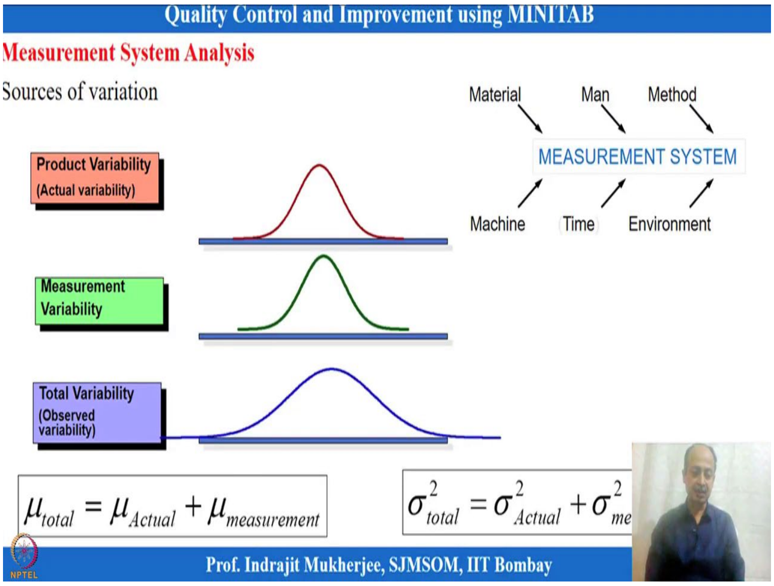
Quality Control and Improvement with MINITAB
Prof. Indrajit Mukherjee
Shailesh J. Mehta School of Management
Indian Institute of Technology, Bombay

Lecture - 32
Measurement System Analysis (Contd.)

Hello and welcome to our session 32 on Quality Control and Improvement with MINITAB. I am Professor Indrajit Mukherjee from Shailesh J. Mehta School of Management IIT Bombay. So, we were discussing in the last session about measurement system analysis and within that we have just stratified into two parts; one is for accuracy and one is for precision.

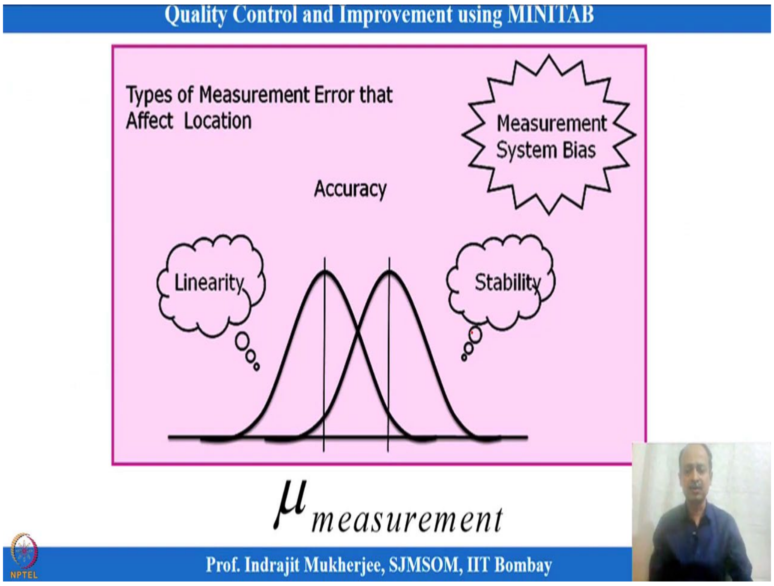
(Refer Slide Time: 00:44)



So, we are discussing about accuracy, and within accuracy what we have discussed bias definition, linearity and stability. Mean of the observations, if there is an instrumental bias, will deviate from the actual observations somewhat and overall observation mean will change.

So, in this case we do not want biasedness in the instrument. So, a measurement can be in different ways. One is known as basic bias that is what is the average observation and how far it is from the reference point. When I have only one reference information like that; one part, one instrument and one reference that I am measuring several times and we get the bias information.

(Refer Slide Time: 01:36)



But sometimes what we intend to do is that, throughout the observation, throughout the measurement range observation, how much is the bias at each and every location. Because the instrument may be measuring different parts based on the process variability, because the parts will be generated at different range.

So, we do not expect that every parts will be in a specific zone. Instrument should be flexible to measure throughout the tolerance zone of the parts. So, what is expected is that throughout the operating range the instrument should be able to measure accurately.

So, let us say in case of vernier caliper, bias at low high ranges should be minimum or near to zero. So, throughout the operating range of the instrument the bias should be minimal.

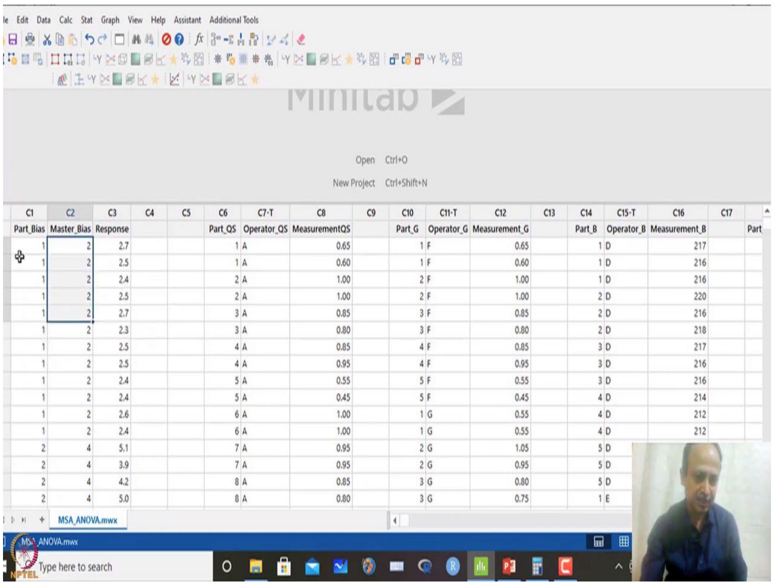
So, that is known as linearity. When we are talking about bias throughout the operating range of the instrument and that is what we consider as process variability, total process variability and that should be having bias should be negligible like that. So, then only the instrument is suitable like that.

And stability study what we have mentioned is that stability is with respect to time. So, the instrument is same and the sample is also same, but sample reading we are getting at different time points in morning and evening let us say, or at different time points throughout for a specific time period longitudinal study.

So, in that case what is expected is that every time it measure, the biasedness should be same. So, there should not be any shift in the measurements that we are observing. So, that is measured by stability using control chart techniques that we are not discussing. So, bias and linearity study, we have an options to see the bias in linearity

So, in that case what we have done is that we have taken a specific example and we are doing that and we will continue from there.

(Refer Slide Time: 03:40)



So, in this example that we have taken, one part measurement is given and master specimen also that is the masters value of the master samples that is collected over here throughout the operating range. So, it can be from metrology labs or tool rooms that we have a masterpiece that we are measuring with this with this instrument.

So, in this case, so how many parts are there in C1 column like that. So, we can just see this one. So, number of observations is part bias over here. So, there are five parts over here and five will have different specimen values like that. So, one so the parts that we have taken over here. So, in this case we have parts which has a specification of 2 over here.

So, that the first part is having a value of 2 basically, the master value is 2 around. And this is the operator who has measured that one. So, actual value is 2 or reference value is 2, and this is the observed value like that. Observer value keeps on changing, because now even if I do not tell the operator what is the measurement of the parts that I have given him.

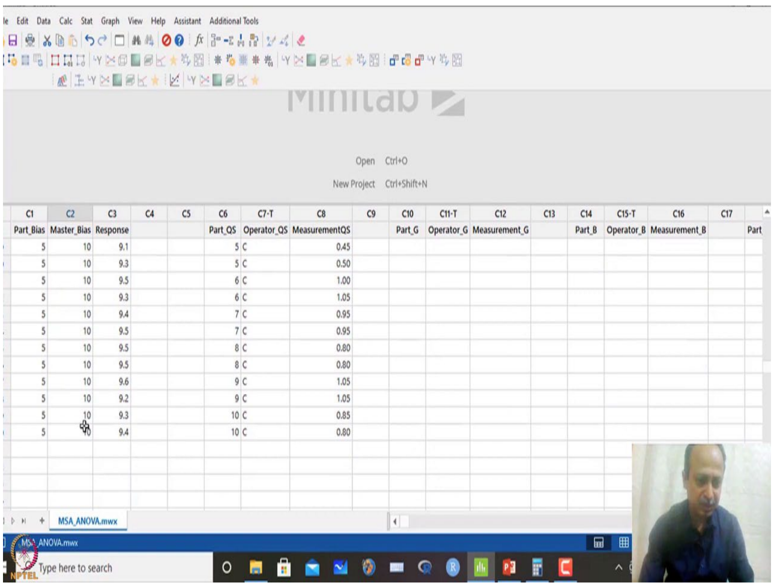
So, in that case he will measure the parts and he will tell me what is the true values of that, what he can measure using the instruments. So, we have to select the operator also very skilled operator over here we. We cannot take the measurements let us say you are an engineer and you are trying to measure that one, that is not feasible.

It has to be done by skilled operator who knows the instrument, who can handle the instrument. Those people will do the measurement system analysi. We will only record and we will only analyze and try to figure out whether the instrument needs calibration, needs to go to metrology lab for further rectification like that or not, that only we can just say about the instrument.

So, and they will take care of the instrument what is going wrong. We have to identify what is going wrong in the instrument then they will take care of that and they will send us either the old one after repairing or what you have to do is that they will change the instrument altogether.

They will say that this is not possible to rectify in that case you can use a new instrument like that. So, and due to wear and tear some at a given time point we have to change the instrument also in production floor ok. So, that is natural.

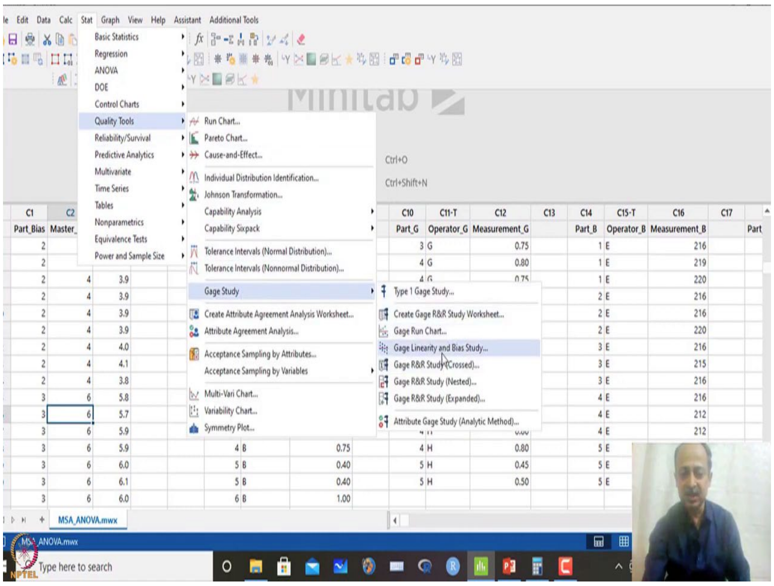
(Refer Slide Time: 06:04)



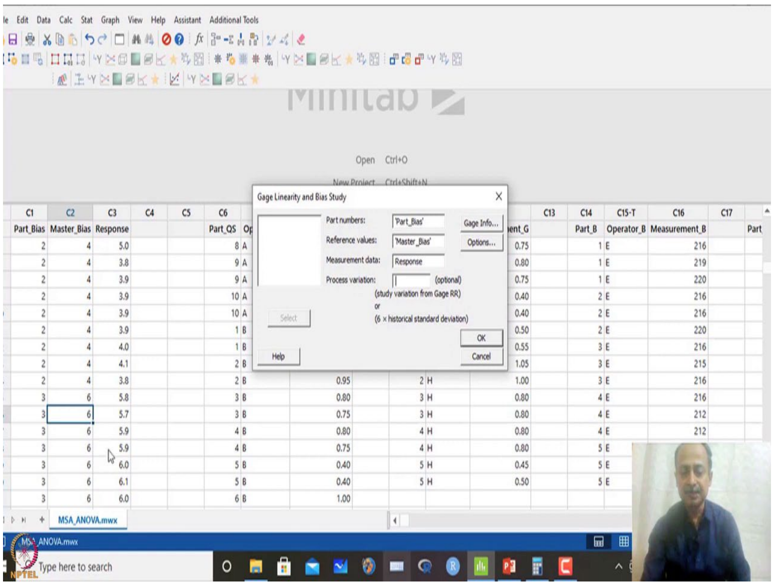
So, in this case we have five different parts. Measurements varies from 2 to 10. So, simultaneously I want to see what is the bias at each of the operating zone that is what is the bias as reference value of 2, reference value of 4, reference value of 6 like this.

And we want to see that overall biasedness, whether it is overall bias in the instrument, whether it is throughout the operating range, whether it is ok or not.

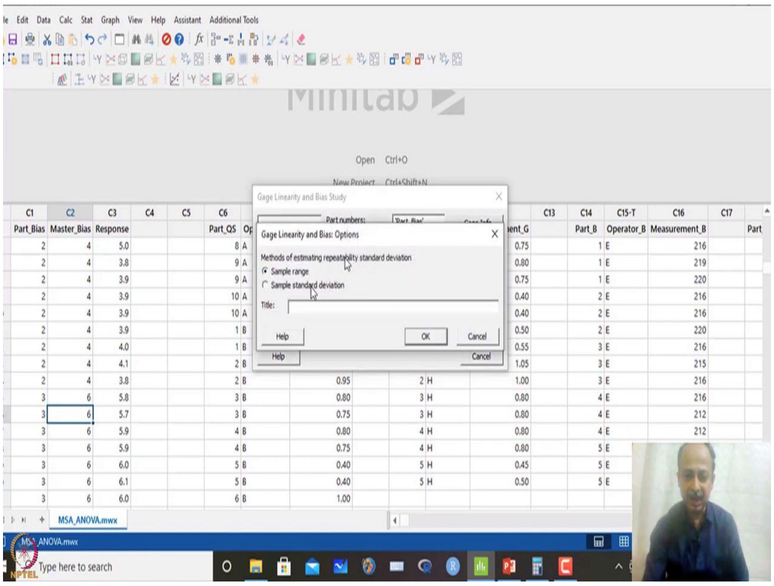
(Refer Slide Time: 06:28)



(Refer Slide Time: 06:34)



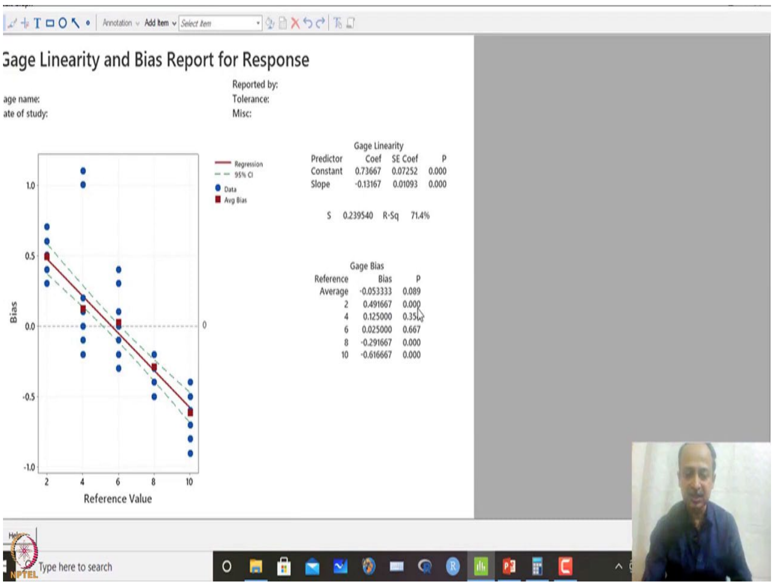
(Refer Slide Time: 06:46)



So, for that what we have done is that statistics, we have gone to quality tools and in that case, Gage studies and linearity and bias over here. So, then we have given the part bias over here, master over here and response over here and here there is option of process variability. So, that I am not giving at present.

Now I select method of estimating standard deviation over here. This will be used for a t statistic that will be used for p value calculation.

(Refer Slide Time: 07:01)



What you observe over here is these are the part observation at reference value of 2, these are the five observations that we have taken and the red points that you are seeing over here is the average value over here. So, bias, average bias is given over here.

So, out of these four measurements, what is the average observation and what is the reference value? That will give you the bias over here. So, bias is in Y axis and reference value is in X axis. We can regress bias with reference value over here and that regression equation is fitted over here with the constant value of the intercept that is given over here, slope is given over here as -0.13167.

And slope is coming out to be significant, that that test statistics is used over here, hypothesis testing is done for the regression and in this case, what is observed is the slope is significant. So, we do not want slope to be significant in a linearity studies like that. If that is so, that means there is something going wrong at different operating range, bias are drastically changing.

So, this slope should be insignificant then only the instrument is ok in linearity aspects like that. So, but the R^2 fit that you are seeing over here is about 0.71.

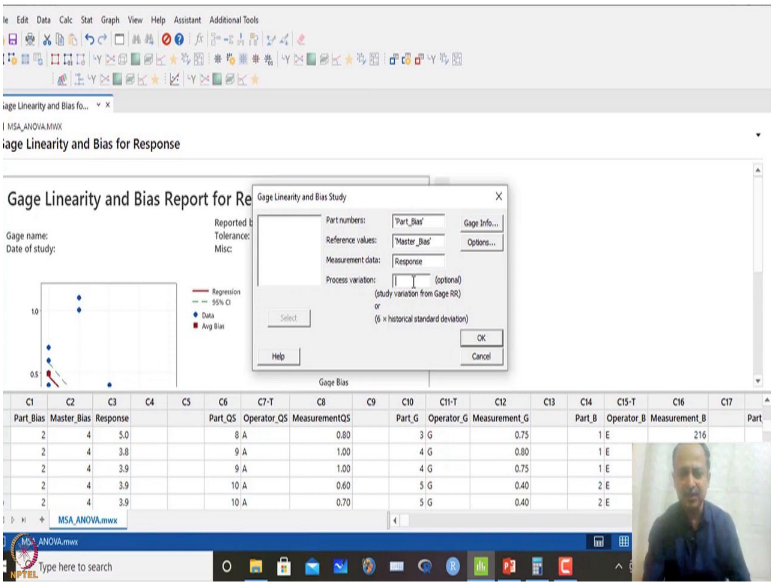
What is the reference value and correspondingly what is the bias, whether at two reference value it is significant or not? It is significant at 2, 4, 8 and 10. But at 6 it is not significant.

So at lower and higher ranges, it is significantly biased but in middle range, bias is not significant.

Although overall the slope is significant over here. At the lower range what we are seeing a positive bias and at higher range we are getting is that negative bias.

So, this is the basic interpretation. Whenever bias is changing in the operating range, we need to correct that one and slope should not be significant that is the overall interpretation that we can make out of this. Now, sometimes you can also calculate linearity index also over here.

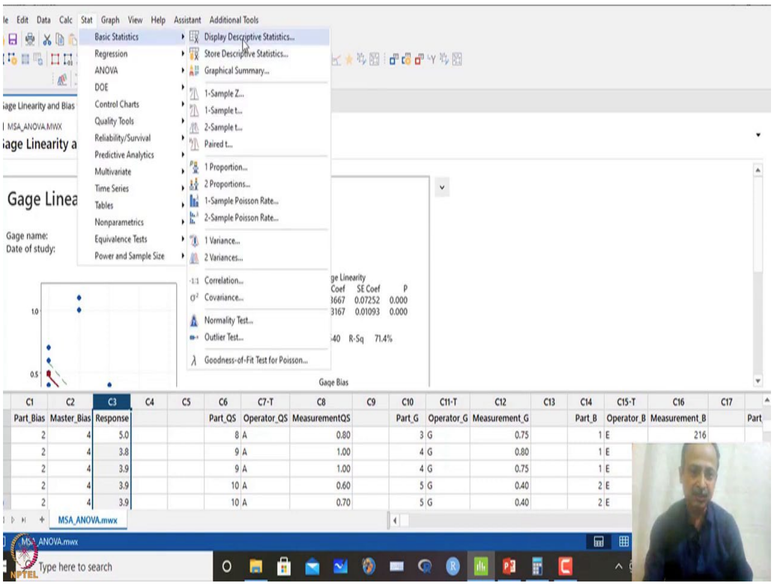
(Refer Slide Time: 09:36)



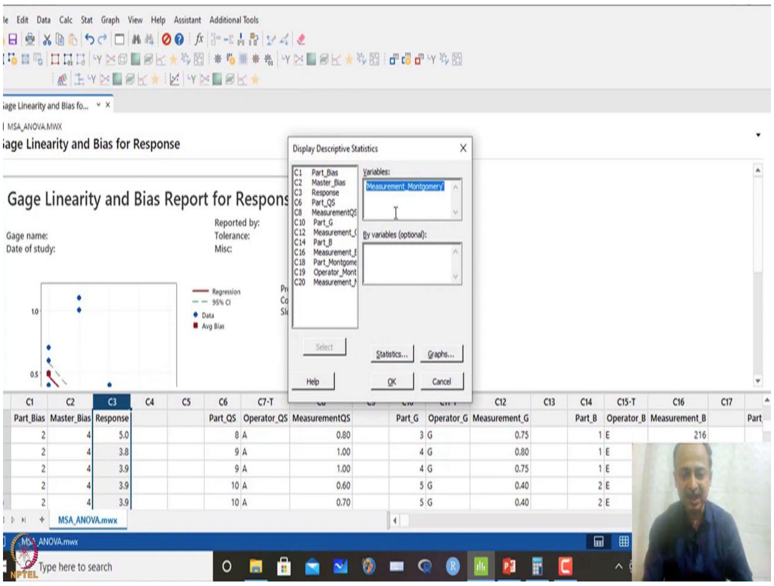
So, what you have to do is that quality tools over here, you go to gage studies over here and you go to linearity over here. Only thing is that process variability you have to mention over here based on which this linearity values will be calculated and based on that whether to accept the instrument or not to accept the instrument that you have to decide.

This is mentioned as 6 multiplied by historic standard deviation of the process like that. So, what we can do is that this is response taken from the process only; that means, the range of values is taken from the process. We can say that this is the part variation.

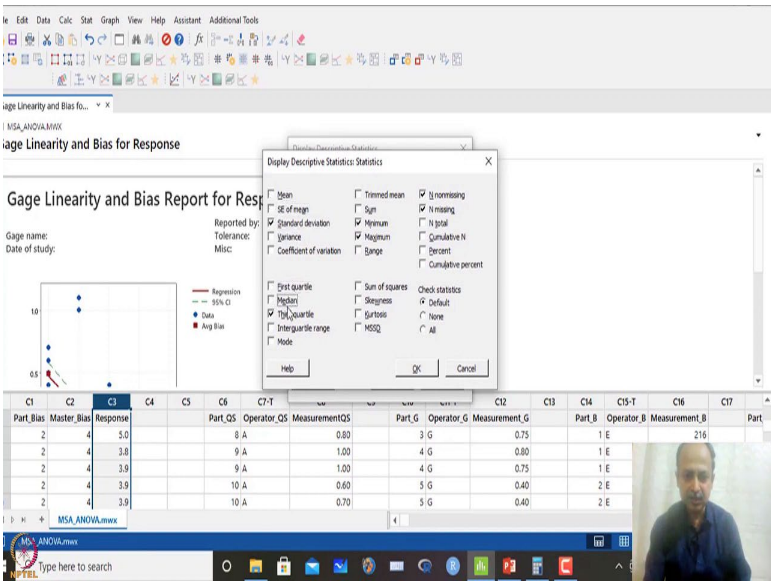
(Refer Slide Time: 10:01)



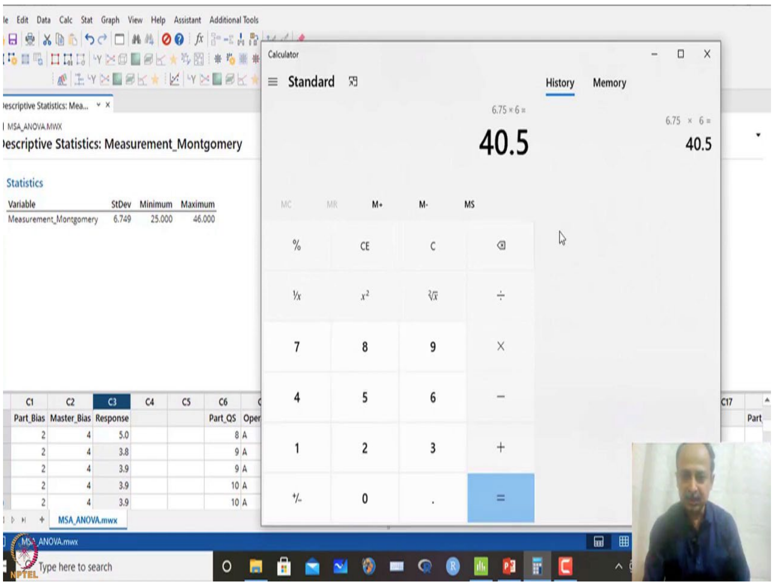
(Refer Slide Time: 10:04)



(Refer Slide Time: 10:08)

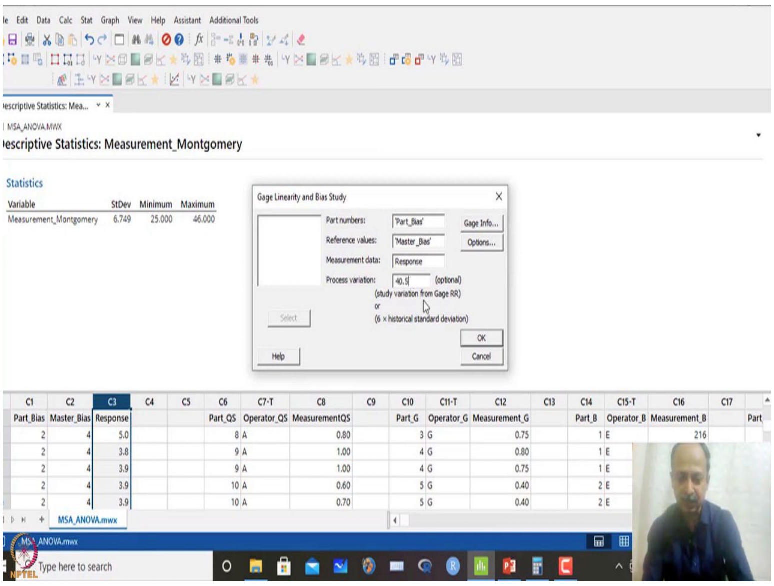


(Refer Slide Time: 10:19)

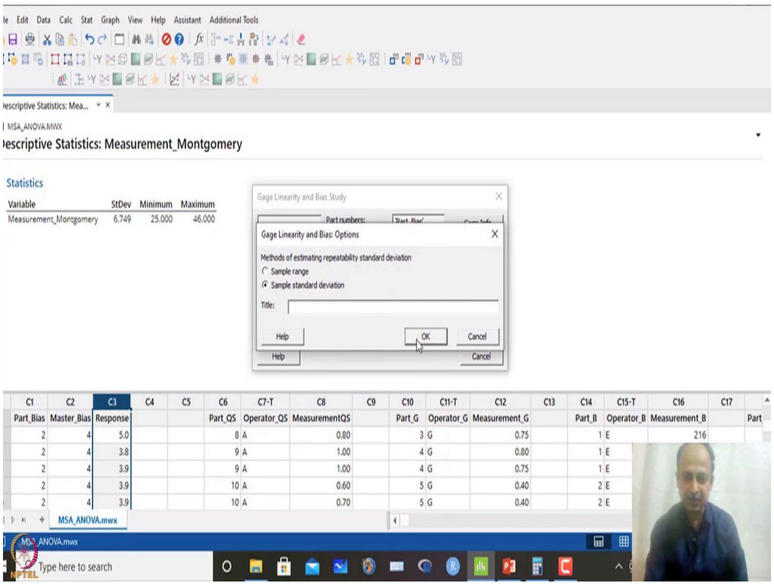


So, what we can do is that we can just see what is the variability over here, standard deviation of this. It is around 6.75 over here. So, in this case I can use the calculator. So, 6.75 over here, if you multiply it with 6 you will get 40.5. So, what we will do is that here, we will go to *quality tools* and then *Gage studies* and *linearity and bias*.

(Refer Slide Time: 10:48)

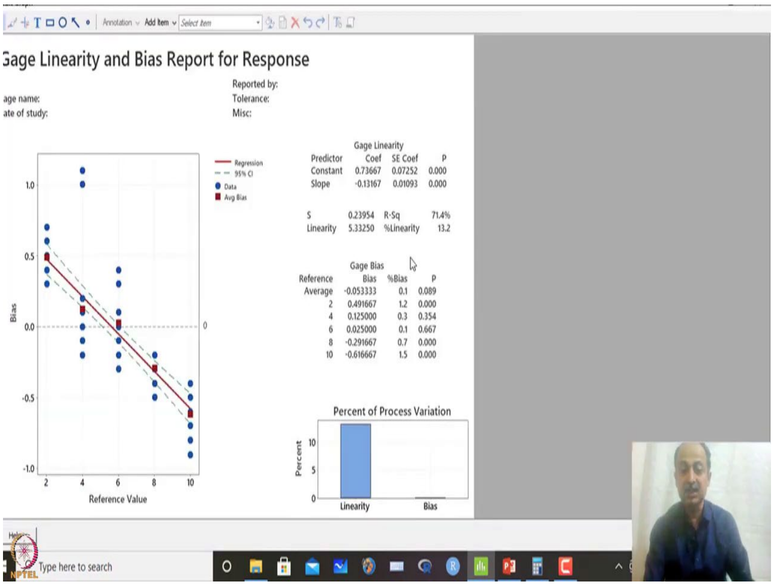


(Refer Slide Time: 10:55)



So, in this process variability we will write 40.5 and I will click ok over here.

(Refer Slide Time: 11:00)



So, when you do this, you will get a percentage linearity over here. So, based on this slope over here, slope value multiplied by process variability that will give me a linearity percentage, linearity values over here that is mentioned at 5.33 over here and we can convert the percentage linearity again multiplied by process variability.

So, one is slope divided by process variability and another is multiplication. So, overall, it will be around 13.2. So, the standard that is followed in industry is that mostly it should be less than 30 percent. Somebody can say 10 percent we will allow, linearity 10 percent more than that we will not allow. But overall what we see is that even if you do not go by this, we see whether the slope is significant or not like that.

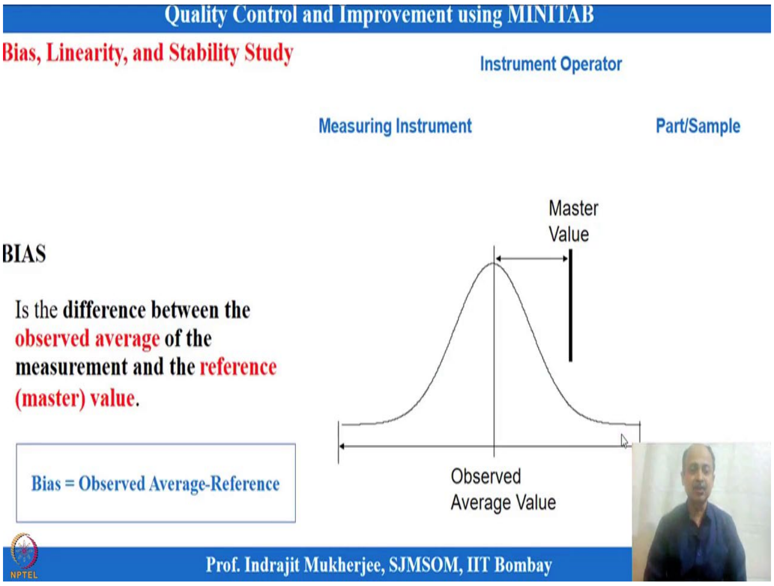
Sometimes statistical significance does not imply it is very high highly significant means practically it may not be so much , but that is why we are using process variability measures over here and we are finding out the percentage. How much is the linearity or this shift deviation with respect to the process deviation like that.

So, these measures can be taken based on the industry standards what you are following in your industry. So, that way we can express linearity over here. But when we are doing this study what we are getting is that one linearity percentage, MINITAB also reports. So and there can be criteria for different industries. So, somebody can take 10 percent, somebody can say anything less than 30 is ok, but there needs to be some corrections over here.

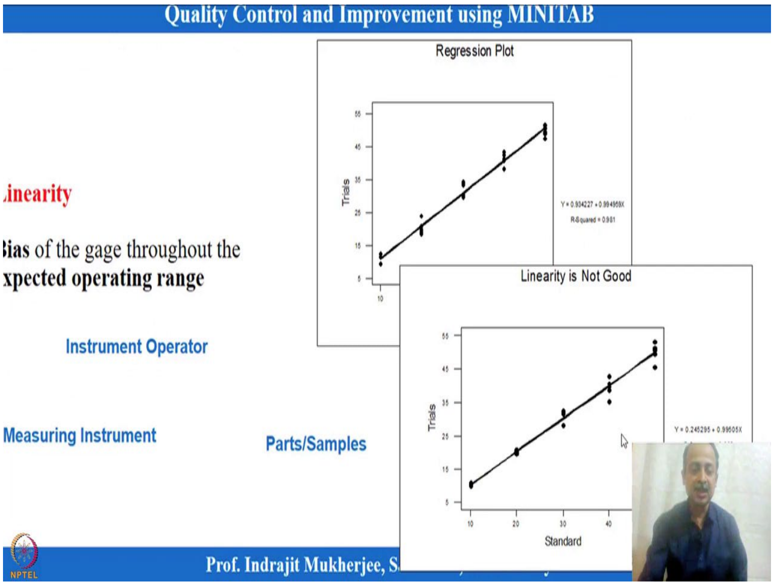
So, percentage linearity is a concern whenever it is more than 30 percent. That means it is highly significant so in that case we have to take some measure, because bias is changing drastically over here in the operating range, but that information where it is changing, we will get this information over here ok.

So, this is one aspects of when we are talking about mean. But there can be also impact on variability. That study what we do is known as repeatability and reproducibility, Gage R&R study.

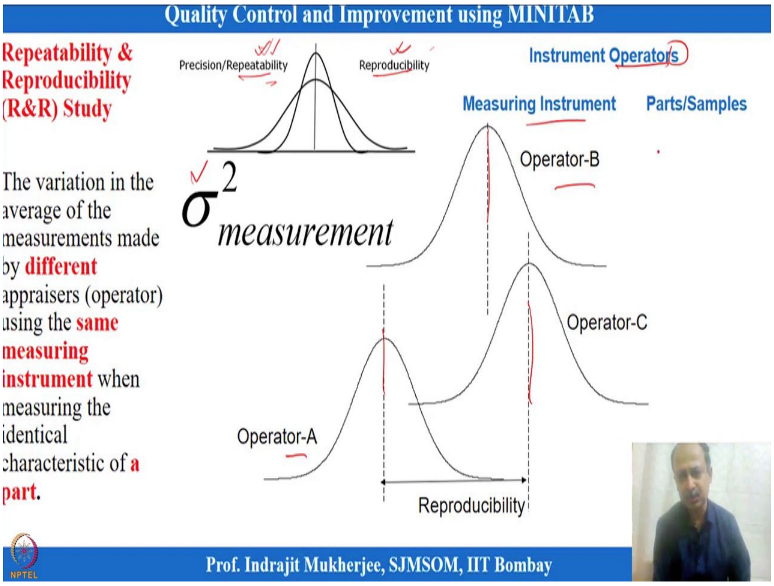
(Refer Slide Time: 13:22)



(Refer Slide Time: 13:24)



(Refer Slide Time: 13:24)



Here, we are more concerned about this σ measurement over here. So, we are concerned about this sigma over here and variation due to the measurement system over here can be contributed by two aspects over here; one is known as repeatability of the instrument and one is known as reproducibility of the instrument over here. What is repeatability? If you are measuring same parts, there will be some variation in the measurements.

So, same operator is measuring repeated times like that and the instrument will have some variations like that that will contribute to the repeatability aspects of that, that is known as error aspects of that in the instrument. So, that is repeatability. So, this is basically common variability.

Everywhere these types of variation will happen. Because even with same instrument, if I am measuring second time, sometimes readings may somewhat deviates in that and that variability that amounts to, that amount of variability is represented by this measure which is known as repeatability over here.

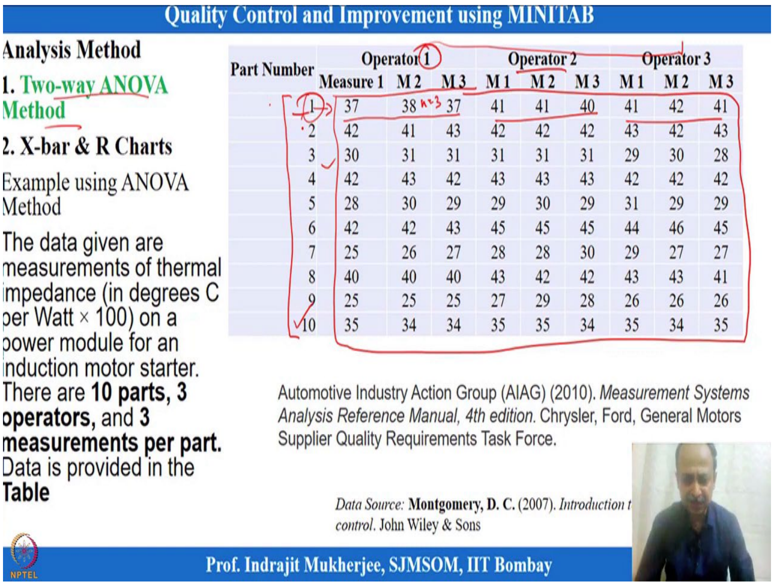
And what is reproducibility? In shop flow what happens is that there are different operators. So, there are different operators over here. So, and in every shift, there can be a different operator. So, what is expected is that all the operators should measure the same parts with same accuracy. However, operator to operator variation can happen.

So, operator A measure somewhere over here, operator B is measuring somewhere over here, operator C is measuring somewhere over here. So, overall mean of location over here for operator a is different from the second one and third one like that. So, this variation that is happening due to operator is known as reproducibility.

So, a specific kind of study is recommended over here which is known as Gage R&R study which is repeatability and reproducibility measure and that we have to. So, in this case what happens is that, I have a measuring instrument and there will be different parts like in linearity study. We will select the parts throughout the operating range like that and then there will be different operators.

So, here we are having a change rather than linearity where single operator was used here, there are multiple operators over here. So, in this case these are three operators that is selected over here and based on that we will do the study and this study will be done using two types of methods over here. I will discuss only one method which is known as two-way Analysis of Variance method which we have already studied.

(Refer Slide Time: 15:48)



Part Number	Operator 1			Operator 2			Operator 3		
	Measure 1	M 2	M 3	M 1	M 2	M 3	M 1	M 2	M 3
1	37	38	37	41	41	40	41	42	41
2	42	41	43	42	42	42	43	42	43
3	30	31	31	31	31	31	29	30	28
4	42	43	42	43	43	43	42	42	42
5	28	30	29	29	30	29	31	29	29
6	42	42	43	45	45	45	44	46	45
7	25	26	27	28	28	30	29	27	27
8	40	40	40	43	42	42	43	43	41
9	25	25	25	27	29	28	26	26	26
10	35	34	34	35	35	34	35	34	35

So, this is two-way analysis of variance method that we will explain over here and the way study is conducted over here that we will explain, how to analyze the data that we will explain and what is to be seen that will be elaborated in this session.

So, here what you have to do is that they have selected different parts like that in the operating range. So, this is the ten parts that is selected over here and these are the observations for a specific part, from a specific operators like that. So, this is basically repeatability of the observations that we are happening.

So, same sample is measured by the same operator several times over here. This is 3 times that is measured n=3 over here. We can think about repeated measurements what we are taking over here. So, similarly operator 2 will measure the same parts like that and the third operator will also measure the same part like that.

Now, this total experiment that you are seeing over here is randomized over here and the operator does not know which part he is measuring. So, part number will be randomly generated over here and it will be given to some operator and measurements will be taken like that. So, this is randomization is ensured so that no biasedness no there is no bias as far as operator is concerned like that.

So, operator does not know next part what is the measurement of that, which part it is coming like that. In total there are 90 observations. So, it is like design of experiment. So, what is the factor over here? So, one is the parts that is the one aspects; 1 to 10 number of parts over here and there are three different operators, operator 1, operator 2, so level 3. So, this is at level 3 and there are 10 parts over here. It will be a two-way analysis of variance that we have already studied. So, we will fit this data into MINITAB and the results we will just try to see over here. So, these parts that we have selected are within the process variability. So, this is we can think of that overall process variation is covered over here.

Generally when parts are selected that will be from the process and it covers more or less the outcome of the process or CTQ outcomes. So, we want to ensure that that part variation will be there, because intentionally we have selected different parts which is having different measurements like that. We cannot select parts which are very similar in observations.

So, 1 to 10 parts are at different range like that and there is some difference between the observations. So, they are basically unique observations that we are having over here. So, this covers the overall variation tolerance zone of the CTQ basically what we are covering over here.

This data set is taken from Montgomery's book 'Introduction statistical quality control is another very good books that you can and the way that we are doing over here is basically following a guideline that is measurement system analysis reference manual which is developed by Chrysler Ford, General Motors, Supplier Quality Requirements Task Force over here.

So, this is AIAG standard, AIAG standards that we are following and there are manuals you can you can see manuals of AIAG for measurement system analysis and we are going by the manual and we will somewhat deviate. If required otherwise more or less what manual says we are going by that and MINITAB also does what is given in the manual basically.

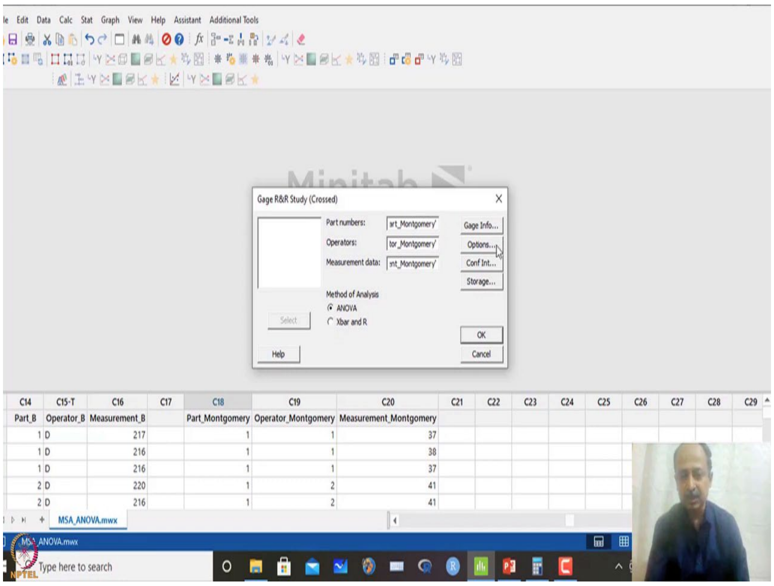
So, and also you can see QS 9000 that is earlier when people use quality systems in automobile industries. There is a certification like ISO 9000 certification, there is a QS certification which is changed recently. So, anyway there you can get the standards of measurement system analysis. So, two-way analysis you already understand. We are doing this experiment. Experiment setup I have told, parts are different, operators are different, and we are taking repeated observations.

So, why we are doing repeated observations? Because we will go by the average value, we will be more accurate. So, we have taken n=3 over here. If we have increased this one, more accuracy we can assure out of the study. So, this is basically design of experiments what we are doing and this is two factor experimentation that we are doing over here.

So, these measurements are there in my MINITAB file. So, this Part Montgomery, Operator Montgomery, and Measurement Montgomery, because this is a Montgomery's example so I have taken from there. So, what I am doing is that these are the three observations, 90 observations is given over here. So, all these 90 observations we are just going to analyze using Gage R&R study like that.

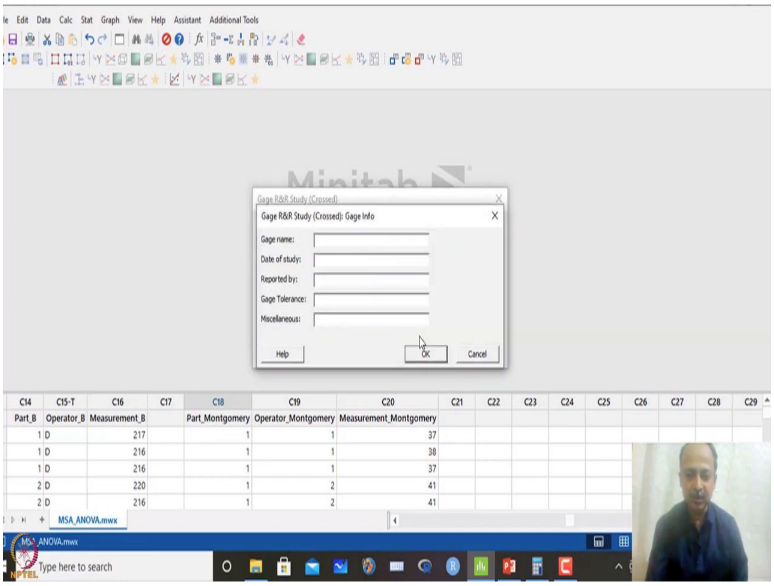
Whenever you have fed the data what happens is that then you have to go to quality tools and then you have to go to Gage studies and then you have to take Gage R&R study crossed. You have to select crossed one.

(Refer Slide Time: 20:57)

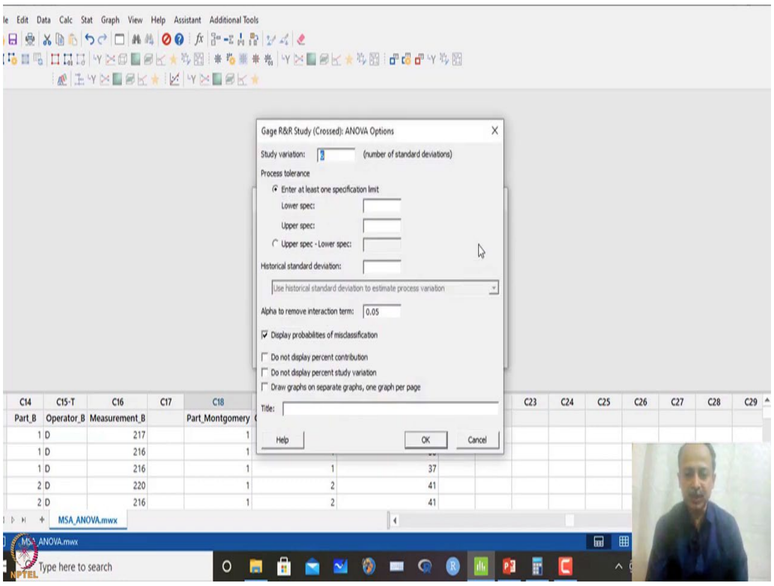


So, in this case what will happen is that it will where is the parts measurement, where is the operator measurements. So, you have to mention which column is what.

(Refer Slide Time: 21:31)



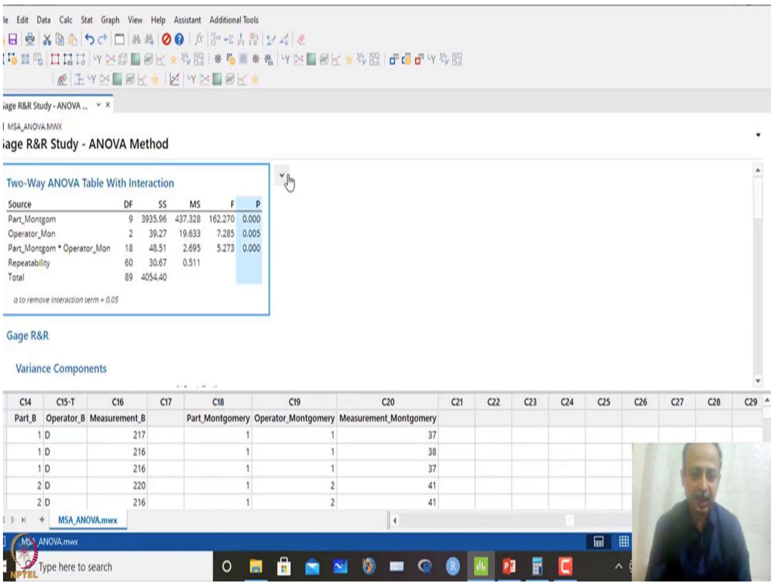
(Refer Slide Time: 21:34)



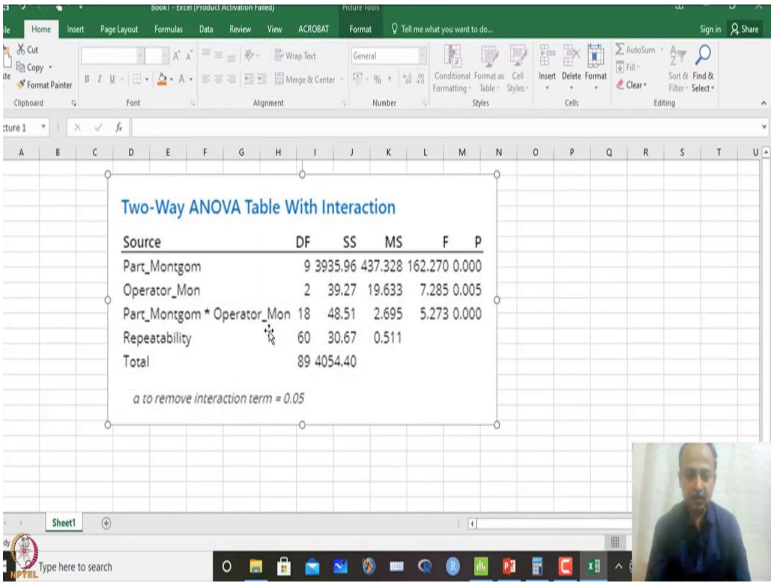
So, in this Gage information you will provide all details over here and in options what you have to do is that that standard deviation study variation is taken as 6 over here. So, and then what you can do is that you can later on we will come back to this historic standard deviation. So that needs to be calculated and put over here so that we can also calculate study variability like that.

So, we will not do it as at this time point. So, in this case what we will do is that we will click OK over here.

(Refer Slide Time: 21:58)



(Refer Slide Time: 22:32)



What you see is that part is one of the factor and in this case that is significant. We are not bothered about this one. We are bothered about the second part which is operator to operator variation that whether this factor is significant or not. That means, when operator A is measuring differently as compared to operator B and C like that.

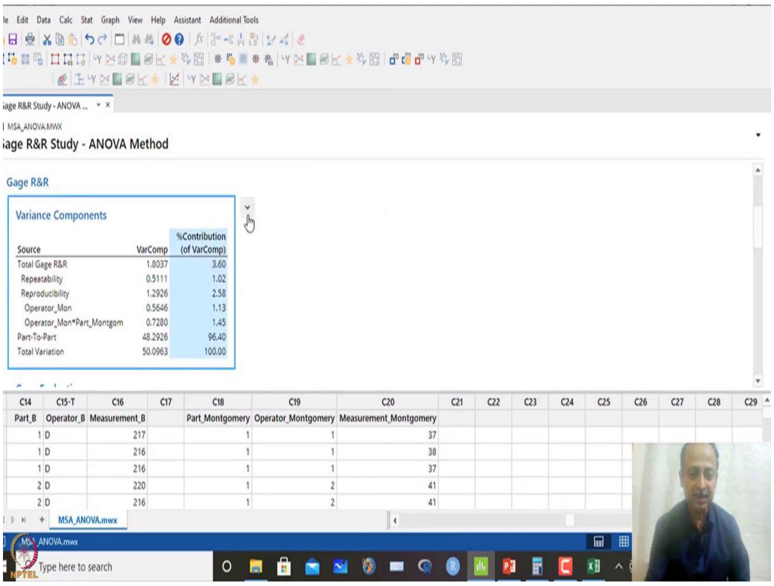
Now, what do you observe over here in the ANOVA analysis or what it signifies is that operator is basically significantly different, because the p value is less than 0.05 over here. So, operator to operator measurements are differing over here. Then is there any interaction between part and operator over here?

That is also significant over here; that means, operator A measures part a differently, but that same operator measures part two differently; that means, the method there is there is some interaction over here. So, depending on the part measurements also comes depending on the part.

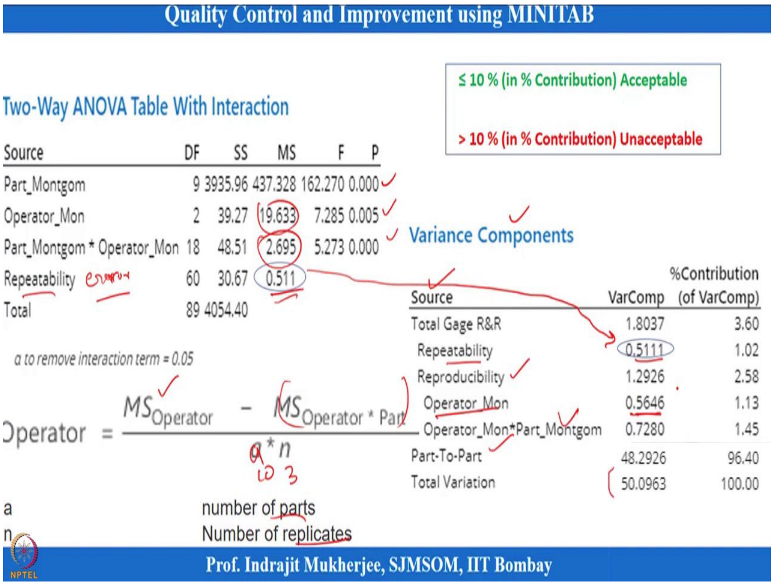
So, operator measures part based on that there is a dependency between parts and operators. So, there is an interaction between part and operator that is also not required. Whenever it is less than 0.05 we are concerned about that, but if it is more than 0.05 that is a favorable situation.

Similarly, operator p value is more than 0.05 is a favorable situation. So, we want part variation to be significant, but these two-operator variation and interaction effect to be not significant like that. So, that is expected, but that is not so over here.

(Refer Slide Time: 24:04)



(Refer Slide Time: 24:12)



So, let us see the next part of that. Next what we have is this variance component and percentage contribution over here. This calculation we have to explain by using a diagram over. This is the observation that you see the first part over here. So, this is the first part that you see p value of parts is significant and that that is expected, but these two are significant; that means, we are concerned about this, but this is statistical significance over here.

So, and this values what you see repeatability or error we can think of error over here that measure is basically repeatability; that means, that is the measure of repeatability and mean square of this is considered as repeatability over here. So, when I say source of variation that MINITAB provides in the variance component that you will see the next result what it shows. So, in this case repeatability is nothing, but this mean square is represented over here.

So, this is same as this one. What you see over here is same as this one over here repeatability. Similarly, we can calculate that what is the operator contribution of this source of variation over here. So, in this case the formula is given as

$$\frac{MS_{operator} - MS_{operator*part}}{a*n}$$

So, if you do that one what you will get is that, you will get operator variation over here which is the variance component over here. Similarly, there are formulas to calculate reproducibility and interaction part of this and part two-part variations. Also you can calculate and overall total variation is given as 50.0963.

So, and this total Gage and R&R values that you are getting 1.8037 is nothing, but summation of these two repeatability and reproducibility that comes as a total Gage R&R variance component over here which is 1.8 like this. In this study most of the variation is contributed due to change in parts. So, this is expected over here and then percentage of that we can also calculate. So, if I convert this 48 out of 50 this is around 96. Similarly, we can calculate the percentage contribution over here and the overall contribution will be 100 percent over here. So, the overall is 50. So, with respect to 50 what is coming we have we are just mentioning over here.

So, whenever we have mentioned this, this percentage contribution is an important measure to accept or reject the instrument like that. So, generally what is taken is that less than 9 to 10 percent we can think of. So, standard says 9 to 10 percent. So, I have just written 10 percent over here. It depends from industry to industry it will differ like that.

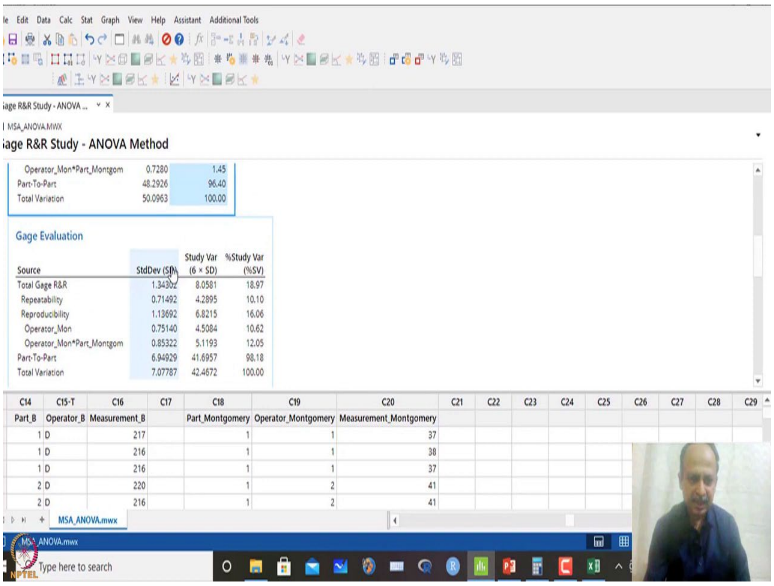
So, generally it is taken as percentage contribution. Whenever it is less than 10 percent we will go by that measures as a acceptability of the instrument as when the variance component is concerned over here. So, in Gage R&R study this variance component should be less than 10 percent that we are recommending over here.

If it is less than 10 percent then we are we are ok with the instrument like that, but what is our concern over here. Although it is less than 10 percent there is some interaction between the parts and operators and operator to operator differentiation is happening over here. We need to see what is going wrong over here. So, if we can minimize that that variability will also reduce. Although, the significant we are not getting high values over here, because this is 3.6.

So, you have to be judgmental over here. You cannot be statistically significant so we will reject that one. Now we have another criteria of acceptance. There are various criteria's in measurement system analysis which needs to be considered before we take a decision whether to use the instrument or not to use the instrument like that ok.

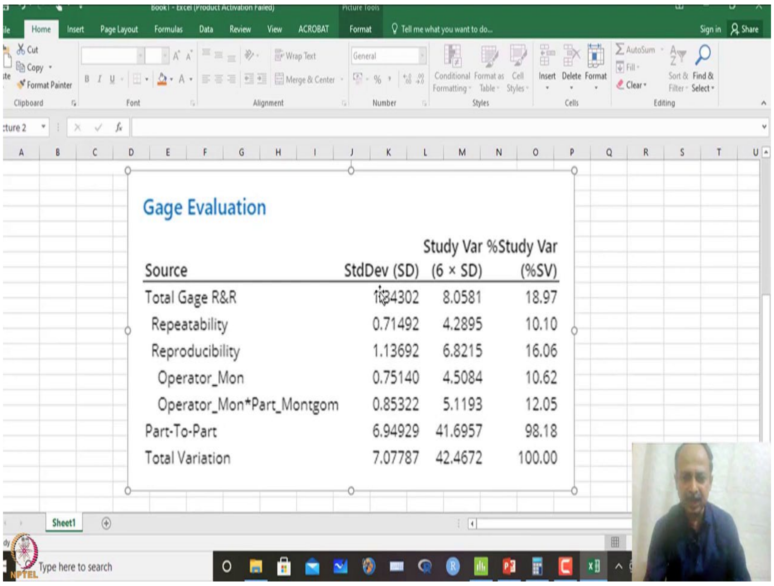
This is one of them is a percentage contribution like this. We can also find out we can also find out the with respect to process variation there is another measure which is which percentage variability.

(Refer Slide Time: 28:07)



So, we can also go to that PPT's over here. So, this is calculated over here. There is another important component over here that you see standard deviation, study variations over here. See, if I copy this, we will copy as picture over here and we can paste it over here. So, we can we can paste this information over here and we can just enlarge this image over here.

(Refer Slide Time: 28:22)

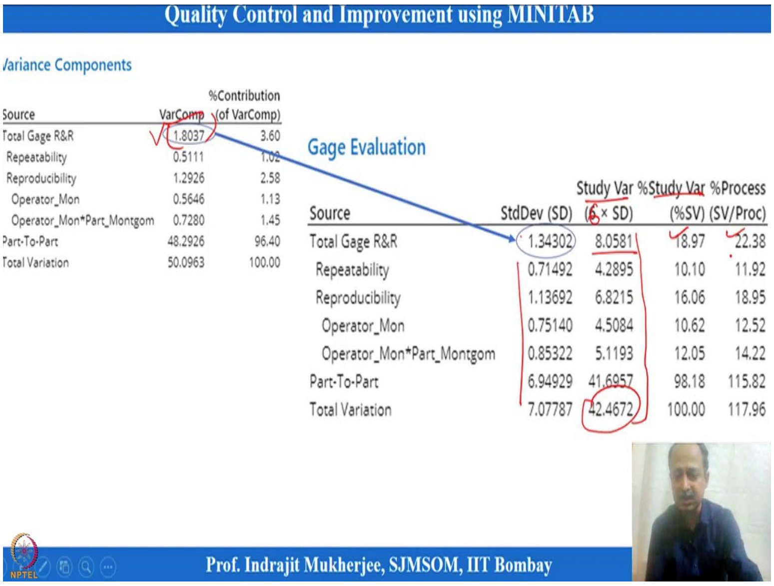


Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	1.34302	8.0581	18.97
Repeatability	0.71492	4.2895	10.10
Reproducibility	1.13692	6.8215	16.06
Operator_Mon	0.75140	4.5084	10.62
Operator_Mon*Part_Montgom	0.85322	5.1193	12.05
Part-To-Part	6.94929	41.6957	98.18
Total Variation	7.07787	42.4672	100.00

So, what you observe is that this standard division 1.34 is nothing, but what you are seeing. So, this is the variance repeatability that you that that you are observing. So, it is σ^2. If you take a square root of this you will get.

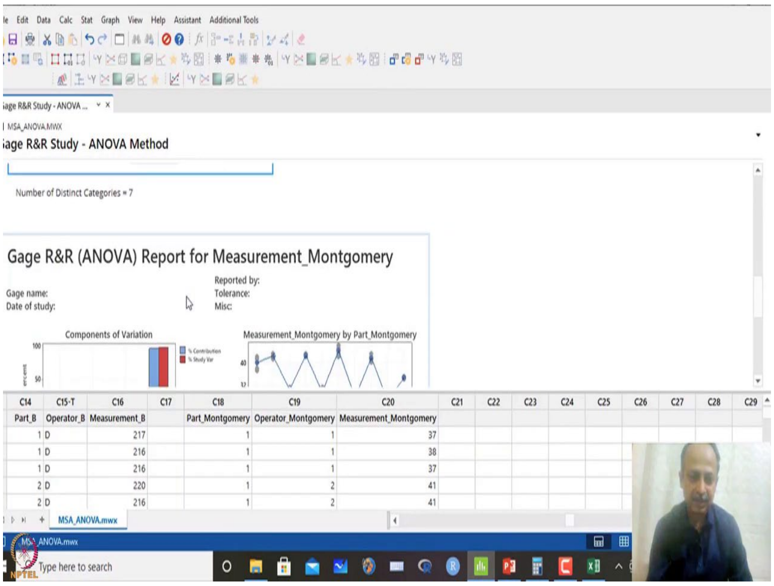
(Refer Slide Time: 28:38)



The variance component is and if I take square root of this it will be 1.34. Similarly, all these values are calculated. So, this is basically represented. Similarly, if you want to see the study variability you multiply it with 6 and it gives you all this measure over here. And based on this we can calculate also study variation percentage study variation.

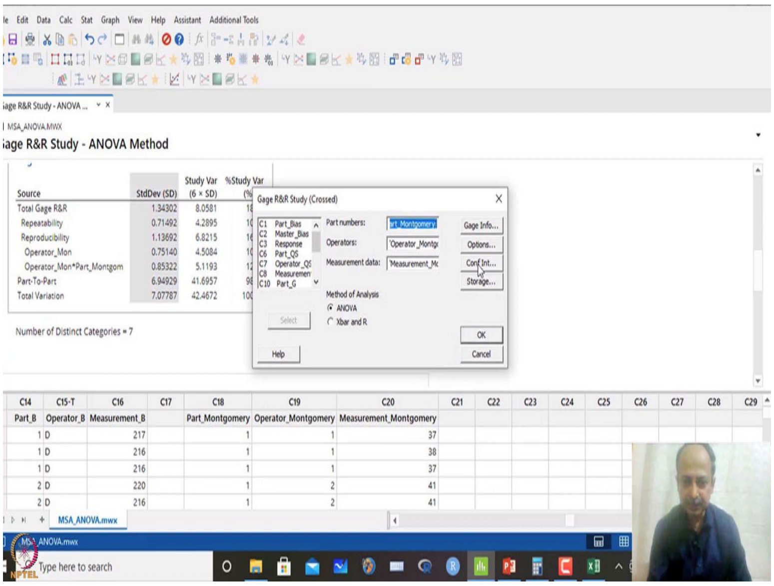
So, 8.051 this is the study variation with respect to total how much it is? It is around 18 percent over here ok. In addition to this what we can do is that we can also add process variability, historic process variability over here that can that is also possible to be incorporated over here and that gives you a different percentage over here which is 22. How this is coming?

(Refer Slide Time: 29:44)

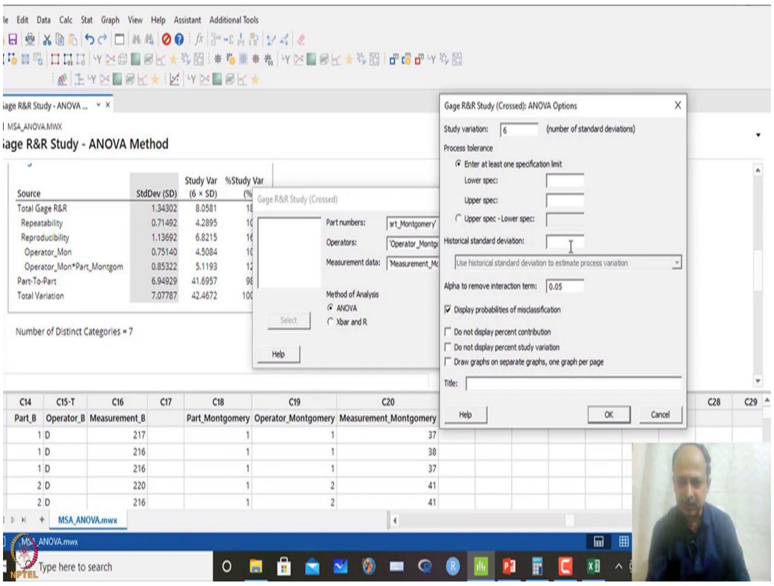


So, that we can see. So, this is how the calculation happens in MINITAB interface.

(Refer Slide Time: 29:57)



(Refer Slide Time: 29:59)

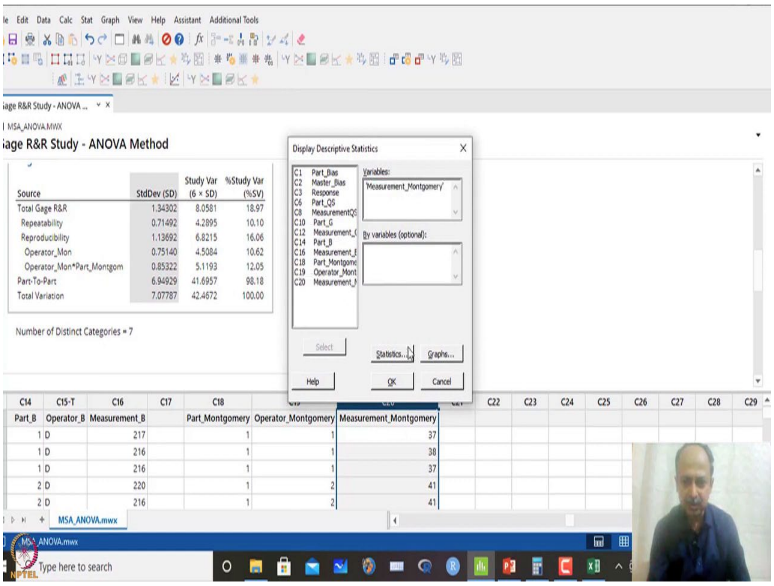


Let us try to see whether we have given this one Gage R&R crossed over here. So, this is options over here. So, in this case 6 standard deviation with respect to percentage standard deviation and this is calculated from the historic information or this is calculated from the sample.

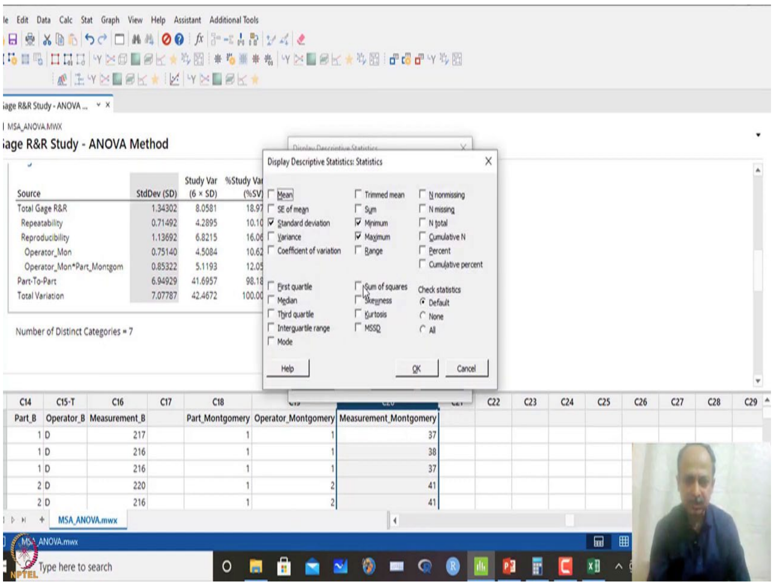
So, we can provide information over here. We have given information of the process variability over here that is why this percentage process variation is calculated over here.

So, let me go back what we can give over here as process variability. So, what is required is that I will go to MINITAB and then let me try to see what is the variation of this process there is the last one, so we can calculate the basic statistics, display basic statistics.

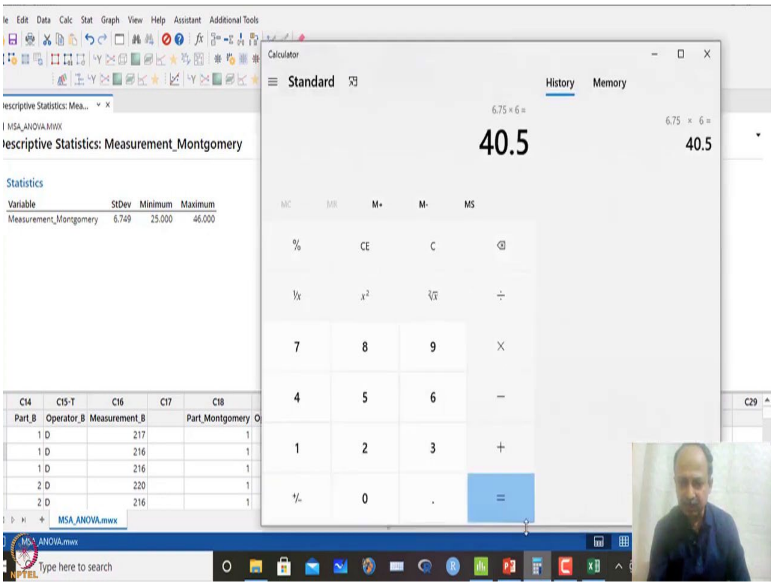
(Refer Slide Time: 30:42)



(Refer Slide Time: 30:45)

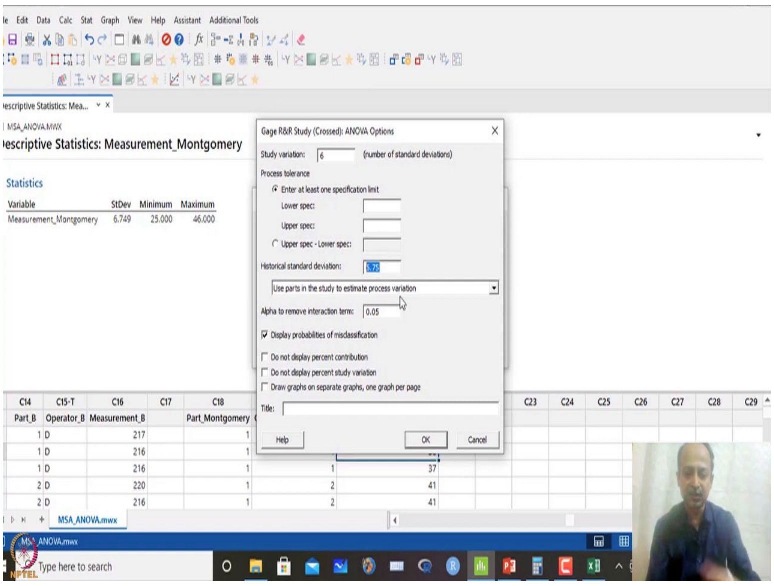


(Refer Slide Time: 30:51)



I want to see the Montgomery's measurement and I want to see the standard deviation we only want standard deviation information over here and this is around 6.75. So, 6.75 multiplied by 6 is around 40.5 that we have done so, 40.5.

(Refer Slide Time: 31:18)

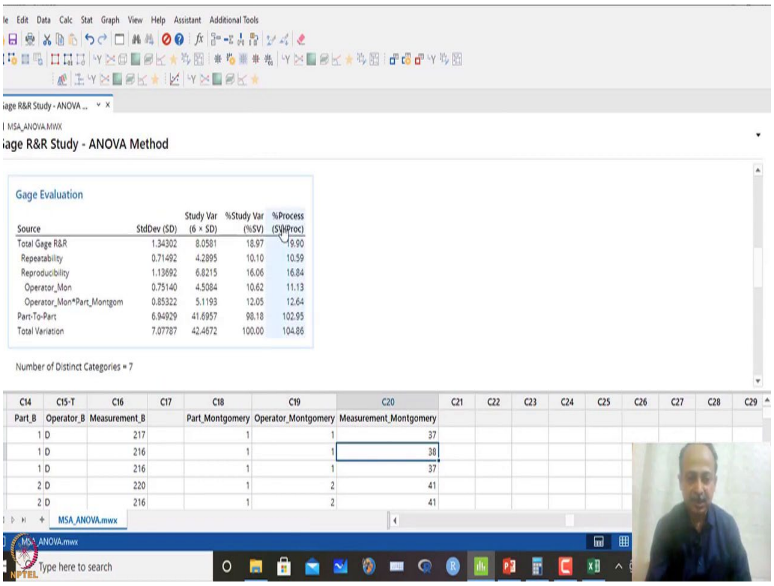


So, what we have to do is that stat, quality tools, and Gage R&R study. So, Gage crossed over here. So, in this case options what we provide is that 6.75, we can write 6.75 what we are getting over here and we can also say that use parts to estimate the process variability over here.

So, I will click observations historic, we can replace that one with the measurement variations what we have, but we can also say use parts in the study to estimate process variability.

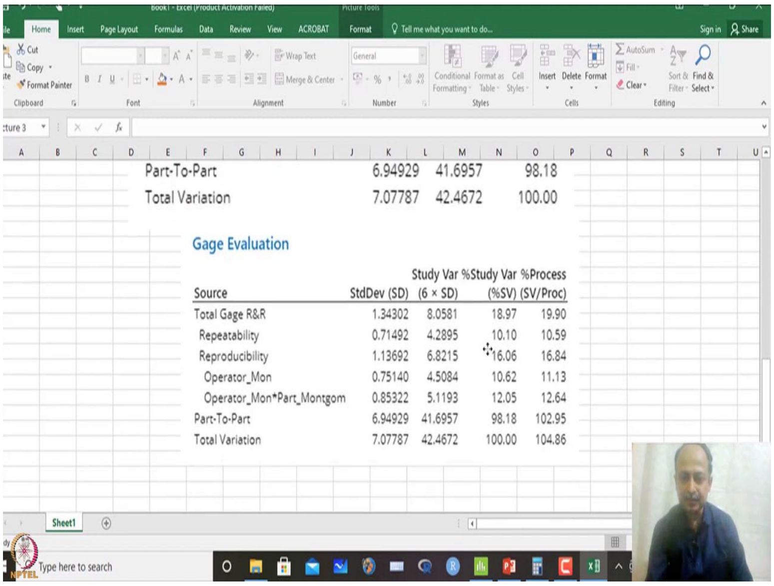
That is the overall process variability we can indicate that one when you click this one and it will go by the that measure only. So, when I have to click this one. So, it will estimate process variability or standard deviation based on the observation that is given in this experimentation that we have we have considered.

(Refer Slide Time: 31:52)



So, if you click ok then you will get this information which is percentage process variability over here. So, if I copy this one and we can paste this over here and then we will have another information over here that is 19.0 what we observe over here.

(Refer Slide Time: 32:04)



So, percentage process variability so, study variation is measured over here in respect to. If it covers the overall process, it will be more or less near to this one, study variation and percentage process variation over here So, the criteria that is used for the study variation, process variation is that whenever it is less than 30 percent, we try to accept that instrument.

So, if it is less than 10 percent very good instrument, 10 to 30 percent. What is recommended is that you need to be very precautious and see whether we can reduce that one variability that is happening, process variation with respect to process variation study variation.

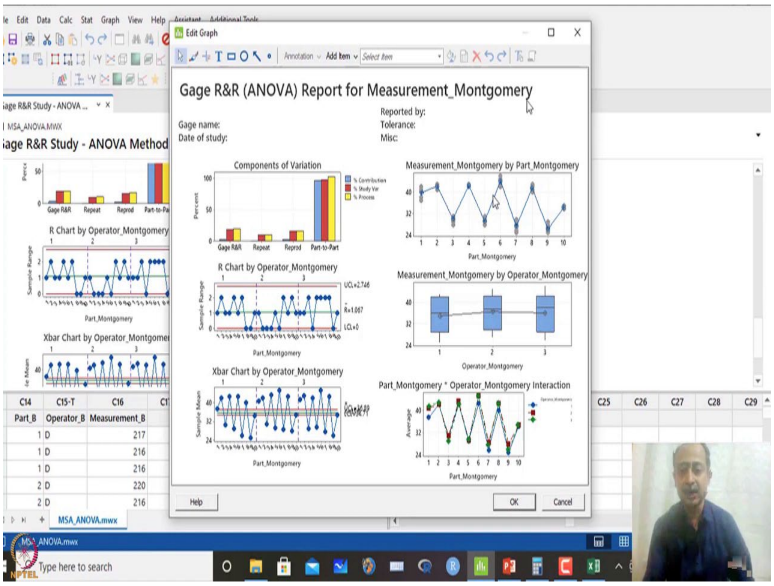
If study variation is contributing more with respect to process variation then that is a concern for us, operating this part to part variability will be high. And this summation of this what will happen is that it will not turn up to be 100 over here. So, this is 100 over here, but this is with respect to ratio that we are taking over here and study variation, and process variation and then percentage we are converting so, it will not be equal to 100 when we sum this up.

So, the criteria over here is that when we go by that contribution it should be less than 10 percent, when I going by study variability or process variations over here. Then their criteria may be 30 and it depends on the industry to industry what is the standard, but overall concern over here is that we have operator to operator variations is happening and also part two operator there is a interactions that is observed.

So, we can correct that one and try to see more into the instrument and figure out what is going wrong but the instrument can be suggested for use for the time being and we figure out how to reduce this one interaction between parts and operators and operator to operator how we can reduce that one further. So, that it becomes insignificant basically.

So, we will stop here what we will do is that we will continue with some more examples on this which is taken from the manual q s, manuals like that ok and some more examples where we have bad instruments like that. So, how to understand that one and graphical display that we are having so we want to explain that one also, because when we when you get the MINITAB information, we also get a graphical interpretation also over here.

(Refer Slide Time: 34:09)



So, what is this graph. Meaning of this graph that we will explain after this before we enter into design of experiments. So, thank you for listening.