Six Sigma

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Lecture - 36
Multi – Vari Analysis

Hello friends. Once again I welcome you and I am here with the new topic in our DMAIC six sigma cycle. We are presently discussing the analyze phase and as a part of that we have seen the hypothesis testing and then, ANOVA analysis one way, two way and as a part of lecture 36, I want to teach you one more technique in the analyze phase that is Multi-Vari analysis. So, many a times, practitioners or industry experts they believe more in conceptual understanding intuitive understanding rather than more of a statistical or mathematical kind of inferences.

Obviously, we cannot just go by descriptive statistics, but that can definitely be used as a advantages tool or approach to develop a better feel into the situation. So, I do not say that there is a substitute of your inferential analysis, but if we have both descriptive and inferential, we can capture the situation well and develop the better internalization for the problem under investigation. So, here it is Multi-Vari analysis. So, we have seen ANOVA that is analysis of variance. Here also there is something called vari. So, vari is about variance again and multi is basically dealing with more than one or two factors. And now, I want to really see that why this analysis is required when I have already done one way, two way and I am comfortable with that.

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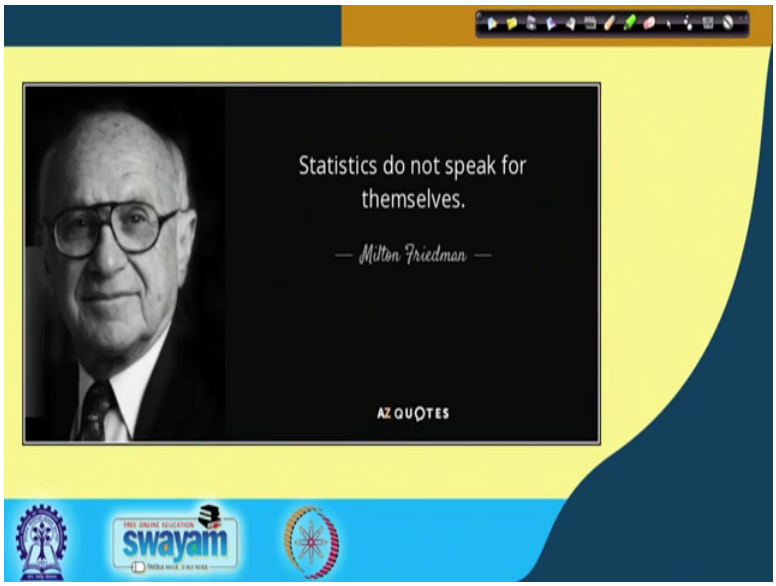

So, once again, I would like to remind you that statistics do not speak for themselves, you need to develop better internalization, you need to have descriptive analysis, you need to have inferential analysis and then, you feel more confident in taking the necessary actions or executing the particular action plan.

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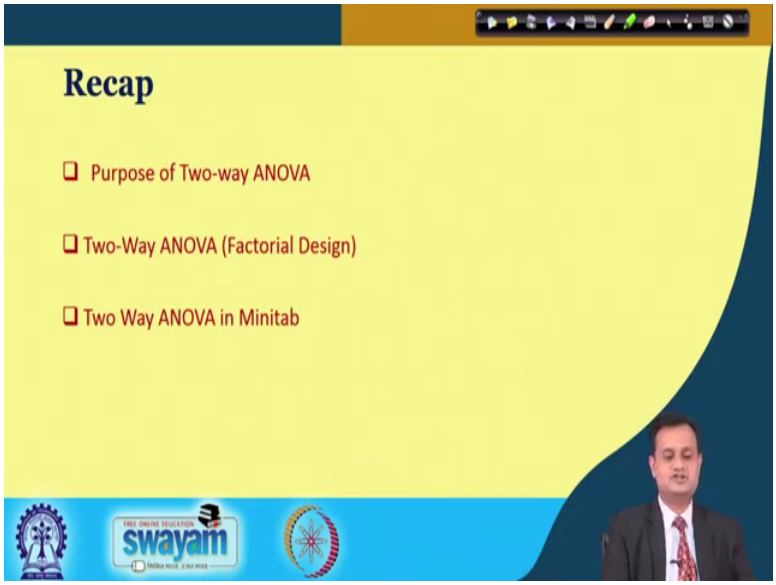

So, we had seen two way ANOVA, we had seen two way ANOVA factorial design illustrative example and two way ANOVA in Minitab.

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Now, let us see this particular topic is very much interesting, very easy to understand and how this can really help to conduct my ANOVA analysis in a more effective manner. So, there is an underline I am putting that how can I not only conduct the multi-vari analysis, but in what way, it can help me even to perform my ANOVA analysis effectively.

Remember, experiments demands resources and you cannot explore or exploit all the possibilities because you have limited resources in terms of say material, in terms of machine hours, in terms of operator and so on. So, fine, we will try to see need of the study, concept of multi-vari studies, construction and interpretation of multivari charts and Minitab exposure. So, typically this is a kind of descriptive tool which is used in as a complementary tool with ANOVA to make certain interpretations before we actually conduct the ANOVA analysis.

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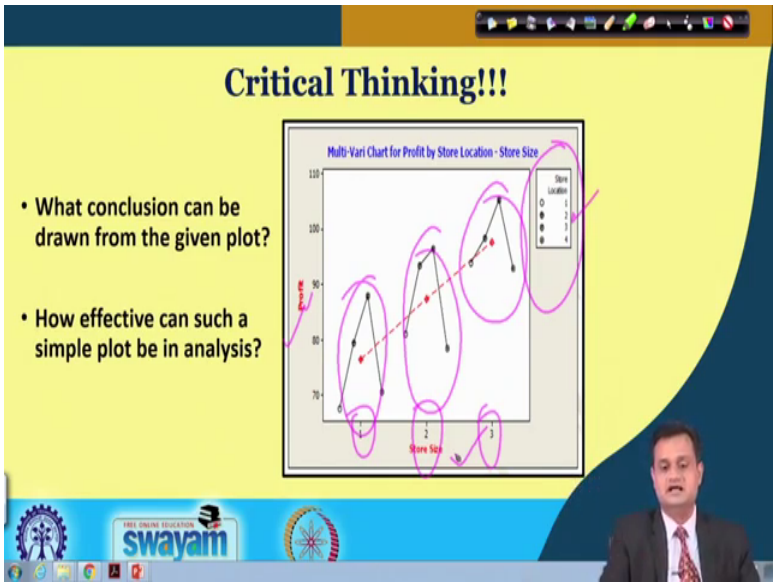

So, just try to appreciate this particular graph and what do you see? Can you just think little bit critically? There is something called say store size and there is something called profit.

So, can you draw some conclusions? How my profit and store size they vary and here you can interestingly see that you have a location. So, suppose let us say there is a reliance fresh or big bazaar. Now, it is located in different area may be of the same city and there is likely possibility that your store size is different and for a given store size, for different location, you can have different profitability and so on. So, here I want to basically capture three things. Number one, my profit; second, I want to see or look at the store size and third is my store location. So, here I have selected four different locations.

Let us say, I have store size which is of 1 you may say some low level. So, maybe in terms of square feet, you can just define maybe. Medium level store size or large store size then, I am trying to analyze these four different locations having the same store size in terms of profit; similar way, this four with store size medium or two and this four with store size three or the large. So, you can see that such a plotting such a simple chart can really help me to immediately get an idea that how my stores are performing and what could be the factor that can have some impact on my profitability.

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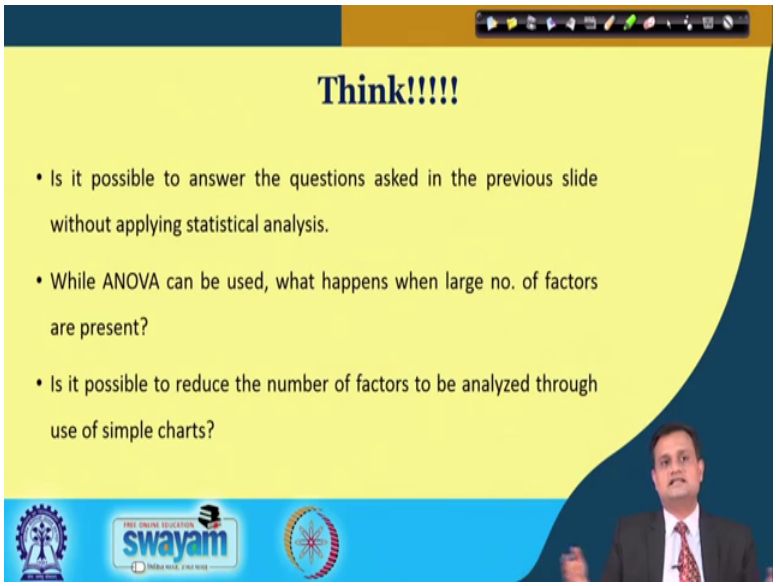

So, this is really interesting analysis and if you do it with very easy say understanding, you can make the interpretations and you can draw some meaningful inferences. So, typically, as I said the manager is interested to know whether both factor affects the profit that is the location as well as the size of the store and which factor has a larger effect on the profits. So, this is just an example to trigger some thinking that what exactly we want to do through multi-vari chats. Now, is it possible to answer the question asked just in the previous slide profit and store location and store size with your statistical analysis ANOVA.

Yes, it is possible. But, when you have large number of factors four location five different sizes of the stores and this, then the experimentation effort would be used and the resources required for conducting such kind of experiments would be enormous. So, the only option is to apply some kind of pareto analysis, we have already done in a logical way to reduce the number of factors and hence to save some effort in my experimentation. So, how can I be more effective in conducting my experimentation and draw the inferential conclusion with limited number of factor and that is where my multi-vari analysis has a role to play?

So, this is a graphical technique descriptive analysis you can do and powerful tool used in analysis of variation in process and helpful in assessing the variability due to three or more factors at the same time and typically it is known as multi-vari charts.

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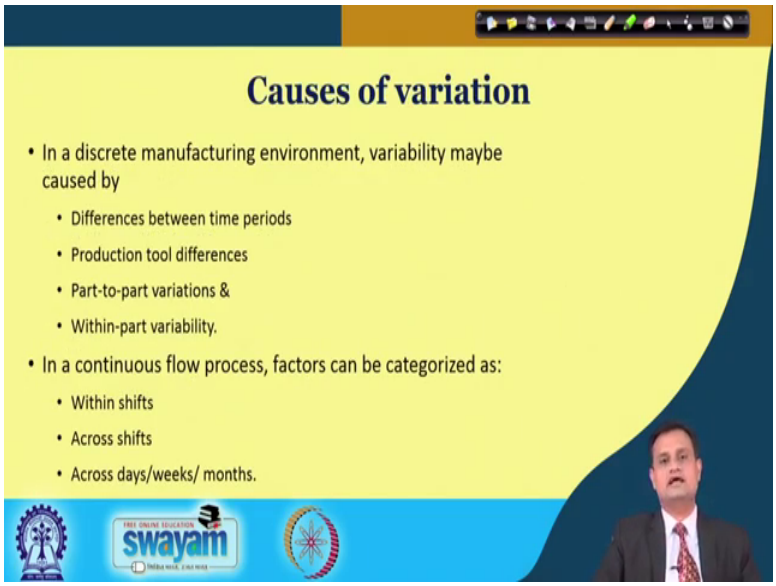

Now, let us try to see that what could be the different causes of variation. So, you can have a discrete manufacturing environment and the variability maybe because of differences between time period shift 1, shift 2, shift 3, production tool, differences, than part to part variability, within part variation and you may have continuous flow process and you can have within shift, across shift, across days weeks and months.

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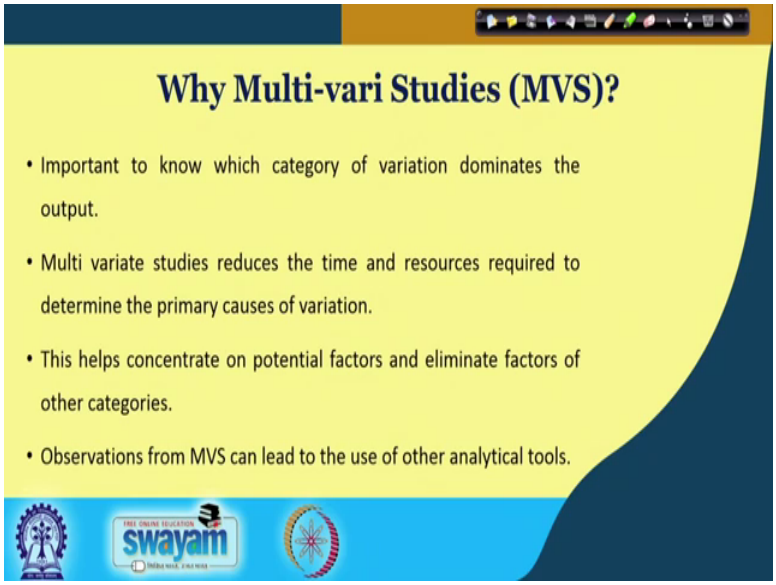

So, typically why multi-vari studies is important to know which category of variation typically dominates the output. Multivariate studies reduces the time and reduces this

resource is required to determine the primary cause of variation and observation from MVS can lead to other analytical tools or inferential techniques like ANOVA and this is where we try to take the advantage of MVS multi-vari studies.

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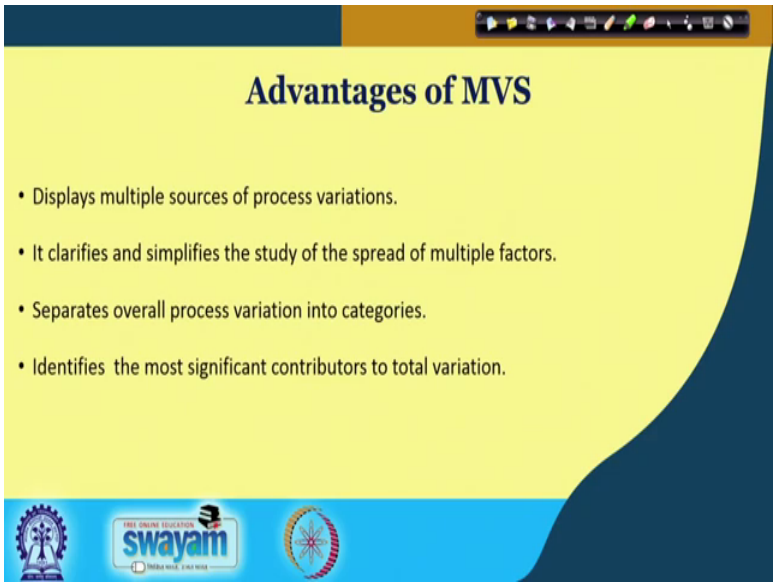

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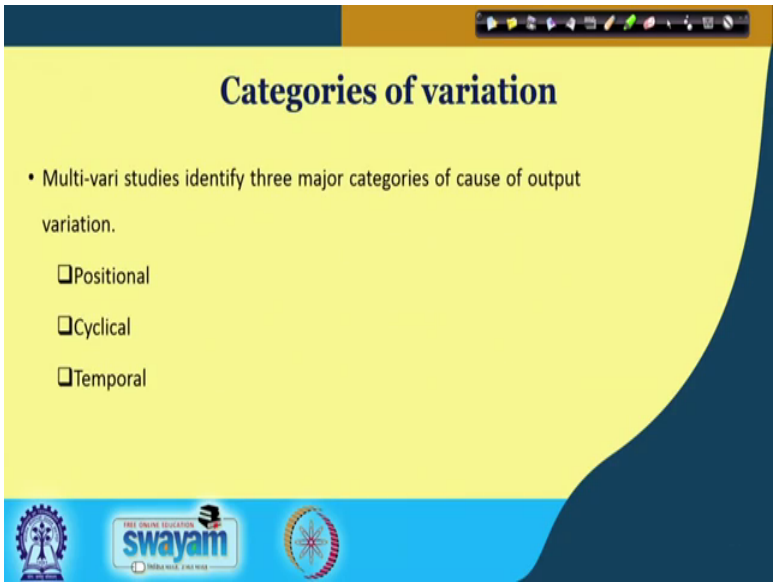

So, this is what we have seen. Now, just try to see that we have three different say categories of variation positional, cyclical and you have temporal.

So, let us try to appreciate that what does it mean?

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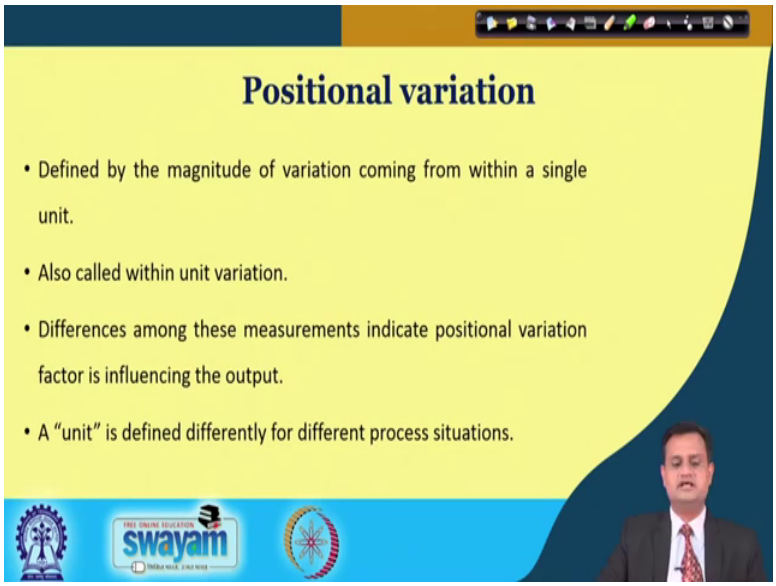

So, positional variation is basically defined by the magnitude of variation coming from within a single unit. It is positional, also called within unit variation. So, suppose your manufacturing a particular component and within this component whatever variability is there that is within component and variation. Differences among these measurements indicate positional variation factor is influencing the output and unit is defined differently for different purpose situation.

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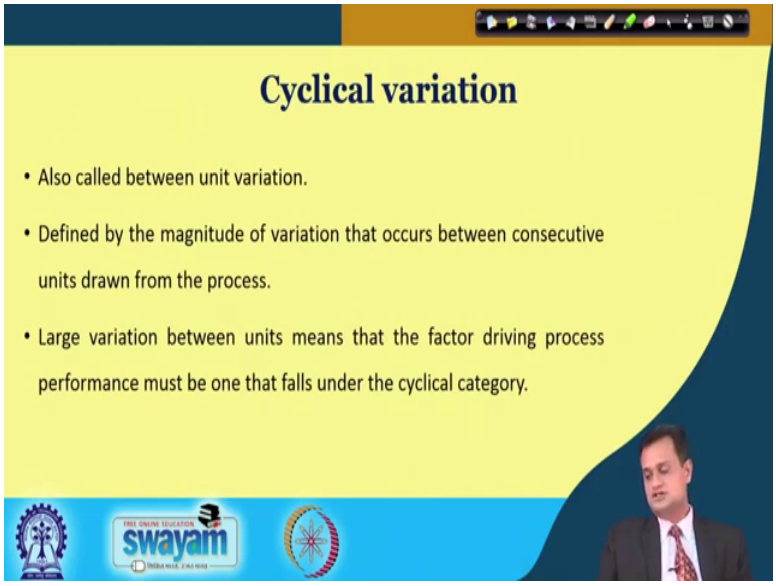

Now, let us see what is my cyclical variation? So, this is typically called between unit variation. I am producing the different components and between unit, there could be some variability.

So, defined by the magnitude of variation there occurs between consecutive units drawn from the process, large variation between units means the factor driving process performance must one that falls under the cyclic variation.

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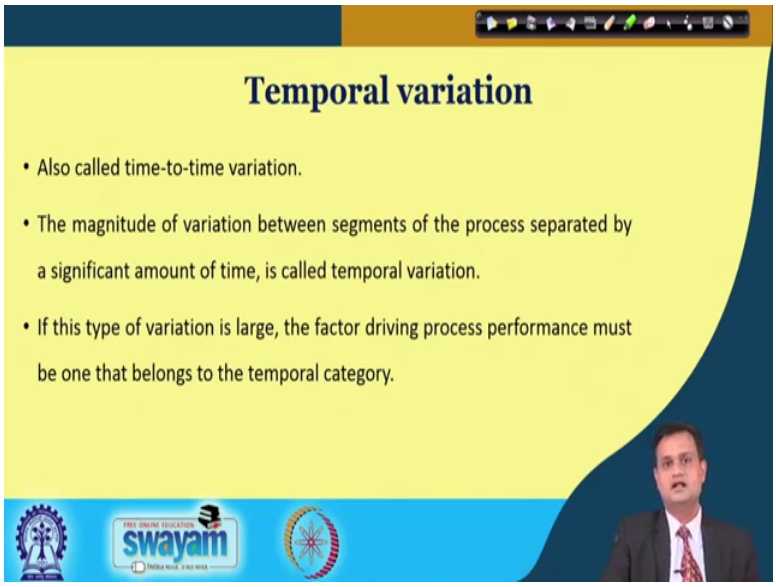

Now, you may have the temporal variation. So, you are manufacturing, let us say in shift 1, shift 2, shift 3 or you have a particular window for manufacturing. Now, there could be some variation time to time. This may be because some setting is disturbed or there is change in the operator or supervisor and I would also like to capture this particular temporal variation.

Basically, you have positional, cyclic and temporal variation.

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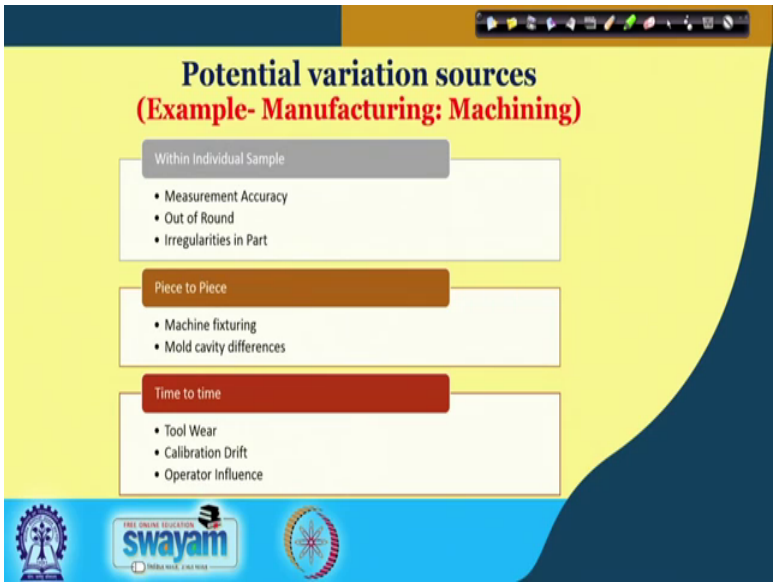

Now, just try to see that if I want to summarize, then within individual sample, measurement accuracy, out of round, irregularities in part. These are three possible reasons or sources for within individual sample piece to piece variability. This may be because of mix machine fixturing, the way you fix the components for machining, mould cavity differences just few examples and time to time variation. There is some problem in the tool or tool wear calibration drift. Your measuring system is not precise, operator influence and likewise.

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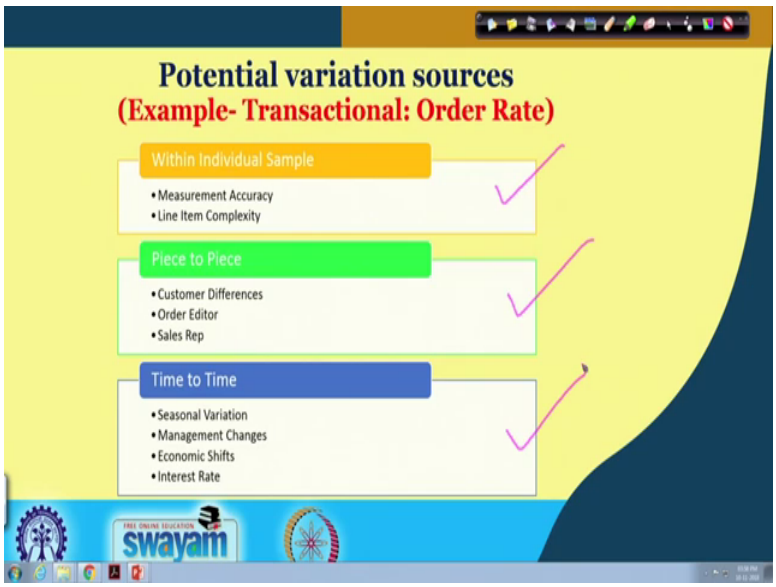

So, we can just see the potential, variation sources and with an example of transactional. So, transactional as I said any kind of say service type of thing or where the administrative work is involved. This is the transactional. Here, I am taking the example of order rate. Just see that within individual sample, I can consider measurement accuracy and line item complexity, piece to piece, customer differences, order editor, sales representative, time to time, seasonal variation, management changes, economic shift and interest rate.

So, this is something that can really help me to figure out that what particular source is really responsible when I am analyzing a process like order rate.

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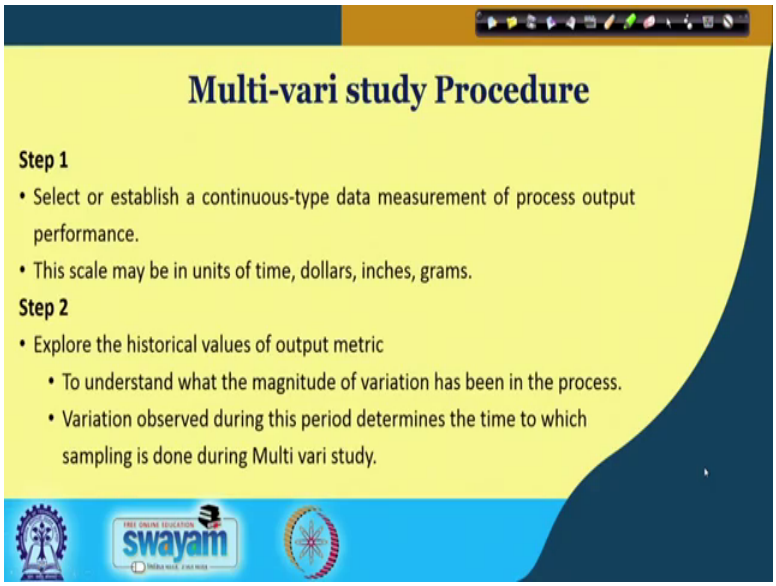

And now, we will see that how can I conduct the multi-vari study and what are the steps involved. So, you have step one, select or establish a continuous type data measurement of process output performance and this scale maybe units of time dollars, inches, grams. Step 2, explore the historical values of the output metric and to understand what the magnitude of variation has been in the process. Variation observed during this period determines the time to which sampling is done during multi-vari studies.

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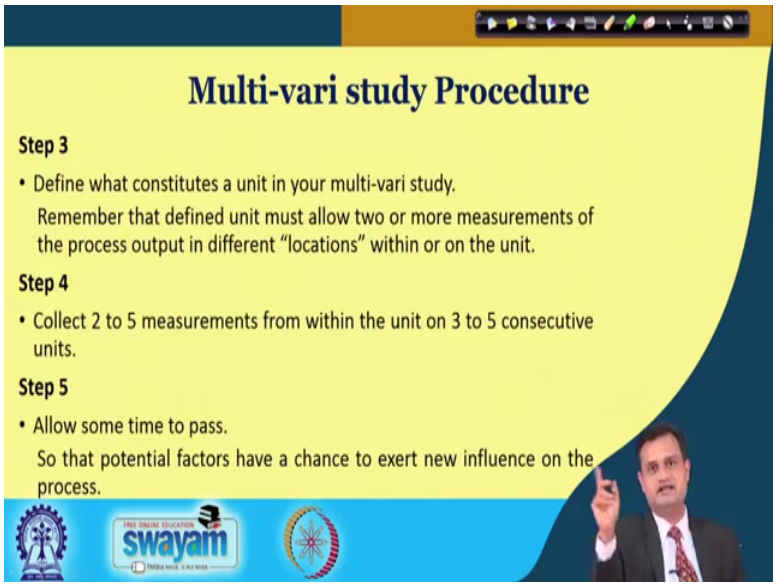

Step 3, define what constitutes a unit in your multi-vari study. What exactly you are focusing on? Remember that, defined unit must allow two or more measurements of the process output in different location within or on the unit. Step 4, collect two to five measurements from within the unit on three to five consecutive units, we want to capture I would like to remind you positional, cyclic and temporal. Step 5, allow some time to pass so that, potential factors of a chance to exert new influence on the process.

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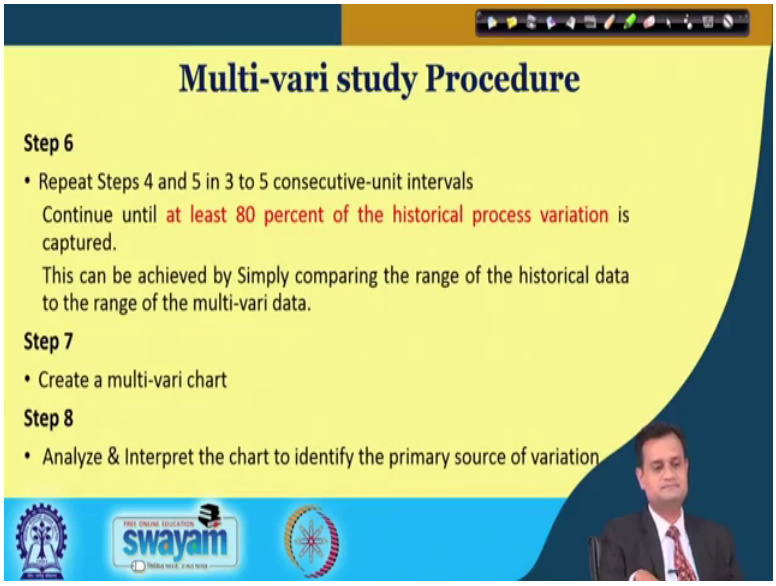

Step 6, repeat step 4 and 5, say in three to four consecutive unit intervals continue until at least eighty percent of the historical process variation is captured. You know the variability of the process and this can be achieved by simply comparing the range of historical data to the range of the multi-vari studies or the data. And step 7; create a multi-vari chart. Step 8, analyze and interpret the chart to identify the primary source of variation.

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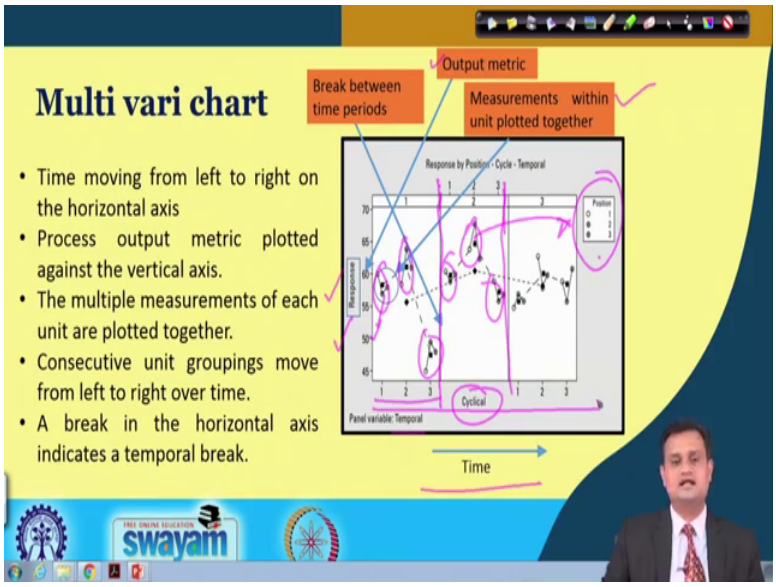

So, such a beautiful technique, very simple to follow, only 8 steps you go ahead and I will also show you the application of Minitab where you can do this analysis very easily. So, this is a typical multi-vari chart and what do you see here that, there is something called cyclical, there is a response there is a position and this positions are basically say indicated by 1, 2 and 3. So, you can see here 1, 2, 3; 1, 2, 3; 1, 2, 3; 1, 2, 3; 1, 2, 3, and 1, 2, 3. So, this is basically refers to this.

Now, you have break between time periods. So, here I am breaking the process. I am breaking the process and I am trying to capture the temporal dimension, I am also trying to capture the cyclical dimension. This is my response that is the output metric and this is my measures within unit plotted together. So, you have the time axis and you have the response. I want to capture the variability in response with respect to say positional. So, this is my positional variability with respect to a particular time window and particular say unit of interest. In previous case, we had seen the location and these locations were

say plotted with respect to the size. So, you choose a particular say window. So, this particular window is basically your temporal and I want to analyze the positional this is the positional, I want to analyze the cyclical and I want to analyze the temporal.

So, this is how I would be able to conduct the analysis using multi-vari studies.

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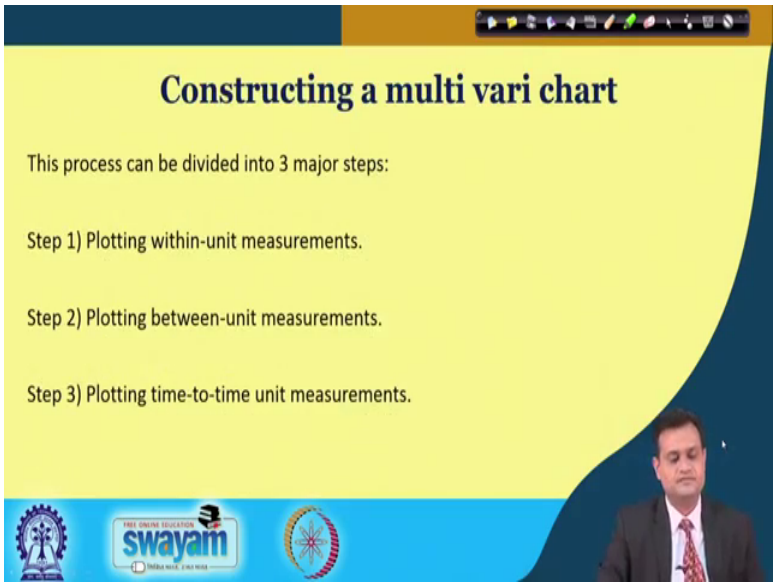

So, now let us see that, you have constructed the multi-vari charts plotting within unit measurement, plotting between unit and time to time unit measurement.

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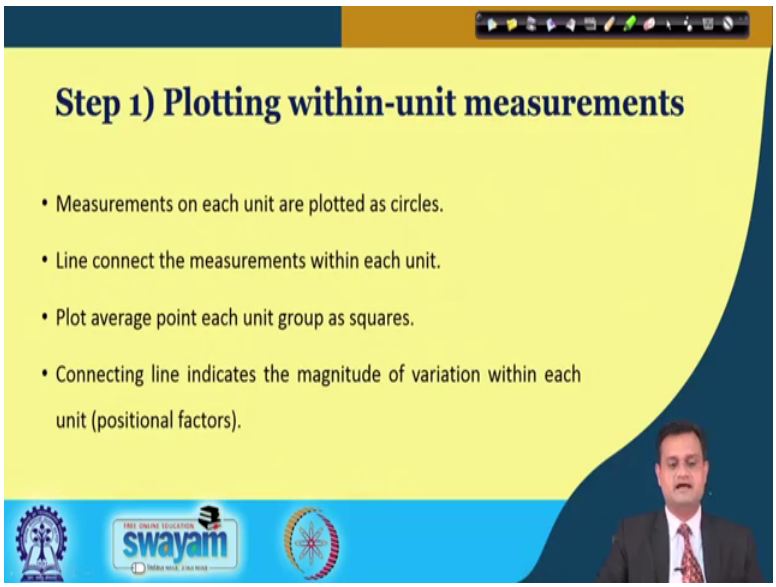

So, plotting within unit, measurements on each unit are plotted as circles as I have shown. Line connects the measurement within each unit, plot average point each unit group has squares and connecting line indicates the magnitude of variation within each unit.

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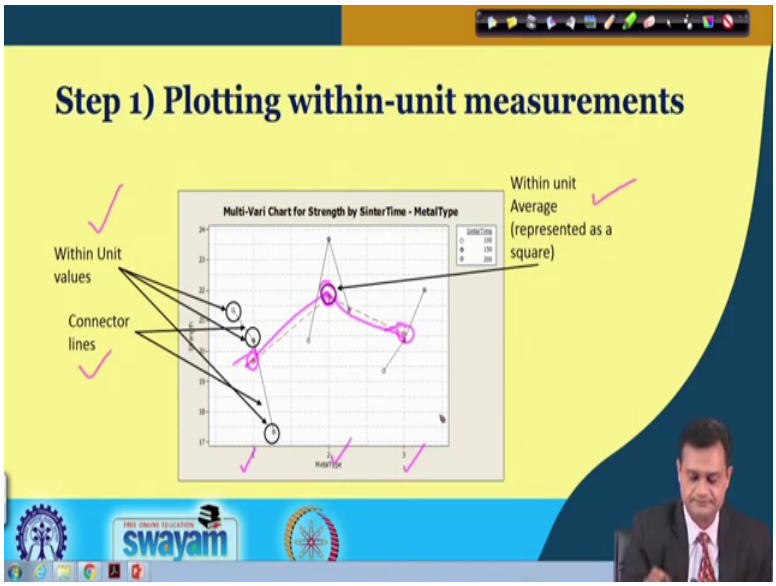

So, just see here we have very good figures available. So, this is my within unit value values and this is the connector line. So, I am trying to connect it through this line and this is within unit average. So, you can see that I am identifying the average value somewhere and this is my basically the square.

So, this is my square, this is my square I am connecting this. So, that will help me to capture within unit measurement with respect to metal type .

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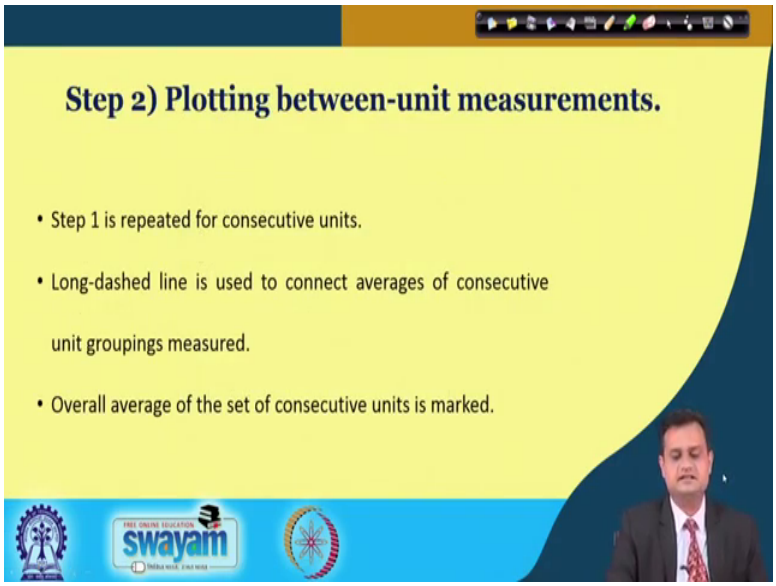

Now, let us see the second one; between-unit measurement. So, you repeat the step 1 and long dash line is used to connect the averages of the consecutive unit groupings measured. And overall average of the set of consecutive unit is marked.

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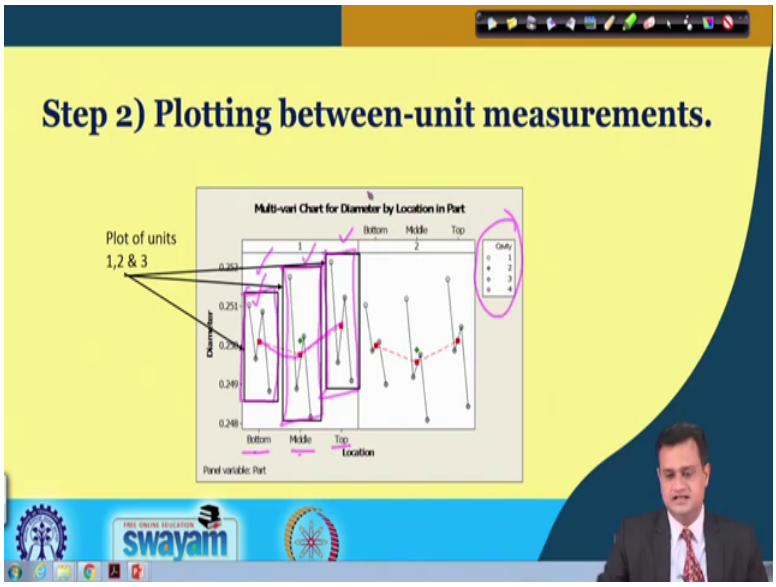

So, just see that what exactly we have done here that you have this particular bottom, middle and top and for each bottom, middle and top, you have different types of cavity. So, I am plotting the cavities here. So, this is my particular within which we have already done in step 1. This is my within step 1 this is my within step 1.

Now, you can just see this redline, this particular line which basically captures the between-unit measurement. So, now, if you recall your understanding on say ANOVA analysis then, we were capturing the within, particular subgroup and the among subgroup variability. And exactly same thing I can capture through multi-vari studies. So, this is where my second step is done and I am trying to capture within unit variability, within unit measurement.

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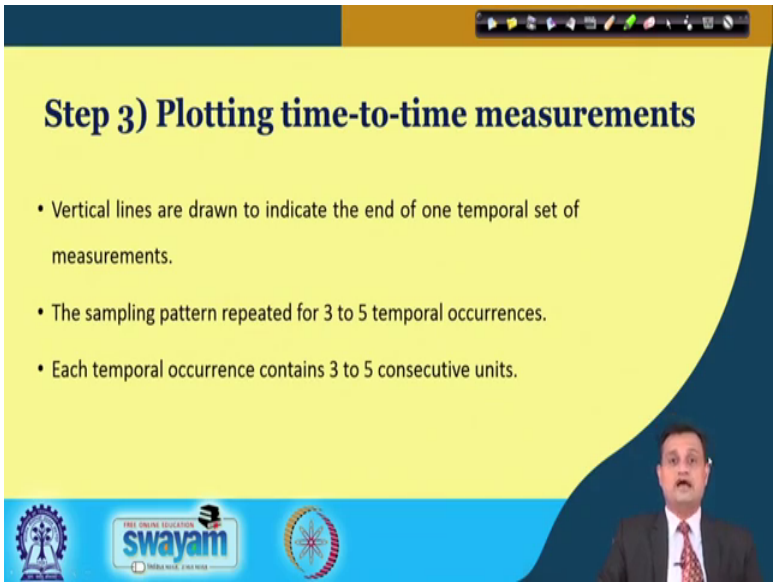

Step 3, I am trying to capture not only within and between, but also time to time variability. And then, I have let us say something like this, that I have within between these two are there, but I have two blocks of temporal variation.

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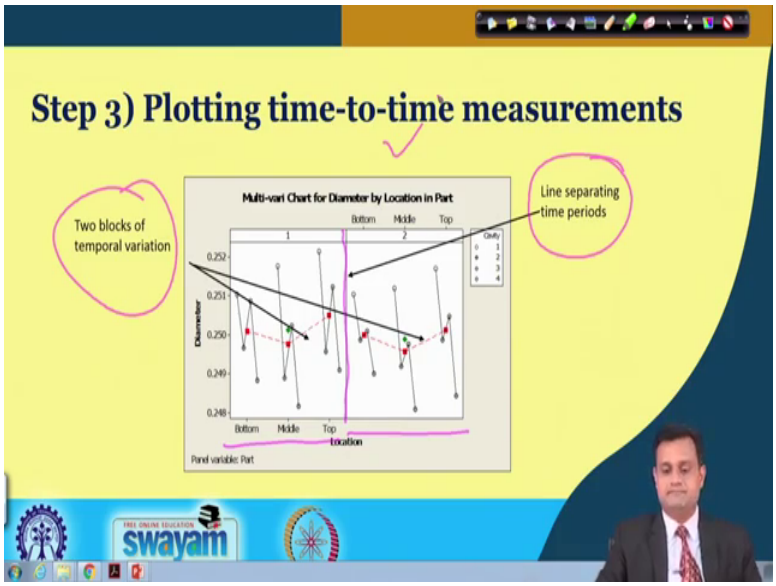

So, I am just trying to separate the time period through a line. And I would say that this much of data is collected may be in the morning shift and this is in the afternoon shift. So, I want to investigate that whether there could be a variation in the shift or suppose restaurant if you take the example, then the service level maybe in morning time and the service level may be in the evening time. When the little bit the rush is more or service level maybe you can select the window like this during the working days Monday to Friday, when the rush is less. And service level Saturday and Sunday, you can just separate it out and this is my third time-to- time measurement temporal variability, temporal consideration.

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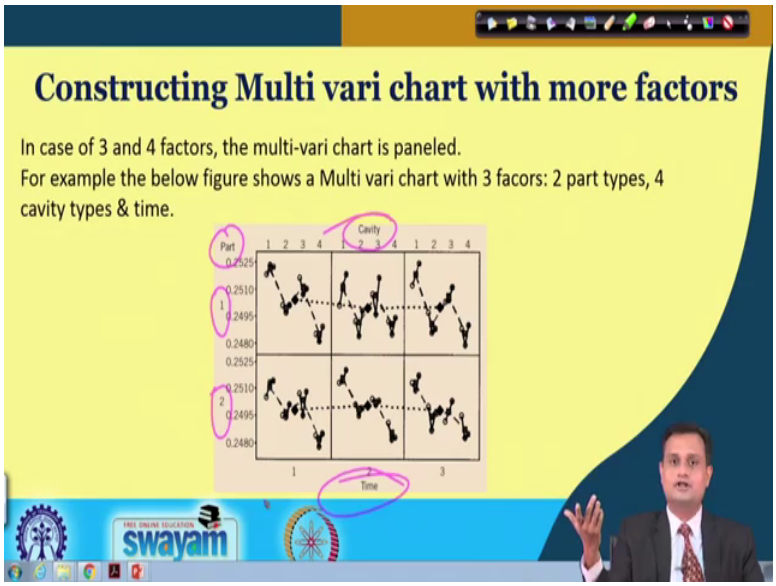

So, typically, you can construct the multi-vari charts with more than one factor. You see, this would be extremely cumbersome and lot of resources you need if you have to do for more number of factors in ANOVA. So, you can do it for more number of factors. So, you have part maybe two types of parts. You have different types of cavities and you are trying to capture the temporal dimension also. So, once you have this plot, you can feel comfortable in atleast identifying the important factors that should be considered for your ANOVA analysis, inferential analysis.

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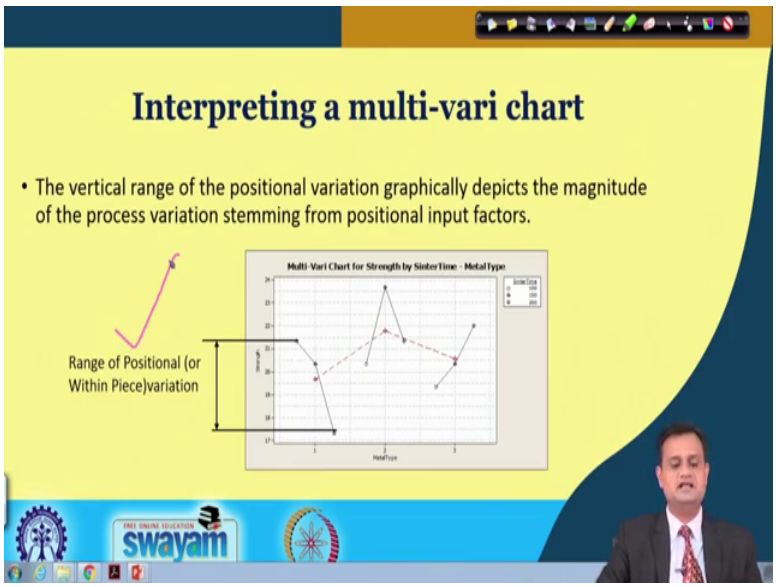

So, this is what exactly we try to gain from multi-vari charts and as I have said that this is just as a small recap of whatever we discuss. This is my range of positional or within piece variability.

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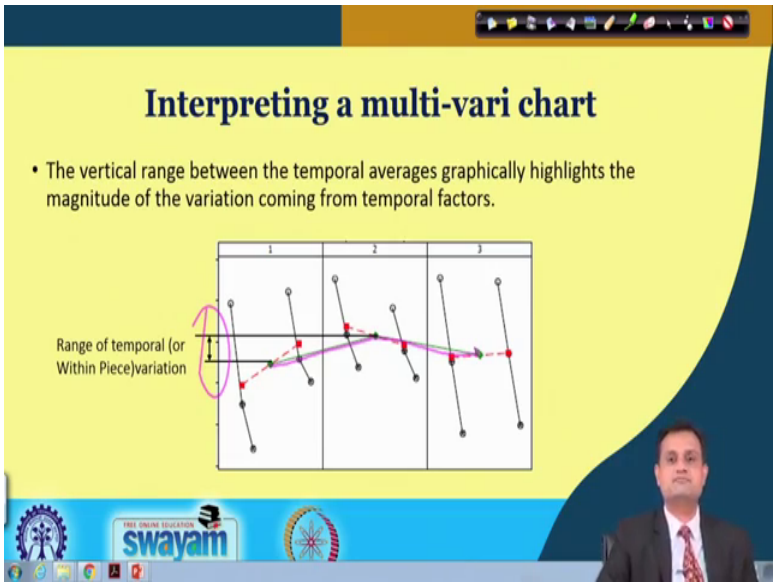

Then, I have this is my range of cyclic between piece variability.

Then, I have temporal variability and this is my typically temporal variability time-to-time what is the change, what is the difference. So, you can see this green line. Now, I have put the pink line. So, you can capture the temporal variability also.

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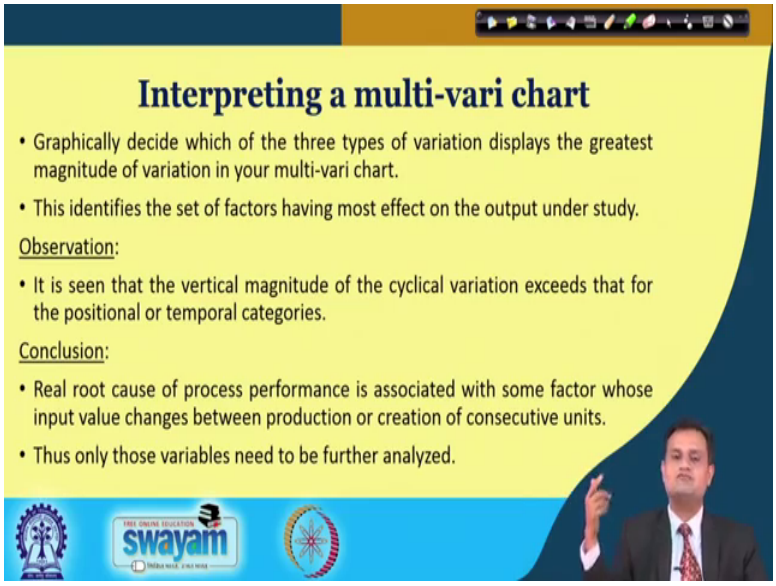

So, now, you can make use of the graph paper. You can do it manually also by following the steps or else, I will show you the application of Minitab for constructing multi-vari charts. So, you can interpret these Multi-vari charts very easily that you can see that vertical magnitude of the cyclical variation exits that for the positional in the shown figure or temporal category. And conclusion you can draw that real root cause of process performance is associated with some factors whose input values changes between production or creation of consecutive units.

So, only those variable needs to be considered for further analysis may be ANOVA analysis and other factors may be excluded.

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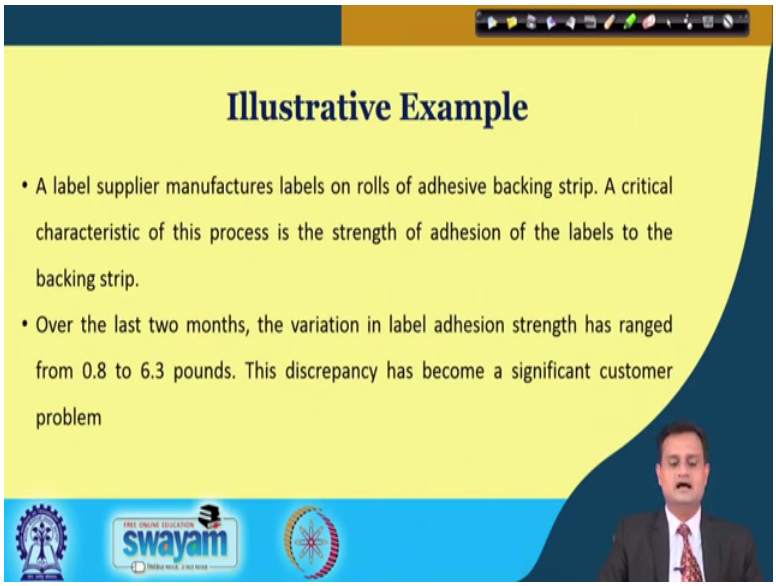

Let us see some illustrative example that a label supplier manufacturer labels on roles of adhesive backing strip. A critical characteristic of this process is the strength of the adhesion on the bonds to the backing strip. And over the last two months, the variation in label adhesion strength as range from 0.8 to 6.3, it is not a joke. You are manufacturing this kind of adhesive say strips and if this much of variation is there then your customer will definitely express the concern and may switch to the other manufacturer. So, this much variability is not accepted.

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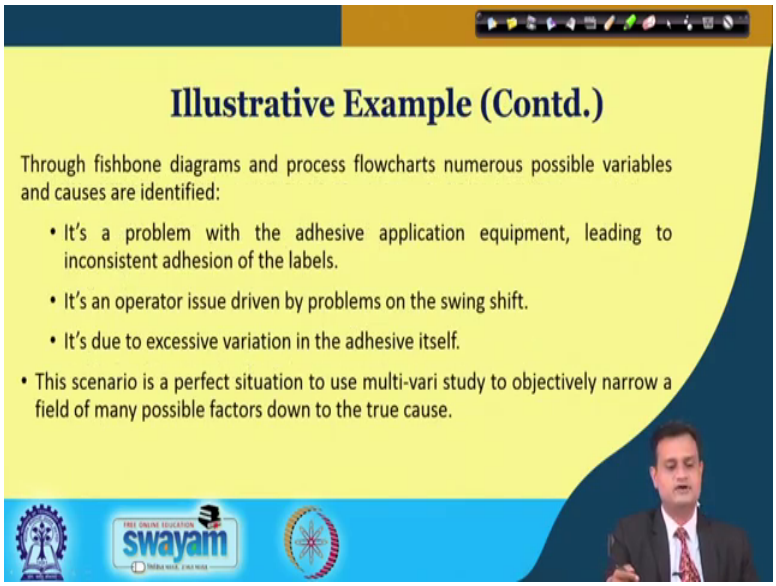

So, let us try to do some analysis using the multi-vari studies. So, it is a problem with the adhesion application equipment, leading to may be inconsistent adhesion of the labels. So, there could be possible variables and causes. So, number one is the, how you apply the adhesion on the strips. Operator issue that operator is not skilled in applying or due to excessive variation in the adhesive itself. The glue material you are purchasing that could be the problem.

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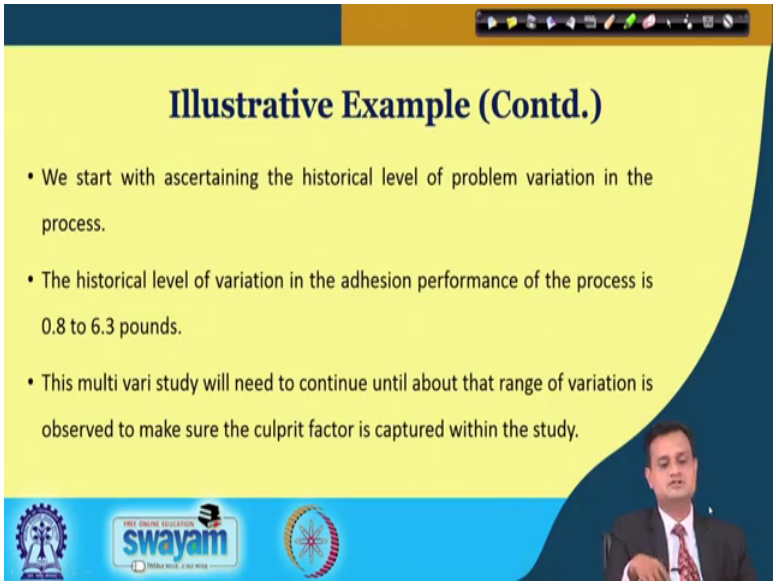

So, you have say different causes and we try to begin with say, asserting the historical level of problem variation and historical level of variation is 0.8 to 6.3. So, there is a need of multi-vari studies.

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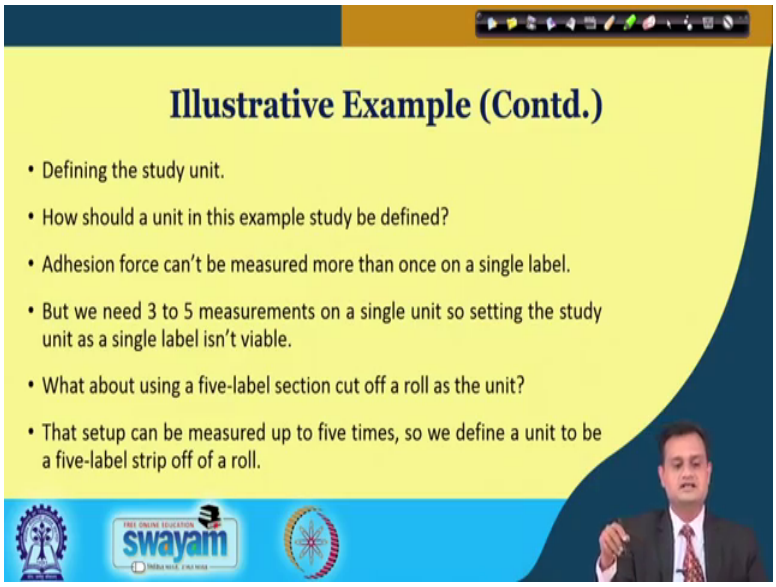

So, we define the study unit, how should a unit in this example study be defined.

Adhesion force cannot be the measured more than once on a single label. We need three to five measurements on a single unit. So, setting the study you need as a single label is not viable. And what about using a 5 label section cutoff a role as the unit? So, that setup can be measured up to five times. So, we define a need to be five-label strip off of a roll. So, you have a big roll. You can cut it and then you can just try to check that across the width, whether your degree of adhesion or the strength of adhesion is same or not.

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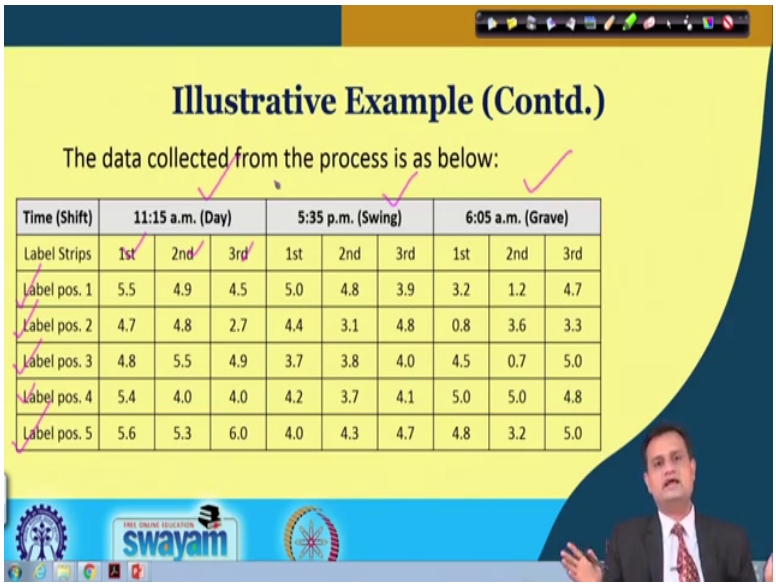

So, just see that is what I did, I have exactly done the analysis for day swing and grave. So, three different timings 11:15 am, 5:35 pm, 6:05 am, I just conducted that analyze say collected the data and I am considering say label position 1, label position 2, 3, 4 and 5 as I said across the width of the roll and you have first, second and third. So, three as say data units you have collected.

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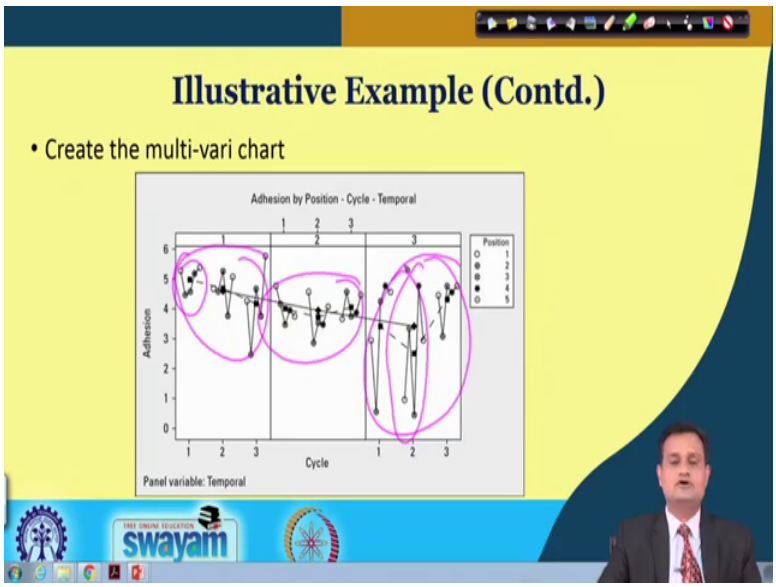

Now, with this particular data set, how do you interpret this graph? We have plotted this multi-vari chart in the Minitab, how do you appreciate? So, you can see that there is a

position and we have selected five different positions. So, these are basically grouped here. You have a particular cycle and you are trying to capture 3 at a particular time and you have selected swing grave three different timing. So, I am just trying to capture the temporal also and this is the response variable that is the adhesion strength. So, this is how you can see and what you can see here that when I look at this. Then, here the variability is not that much. But when I look at these then within, there is a huge variability in the third shift or third timing.

And when I look at overally, then the variability is not that much, but when I look at this third, so variability is very high. So, you can capture the temporal, you can capture the within and you can capture the between.

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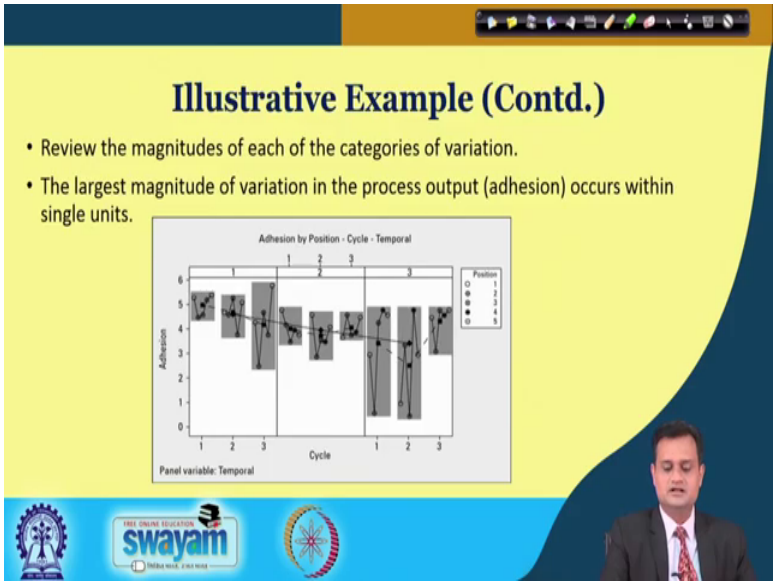

So, this is the advantage of multi-vari studies and exactly, it is explained here that adhesion versus cycle and temporal.

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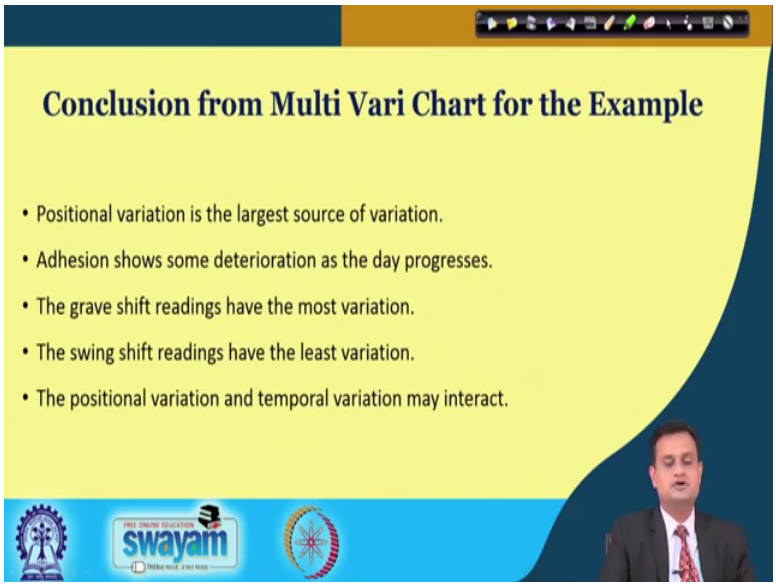

So, you can conclude from this particular example that positional variation is the largest source of variation. Adhesion shows some deterioration as the day progresses and that is why, the third time is having maximum variability. The grave shift readings have the most variation that is what we said. The swing shift reading have the list variation and the positional variation and temporal variation may interact because we have seen that they go one to one and there is a magnifying impact of these two on the variability of adhesive strength.

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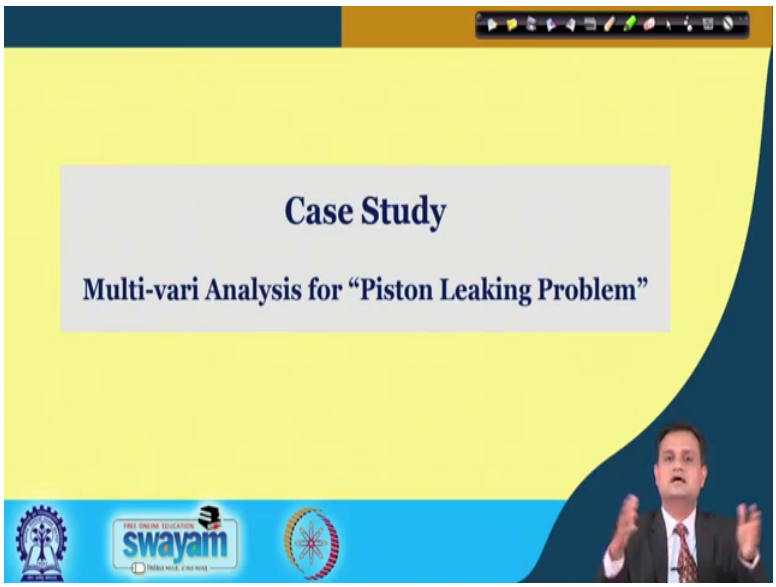

So, we can just look at some small case study and this piston leaking problem. So, suppose you are manufacturing an engine and suppose there is a leak in the piston or piston is leaking, your oil is coming out, it would be a very serious problem.

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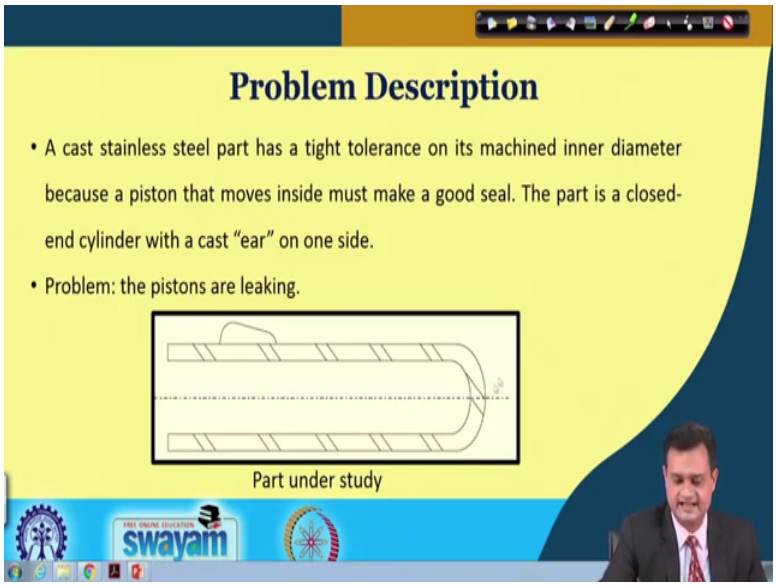

So, let us see, I have the component like this. This is my piston and it is a casted standard steel component and machine inner diameter because a piston that moves inside must make a good seal. The part is closed end and cylinder with cast here on the say one side. So, this is the cast here on this side.

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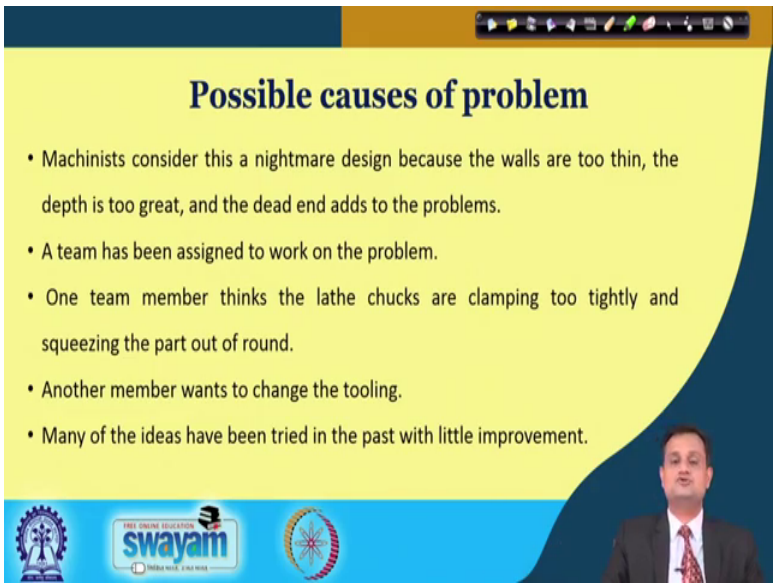

So, this is my component and what I did is like this. I want to figure out what is the reason for say my leakage or the eccentricity may be in the piston.

So, machinists consider this as nightmare design because the walls are too thin and the depth is too great dead and add to the problem. Team has been assigned and one team member thinks that lathe chucks are clamping too tightly and squeezing the part out of round. So, there is an eccentricity. Another member wants to change the tooling many of the ideas, they came up.

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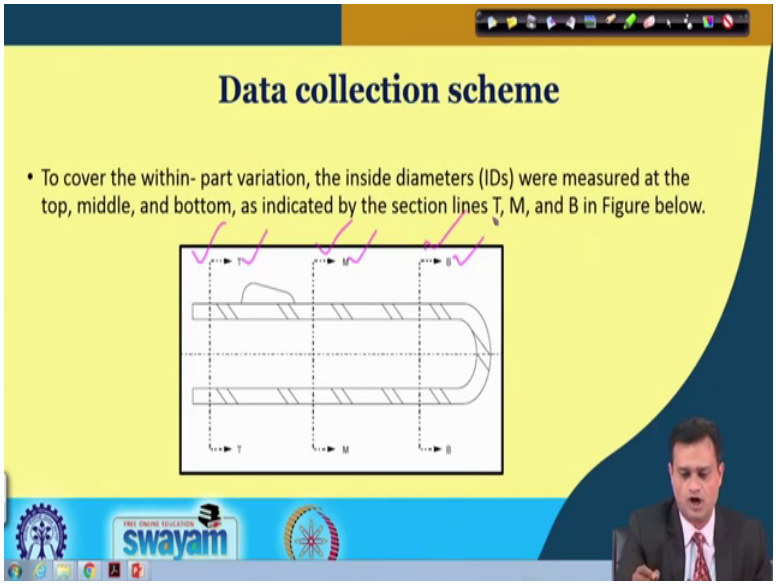

Now if you start a taking on all the ideas, you are nowhere, so this is where multi-vari studies can help us. So, what I am doing, I am just taking the cross section because there could be eccentricity across the length and because of length, there could be some banding while machining in another processes. So, I am taking T, M and B. These are three a top, middle and bottom section.

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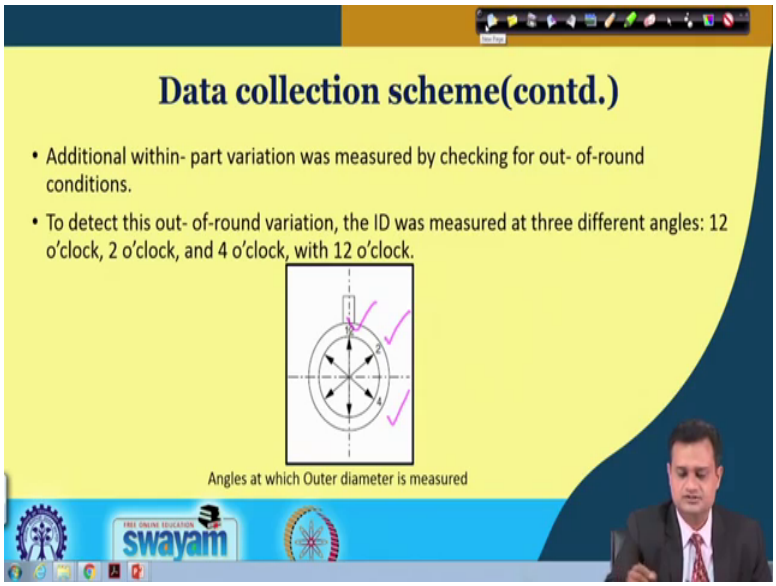

So, I am taking the cross section and this is what you can see that to detect out of round variation, the ID was measured at three different angles, 12 degree. You can see a 12 degree, then 2 o' clock or 4 o' clock. And I am trying to consider this also as a part of my data collection.

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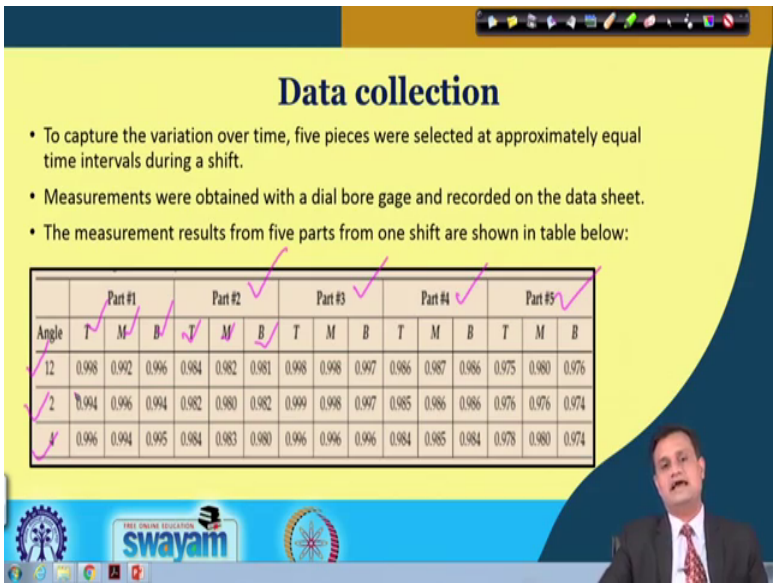

	Part #1			Part #2			Part #3			Part #4			Part #5		
Angle	T	M	B	T	M	B	T	M	B	T	M	B	T	M	B
12	0.998	0.992	0.996	0.984	0.982	0.981	0.998	0.998	0.997	0.986	0.987	0.986	0.975	0.980	0.976
2	0.994	0.996	0.994	0.982	0.980	0.982	0.999	0.998	0.997	0.985	0.986	0.986	0.976	0.976	0.974
4	0.996	0.994	0.995	0.984	0.983	0.980	0.996	0.996	0.996	0.984	0.985	0.984	0.978	0.980	0.974

So, you can very well see that I have part 1, and for top middle and bottom I have taken the reading. I have part 2, top middle and bottom part 3, part 4 and part 5. And I have considered the inner eccentricity a 12, 2 and 4 o clock angle.

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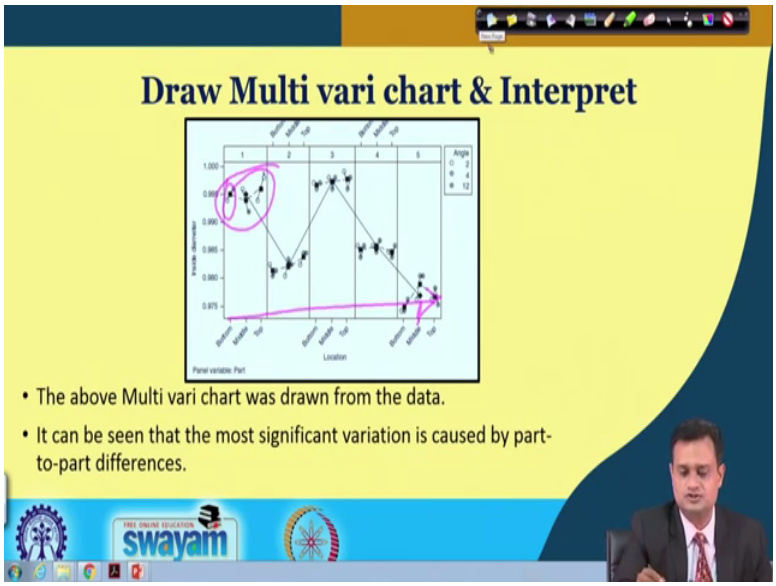

And now with this data set, I am plotting the multi-vari chart. So, my multi vari chat looks like this.

And I hope it would not be difficult for you to make the inferences. You can see within, you can see within particular subgroup, you can see between subgroup and you can also capture the temporal variation.

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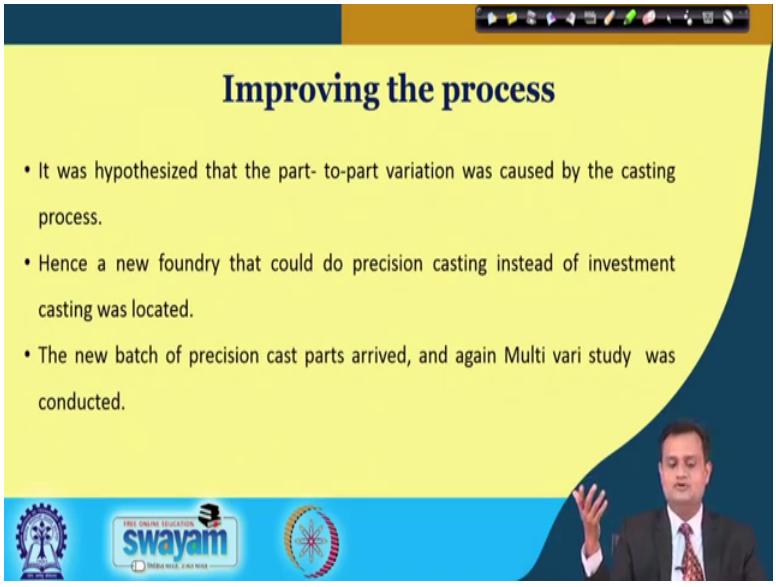

So, this is what I did and typically say you need to improve the process. So, it was hypothesized that part to part variation was caused by causing the because of casting

process. New foundry that could to precision casting instead of investment casting was located. So, the process was a problem and new batch of precision part arrived and again multi-vari study was conducted.

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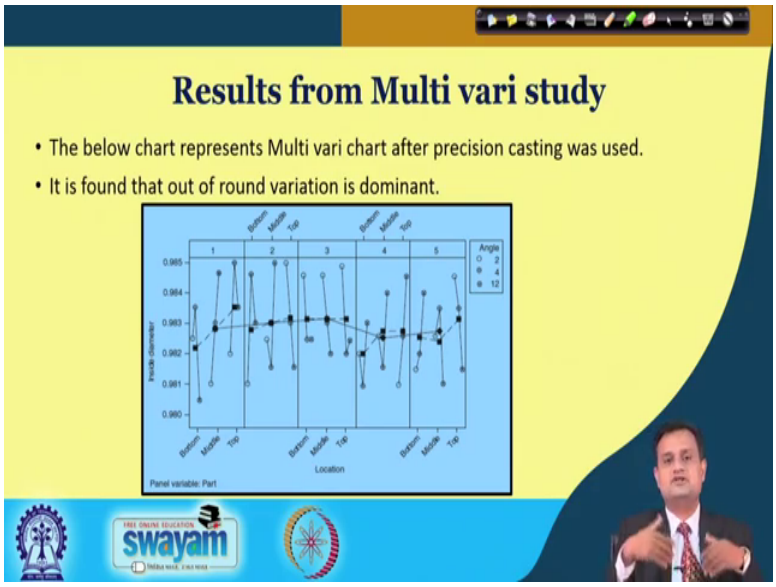

So, this is the result after multi-vari study, post say intervention. So, you established a new, for new particular process, investment casting and once again you took the reading.

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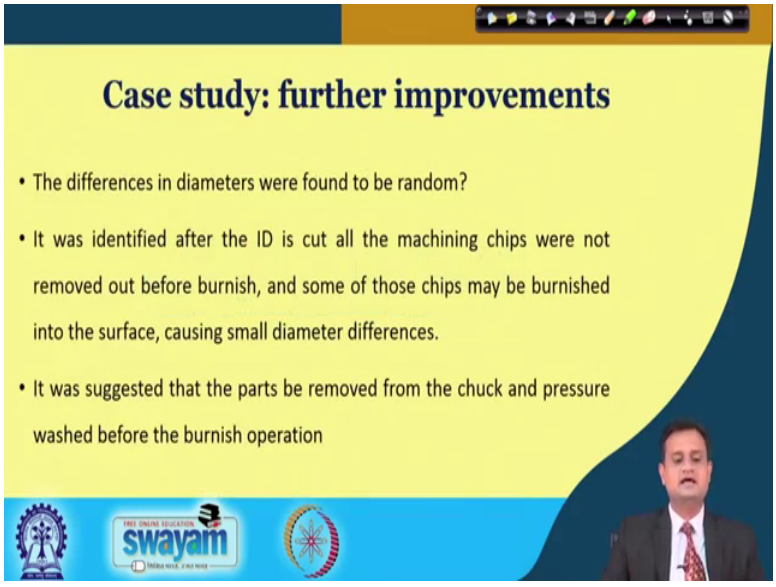

So, difference in diameter where found to be random. It was then unidentified the IDs cut all the machining chips were not removed out of before burnish and some of those chips

may be burnished into the surface causing small differences. And it was suggested that the parts we removed from the chuck and pressure washed before the burnishing operation. So, if you have little knowledge on manufacturing, you can appreciate this.

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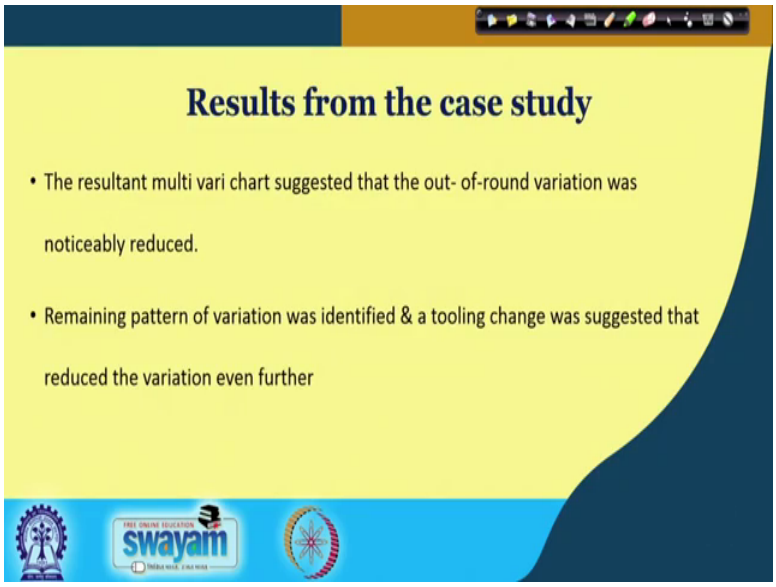

So, this where the results that out of round variation was noticeably reduced and whatever action you took, that has really help the company to reduce the say time. So now, these were the results from the case study.

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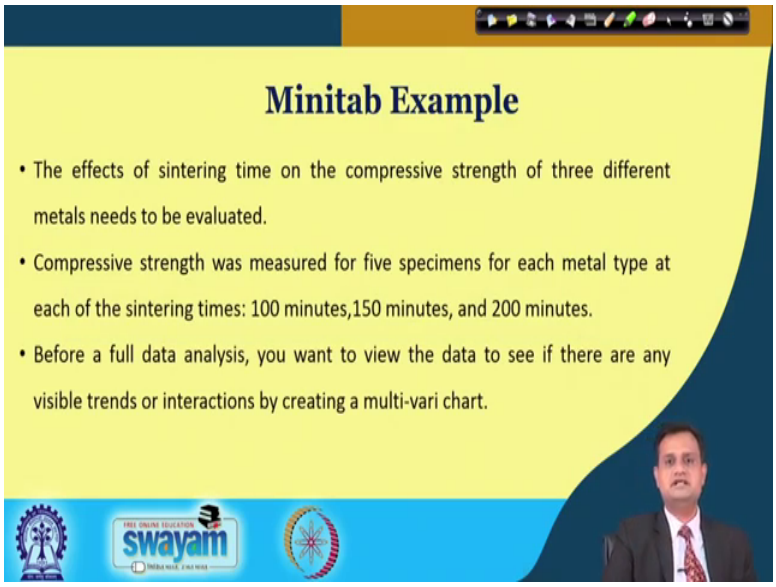

Now, quickly I would like to show the application of minitab, for conducting minitab conducting multi-vari charts. So, you have the example like this. The effect of sintering time on the compressive strength of three different metals need to be evaluated, compressive strength was measured for five specimens for each metal type at each of sintering time 100 minute, 150 minute and 200 minute and before, a full data analysis you want to conduct multi-vari chart.

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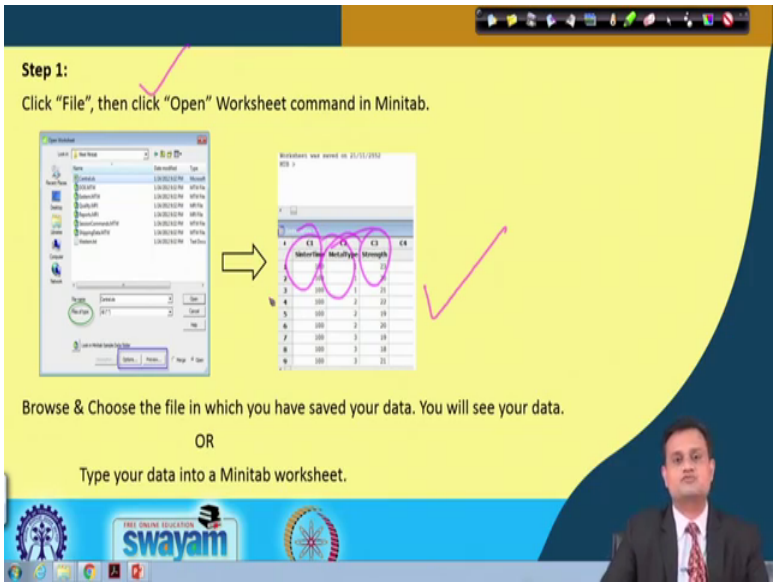

So, the procedure is very simple. Click on file. Click open, worksheet command in Minitab. So, you have sintering temperature, you have metal type and you have strength that is your response variable.

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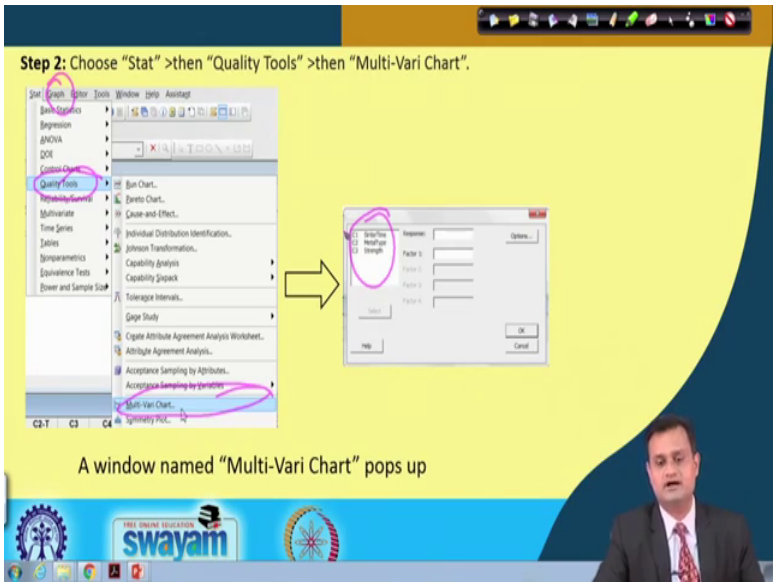

Now, once you do this, you go ahead and you go to your say graph because it is a graph graphical technique, quality tool, you go to multi-vari chart and then you will see this three variables from your worksheet.

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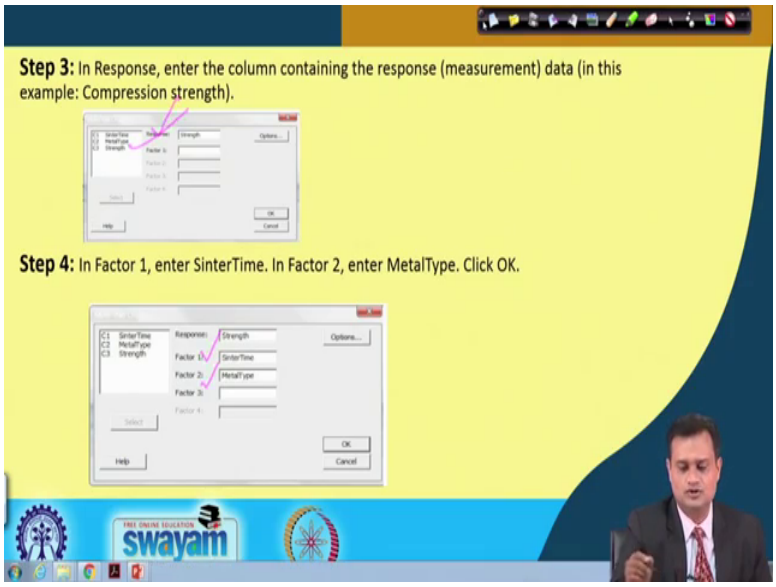

And then, you can go to step 3. So, step 3, you define or you pull the response variable that is the strength and then you define the factor 1, factor 2 and then press Ok.

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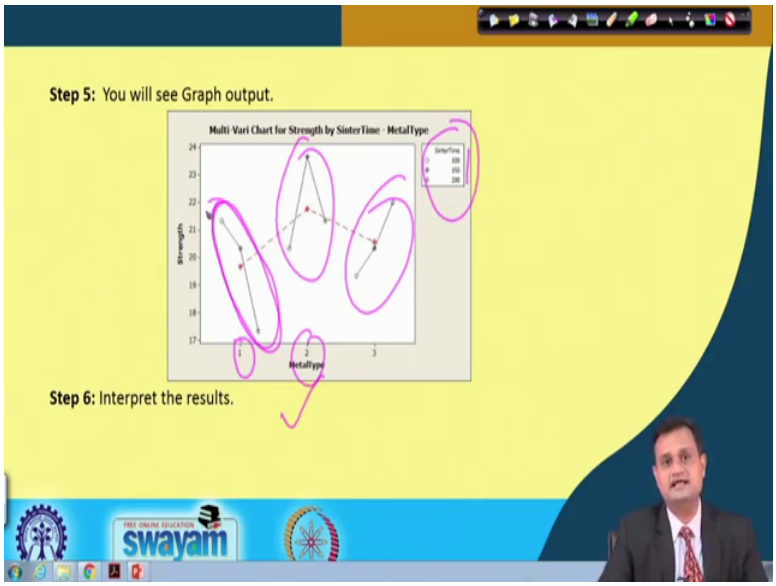

So, you will have another window and your multi-vari chart is available. So, what you can see here again, that this is your sintered time. So, this is for a particular metal type, three sintered time with respect to strength for a metal 2 3 sintered time and this. And you can easily make the inferences that for metal 2, one observation you can make that for metal 2, average strength is higher than the metal one and metal two.

And then, you can also think that is there an interaction between your sintering time and the metal or sintering time, really has an impact or not. So, when you see the sintering time 100, 150 and 200, you can see that yes, within subgroup variability is also very much. So, sintering time also has some impact. So, what we can do from this analysis, and what we cannot do; we can say have the complete picture of n number of factors with respect to positional cyclic and temporal and we can figure out that what are the factors that are really important, worthy for detailed analysis through ANOVA. What we cannot do? We cannot prove our null or alternate hypothesis by having some significance level and inferential analysis.

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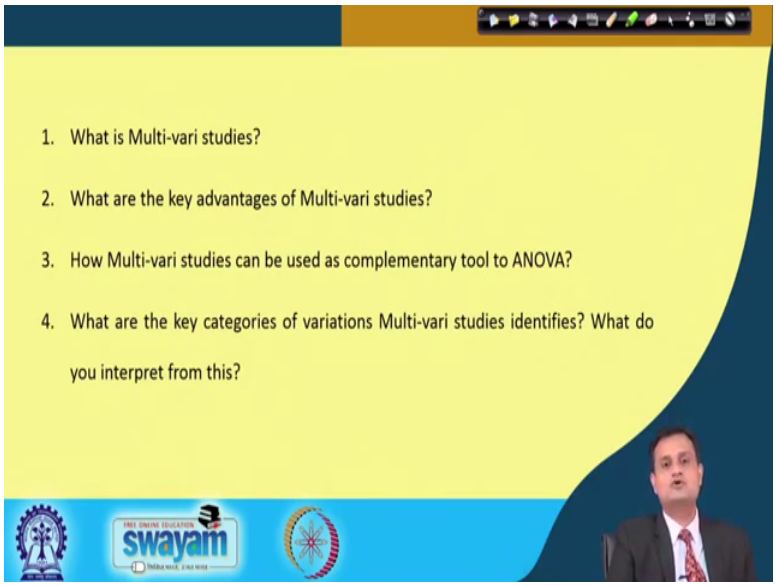

So, just think it for your introspection what is multi-vari studies, what are the key advantages, how it can be used as a complementary tool to ANOVA and what are the key categories of variations in this and what do you interpret from this.

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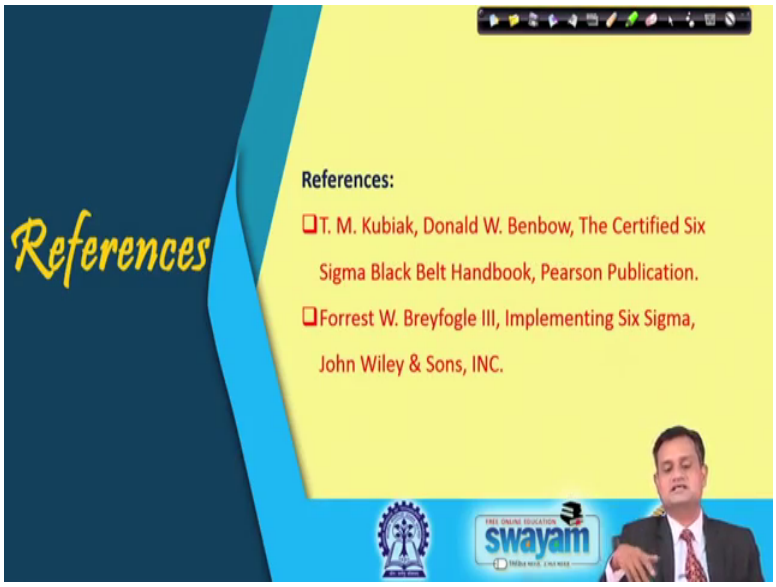

These are the books you can refer.

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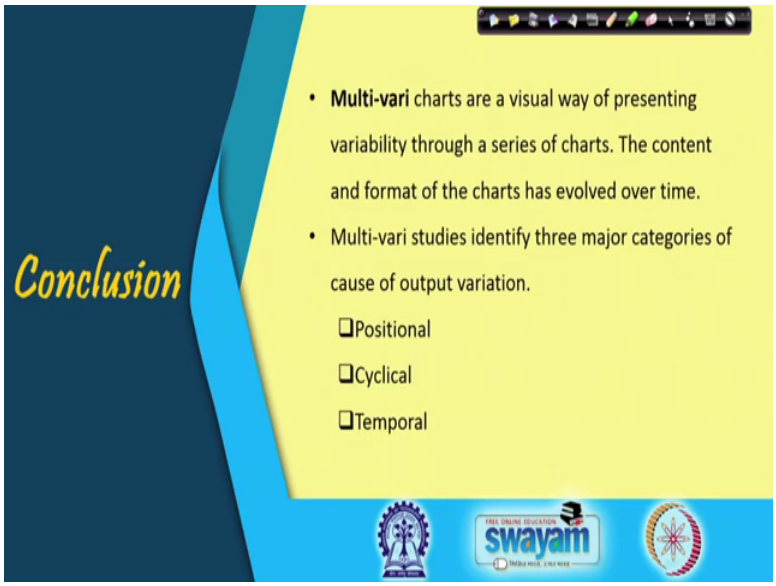

So, multi-vari chart is a visual way of representing the variability. It helps us to conduct ANOVA analysis more effectively, do our experimentation with less number of say important and key factors rather than focusing on all the factors and then proving that they are insignificant through statistical analysis. So, thank you very much for your interest in learning multi-vari studies. I hope this lecture would have provide you good insight into conducting multi-vari charts and how to use it as a complimentary tool to ANOVA. Keep revising, be with me, enjoy.