Quality Design and Control
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Lecture – 26
Process Capability Analysis

So, during the 6 week I will be discussing an important topic called process capability analysis. In fact, on the any say exercise we carry out on quality or say quality engineering or quality control you know the directly or indirectly all sorts of analysis quality related analysis are related to process capability.

So, process capability is considered a very important topic now there will be 5 lecture sessions in the very first lecture I will be referring to the Basics of Process Capability and Process Capability Analysis.

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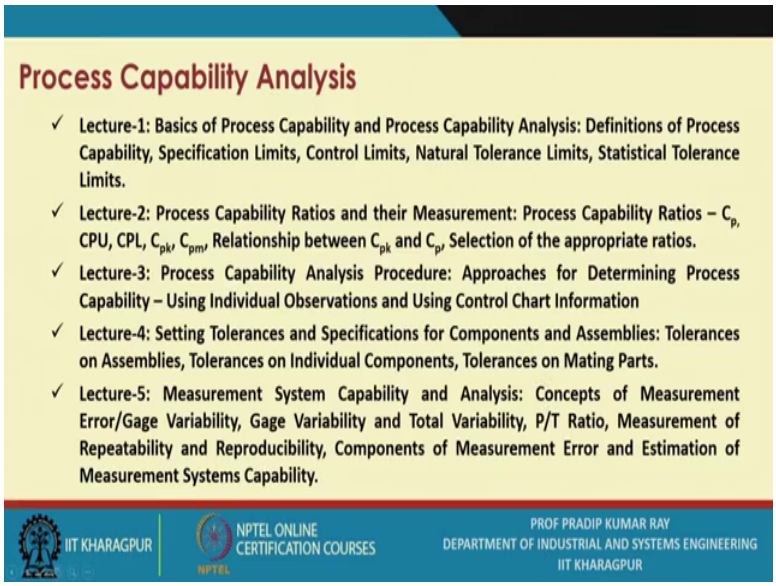

Where I will be referring to the definitions of Process Capability, Specification limits, Control Limits, Natural Tolerance Limits and Statistical Tolerance Limits. So, on the next lecture, lecture 2 will be referring to the Process Capability Ratios and their Measurement and under process capability ratio there are many ratios we here which are relevant some of these ratios as a Cp, CPU, CPL, C pk, C pm relationship between C pk and Cp will discuss and the direction of the appropriate ratios what is the basis of selecting an appropriate ratio.

In during lecture 3 the Process Capability Analysis Procedure in detail we will discuss and particularly the approaches for determining process capability using individual observations as well as using control chart information. During lecture 4 others will be discussing Setting Tolerances and Specifications for Component and Assemblies, Tolerances on Assemblies that is the first topic, the second topic will be the Tolerances on Individual Components and the last one will be the Tolerances on Mating Parts.

During lecture 5 we talked about Measurement Systems Capability and Analysis Concepts of Measurement Error Gage Variability, Gage variability and total variability the so, called P by T ratio, Measurement of Repeatability and Reproducibility, Components of the Measurement Error and Estimation of Measurement Systems Capability, this will be your coverage under process capability analysis.

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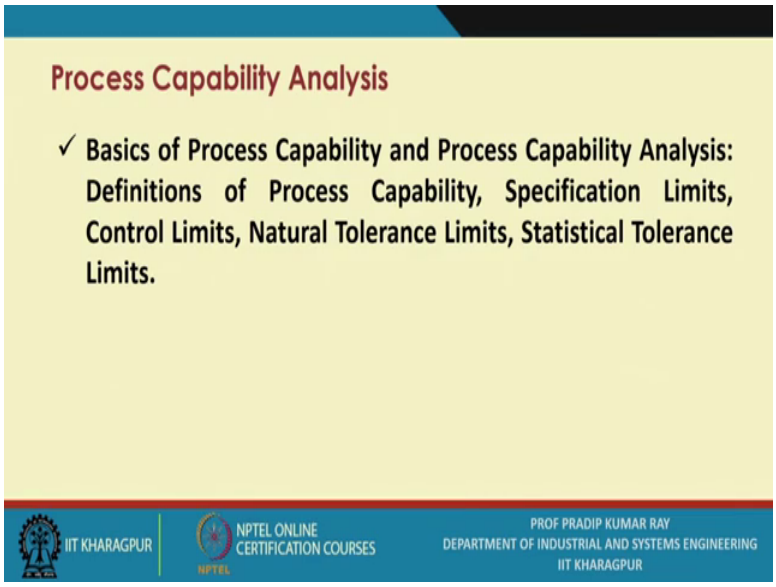

We will be discussing the few important said the in the issues related to process capability we call it the Basics of Process Capability and Process Capability Analysis. So, under definitions of process capability specification limits, control limits, natural tolerance limits, statistical tolerance limits. So, as a student, as a learner, as a practitioner you must have very clear understanding of all these concepts. So, we will be discussing all these you know the topics.

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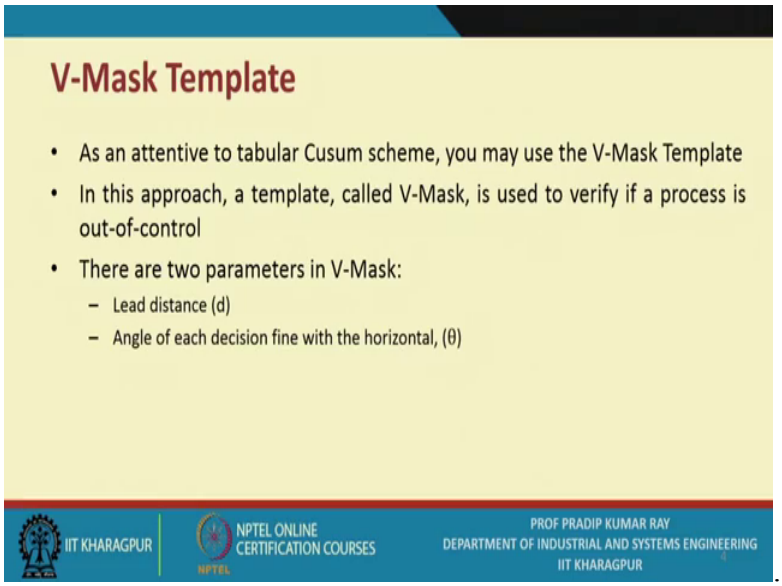

Now, before say discussing this process capability analysis you know just I will be taking few minutes of time to discuss the Cusum control chart. So, I will be just taking because we have referred to say the 2 approaches and for cusum control chart the first one already we have discussed at length that is the algorithmic say as in the cusum or say tabular cusum whereas, the alternative to algorithmic cusum always we prefer to use algorithmic cusum but because of some reason suppose you seek an alternative so; obviously, the alternative could be the V - Mask template. So, I will just in the referring to some import in interesting features related to V - Mask template. So, as an alternative to tabular cusum scheme you may use the V - Mask template.

So, in this approach a template called V - Mask is used to verify if a process has gone out of control or not. So, there are 2 parameters in a V - Mask one is the least distance d and the second one is the angle of each decision line with the horizontal. So, there will be 2 decision lines you will find in the template upper decision line and the lower decision line.

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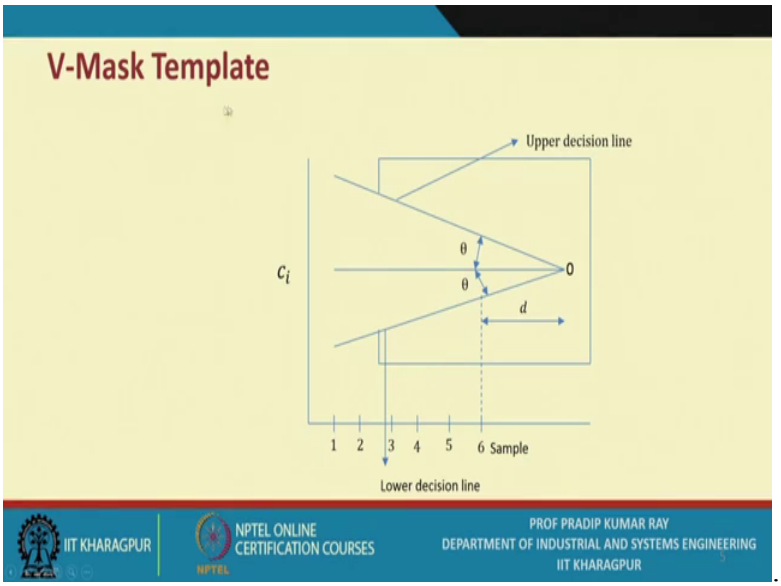

This is a typical V- Mask template you will find that this is the lead distance and this is your upper decision line and this is your lower decision line and you have this angle theta with the horizontal line. So, in x axis represent the samples and the y axis represents the Ci is it the Ci means the cumulative the deviation from say at a sample I what is the cumulative deviation of the observations from say the target value. So, we have already defined Ci. So, it is basically Ci versus sample numbers. So, what do you need to do you need to determine the value of theta and the value of or the lead distance?

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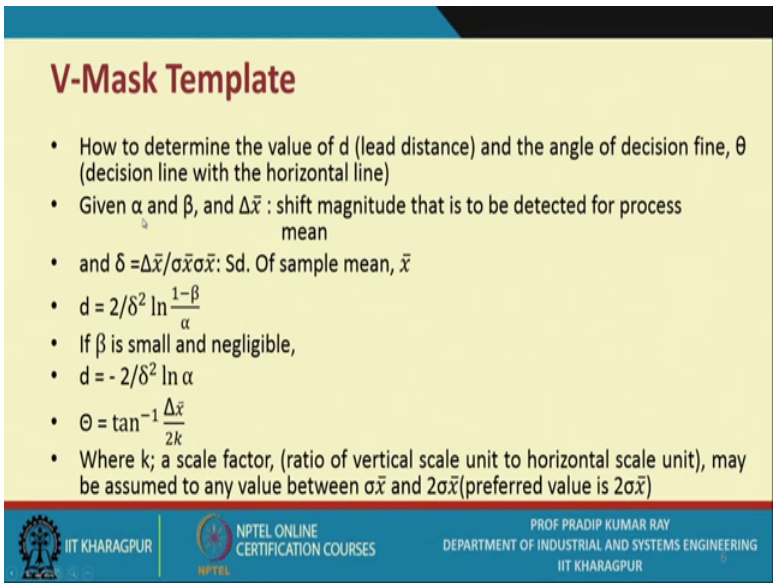

So, how to determine the value of d the lead distance and the value of the angle of decision line theta with the horizontal line; that means, decision line with the horizontal line. So, given alpha and beta what is alpha; that means, once you try to design this template what you need to do; that means, you must specify that what is the probability of making type 1 error and what is the probability of making type 2 error. So, these 2 values should be specified and as is as we always say that these 2 values should be as minimum as possible is it and delta x bar is basically a shift magnitude that is to be detected for process mean.

So, what you try to do; that means, you define small delta that is you know that is delta x bar divided by sigma x bar is it that is the standard deviation of the samples and this is delta x bar is the basically the standard deviation of the sample mean x bar is it. Now we have these 2 expressions; that means, the lead distance is given by 2 upon delta square natural logarithm 1 minus beta by alpha if beta is small and usually it has to be very very small and negligible, then we can ignore beta over here.

So, the expression for d is approximately minus 2 upon delta square natural logarithm of alpha and the angle theta is given by tan inverse delta x bar by 2 k where k a scale factor and the scale factor, how do we define the scale factor a ratio vertical scale unit horizontal scale unit is it like say when you use the steam plate; that means, x axis versus the y axis. So, that is as the ratio is referred to as a scale factor and where the key may be assumed to be any value between sigma x bar and 2 sigma x bar. So, preferred value is twice sigma x bar is it.

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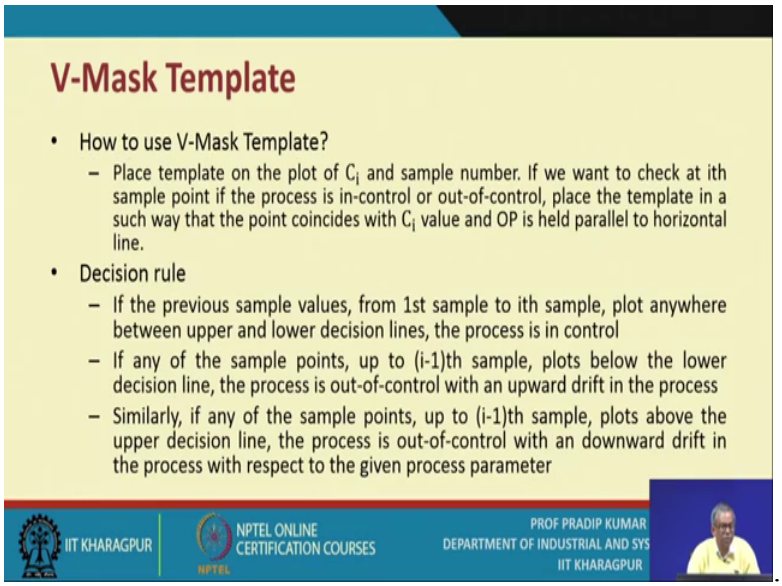

So, this is way we design the V- Mask template and how to use this V- Mask template place template on the plot of Ci and the sample number I have already shown if we want to check at ith sample point if the process is in control or out of control ith may be say fifth sample point or tenth sample point place the template in such a way that the point the coincides with Ci value and OP is held parallel to horizontal line is it.

So, this way you use the template and then what is the decision rule decision rule is very simple if the previous sample values from the first sample to the ith sample plot anywhere between upper and lower decision lines and that is the area the process is assumed to be in control if any of the sample points up to i minus 1th sample plots below the lower decision line the process is out of control with an upward drift in the process.

Alternatively if any of the sample points up to the i minus 1th sample plots above the upper decision line it may happen the process is out of control with a downward drift in the process with respect to the given process parameter. So, this is this is the rule of using V- Mask template.

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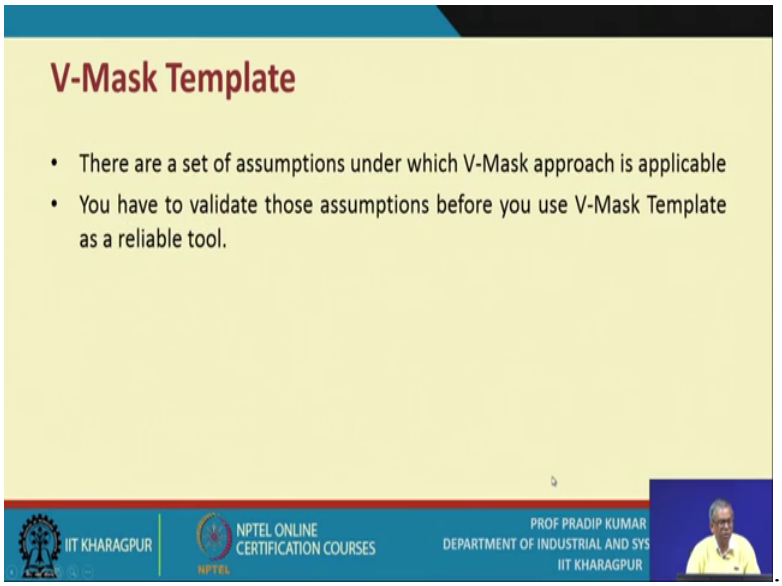

There are a set of assumptions under which V - Mask approach is applicable is obvious you have to validate those assumptions before you use V - Mask template as a reliable tool. So, at this point is to be remembered that whatever the assumptions you have in the V - Mask later on we will discuss we will refer to these assumptions now in a given situation for a given process if those assumptions hold then only you are supposed to use V - Mask template.

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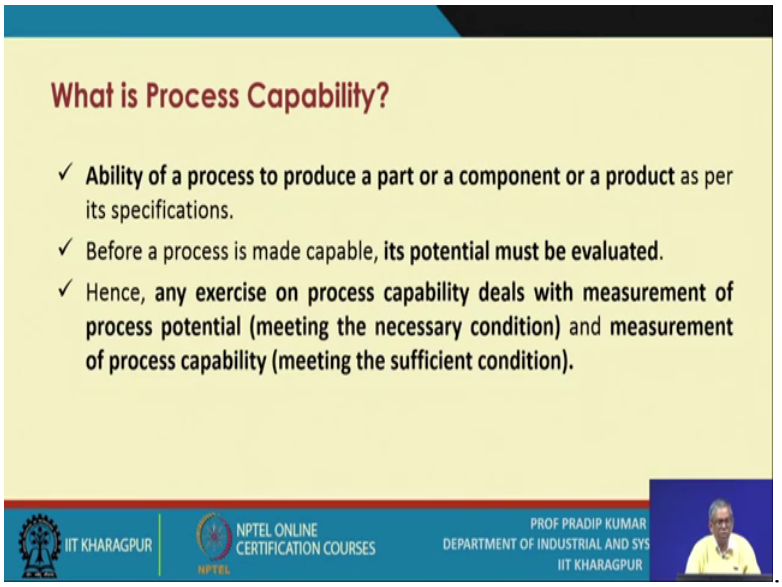

So, concluding our discussions on the special purpose control chart now let me first define the term called process capability. So, what is process capability in plain and simple terms it means ability of the process to produce a part or a component or a product as far the specifications. So, I am assuming a manufacturing process and essentially it refers to the ability of the process to produce as per the specifications of a component.

Now, before a process is made capable it is potential must be evaluated is it first we must know that whether a right kind of you know the process has been installed or not and if you say it is a right kind of the process; that means, in this context to say the whether the process has got enough potential to be capable. In this particular context any exercise on process capability deals with measurement or process potential ; that means, the first you check whether it has got the adequate potential to be capable or not, you need to meet the necessary condition.

Once you are you succeed in meeting the necessary condition then you check whether you know you are able to meet or you have become or your process is really capable or not; that means, it deals with the measurement of the process capability and you are trying to meet the sufficient conditions is it I think you know. So, whenever we discuss a topic called forces capability you know inherently you know you must we assume that suppose I say the process is capable. Now; that means, we assume that the process has got inherent say the ability to be to ability to be to have the potential. So, this is the first point to be remembered.

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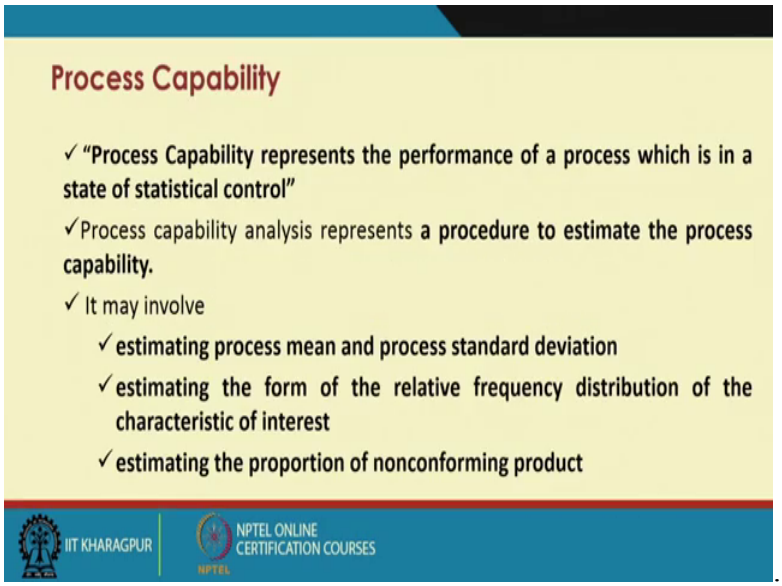

So, process capability represents the performance of the process is it. So, many a time you know you say that the performance is acceptable. So, essentially we are referring to the process capability now and whenever you say that the performance is acceptable or the process capability represents the performance of the process we assume that the process is in a state of statistical control; that means, what is our recondition; that means, before you go for measuring process capability you first verify that the, whether that the state of the process is acceptable to you or not, whether the process in a state of statistical control. So, which kind of tool you need to use; obviously, you need to use one or more of that of the control charts or the relevant control charts you must use.

Now, the process capability analysis represents a procedure to estimate the process capability now it may involve few things like estimating process mean and the process standard deviation that is the first exercise you have to do; that means, for that you have to collect data and after analyzing the data you will come to know that what is the estimate of the process mean as well as what is the estimate of the process standard deviation, that is the first step.

In the next step what do you estimate the form of the relative frequency distributions you can already you know what is the frequency distribution like when we discussed or the 7 tools of quality management. So, we have referred to these frequency distributions. So, what you try to do you estimate the form of the relative frequency distributions of the

characteristics of interest; that means, for a given quality characteristic estimating the proportion of nonconforming product. So, that is actually that is you know the proportion of nonconforming product is ultimately the measure of process performance.

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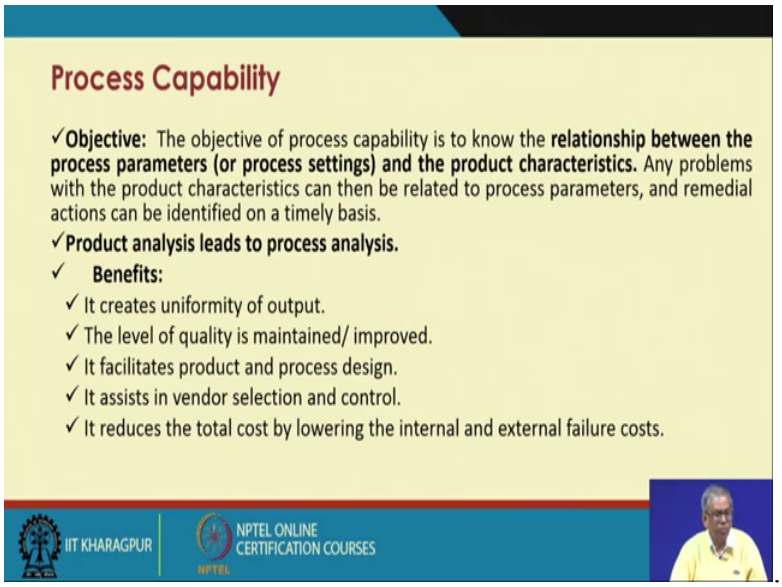

So, what is the objective, objective of process capability analysis is to know the relationship between the process parameters or the process settings and the product characteristics. So, this is very very important though we will be collecting data initially one quality characteristics and we will analyze the data related to quality characteristics of a component, but ultimately what you need to do; that means, in any process capabilities today; that means, first you go for product analysis and what extend the process is affecting the you know the product analysis the relationship between the product analysis and the process analysis is a must.

And whenever we talk about the process analysis essentially it is exercise on determination of the appropriate process settings. So, their values any problems with the product characteristics can then be related to process parameters and remedial actions can be identified on a timely basis.

So, the product analysis needs to process analysis. So, we will start with the product analysis later on when you talk about when we take up some case studies or we take up some numerical problems. So, we will discuss the relationship between the product analysis and the process analysis.

Now, what are the benefits there are many kinds of benefits you may have through process analysis it creates uniformity of output that is the first thing as I have been telling you that any exercise and quality is essentially an exercise on consistency or the uniformity of output.

The level of quality is maintained or improved; that means, it is the ability to meet the specifications so; obviously, it is expected that through process capability the level of quality you can maintain or even in many cases as a quality improvement exercise you might say that the level of quality can be improved it facilitates product and process design it assists in vendor selection and control and it reduces the total cost by lowering the internal and external failure cost.

So, it is expected that a; obviously, your goal should be the 0 defects through process capability analysis is it all right so; obviously, if you have 0 defects what you can expect that both internal and external failure cost will be at the minimum level.

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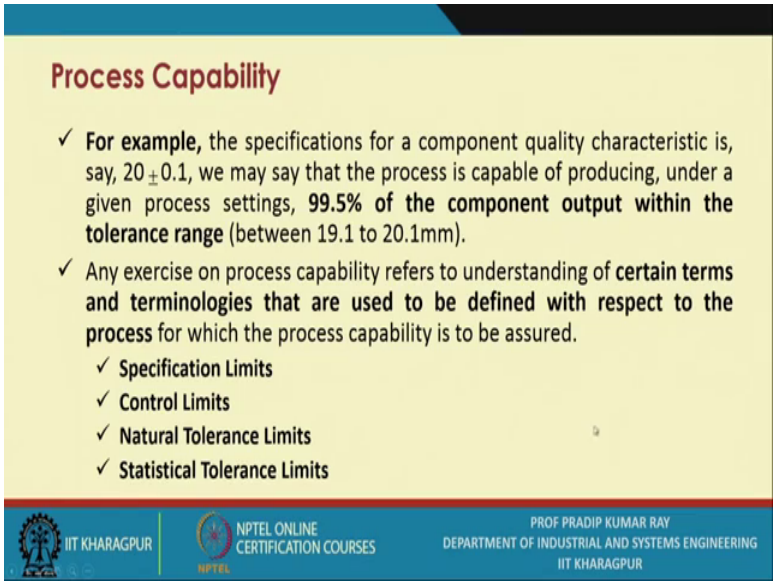

Now, this is just an example like for the specification of a component quality characteristic is say 20 plus minus 0.1 is a millimeter fine we may say that the process is capable of producing under a given process settings 99.5 percent of the component output within the tolerance range, what is the tolerance range; obviously, tolerance range will be 19.9 to 20.1 millimeters.

Any exercise on process capability refers to understanding of certain terms and terminologies this we always you know we insist on that will be using certain terms and terminologies related to process capability all related to any topic and you must have a clear idea you must know that, what is the exact definition of those terms and terminologies.

These terms and terminologies will be used and they are to be defined with respect to the process for who is the process capability is to be assured is it. So, the context is the process capability now the first term we use that is the specification limits, the next term we use already we have defined the control limits, the third term we use that is the natural tolerance limits and then we also use a term called statistical tolerance limits.

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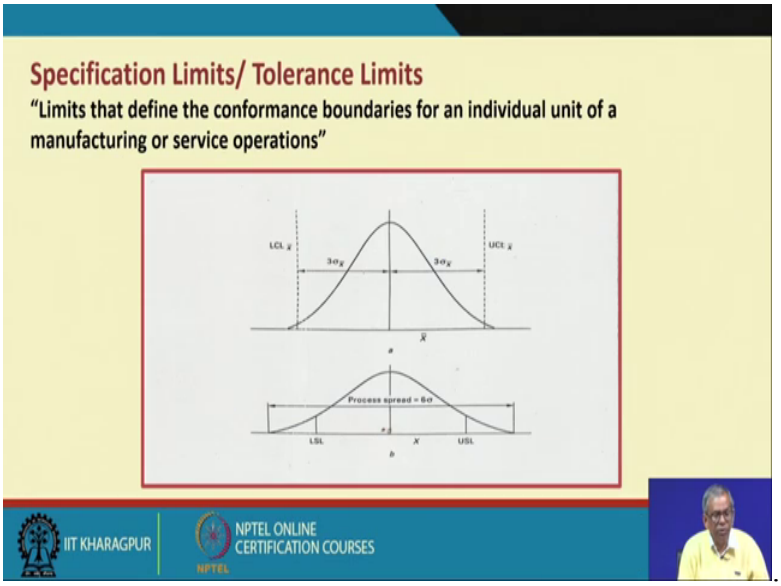

So, let me first explain let me define what is the specification limits and when you refer to the specification limits actually it is a general term which refers to for the entire product or the entire system.

Now, when we say the tolerance limit actually we refer to the physical quality characteristics of physical dimensions right and in many cases you know unless otherwise specified you know these 2 terms are used interchangeably when particularly when you deal with the physical dimensions of a product or a component.

So, how it is defined limits that, define the conformance boundaries for an individual unit of a manufacturing or service organizations. So, the conformance boundaries like in a given case you may have for a given quality characteristic say x. So, you may have USL, you may have LSL, is it and here we say that the specification limits can be of 2 types like say and the single specification limit case either upper or lower or it could be the double specification limit case depending on the quality characteristics you use is it.

So, we have already defined them. In fact, the specification limits.

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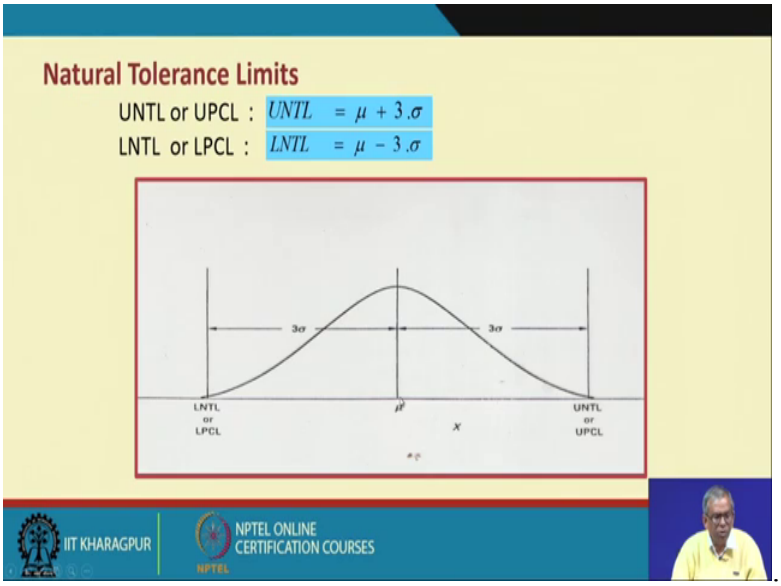

So, now what we try to do; that means, we try to define the natural tolerance limits. So, what is a natural tolerance limit; that means, here you say how there will be upper natural tolerance limits there will be what natural tolerance limits. We have you just refer to the distribution of x and under certain conditions in most cases you will find for running production system and when the value of x is dependent on I know the so many other the factors or the variables. So, and x you get from say the downstream whereas, these factors are affecting at the upstream processes. So, many a time the assumptions regarding in normality with respect to x these assumptions these assumption is valid.

Now,, you have the upper natural tolerance limit and you have also lower natural tolerance limits. So, how do you define upper natural tolerance limit. So, mu is basically the process mean is. So, mu plus 3 times sigma is it and what is a lower natural tolerance

limit that is mu minus 3 c sigma minus 3 into sigma what is sigma, sigma is actually the process standard deviation.

Now, instead of writing UNTL also you can you can write UPCL; that means, upper process capability limit and similarly LNTL is also known as LPCL; that means, lower process capability limit is it so you have defined, what is a natural tolerance limit.

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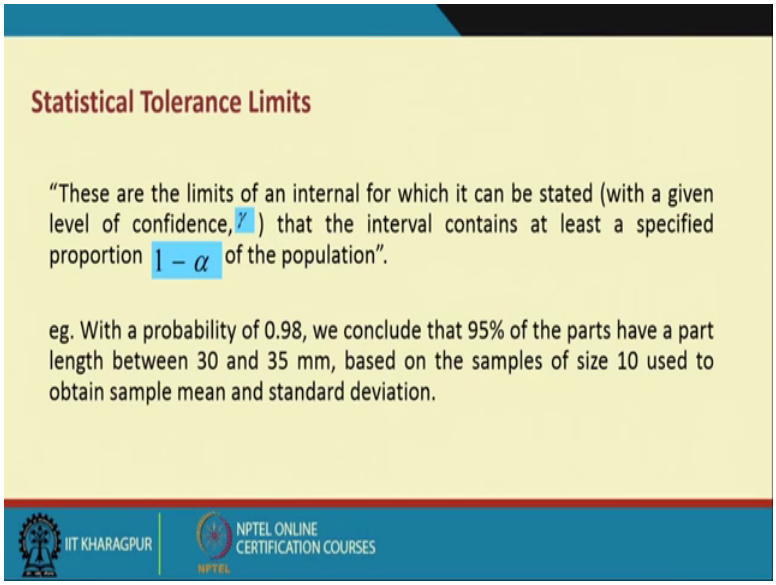

Now, what is statistical tolerance limits, the statistical tolerance limit is basically the generalization these are the limits of an interval limits of an interval for which it can be stated with a given level of confidence level is say gamma that the interval contents at least a specified proportion 1 minus alpha of the population.

So, this is the most generalized definition and so, with an example with a probability of 0.98 we conclude that 95 percent of the parts have a part length between 30 and 35 mm is it; that means, I am getting you the population so; obviously, I get a representative sample and the sample size is 10 and what I conclude that 95 percent of the parts from this sample I conclude that their values will be lying between 30 and 35 mm and I will say with the confidence say 95 percent of the parts that is the proportion that is 1 minus alpha; that means, alpha is essentially 5 percent.

So, 95 percent proportions of the parts and with a probability of 0.98; that means, my confidence is 0.98 is it. So, 98 percent of the time I am sure or 95 percent of the time I

am sure in some cases suppose you are not that sure you say the 90 say 85 percent of the time I am sure that the values will be lying between 30 to 35 is it, but you also specify the sample size getting my point.

Now, this is the statistical tolerance limits and many a time you know we refer to the statistical tolerance limits also.

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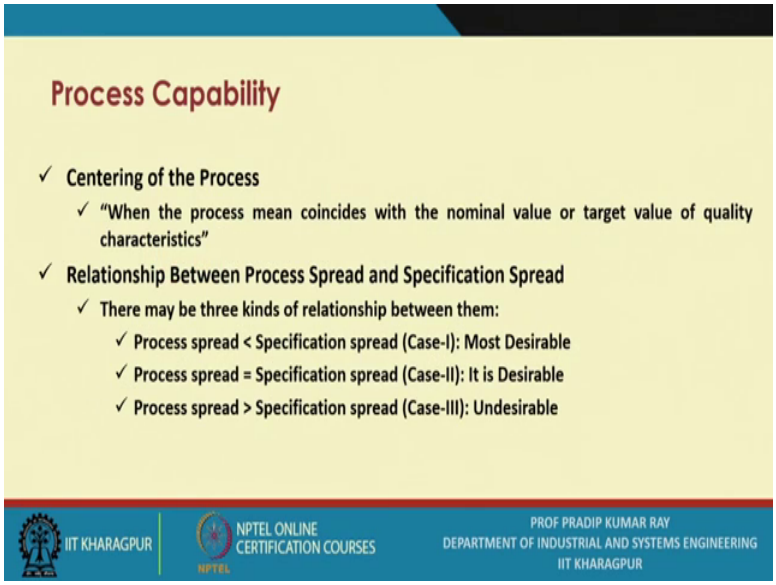

Now, what is the centering of the process this is an important term whenever you get a process and you try to improve the process performance. So, you carry out the process capability study, the first thing you must know that how to achieve a condition, which is referred to as the centering of the process, when the process mean coincides with the nominal value or the target value of the quality characteristic.

So, this is very very important; that means, if it is a double specification limit case you know that usually the desired value of the nominal value of the quality characteristics lies at the midway between upper specification limit or upper totally tolerance limit and the lower specification limit or the lower tolerance limit is it that is the midpoint.

Now, if for the process condition is such that you are getting the value of the process mean exactly at the nominal value of the target value then you say that the process has been centered. So, that is the first condition you have to achieve that is point number 1 for the any exercise on process capability.

Now, the next important aspect you must be aware of that is the relationship between the process spread and the specification spread is it. So, as I have already mentioned that what is a process spread then the process spread is actually you know related to this; that means, in the distance between say upper natural tolerance limit and the lower natural tolerance limit, that is basically a process spread.

So, if you assume that UNTL lies at 3 sigma on one side and LNTL is lying at 3 sigma away from the mu on the other side then; obviously, in this particular case the process spread is 6 into sigma. Now what do you try to do; that means, you first you check that with the data with your observations you first measure the process spread and then you relate it to the specification spread.

So, the relationship between the process spread and the specifications spread. So, what is the specification spread, specification spread is basically that is the distance or the difference between say the USL and LSL, so, USL minus LSL. Now, there may be 3 kinds of relationship between them. So, the first one is see the process spread is less than the specification spread. So, this is case one; that means, most desirable why I am saying it is most desirable because if we achieve this condition the proportion nonconforming from the process will be negligible to very very less is it.

Now, always we say that there could be drifting in the process it may. So, happen that if you are unable to control the value of sigma it may. So, happen that the process spread may increase is it usually the specification spread remains constant whereas, the process spread becomes a function of time.

So, now suppose the process spread increases and at certain point in time you know the process spread is equal to the specification spread is it. So, it is a theoretical possibility; that means, momentarily it might happen, but it is also desirable, but still what do you find that if you know if you use say plus minus 3 sigma limits from sigma from the mu as the upper natural tolerance limit as well as the local lower natural tolerance limit and you fixes x is assumed to be normal you know out of say 10000 pieces you produce is it. So, 26 parts you may find as not conforming is it, that is cannot be avoided.

But this is just in a transitory phase and you will have these conditions, but then again if you at the third condition you will arrive; that means, where the you lose control on the sigma; that means, the process spread is increasing and ultimately you reach to these

undesirable state or undesirable condition that is the process spread is becoming greater than the specification spreads that is case 3 it is most undesirable.

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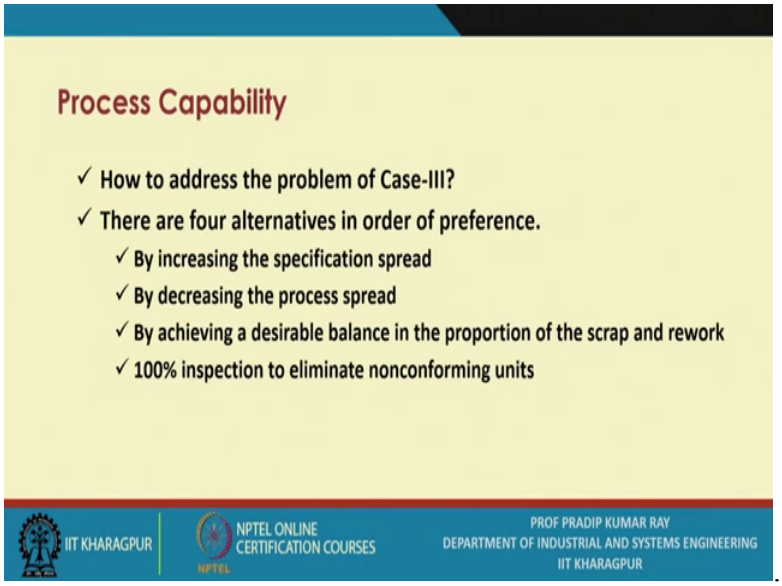

Now, before I conclude this session. So, I will just refer to one aspect like that is how to address the problem of case 3 case 1 is acceptable case 2 is also acceptable, but you are on tours you must be able to; that means, slowly very soon you may lose control on the value of sigma. So, that is to be avoided. So, usually you from case one you may directly go to case 3 in majority of the cases.

So, how to address the problem of case 3 now there are 4 alternatives in order of preference. So, first you know the alternative could be by increasing the specification spread; that means, whose responsibility is this one basically the designer responsibility many time what we have found that unnecessarily you may have a very tight tolerances. So, whether design department can or the designer can change the specification spread; that means, instead of very close the tolerances or the tight tolerances can it be made slightly loose wide.

So, if that is feasible no problem; that means, the process is a high chance that the process will be producing very less number of nonconforming a units if this is not possible then you go to the next one by decreasing the process spread how do you do this as you know there is a point to be noted that the sigma of a process which basically the a

represents the inherent characteristics and it depends on what sort of a the design you have.

So, if you change the process altogether which is the better technology now the decreasing the process spread is possible if this is not feasible suppose for that you need investment as a new technology the new process you have to install suppose this is not possible then what you do the third alternative by achieving a desirable balance in the proportion of the scrap and rework is it, this is also do when you take up an example we will find that you know always you try to avoid the scrap because the between scrap and rework if you compare; obviously, the scrap will be more expensive.

So, you change the settings in such a way that the proportion of you work will be more say 90 percent of the cases whereas, only in 10 percent cases in the scrap if you do that; obviously, there could be improvement in your performance and if suppose all these 3 alternatives are not feasible you tried your best, but you have failed then what to do you have to go for 100 percent inspection to eliminate nonconforming units; that means, as and when they occur you may be must be prompt enough to remove them from the system, with this I conclude this session.