Quality Control and Improvement with MINITAB
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Lecture - 12
Attribute Control Chart

Hello and welcome to session 12 of our course on Quality Control and Improvement using MINITAB; I am Professor Indrajit Mukherjee from Shailesh J Mehta School of Management, IIT Bombay.

So, we discussed about Attribute Control Chart in last session; so two charts we have discussed C chart and U chart which is used for monitoring the defects and C is used when constant sample size are used to monitor defects and U is used when sample size varies at different time points like that ok.

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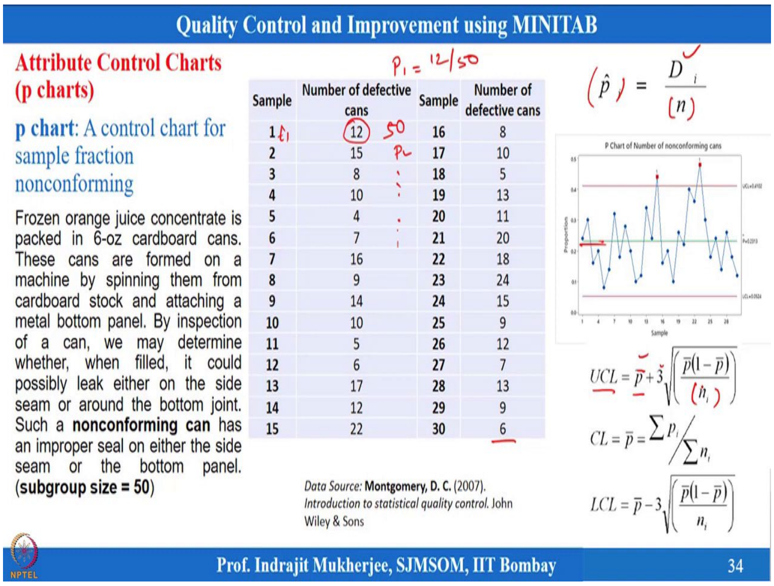

So, we will move on with other attribute control charts. So, beyond this what is there is P and NP chart; we will discuss both the charts over here. So, P is proportion defective which is monitored, earlier case was defects; this is defective over here and defective means 0, 1 condition; either it is useful or it cannot be used like that. So, in this case either useful or scrap we can think of.

So, in this case one of the example that is showing over here is number of defective cans when every time I am inspecting 50 samples; subgroup size we can think of. So, number of samples at a given time point; what we have at time point t_1. So, these are the 12 cans which was found defective and 50 cans were inspected basically.

So, over here assumption was taken as binomial distribution assumption and based on that formulation is given over here; what you can see is that UCL will be p average; p average will be calculated based on individual proportions over here. So, proportions can be calculated for a specific values over here. So, if I take this value p_1, it will be $^{12}/_{50}$ basically.

So, then I can calculate what is the value proportion over here p_1. Similarly, p_n like that; so p_i is given over here which will be number of defective items, divided by sample size that we have taken at specific one. So we will get 30 p_i and then average of this 30 p_i will give me $\overline{p}$ or average defectives of the process.

So, that will be the central line over here and then we can calculate UCL as

$$UCL = \overline{p} + 3\sqrt{\frac{\overline{p}(1-\overline{p})}{n_i}}$$

and n_i will be constant in case we are taking constant sample size and it will be different if I am taking a different sample size at every time point like that. So, we can vary the sample size also; if you have varied sample size also, we can plot that one.

So, this is for scenarios where we are interested in plotting the defectives like that. So, somebody may be number of rejections in a number of rejections of maybe engine assembly, in that case how many engine are rejected. I produce these many engines in a shift and how many produced defective like that. So, that scenarios also can be monitored which is abnormal which is normal which is abnormal like that.

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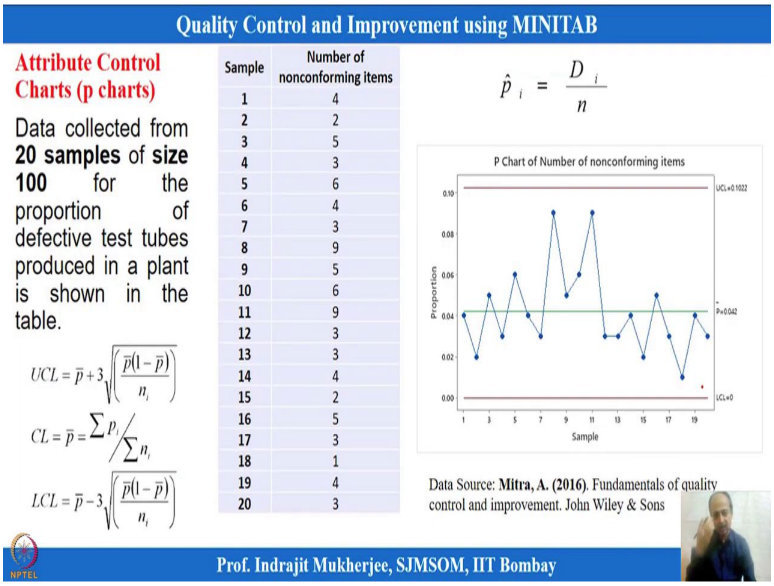

So, this is one example and we have some other example also on this. So, this is also another example where 20 samples of size 100; so every time I take 100 samples and this is taken from the book Amitava Mitra. So, both the case we will solve and try to see how P charts can be used for interpretation of the data.

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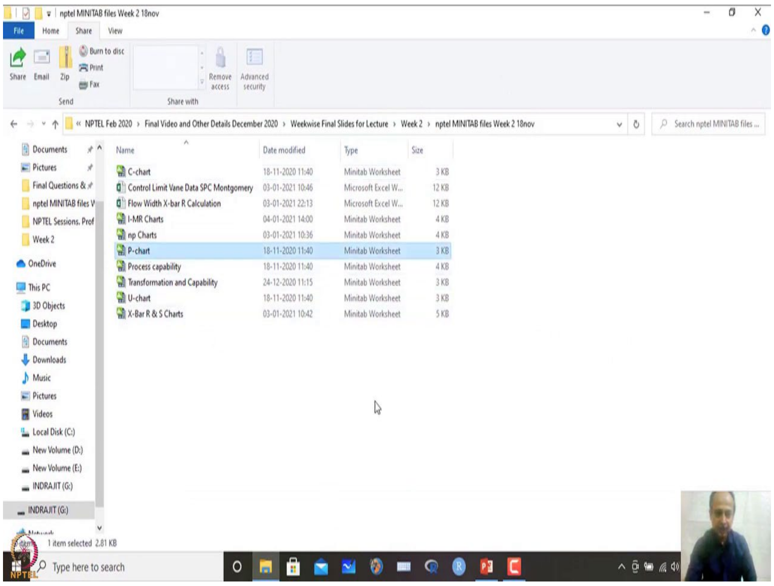

So, what we will do is that; we will take some examples over here; so, I will open P charts and then I will illustrate how this can be done in MINITAB.

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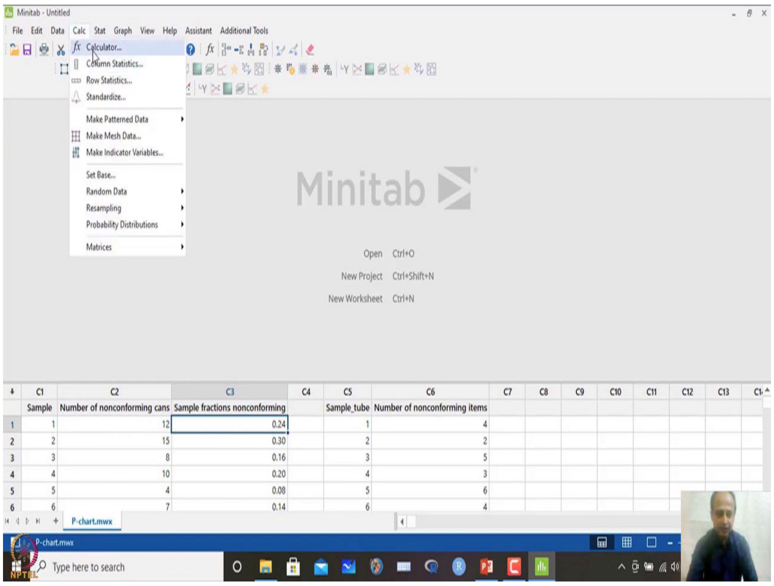

So this is the two examples that we are talking about nonconforming cans first one and then the sample fraction defective what you see is that $^{12}\!/_{50}$ was done and this is 0.24; like this, I get proportion defectives and that can be monitored like that.

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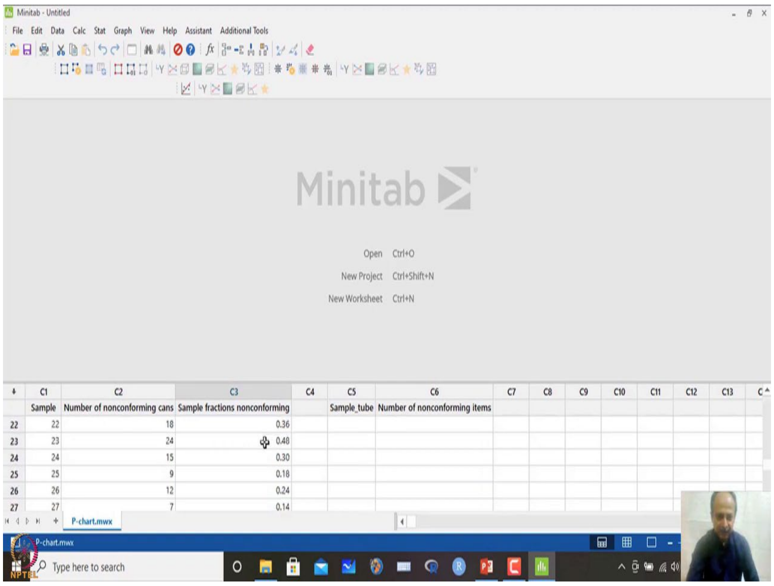

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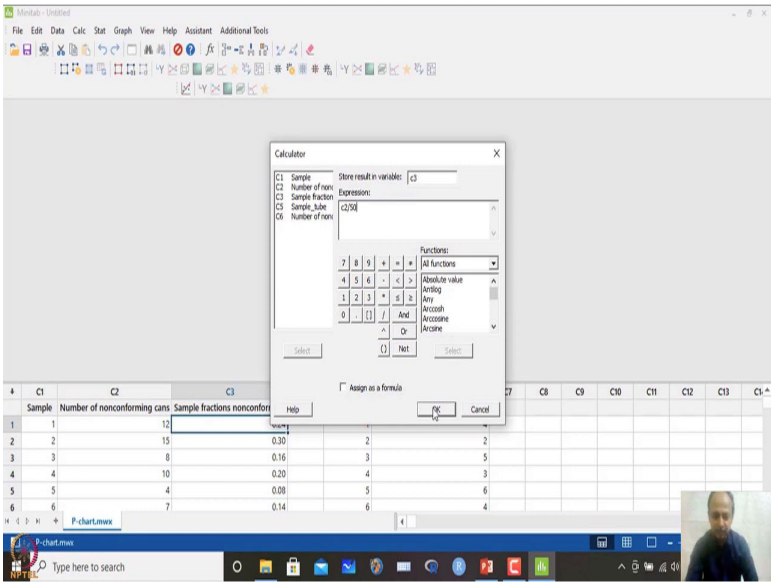

So, we can use calculator over here to calculate this one. If you want to calculate this one; so this store results in if I say C3 over here, what I can do is that I will write down that C2, divided by 50; let us say. So, that is the expression I want to use over here and if you click that one, automatically these values will be replaced and you will get all this observation that you see over here ok.

So, the observations are saved over here ok. So, this is same numbers what I can see over here; so this is 12; 12, 15 like that. So, sample size or sub group size was 50; so that division was done.

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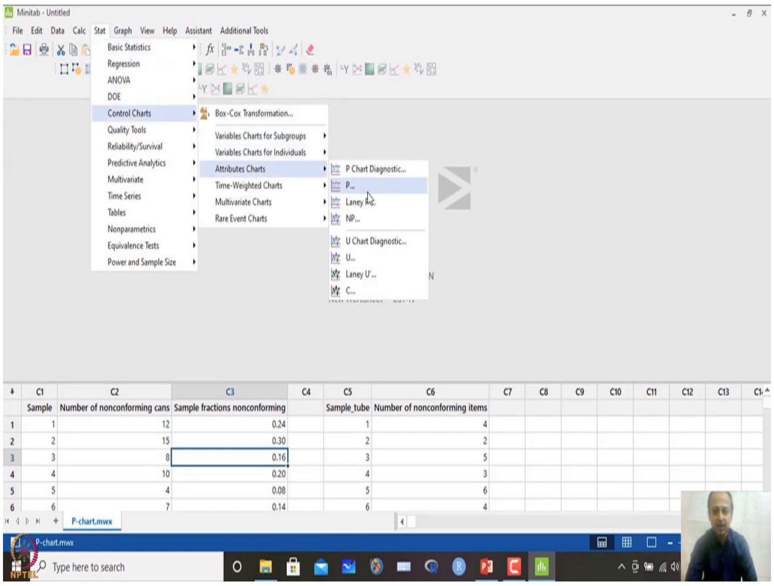

In, MINITAB you do not need to divide this one; so what you do is that stat you go to I know this is for defectives and I go to control charts, attribute control chart I go to P chart directly right.

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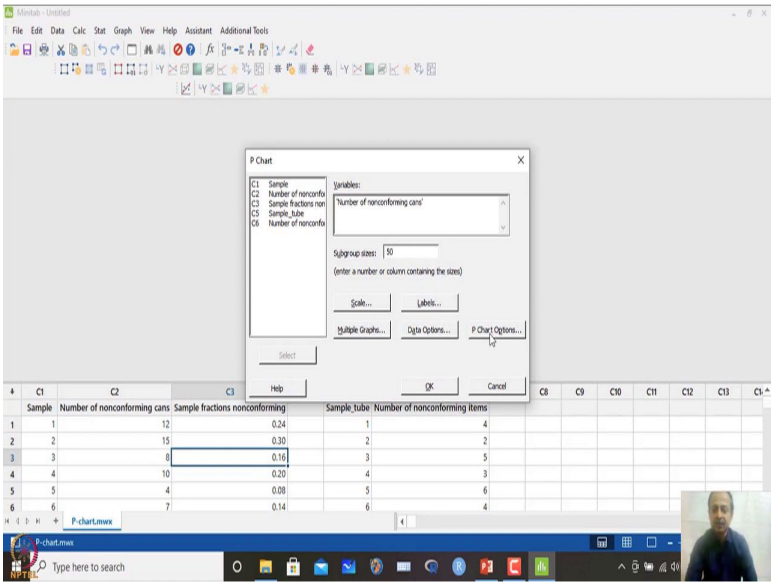

What I do is that; which is the variable? Number of nonconforming cans over here.

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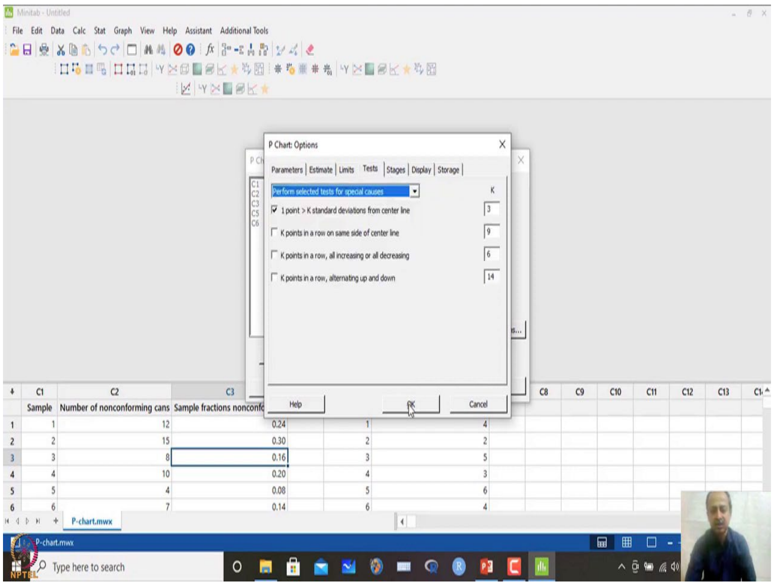

What is the subgroup size? I mention 50 over here and P chart option, again the same thing I test. I want to test anything beyond three sigma limits like that which is abnormal scenarios, I click ok what will happen is that you will get the corresponding P chart.

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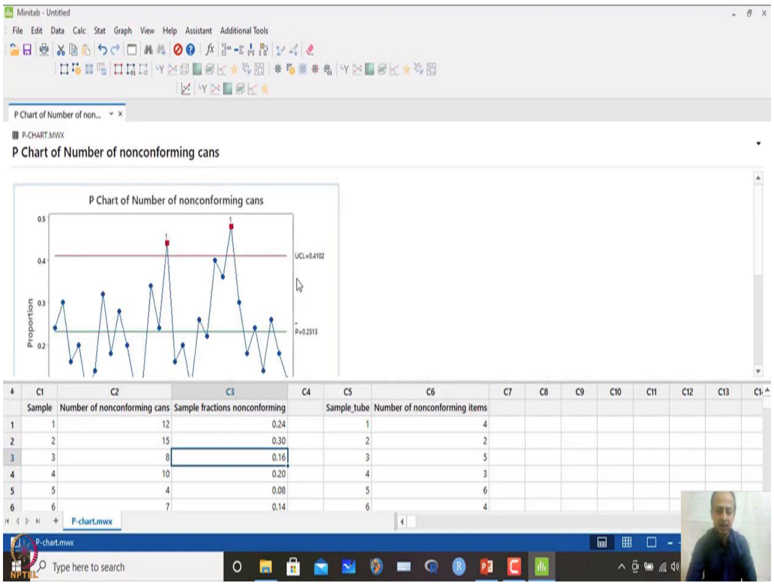

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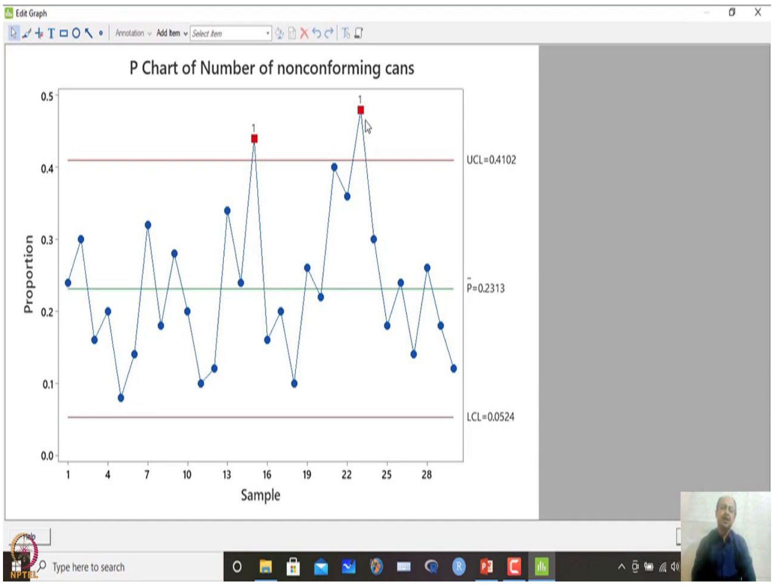

So, in this case what happens is that two points are going outside and these are the abnormal scenarios. So, proportion defectives goes outside; so proportion defective what you see is that upper limit line is 0.41, average is 0.23 and lower control is 0.05. So, two points gone outside; so we have to find out, figure out what has gone wrong at this time point when proportion nonconforming are very high in these two points.

Now, the problem with this is that; so in this case, this is proportion defectives and if this proportion defective changes and when the sample size changes in that case what will happen is that, I will have a variable UCL and variable LCL like that. So, that is one aspect.

So, but what generally happens in production floor is that proportion defectives people understand defectives; one defect, one defective, two defectives like that.

When you say in fraction, they do not understand because engine fraction defective does not make any sense. So, what they do is that they multiply the n with p; so they call it as NP chart; that makes an impression that number of defectives then we can immediately understand over here ok.

So, in this case what you see is fraction in the central limit UCL and LCL like that. So, operator may not understand; what is fraction that he was saying average defective is 0.04, but I understand that it should be more than 1 like that.

So, it should be more than 0 or on the higher side or on the positive side; we want to we do not understand how this average is 0.04 like that. Proportion, I don't understand make it much simpler like that. So, in that case what they do is that; they will multiply it with n, nothing else they are doing over here.

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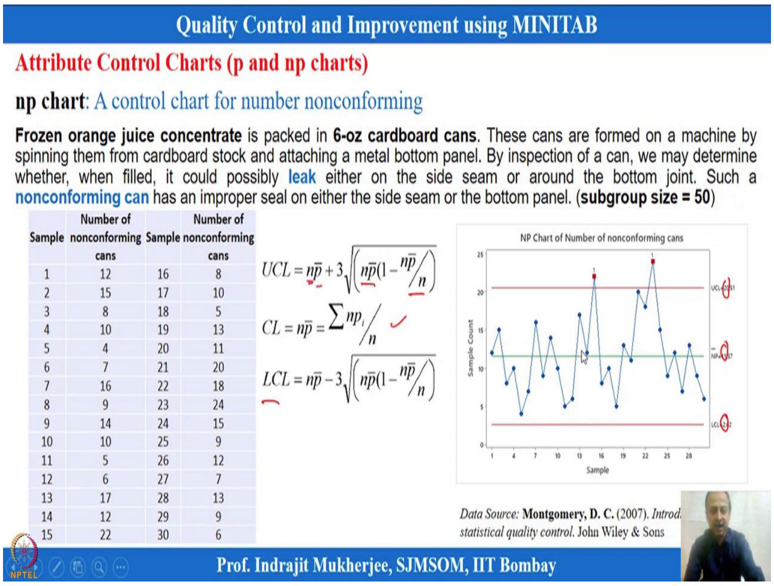

Sample	Number of nonconforming cans	Sample	Number of nonconforming cans
1	12	16	8
2	15	17	10
3	8	18	5
4	10	19	13
5	4	20	11
6	7	21	20
7	16	22	18
8	9	23	24
9	14	24	15
10	10	25	9
11	5	26	12
12	6	27	7
13	17	28	13
14	12	29	9
15	22	30	6

So, in this case what they will do is that; they will have a different limit line. So, in this case NP charts are recommended over here. This n is multiplied over here with p and formula somewhat changed. So, this will be the central line and this will be the lower control limit line.

So, in this case; what you will observe is that the numbers are in whole number with some fractions like that. So, now 20, 11; this is understood, so this is 2. So, this is understood by the operator, lower control is two defectives like that.

So, we expect out of 50, this 2 is the lower control limit line, so we should be above this one and the upper is around 20 or something like that; so that is what is the upper limit. So, number of defectives a out of 50 inspection should not go beyond 20 like; that that is the general feeling of the operator like that. So, that becomes easier to monitor for the operator like that. So, we have a chart which is known as NP chart which is just a variant of P chart.

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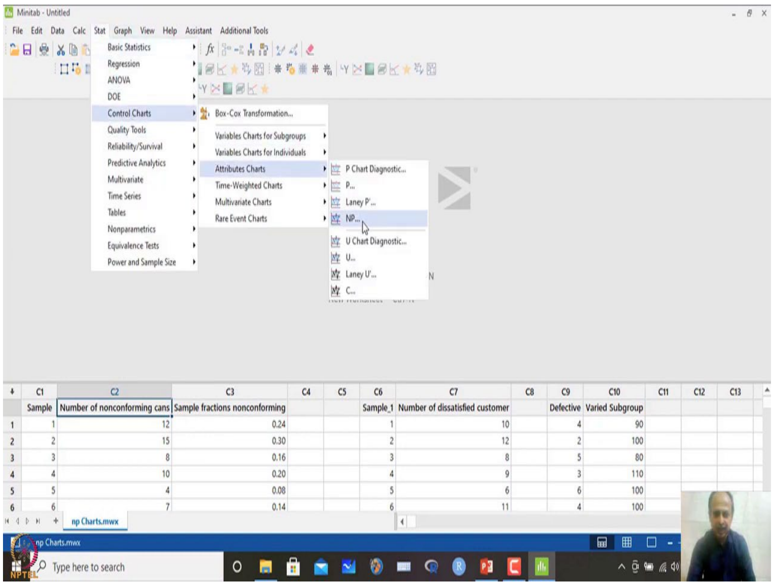

So, we can also see NP charts and way we can, I go to stat; control chart, attribute chart I click on NP charts.

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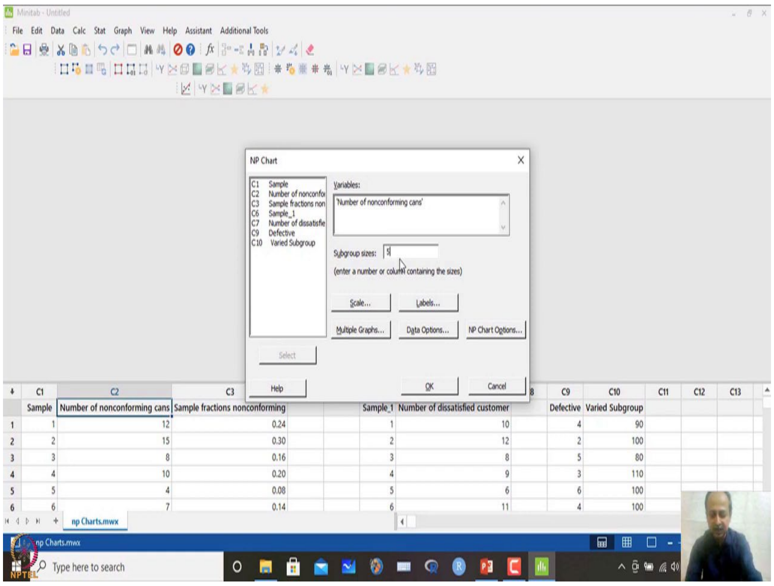

So, I don't want to see proportion and their upper limit, lower limit like that; I want to see number of nonconforming one and I will say subgroup size is 50.

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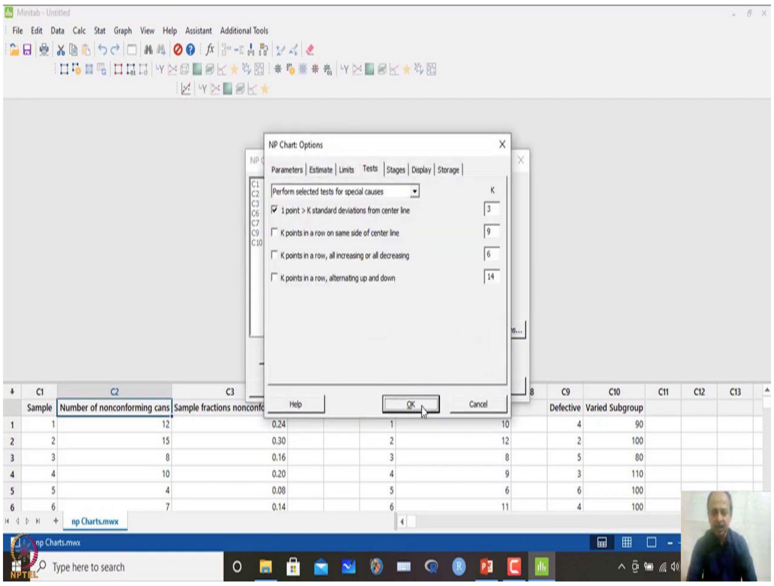

Because and other conditions remain same and then what I do is that I click ok.

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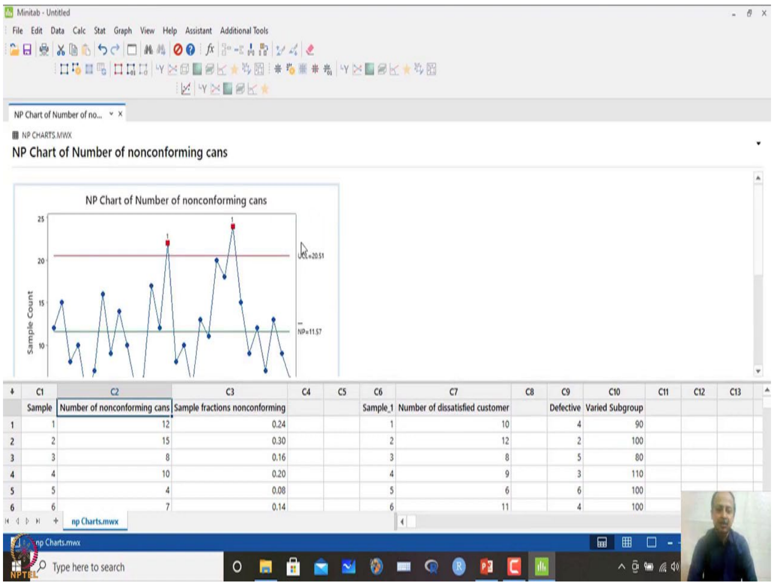

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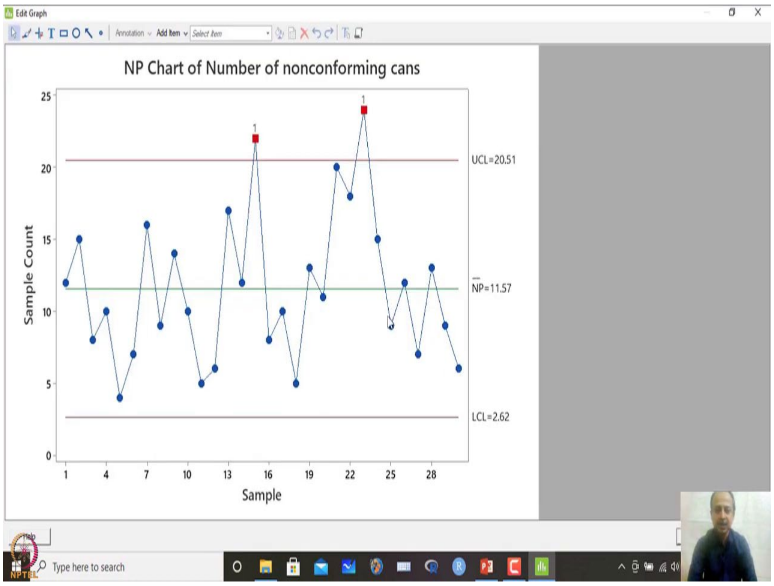

And then I get the control limit lines that this is the NP chart which is done by MINITAB and here you see the numbers are 20; so this is easily understood by the operator that 20 defectives, if it is going beyond that then I should be very much cautious like that. Out of 50 more than 20 is defective then; that means, something unnatural is happening ok.

The average should be around 11; so out of 50, my process is like that. So, on an average, I am getting 11 number of defective items and the lower limit is around 2. So, and here we can see two abnormal scenarios which is coming up.

So, it becomes easier for the operator to understand this type of representation of the data otherwise P and NP are both used for defective. Any of the one you can use.

So, only one thing is that there can be variable sample. So, maybe some example; this is variable subgroup size what do you see C9 and C10.

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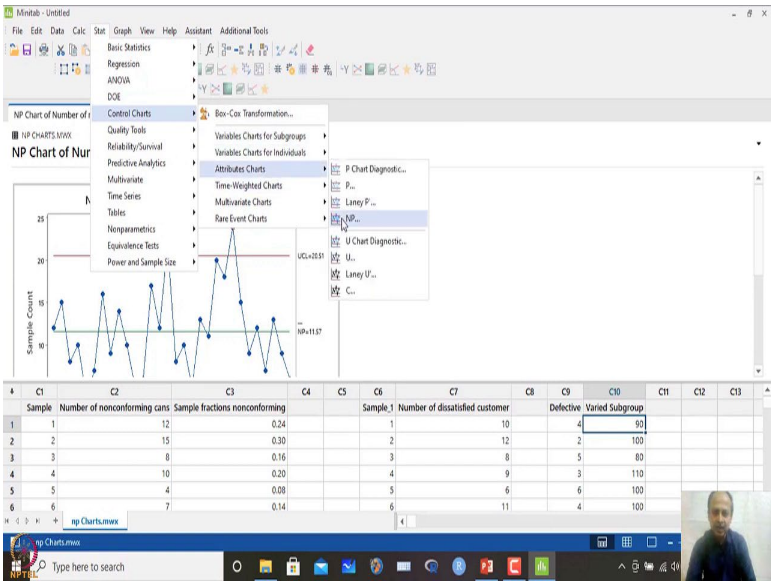

So, defective number of effective sample size changes and in that case also if you plot this one; so control chart and attribute chart; NP charts like that.

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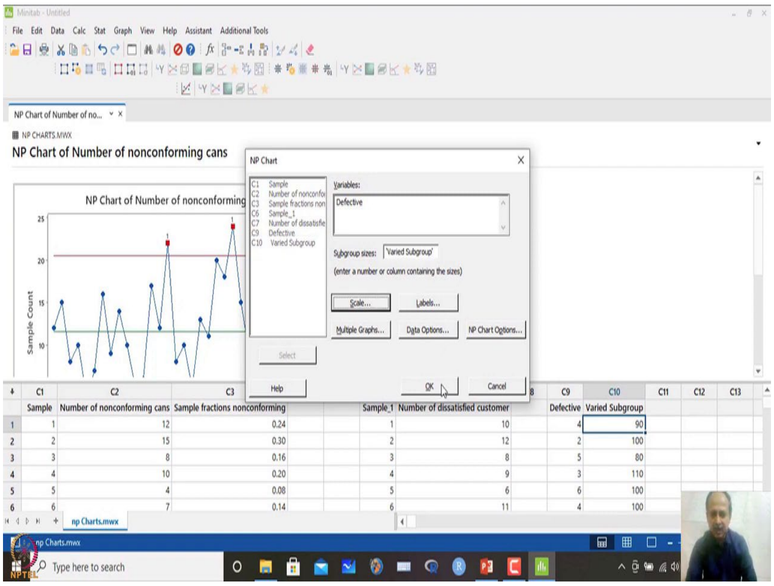

And I mentioned that I want to see defectives and instead of 50; I say that this is in column C10 and I want to see what happens like that.

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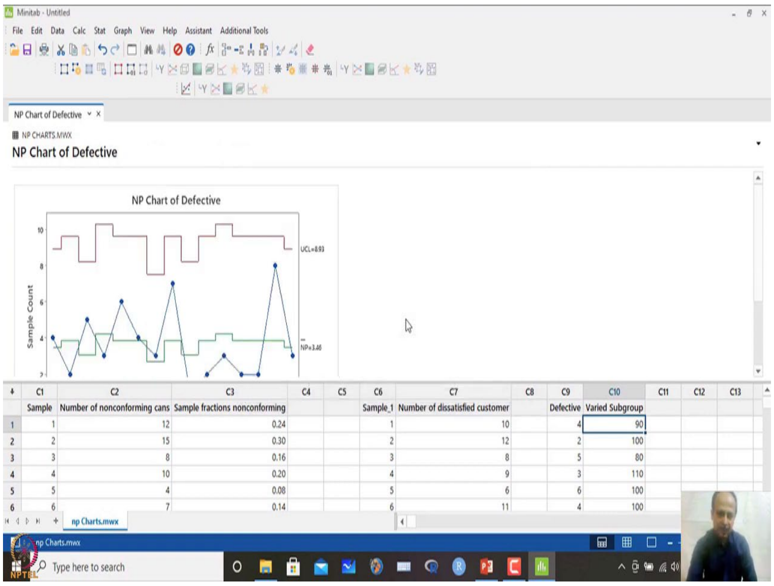

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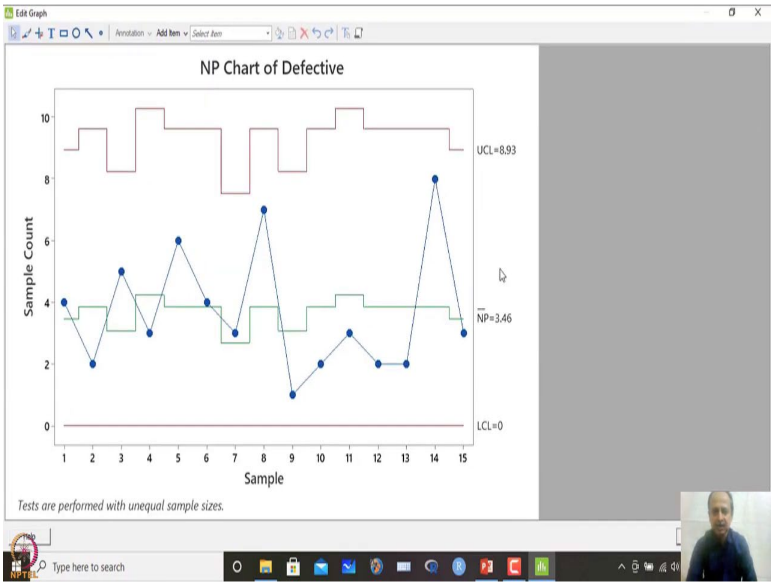

So, then what you get is that this type of control chart. This is NP chart where N is varying. So, number every time I am inspecting is changing. So, in this case, limit lines are also changing. So, central line is changing because it is multiplied by N.

So, central line is changing, upper limit is also changing and lower line what you see is that; this is taken as 0. So, many times considering this as 0 because; every calculation is negative coming out to be.

So, whenever you see attribute charts and lower limit is coming out to be negative; what happens is that I freeze that one to 0 because negative defects or defectives does not make any sense; so in this case. So, that is why you don't see uniform; uniformity in central line and the upper control limit line and lower control limit line. So, that will always happen; so when we are talking about defects and defectives it cannot be less than 0, so that is the constraint that we have.

So, and the underlying distribution I told that this is binomial based on which this control chart is developed. So, this is a prominent chart which is used nowadays in any quality control aspect; so these are the main control charts; so when we talk about control chart, generally we try to understand X bar R; X bar s, individual moving range and C chart, P chart, NP charts like that.

So, these are the common types of control chart that is used to monitor any CTQ's if it is in continuous variable; so, that can be otherwise if it is attribute like the defects and defectives like that, we can use this type of, but it is always preferable to go to a CTQ which can be measured in continuous scale; that I have mentioned earlier also.

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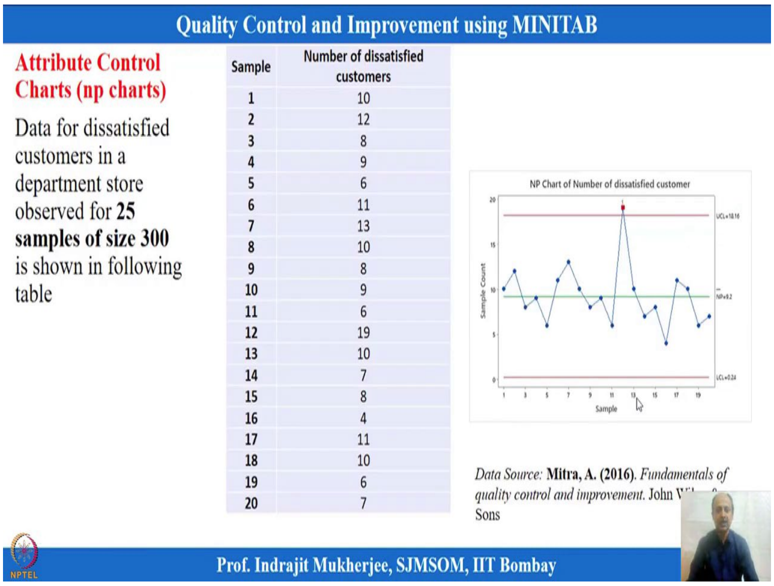

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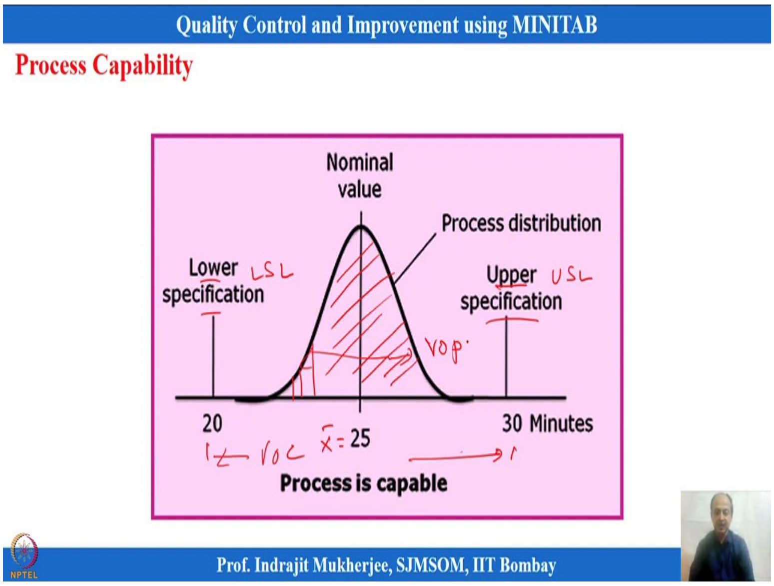

So, with this information over here we will move on to a different topic which is also an important topic in quality because we are assessing the quality. Before we go into improvement, we are trying to control and we are trying to see that what are the measures that will help us to go towards improvement like that. So, one of the measures that is used is known as process capability.

Earlier what we are talking about is the natural variability based on which I am giving upper UCL control limit line and LCL control limit line. But when we are talking about process capability, we are talking with respect to customer specification basically; ur natural behavior with respect to tolerance where we stand basically.

So, what you see is the natural variation over here. So, this is the region of my natural variation of the process and then I compared it with the upper specification which is known as upper specification limit and this is known as lower specification limit which is the LSL over here.

The process average is around 25 let us say, but my specification given is between 20 and 30. So, with respect to my tolerance; how I am, basically performing; so, that comparison when I am doing that is known as process capability analysis or we will use some indices for this; so that will be known as process capillary index. Some index we will use to express this one process capabilities; so, that is known as process capability index ok.

So, it is basically how where is my process; as compared to the specification width that is given by the designer. So, voice of the customer is what you see is that lower specification to upper specification. So, this is the voice of the customer we can say and if I consider this one; the plus or minus three standard deviation, this is voice of the process basically.

So, I am just comparing voice of the process with voice of the customer; which will give me process capability measures.

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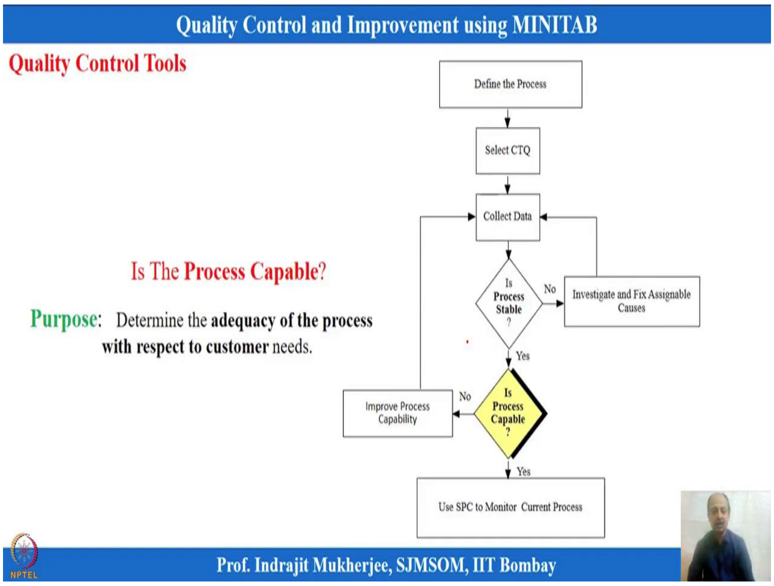

So, before I go into process capability, we should have stability in the process. So, that is the primary condition; so before we calculate the process capability, my process should be stable; so that is the basic criteria which is used.

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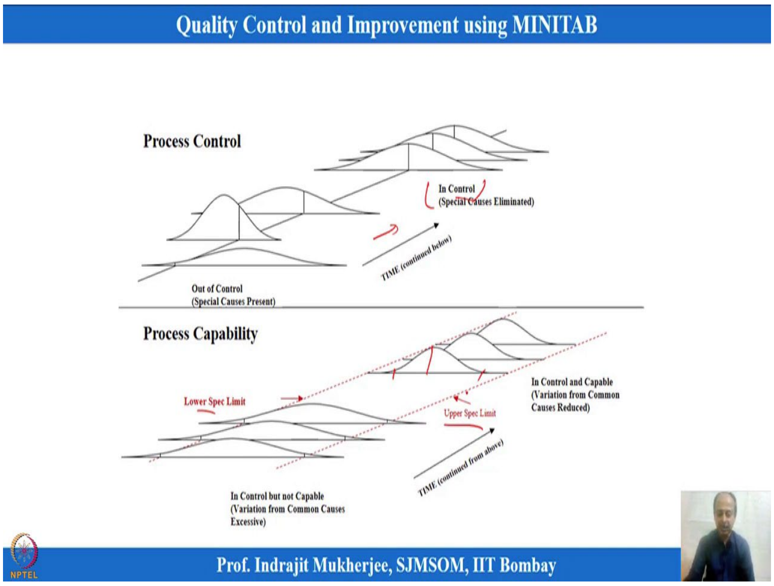

So, in this case how this calculation is done. So, every time process is moving; in this case with respect to time what do you see over here. So, in-control scenario is taken to calculate the process capability and in that case this is upper specification, this is lower specification and how the process is behaving.

So, where we stand with respect to my variation, with respect to specification that is what is seen in process capability analysis, based on which I will decide whether I need to improve and how much improvement is needed.

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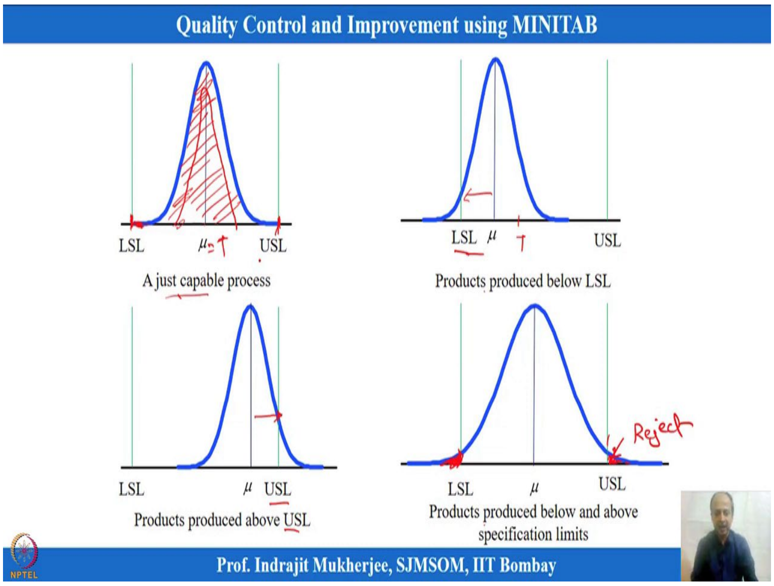

So, this is graphical representation with respect to normal distribution. What you see is that this is a just capable process. So, this is the tolerance that is given by the designer which is voice of the customer and we are performing exactly, we are matching with the specification over here. My voice of the process is about using the same width and if you are using that one; I am just capable basically. So, I am just fitting into the specification like that, my variation is there.

And if you see on this side; so my mean as a if I am assuming mean equals to target over here. So, I am exactly on the target as far as accuracy is concerned, but precision wise, I am using the total tolerance like that whatever is given by the designer. Here what you can see is that variation is high, but I have shifted to the lower specification side; this is also I have moved away from the target values.

So, this is undesirable; so we have variation, we are also moving away from the target values like that.

Similarly, what you see over here is that I am moving away to the other targets; I am moving over towards the upper specification. So, I am moving to the one end of the customer given specification like that.

So, which is known as upper specification limit and this is known as lower specification limit which is which designer. This is different from the upper control limit and lower control limit. So, lower control limits are defined by the process variability and process centering. Designer over here defines USL and LSL.

So, if my variation is very high; so in that case what you can expect is that there will be certain fallouts over here. Because if you remember normal distribution, in that case some fallouts will happen over here and this is rejection basically.

So, this is rejected whenever some products are falling within this. So, normal distribution; if you can think of a normal distribution graph you know that does not touch the axis over here, there will be certain rejection.

But in this case because we are centered and this scenario is much better because the tail is much thinner as compared to this one. So, whenever it touches; so there is some probability high probability over here which is greater than this one what you see over here.

So, this scenario is just capable and capability will be much less also, as compared to; this will also be less capability over here ok. So, most suitable scenario is that I am hitting the target and my variability is also less; so I have less variability.

So, that is the scenario we are looking for over here ok. So, there are different index to measure the capabilities and we will talk about two indices over here.

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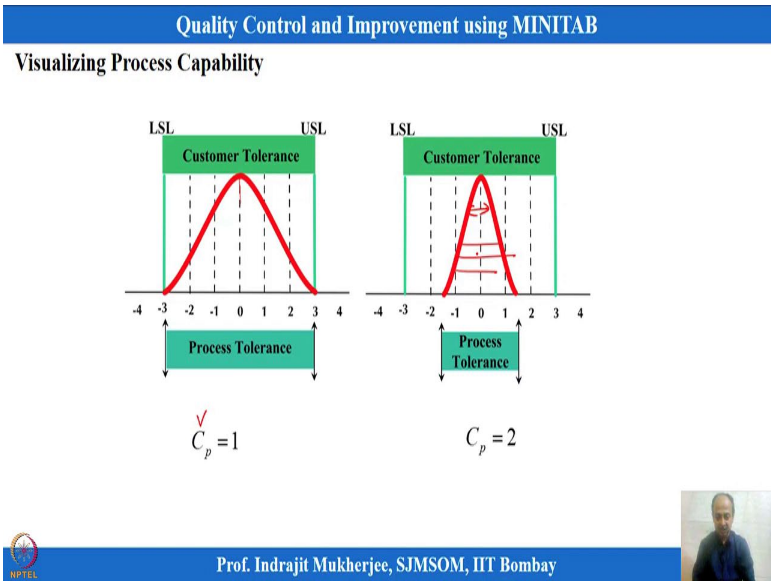

If you want to visualize this one, if we divide this; we call it as process capability index. So, process the visualization is that if this is the scenario, I am using the full tolerance and this is the scenario; I am using a much less tolerance as compared to what is given by the designer.

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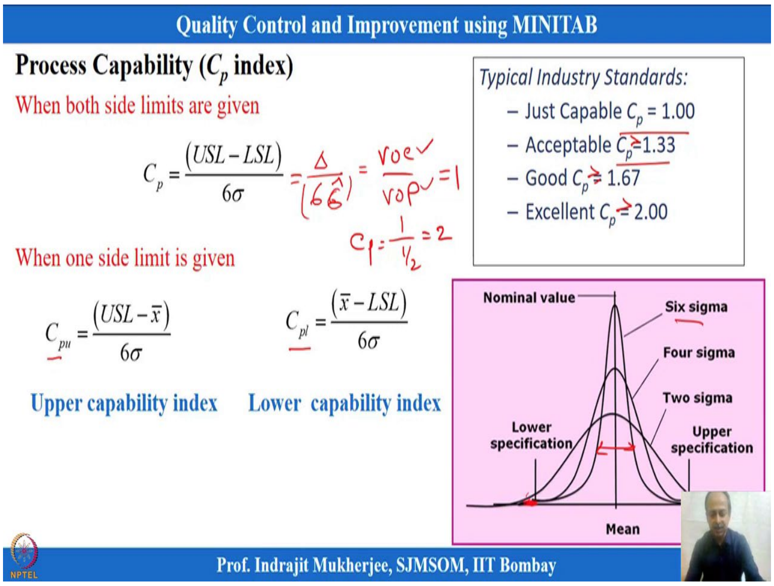

So, index C_p is expressed as tolerance divided by; so we can say that what is voice of the customer and this is the voice of the process which is known as 6 standard deviation. And standard deviation may be estimated over here; so this is the expression for this.

$$C_p = \frac{(USL - LSL)}{6\sigma} = \frac{\Delta}{6\hat{\sigma}} = \frac{VOC}{VOP}$$

So, voice of the process means how much of the tolerance my process is basically using; that ratio is known as C_p. So, earlier examples what you see is that total my voice of the process is this much and my variability plus or minus 3 standard deviation I am using; the full tolerance I am using basically.

So, in this case, the ratio will be same; so our ratio will be this voice of the customer will be exactly equals to voice of the process. So, this will be equals to 1, what you see in the earlier diagram.

And in this case second scenario what you see is that; my tolerance is just maybe double of the voice of the what we are using over here. So, in this case voice of the process basically. So, voice of the process is just half of voice of the customer. So, this will be; we can represent this as if I represent this one as 1, this will be half. So, C_p index will come out to be equals to 2, what you see is shown over here.

So, favourable scenario is that; I am using less as compared to what is given by the designer and I want to reduce it further. So, it is like you are moving a car in a tunnel like that and if I am just fitting into that is not the best scenario, if I can go into the tunnel with the with ease. So, that is the that is the open that is the that is the best scenario what we can; what we can think about ok.

More and more, I reduce the variability; more and more favorable situation assuming the target remains same like that ok. So, this C_p index; what it shows is that, it shows how much of the variability; my variability is with compared to the tolerance that is given by the designer or given by the customer like that ok.

So, if you have one sided scenarios; so in this case, you can calculate C_{pu} and C_{pl}. MINITAB does it automatically for you. So, just capable process we can think of C_p is equals to 1, industry standard I am talking about.

This may be scenarios some of the industries follows that you should be C_p should be exactly equal to 1.33 or more than that is the acceptable scenario or somebody can say it should be greater than equals to 1.67 that is the most favourable scenarios over here and if it is excellent means if it is more than 2, it is always excellent.

So, process capability if it is 2; if it is greater than equals to 2. So, in that case that is the most favourable scenarios and excellent performance we can say for the process. So, this can be calculated and this will be done automatically; like what you see over here, like philosophy of six sigma which we will discuss afterwards; maybe in some of the sessions where it says that higher the capability, better is the process condition and very less variation; so less rejection basically.

If you see with respect to specification in that case lesser is the width of this. So, thinner is the proportion which is going outside over here or the probability of falling outside the specification; that is the philosophy of six sigma. So, I hit the target and it reduces the variability. Generally, C_p equals to 2 indicates that it is a six sigma process, but there are other conditions which needs to be satisfied for that ok. So, how do we calculate process capabilities that we need to see in MINITAB.

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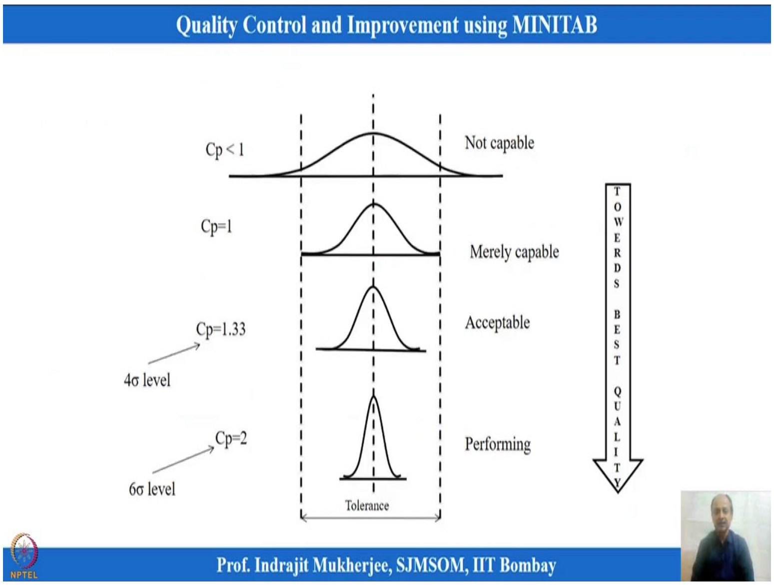

So, in this case for a given set of data; I want to calculate the process capability and what is the option that we have.

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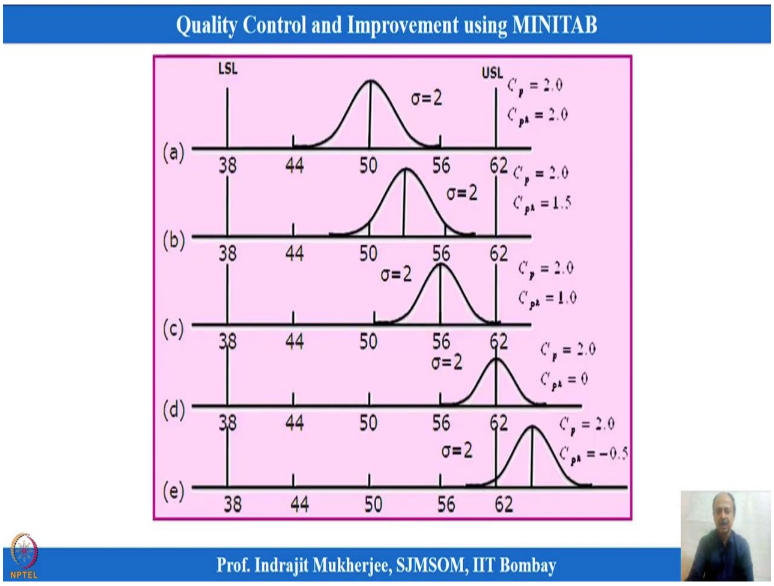

So, in this case we will take some example maybe and we will see how this capability index can be calculated.

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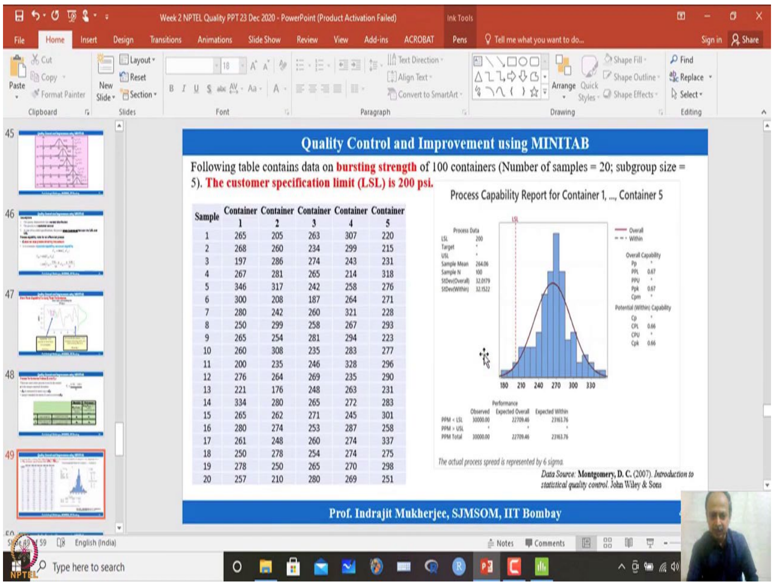

So, let us take some data set what is provided in this. So, this is one bursting strength of 100 containers. So, at a given time point; it was taken some observation was taken container 1 to 5; 5 subgroups were taken over here. And this is observation that we have and for this data set some specification is given; customer specification, lower specification limit is given over here.

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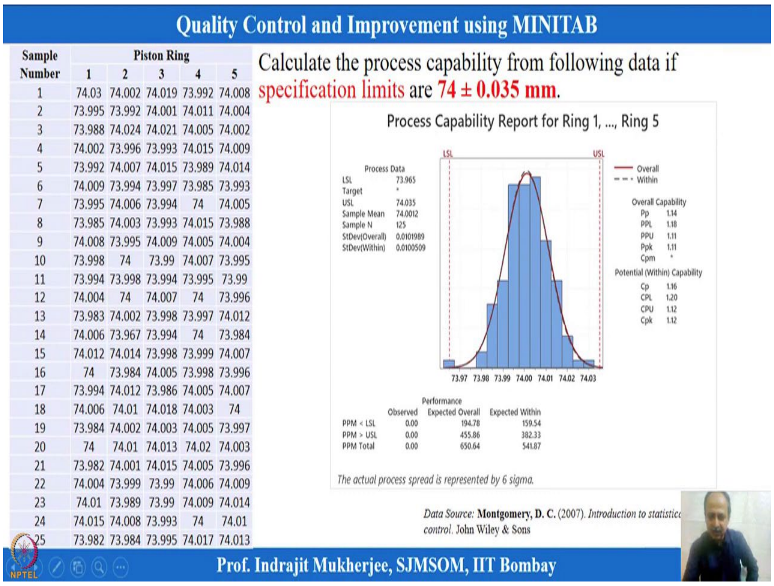

And we want to calculate or we can take this piston ring which is both side of specification over here. So, this becomes easier to understand. So, this is 74 + 0.035 and 74 - 0.035; that will be the specification for this product over here.

So, and we will place this into MINITAB and try to figure out what is the C_p index, what is the value of C_p index. So, this is the data that was collected at a given time point. So, piston ring 74 and this is the data set that we have; every time we have five subgroups. So, we will calculate the process capability index over here.

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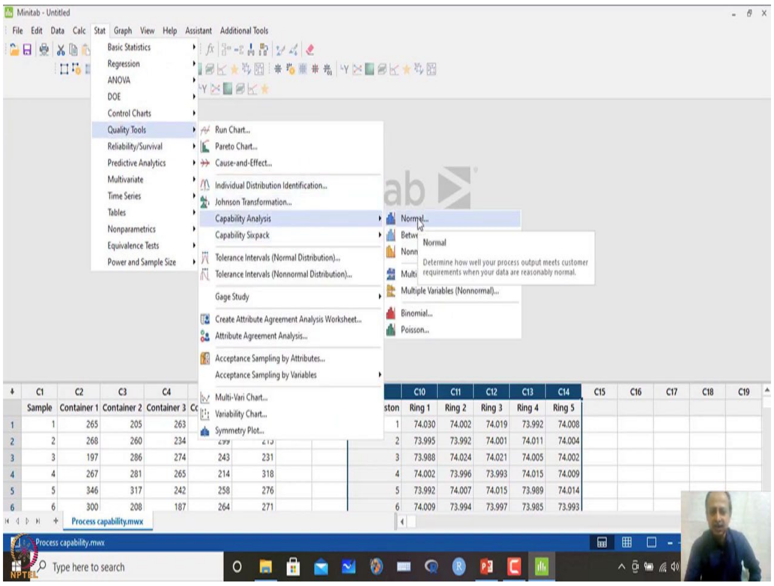

So, if you go to the dataset; so we will close this one and we will open capability analysis process capability analysis MINITAB file which is already stored with me. And this is the piston ring examples that we are taking over here and this example we are taking first.

So, in this case we have both sides specification what we have seen. So, 74 ± 0.035, this is taken from Montgomery's book example. So, we will try to illustrate that one ok. So, what you do is that stat, quality tools and capability analysis over here. So, assuming normality over here; there are various options over here, I will take the simplest one; assuming normality over here; normally can be checked.

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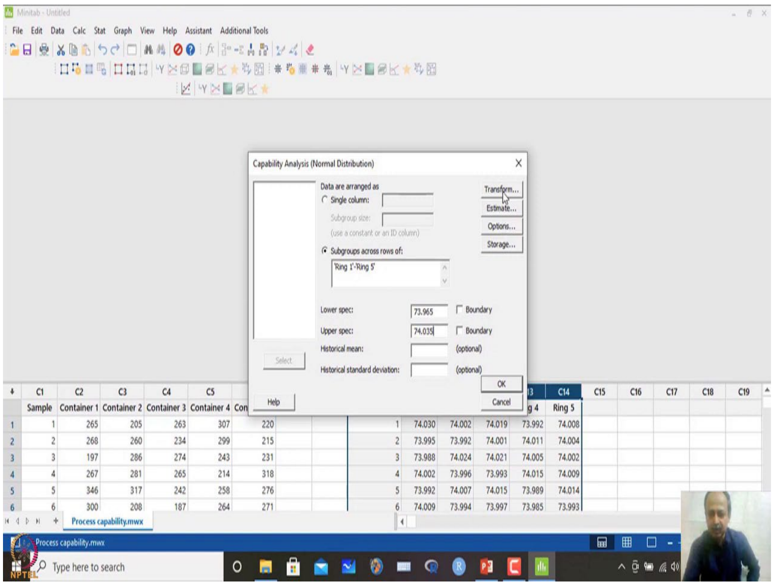

So, we are not doing that at present. So, are they in single column? No, there in subgroups are in different one. So, this is ring 1 to ring 5; we will highlight this one and enter over here. Now specification; lower specification we will enter like that. So, this is given as; so let me just check this one.

So, 73.965 that I will put as lower specification 73.965; that is the specification mentioned by the designer and the upper specification will be equal to 74.035. So, that be 74.035.

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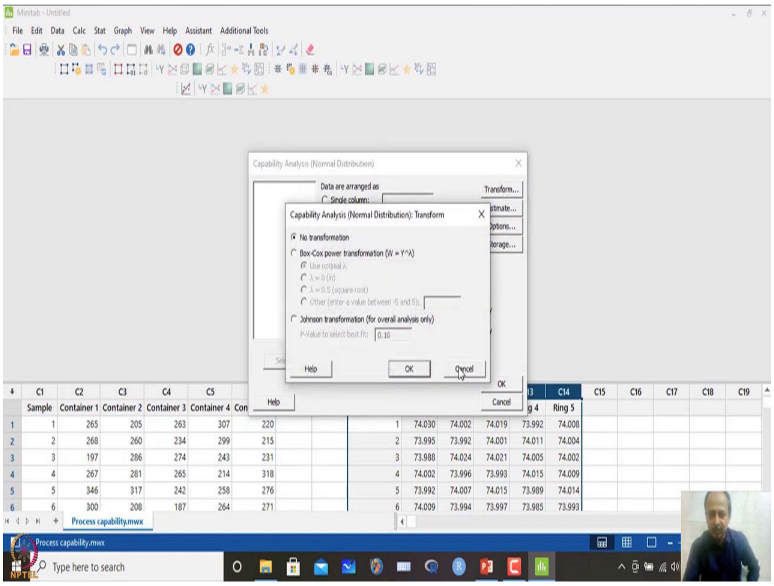

So, now options over here; so this transformation, you ignore at present.

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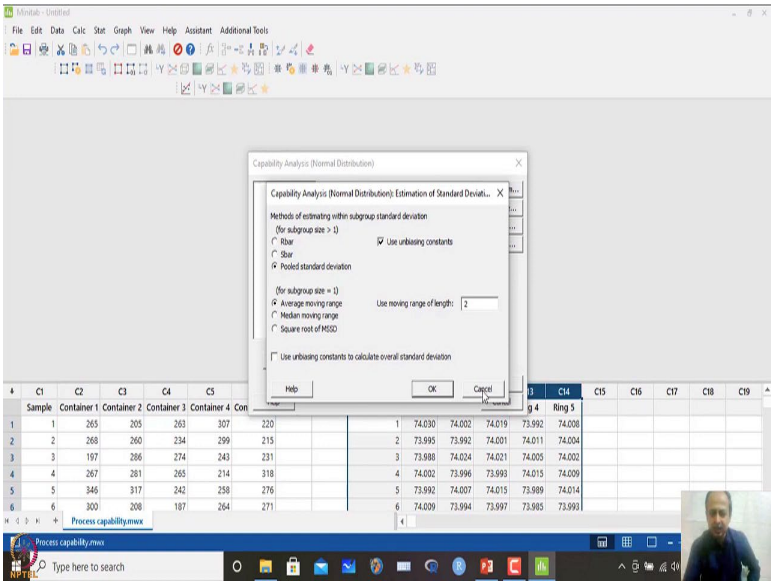

Estimation over here; so this is we can ignore at present.

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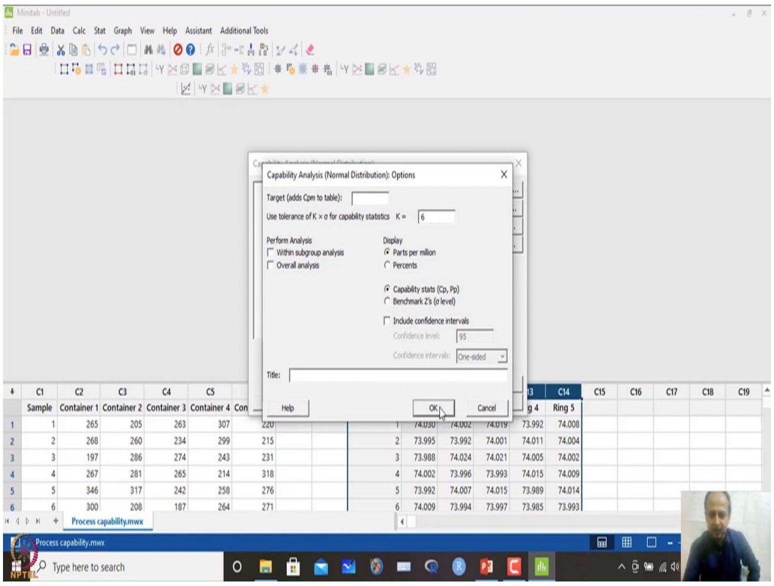

We will only see the C_p index what is the value of that. So, this analysis is not required at present. So, these things we can ignore at present whatever value comes. So, I want to see only the C_p values.

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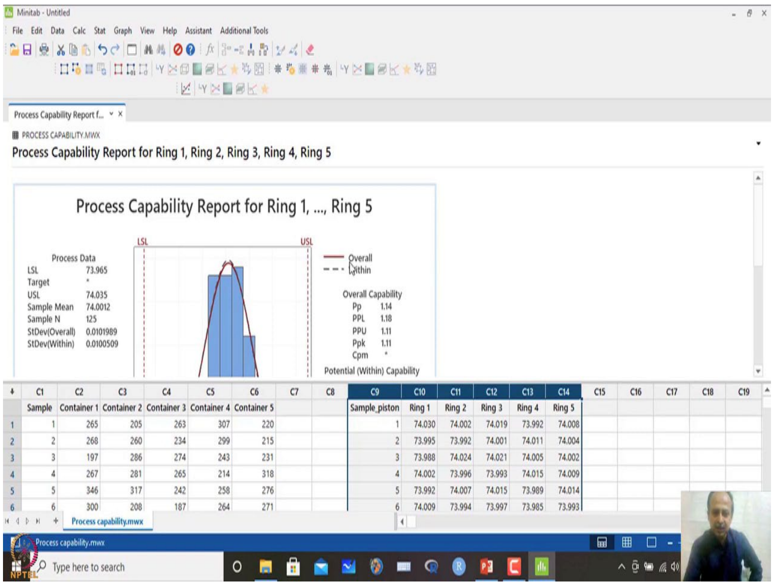

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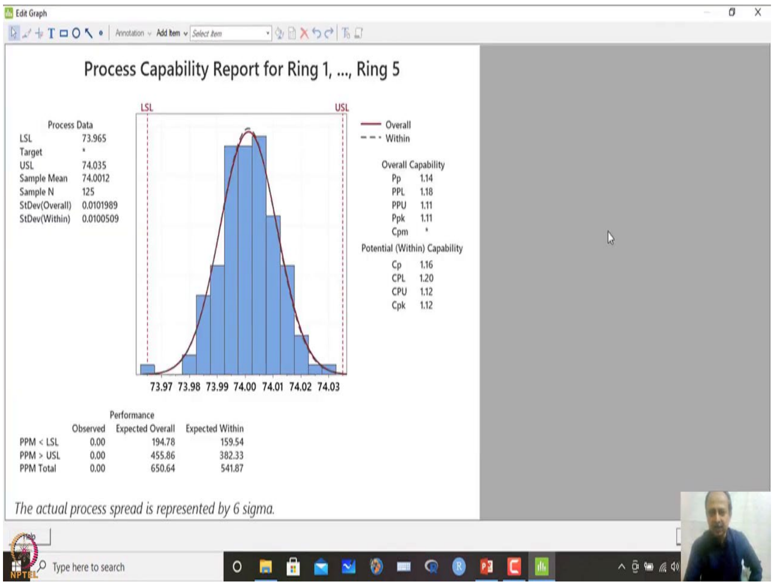

So, from here we can see; so if you click ok; what will happen is that it will do some analysis and it will come up with some diagram over here. At present, we do not want to see all of that; so what you see is that just note that LSL is taken as 73.965, USL is taken as 74.035.

I have not given the target over here I have only given the width band that is given by the customer and then I will only see the C_p index that you see over here. So, this C_p value is 1.16 and that is the formula that we are using over here C_p formulation will be this one. So, which I am using over here.

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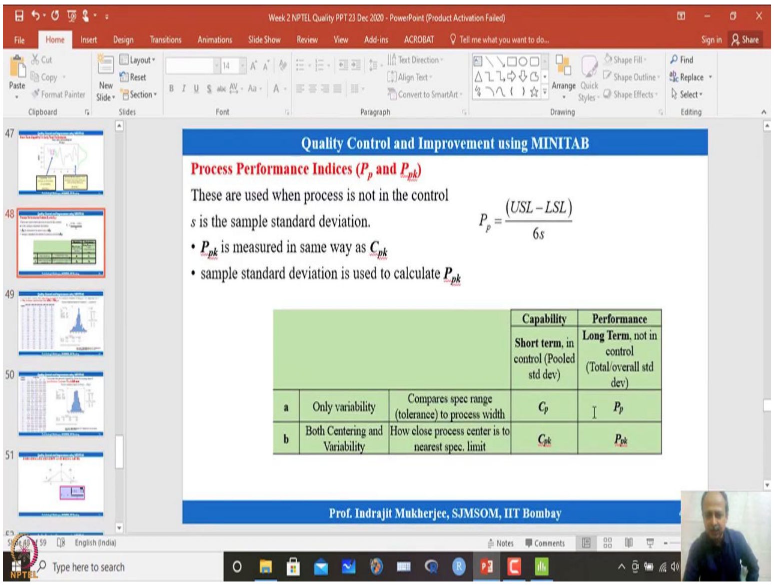

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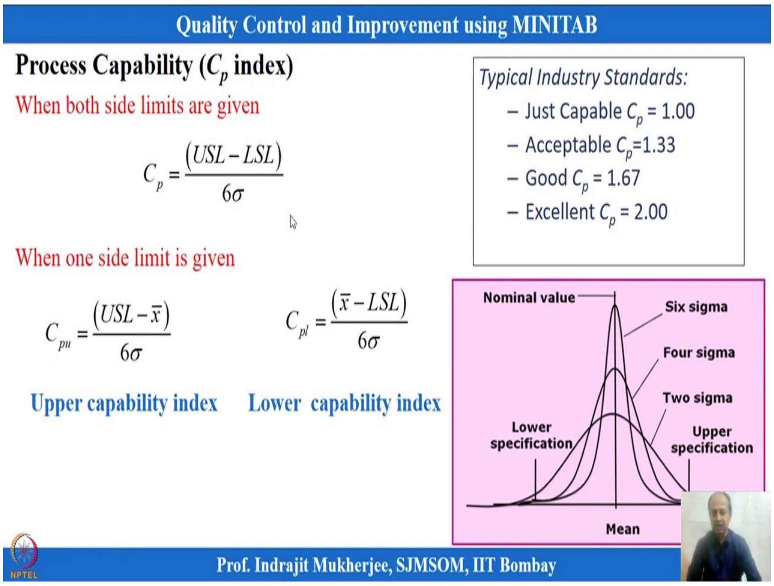

So, this is the formulation:

$$C_p = \frac{(USL - LSL)}{6\sigma}$$

So, there is a method of calculation of standard deviation; so that we have to discuss afterwards. So, at present we will assume that MINITAB has calculated some standard deviation. So, this is taken and the output gives given over here is $C_p = 1.16$.

So, some way they have calculated the standard deviation which we will discuss in the next session; how MINITAB is calculating this one. And I have also told that we do capability analysis whenever the process is stable like that.

So, we will check that whether the process is stable and then if the process is stable; how do I calculate the standard deviation which will be used in process capability analysis to calculate C_p index; that means, delta divided by when I am doing the specification total tolerance that is given.

And divided by six process; voice of the process. So, voice of the process this sigma is calculated based on certain assumptions like that that is process is under statistical control and then we can calculate sigma and there are ways to calculate sigma which is calculated from X bar R charts like that.

So, R is used as a measure, $\overline{R}$ is used as a measure and number of subgroups here it is 5; so that ratio is used $\overline{R}/d_2$ is used to calculate the process standard deviation. So, that multiplied by 6 gives you the denominator and numerator is the tolerance that we are having like that ok.

So, based on that; we will discuss we will start discussing about how they calculate this C_p indices like that ok. So, sigma calculation we will see and that sigma calculation is given over here; what you see standard deviation; within what you see over here and this is basically calculated based on control chart concept and $\overline{R}/d_2$ is the formulation that is used to calculate standard deviation within and many other calculations we will see. So, ignore all other information just see USL and LSL that is given.

And the difference between them will give you the voice of the process voice of the customer and 6 multiplied by the standard deviation within what is the way we will calculate next time and that will give you the voice of the process. So, ratio of this gives me 1.16 and we can say just capable; it has not reached 1.33 which was the standard in many of the companies, but it has just crossed 1, we can think of.

So, there is a need for improvement of this process; we need to reach around $C_p = 2$. So, that is our objective we want to reduce the variability and more and more I reduce the variability; more and more my C_p index increases like that ok. So, that will be our point of discussion.

So, we will see first how the sigma is calculated and based on the concept that they are under; whether they are under statistical control that we will also cross check with these examples like that. And then we will see other measures which is used to check capabilities like that ok.

So, we will stop over here and we will continue discussion of this capability analysis. So, these two example; we will use to illustrate our many of the measures that we will see that MINITAB provides and what is the meaning of each of these outputs that you see.

Thank you for listening this session, we will continue in the next session from here.

Thank you for listening.