models and then I have also published, I means with my students probably some of the papers which are available for control chart. I think one of the one of my papers is refer referred here that you will see later on. So, if anybody interested to know that how these things are coming so, please go through that paper and the cross references so, you will be able to find.

So, essentially what happened that way if I know LCL and UCL and CL. CL is the mean value here so then what happened ultimately your control chart is designed. So, now,

your only thing is that you have the data collected and just plot the observation on the control which and then see the patterns ok.

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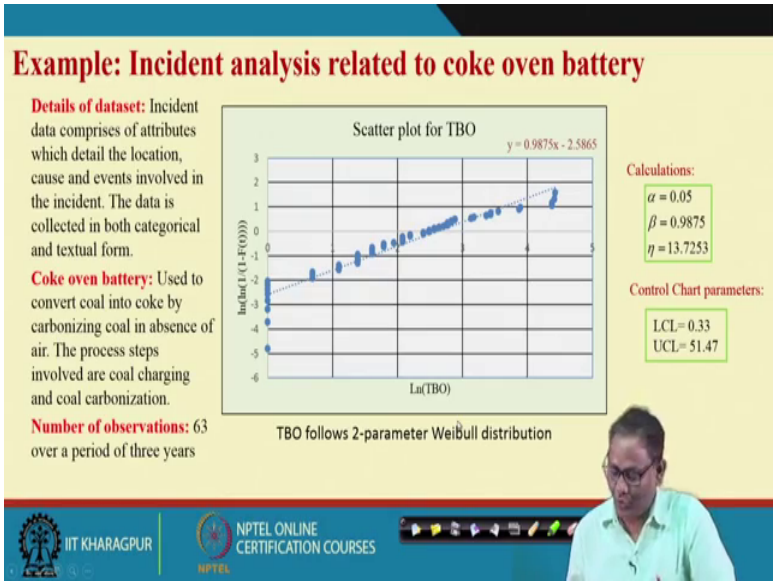

So, it is detail of data set incident data comprises of attribute, which with detail of location cause effects etcetera and it is basically study in a coke oven battery used to convert coal coke oven battery used to convert coal into coke by carbonizing coal in absence of air.

The process steps involved are coal charging and coal preparation. Number of observations we considered we got 63 observations over a period of 3 years. Then we have seen that whether this data is following Weibull to parameter Weibull distribution or not. Then we plot and we found that the plot shows there assembles a straight line pattern.

So, we are saying it is Weibull distributed. Then ultimately that beta and eta these are calculated. And that mean then using alpha equal to point 0.05 and the formula for LCL and UCL formula sorry; this LCL and UCL this formula we have used using this formula you got that LCL is this and UCL is this that is what I use this chart I have shown you earlier. So, that is 63 data points we capture and we have used it and then see the plot.

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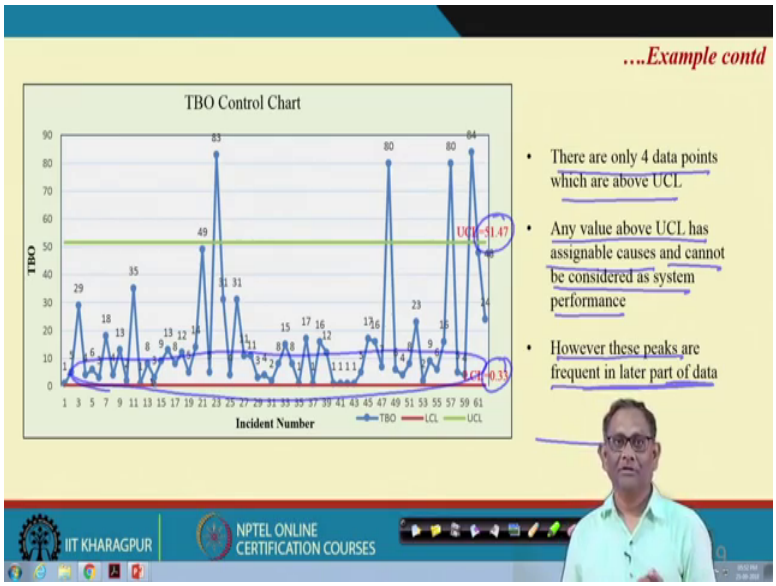

So, now you at the beginning I started with this UCL 51.47 LCL 0.33. Now you understand that where from this 51.47 and 0.33 these two values are obtained. Now, if you want to ask me to read this chart. So, I will read like these there are only four data points which are above UCL, UCL in a upper control limit; any value above UCL has assignable causes and cannot be considered as system performance, please understand. This has happened because of some assignable reasons.

So, it is not the system performance. What is the system performance? Anything in between UCL and LCL that is system performance beyond UCL below LCLs are not system performance, there are certain causes you have to identify. However, these peaks are frequently later part of the data ok; that mean here very frequently.

Now, if I considered TBO time between occurrence this is basically injury (Refer Time: 18:40) accident free incident free period. So, it is beyond UCL means the accident free period is more it is accident free period is stretched. So, it is a good indication ok, but if it anything below, but there are many at the lower level; so in performance many cases performances very poor ok. So, that is the inside from this control chart this is required this is this helps you to understand whether you are improving or not from the safety performance point of view.

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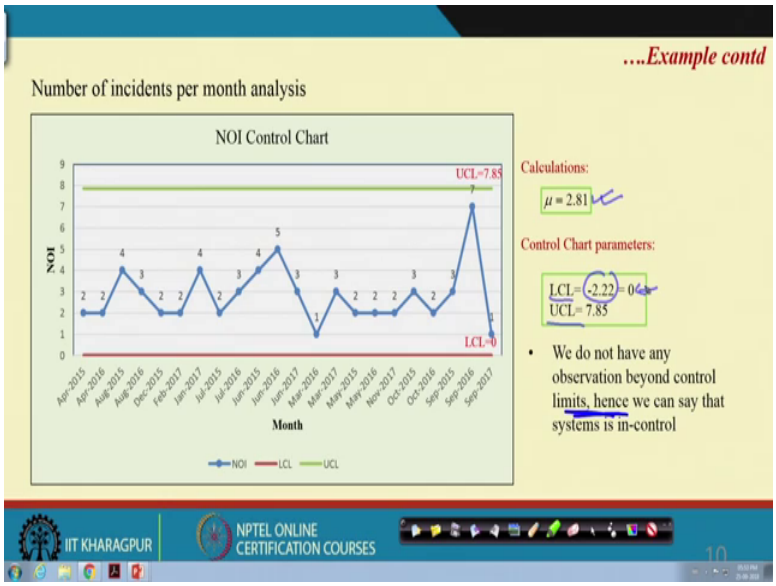

Now, if you see the number of incident per month for the same data set, then what we are finding out that we calculate it is a Poisson distribution and we calculated the parameter of the Poisson distribution and corresponding LCL and UCL please remember if LCL is minus it should be converted to 0 ok.

So, here interestingly data we do not have any observation beyond control limits. Hence we can say that system is in control, but when in terms of TBO you got one picture (Refer Time: 20:03) NOI you are getting another picture. So, definitely because these all relate although from the same system, but different variables give different picture. So, ultimately you have to choose which one is best suitable variable for your case in terms of safety performance improvement. And accordingly (Refer Time: 20:22) or you choose many of such safety variables and variable safety variable for which the system performance is deteriorated there you concentrate on ok.

So, now, I will just show you some of the general things, which are applicable not only for the NOI chart or TBO chart, but it is it is applicable for any other chart and not necessarily related to incident data it can be related to any other data. So, very quickly I will finish that part.

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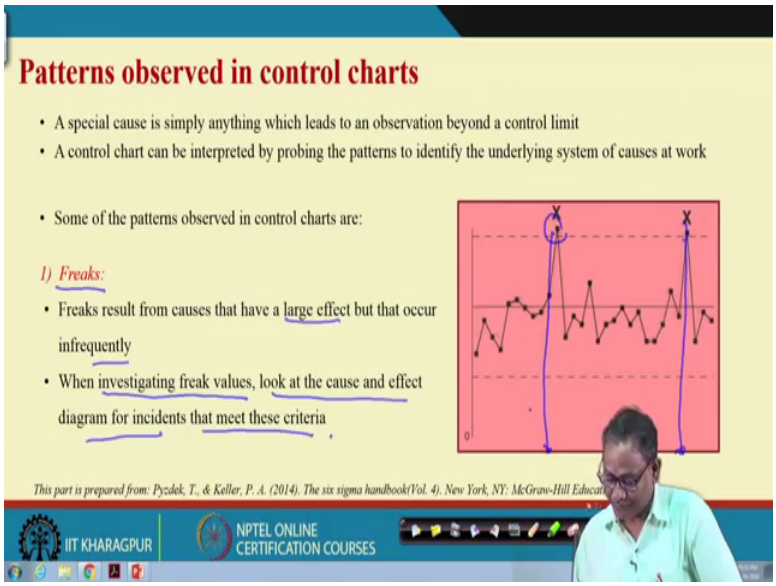

So, there you will find out the different kind of pattern in the control chart, here you see that these and these are basically that freaks result from causes that have large effect, but occur infrequently. If you see the entire the (Refer Time: 23:13) two times it occurs beyond UCL. So, I am not saying that this is basically incident data this any kind of data. So, then the large effect may be positive or may be negative, but what will be the large effect of there, but this will occur in frequently.

So, when investigating such freak values look at the cause and effect diagram for incident that meet these criteria. So, that mean here during these particular time what was the situation for the plant. So, we have to investigate thoroughly ok. So, let me tell you this charts we have taken from this book that Keller and Pyzdek 6 sigma handbook from that book we have taken these figures ok; most of the words also we have taken from that book.

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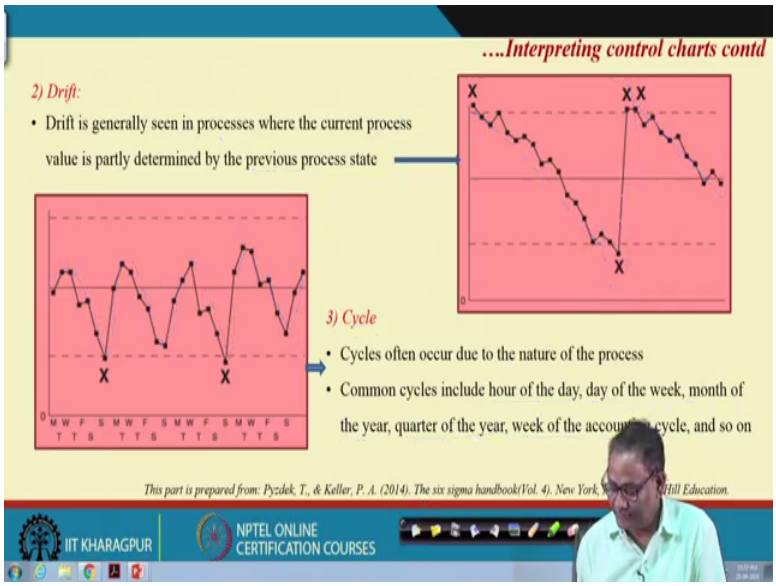

So, one is Freaks, second one is Drift. If you see this figure you see that the purpose system performance is decreasing suddenly there is a jump and again started decreasing. So, this is the point this drift has taken place. Although it is showing one pattern decreasing pattern, this also showing decreasing here decreasing here, but there is a sudden. Drift is generally seen in process where current process value is partly determined by previous process states.

Another one is a Cycle, you see the cycle is happening here cycle. So, this is also not in control this is also not in control status. Cycles often occur due to nature of the process. Common cycles include hour of the day, day of the week, month of the year, quarter of the year, week of the accounting cycle and so on. So, this cycles you must understand and these basically helps you to take appropriate care, because if this is the nature of the process then the cycle will occur and accordingly you have to take care properly.

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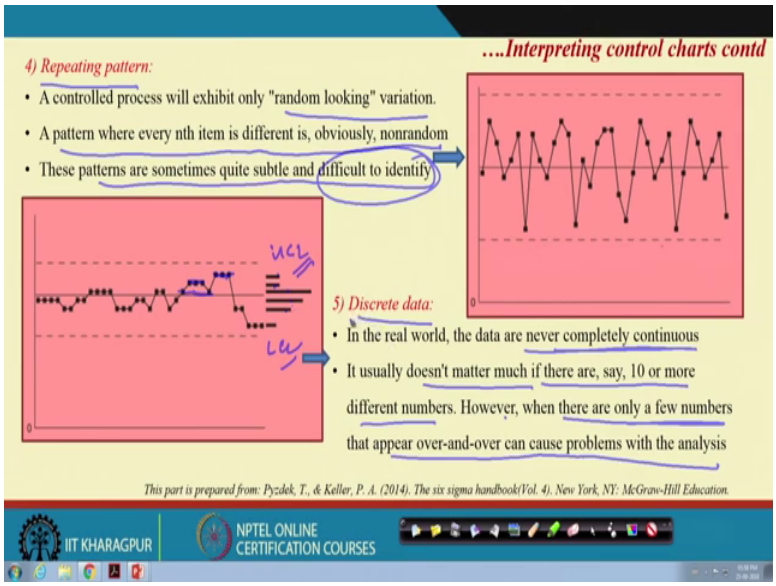

Then another one is the Repeating pattern. You see it is a repeating pattern here a control process will exhibit only random looking variation. A pattern where every nth item is different is obviously non random. These patterns are sometimes quite subtle and difficult to identify. Why it is happening? It is very difficult to identify, but it happens and if it happens it is a things to be investigated it is not in control.

Another one here this is UCL then this is LCL you may think it is very much under control, but this is discrete data that is also a question things to be investigated. In real world the data are never completely continuous, it is usually does not matter much if there are 10 or more different numbers. However, when there are only a few numbers that appears over and over then the problem will occur.Because here 1, 2, 3, 4, 5 you see five different this is one type of value another values this is another values.

So, five different values this variable which variable you cause that it takes only five values and then you will get this kind of plot and when you develop the UCL and LCL you will find it is within control, but actually not because this is a discrete data problem. So, that is why the recommended one is that at least the data should have 10 or more different numbers different values (Refer Time: 25:05) ok. So, this is what is the way to understand the control chart.

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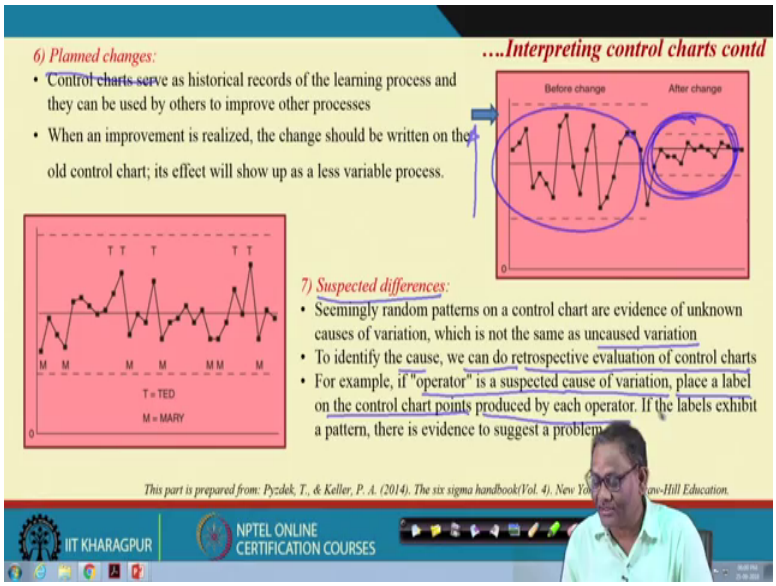

Control chart will basically really helped you ok. So, apart from what we have discussed there can be situations, where you have changed your plant or the procedure or something you have changed, because further cause of improvement you have changed, but it is also to be recorded in the control chart.

So, before change this is the chart and after change this is the chart. So, if you say this is the higher the better kind of variable then this is definitely a better performance. So, that is what we are saying if that change is not known to the person who are evaluating the process then he will think that what happened here the performance and here performance are different. So, it is always better such changes to be recorded in the control charts, and there is another one that suspected differences ok.

So, seemingly random patterns on a control chart are evidence of unknown causes of variation which is not the same as uncaused variation. To identify the cause we can do retrospective evaluation of control chart. For example, in operator is suspected cause of variation place a label on the control chart point produced by each operator if the label exhibit a pattern there is evidence of suggested problem. That any have many people working together you know that the some worker who are problematic worker.

So, when they are operating the machine. So, you for that time that they are basically suspected operators or suspected worker or suspected machine also maybe not necessarily on the operator suspected things. So, just label them. And then you see

whether you are get for those label values you are getting any pattern or not. And then obviously, if you get any pattern exhibit any pattern that conduct of labeled observation, it suggests that the suspicion of the hypothesis of suspected hypothesis is correct ok.

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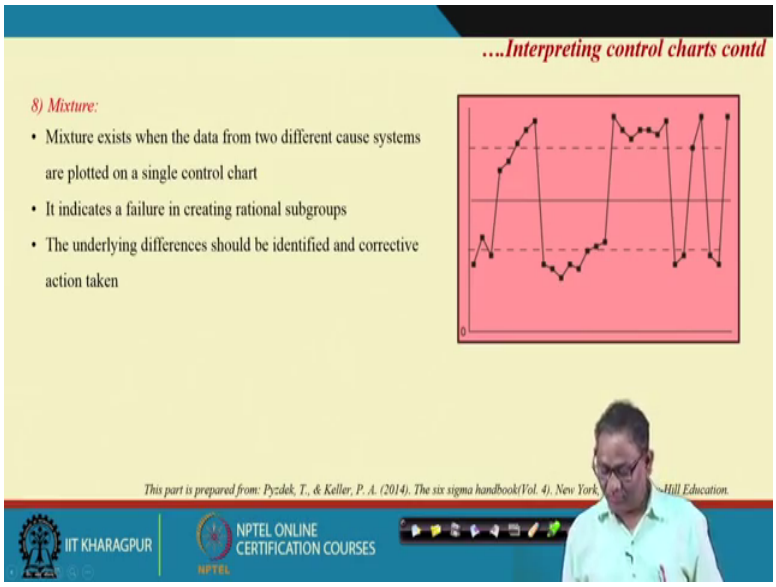

Then final one is the Mixture. What is the mixture? Mixture exhibit when data from two different cause systems are plotted on a single control chart it is not one. So, you have mixed with many things maybe from to department that are mixed together and you plotted to different machine to different process mix to this plotted. Then this kind of mixture chart pattern you will get if you get mixture pattern you assure that you have basically blended data from different sources this should not be done this is not a control in control process and this is problem with the control charting, ok.

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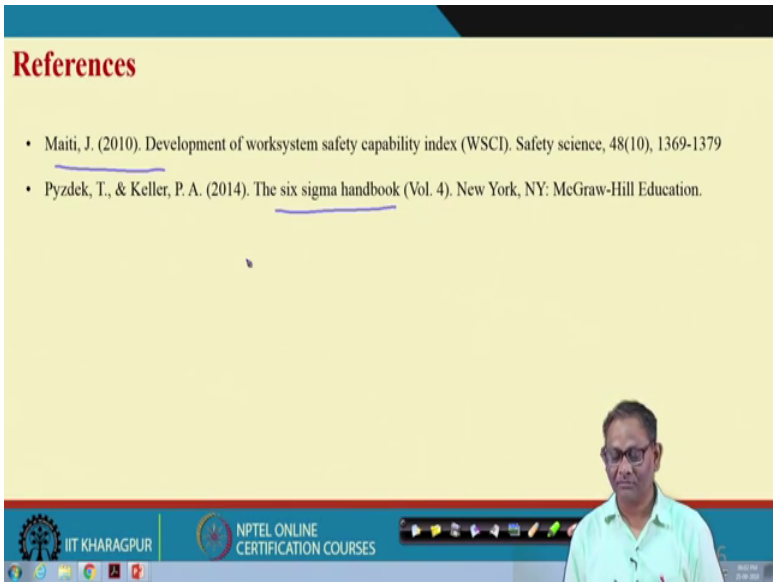

So, it is interesting to one I hope you have all enjoyed. And this is the paper you can go through we will get more detail of this control chart principal and also safety capability. And this is the book from where the patterns I have taken and I really acknowledge the authors for this book and also really helped by this.

Thank you very much. See you in the next class.