Product design and Management
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Lecture – 21b
Quality Assurance

Welcome to the next lecture on Quality Assurance. In the last lecture, we discussed about quality. Quality is a very interesting terminology, but is very hard for developing a definition. People say, if it can confer to all the specifications, whatever you have given, then we say it is a quality product.

Quality is very difficult to have direct units to measure. We always use indirect ways of measuring, and then we try to link it with the quality. Though quality is very difficult to measure, but it has to be measured, and without that, people will not accept your product.

For example, you can take a hotel industry, or quality of the hospitality, you might take a pen, quality of its writing, you might take a TV, quality of the eye comfort it gives. Quality of the sofa, quality of your pant, what you wear. And interestingly, if you buy a jeans pant and it worth 2000 rupees and one of its parts, that is the button, which is there on your jeans pant, button may cost one-fifth of it, or one-tenth of it or maybe even one-hundredth of the cost of the entire jeans pant. But, if the quality of that button is bad, then the entire pant sale dies off.

So, quality at every part, at every product is very important. And nobody is going to pay extra money for the quality. For example, if somebody comes and says, here is a product which worth 10 rupees, and I have made a 100 percent quality check, give me 12 rupees, people will say, hell with you. So, if you say 2 rupees more just for quality, people are not going to accept it. So now, it is very clear, that quality has to be integral part of your manufacturing itself. So there has to be an assurance, which has to be generated, while you develop or while you produce in the process.

(Refer Slide Time: 02:51)

Contents:

- Introduction
- Process capability
- Process capability analysis using control charts
- Process capability analysis using DoE (Design of Experiments)
- Engineering Process Control (EPC) and Statistical Process Control (SPC)
- Process Monitoring and Process Regulation
- Process Control by feedback adjustment
- Combining SPC and EPC.

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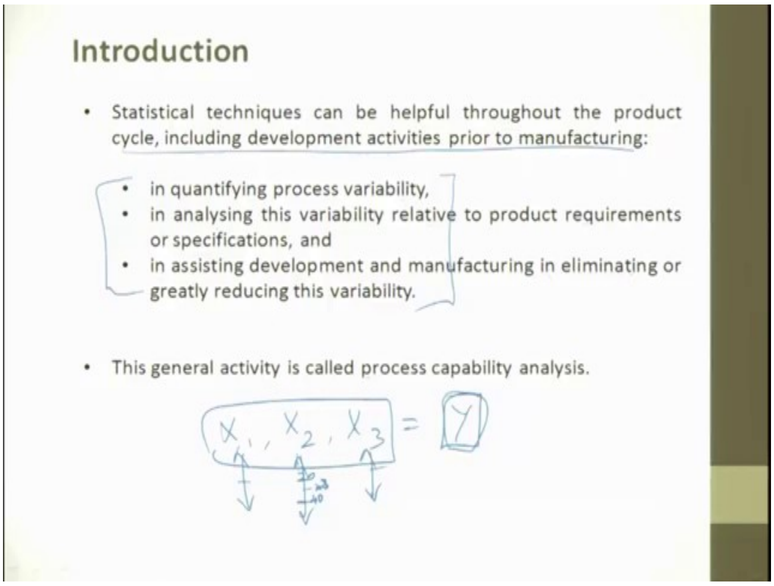

So, 100 percent inspection is not possible, so we always try to do a random checking. The statistical techniques come up in a big way to help in maintaining good quality products.

- Statistical techniques can be helpful throughout the product cycle, including development activities, prior to manufacturing.
    - In qualifying process variability
    - In analyzing this variability relative to product requirements or specifications
    - In assisting development and manufacturing, in eliminating or greatly reducing this variability.
- This general activity is called process capability analysis.

So, there are process variables involved in producing a part, and the output of the part is Y, and input process parameters are X1, X2, X3. So, each parameter will have a range of values, so, which value to take, such that I produce a good quality output in my product. So, in this range, say 20-40. So, if I take 35, then what is the variation I can allow, such that I can try to produce the required output.

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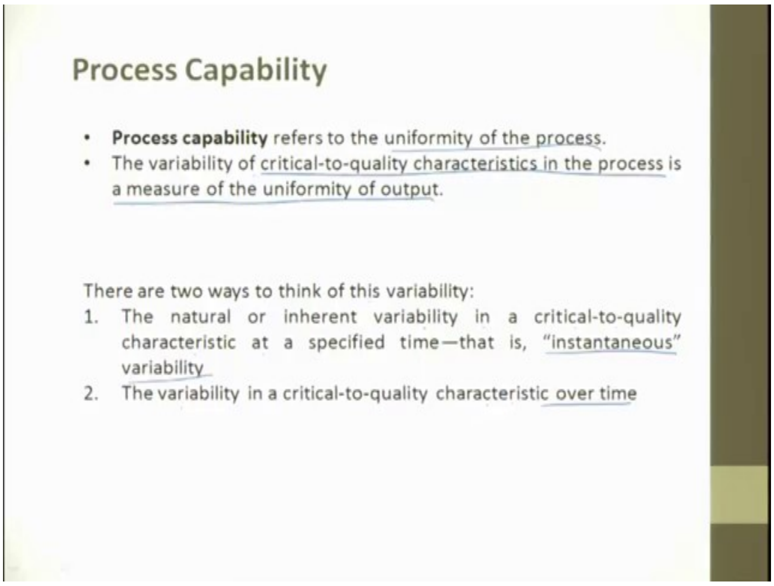

Process Capability:

- Process capability refers to the uniformity of the process.
- The variability of critical-to-quality characteristics in the process, is a measure of uniformity of the output.

For example, let us take a process, in this process, there are machines and lot of moving parts, there is always a variability in the process parameters. So, how uniform I can maintain it, such that the quality of the product is consistent.

- There are two ways to think of its variability:

  1. The natural or inherent variability in a critical-to-quality characteristic at a specified time, that is instantaneous variability.

  2. The variability in a critical-to-quality characteristic over time.

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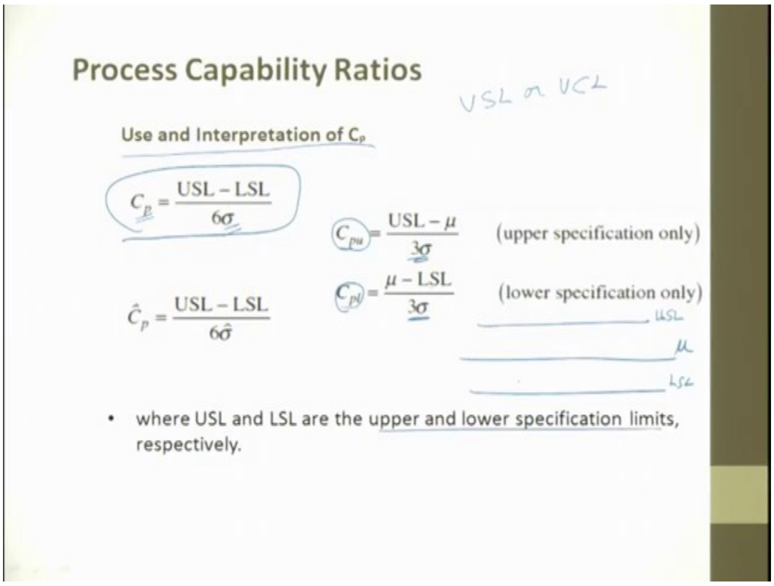

Process Capability Ratios:

- Use and interpretation of C_p

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

$$C_{pu} = \frac{USL - \mu}{3\sigma} \quad \text{(upper specifications only)}$$

$$C_{pl} = \frac{\mu - LSL}{3\sigma} \quad \text{(lower specifications only)}$$

$$\hat{C}_p = \frac{USL - LSL}{6\hat{\sigma}}$$

- where USL and LSL are Upper Specification Limits and Lower Specification Limits respectively.

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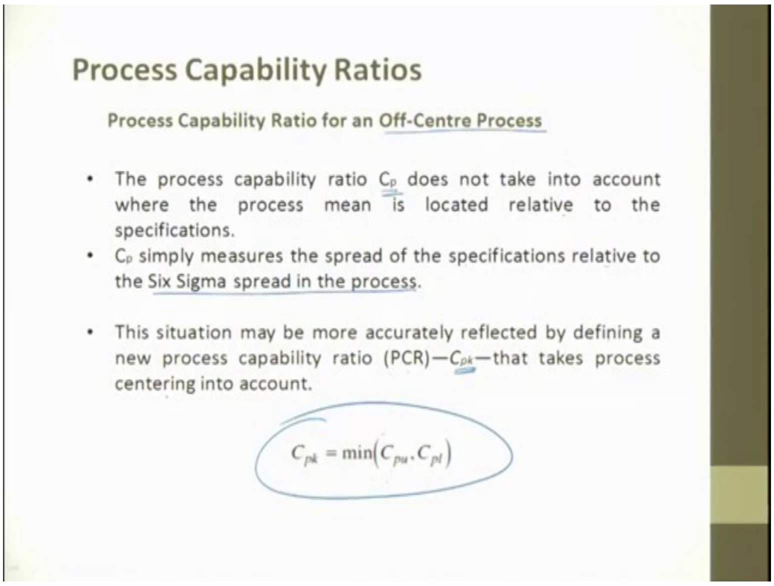

The process capability ratio of an off-centre process:

- The process capability ratio C_p does not take into account, where the process mean is located relative to the specifications.
- C_p simply measures the spread of the specifications, relative to six sigma spread in the process.
- This situation may be more accurately reflected by defining a new process capability ratio, process capability ratio C_{pk} that takes process centering into account.

$$C_{pk} = \min(C_{pu}, C_{pl})$$

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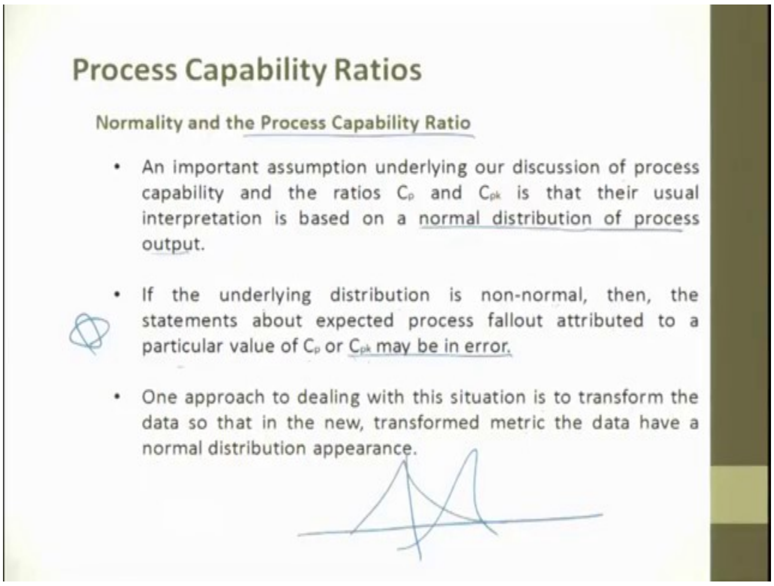

The normality and the process capability ratio:

- An important assumption underlying our discussion of process capability and the ratios C_p and C_{pk} is that, their usual interpretation is based on normal distribution of the process output; it follows a bell shape curve.
- If the underlying distribution is non-normal, then, the statements about expected process fallout attributed to a particular value of C_p or C_{pk} ,maybe in error.
- One approach to deal with this situation is to transform the data, so that in the new transformed metrics, the data have a normal distribution appearance.

So, what do you do is, you try to convert the skewed information into a normal distribution, by some transformation.

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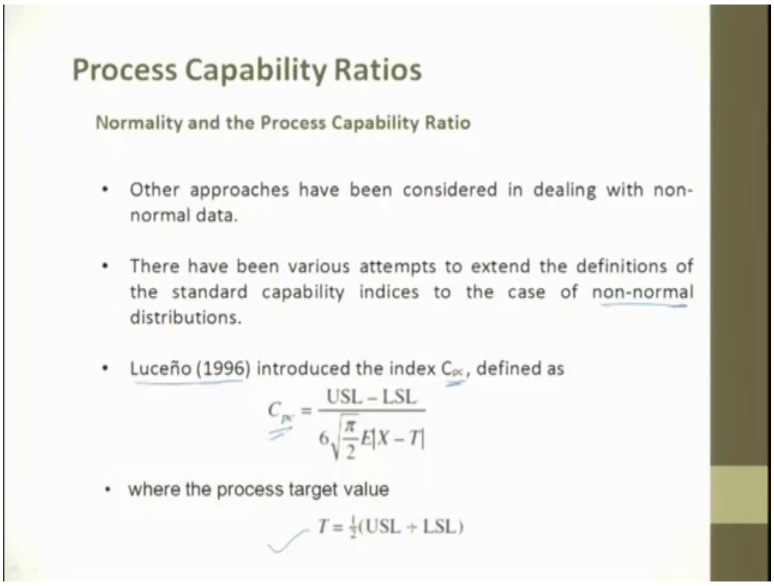

Normality and Process Capability Ratio:

- Other approaches have been considered in dealing with non-normal data.
- There have been various attempts to extend the definitions of the standard capability indices to the case of non-normal distributions.
- So, in 1996, Luceño introduced a new index called C_{pc}

$$C_{pc} = \frac{USL - LSL}{6\sqrt{\frac{\pi}{2}}E|X - T|}$$

- Where the process target value is :

$$T = \frac{1}{2}(USL + LSL)$$

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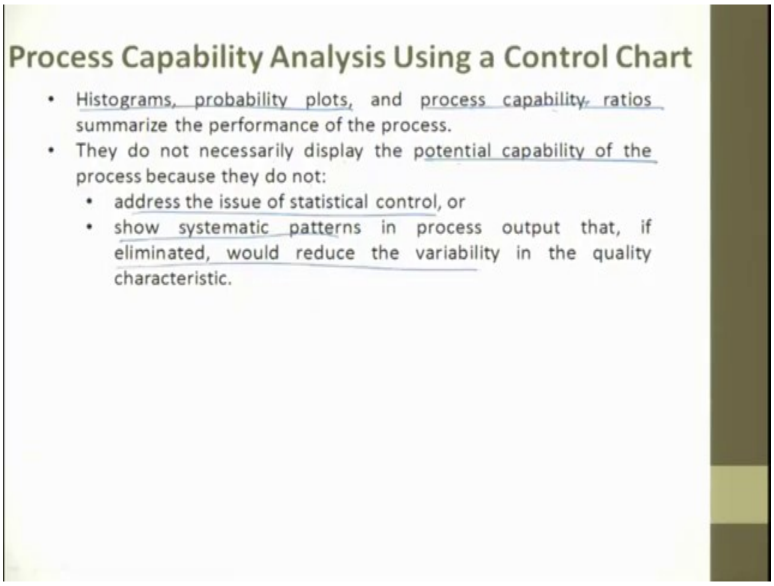

- Histogram, probability plots, and process capability ratios, summarizes the performance of the process.

So, they are very important to test/examine that whether the process is good and whether the product produced from this process will meet the specifications.

- They do not necessarily display the potential capability of the process, because they do not:
  - address the issue of statistical control, or
  - show systematic patterns in process output that, if eliminated, would reduce the variability in the quality characteristics.

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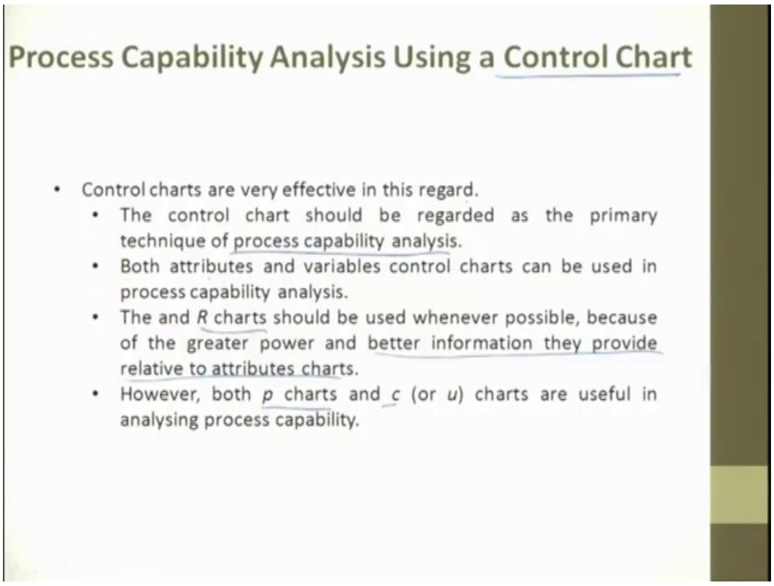

- Control charts are very effective in this regard.
  - The control chart should be regarded as the primary technique of process capability analysis.
  - Both attributes and variables control charts can be used in process capability analysis.
  - The R charts should be used wherever possible, because of the greater power and better information they provide relative to the attribute charts.
  - However, both p charts and c (or u) charts are useful in analyzing the process capability.

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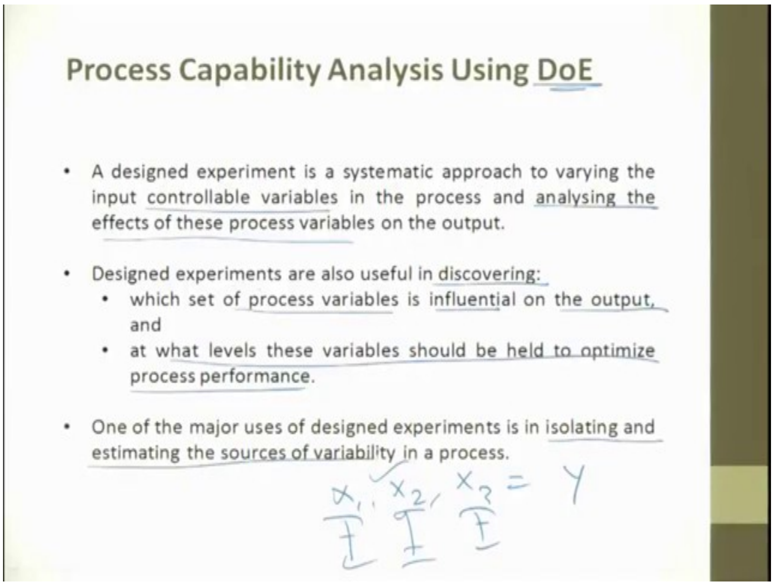

- A designed experiment is a systematic approach to vary the input controllable variables in the process, and analyze the effects of these process variables on to the output.
- Designed experiments are also useful in discovering:
- which set of process variables is influential on the output
- at what levels these variables should be held to optimize process parameters.
- One of the major uses of design of experiments, is in the isolation and estimation of the sources of variability in the process.

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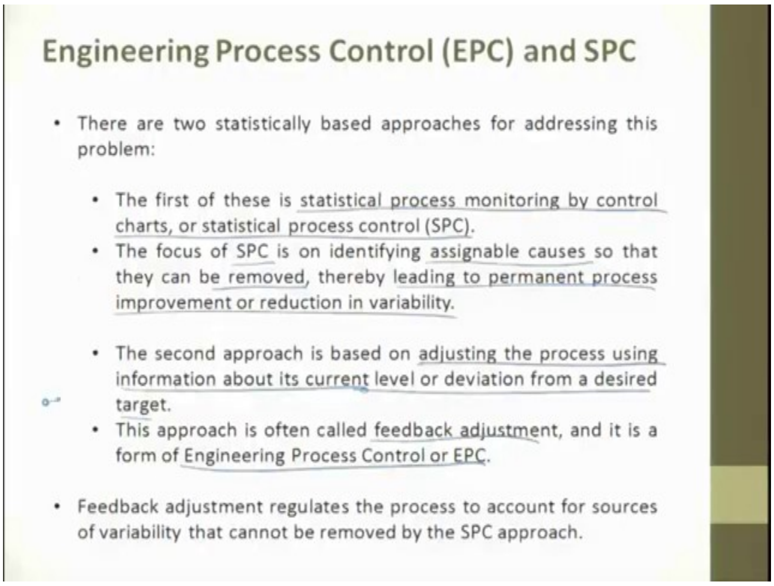

- There are two statistically based approaches for addressing this problem:
  - The first of this is statistical process monitoring by control charts, or SPC (statistical Process Control).
  - The focus of SPC is on identifying assignable causes, so that they can be removed, thereby leading to permanent process improvement or reduction in variability.

For example, a newborn baby is to be given medicine for curing. So, if the newborn baby is put in the free atmosphere, the temperature will keep on changing. So, what people do is, they put the newborn baby in an incubator. What do you do in an incubator; you try to convert all the variables which are uncontrollable into controllable variables, or into a controllable space. And here in the incubator, we vary the temperature, we vary time, we vary fluid input, whatever it is. What are we done is, we have converted uncontrollable to controllable.

  - The second approach is based on adjusting the process using information about its current level or deviation from the desired target.
  - This approach is called as feedback adjustment, and it is a form of Engineering Process Control (EPC).

- Feedback adjustment regulates the process to account for sources of variability, that cannot be removed by the SPC approach.

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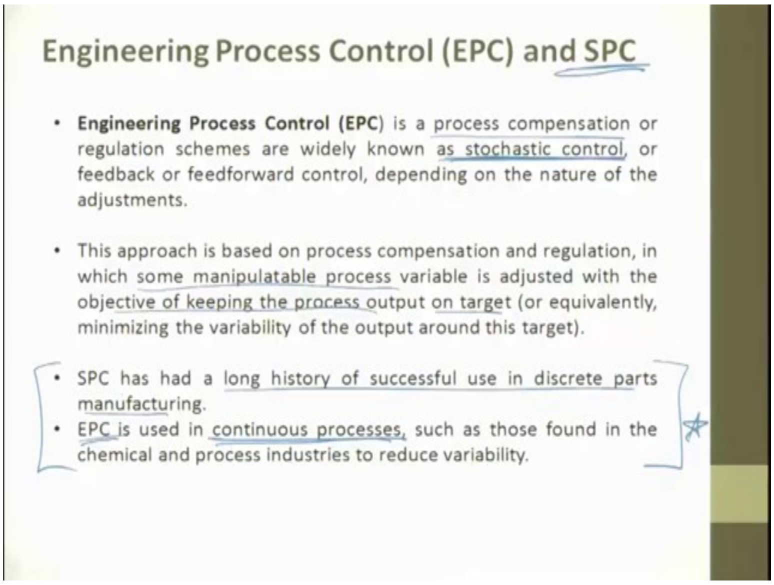

So now, we are trying to compare EPC and SPC. SPC does not get a feedback adjustment. So, EPC and SPC, if you see, engineering process control is a process compensation, EPC is always a feedback based process compensation or regulation scheme are widely used as stochastic control, or the feedback or feed forward control, depending on the nature of the adjustment, it is stochastic, so random in nature.

But, whereas in SPC, binomial distribution has to be followed, it is controllable, and you follow some charts. This approach is based on the process compensation and regulation, in which some manipulatable process variables is adjusted, with the objective of keeping the process output on target. SPC has a long history of success used in discrete part manufacturing. EPC is used for continuous process. In chemical industry and process industry, we follow EPC, whereas SPC is followed, wherever there is a discrete part manufacturing.

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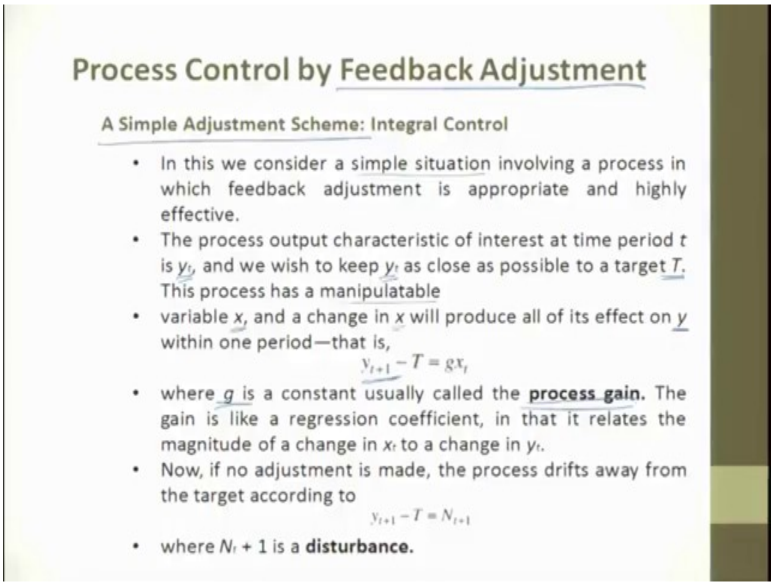

A simple adjustment scheme: Integral Control

- In this we consider a simple situation involving a process in which feedback adjustment is appropriate and highly effective. For example, pharmaceutical industry, shampoo producing industry, food producing industry, etc.

- The process output characteristic of interest at time period t is y_t, and we wish to keep y_t as close as possible to target T.

- The process has a manipulatable variable x, and the change in x, will produce all its effects on y, within one period, that is:

$$y_{t+1} - T = gx_t$$

- where g is a constant which is called as process gain.

- The gain is like a regression coefficient, because it relates the magnitude of change in x to the change in y.

- So, if no adjustment is made, the process drifts away from the target according to:

$$y_{t+1} - T = N_{t+1}$$

- where N_{t+1} is called disturbance.

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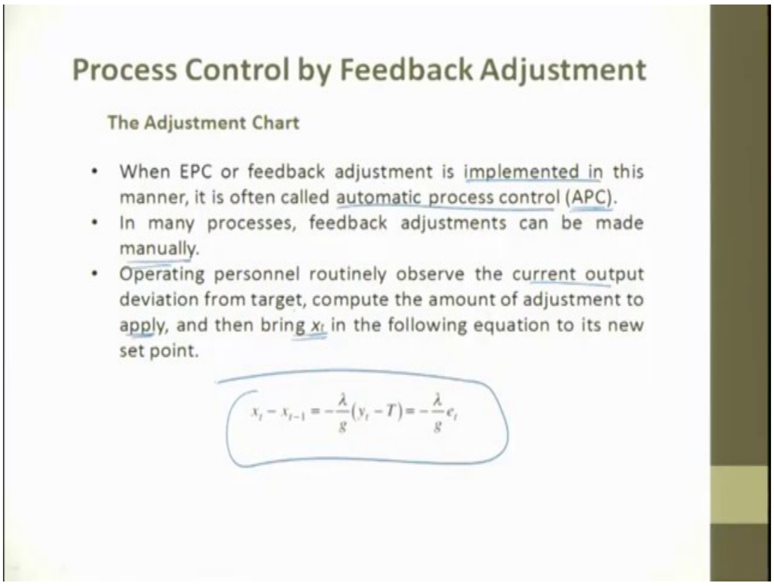

The Adjustable Chart:

- When EPC or feedback adjustment is implemented, it is often called an Automatic Process Control (APC).
- In many processes, the feedback adjustment can be made manual.
- The operating personnel routinely observes the current output deviation from the target. Computes the amount of adjustment to be applied, and then brings x_t in the following equation to its new set point.

$$x_t - x_{t-1} = -\frac{\lambda}{g}(y_t - T) = -\frac{\lambda}{g}e_t$$

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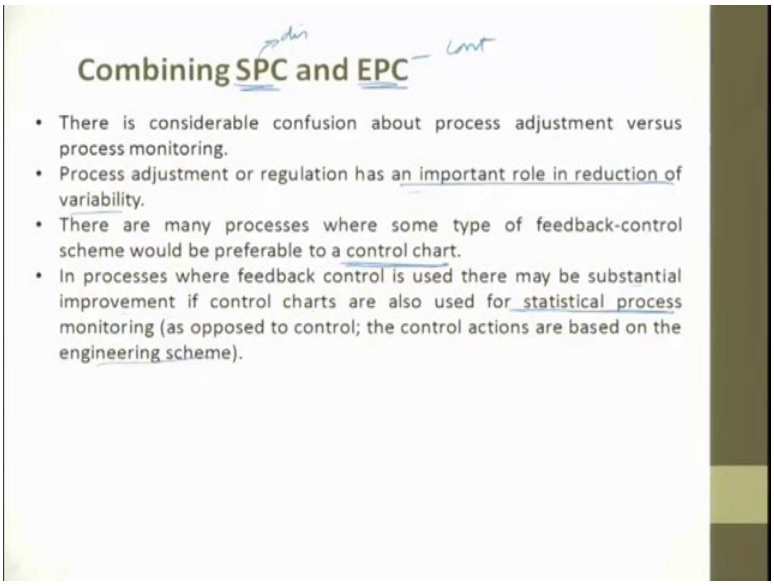

Combining SPC and EPC:

- There is considerable confusion about the process adjustment versus process monitoring.
- Process adjustment or regulation has an important role in reducing the variability.
- There are many process where some type of feedback-control scheme would be preferable to a control chart.
- In processes where feedback control is used, there may be substantial improvement, if control charts are also used for statistical process monitoring, ok. In process, where feedback control is used, there may be substantial improvement in if, control charts are also used for statistical process monitoring.

So, SPC process control charts, EPC continuous, EPC feedback monitoring, they have found out an equation, and then they try to bring it back to the target. A combination of these two, is really very good, which people are nowadays started working on.

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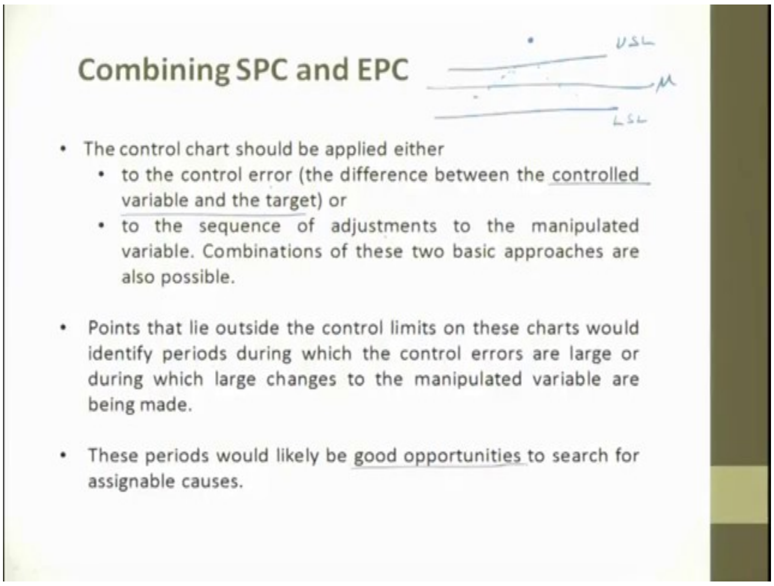

- The control charts should be applied either
  - to control error (the difference between the controlled variable and the target), or
  - to the sequence of adjustments to the manipulated variable. Combination of these two basic approaches are made possible.
- Points that lie outside the control limits of these charts would identify periods, during which the control error are large, or during which large changes to the manipulated variables are made.
- So, these periods would like to be good opportunities for search of assignable causes.

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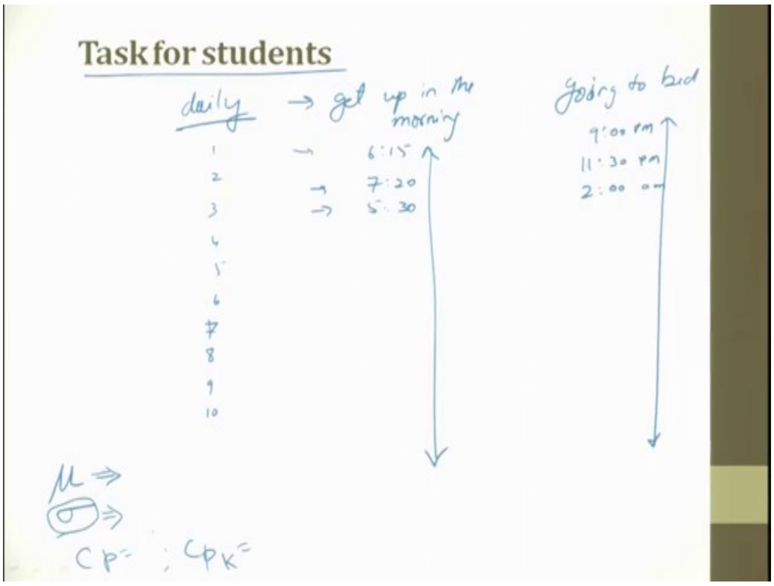

So, let us try to do an activity daily, for example getting up in the morning, and going to bed. So, please note down your daily scheme for 10 days, note down the time, whatever, it is 6.15, 7.20, 5.30, whatever it is. And here you can say 9 pm, you can also say eleven 11.30 pm, you can say 2 am, whatever it is.

So, you try to list down all your processes. And then you try to calculate the mean for your process, you try to calculate the standard deviation for your process, right. So, you will now try to understand the process of getting up in the morning, and going to bed, it does it follow a process sequence. And how good is your C_p and your standard deviation.

So, you can try to figure out in real time, what is your process mean, what is your process deviation, what is your C_p and what is your C_{pk} so that you will try to understand the entire process, you just work on it. Then you will know, how good is your system, by knowing this, you will try to understand, what are the process variables.

Now, you have got the mean, you have got the standard deviation, you have got the C_p for that system, you have got the C_{pk} for your system. Now, you try to do a correction in your daily work, and then rerecord for the next 10 days, after you have taken some necessary modifications in your regular routine.

For example, every day before going to bed, I used to watch a serial, so because of the serial, I sleep at varying time. So, I stopped watching serial, so now every day, I go to bed at 9’o clock. So, what have you done, you have first understood the process, then you have understood the standard deviation for the process , i.e. C_p and C_{pk} .

So, you have list down all the causes why your sigma is very high, and now, you have tried to correct your process. And now you have once again recorded your mean, and sigma, C_p and C_{pk}, and see whether there is any process improvement. So, you have found out the cause, and then you have rectified the process, such that it can be controllable.

Thank you very much.