Quality Design and Control
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Lecture - 59
Robust Design and Taguchi Method (Contd.)

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During this session on the robots design and Taguchi method, I will discussing an important topic called the determination of Manufacturing Tolerances and Tolerance Design and Tolerancing as you are aware of that.

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That whenever we try to apply the Taguchi method, we first referred to the customer tolerance with respect to a given quality characteristic.

Now; obviously, the customers the tolerance when you specify, you mention that what is the nominal value or the target value as well as the upper tolerance limit or upper specification limit and the lower tolerance limit or the lower specification limit if it is a two sided specification limit case.

Now, this is the customer tolerance and as we know the definition of quality as given by the Taguchi; that means, essentially you need to compute the loss and for computing loss, you have to assume the quadratic loss function, we have already discussed how to get the expression for quality loss functions for different types of quality characteristics.

Now, whenever we try to define this loss, this loss is computed with respect to the customer tolerance. Now the customer is using the product and he is using a product which is getting a manufactured in a manufacturing system. So, while the customer is given this product; that means, suppose the manufacturing unit is supplying this product, before it supplies the product, make sure as a manufacturer that the that the tolerances are conformed with; that means, the customer tolerances are com conform with.

Now, if you believe in the concept of say the societal loss it may so happen that if you cannot take any precautionary measures or the preventive measures at the manufacturing stage means before you send the product to the customer now it may so happen because of the existence of different kinds of losses mostly the external failure losses or the external failure costs. Now, you may get a customer tolerance which may not satisfy the customer.

So, in this context, you must also know, what is the concept of manufacturing tolerance? So, in this particular discussion, we will be referring to four types of quality loss functions, we have already pointed out, first one is the target is best or the nominal is the best case that is a one kind of quality characteristics, the next one is the smaller the better case this case also, we have considered and the larger the better case that is the third case and the fourth one is the asymmetric nominal the best case.

So, these four cases, we know and we know how to compute the quadratic the loss function, today at this point in time you must know that how to determine the manufacturing tolerance against each of all the four types of quality characteristics.

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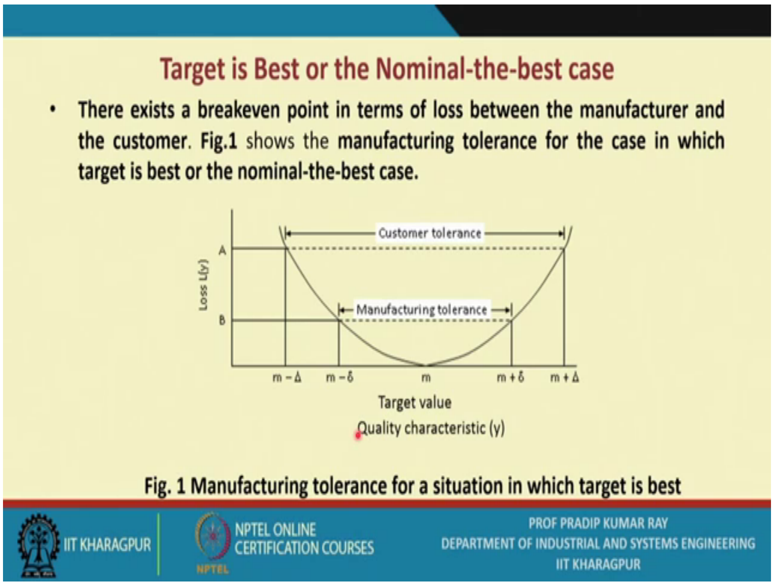

Fig. 1 Manufacturing tolerance for a situation in which target is best

Now, here for the case when the target is best or the nominal is the best how to you know represent the manufacturing tolerance. So, as you know that for the given quality characteristic y you have the nominal dimension and how do you specify the customer tolerance you have the upper specification limit.

So, at a distance of plus capital delta from m and the lower specification limit at a distance of minus delta from m ok; So, you have to specify this customer tolerance you as a designer you specify this one.

Now, what do you try to do; that means, you also try to define the manufacturing tolerance? So, what is the manufacturing tolerance; that means, at a distance of this plus a small delta from the nominal value that is m you have this value that is m plus small delta that is the upper manufacturing tolerance and similarly at a distance of minus small delta from m; that means, at m minus small delta you have, this the lower manufacturing tolerance limit.

Now, you need to specify the idea is very simple; that means, before you ship the product or you ship the component with these customer tolerance. Now make sure that that actually the value of the quality characteristics, before it is shipped, it must lie within this range; that means, within this manufacturing tolerance range; that means, between m plus small delta and m minus small delta.

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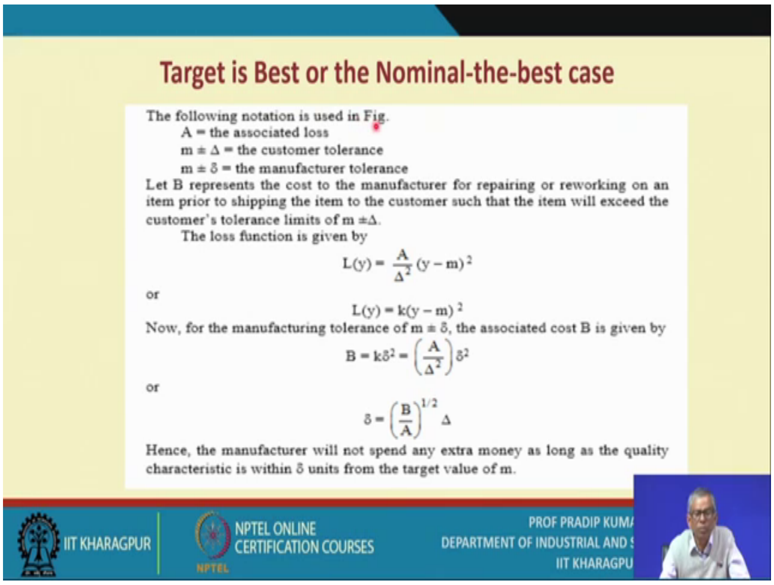

So, very you know if you find that the point is the value is somewhere here or here, but it has not crossed this value m plus minus plus delta or m minus delta, then comfortably you say, I will send the item, I will send the component, I will send the product to the customer and in all likelihood, when the customer starts using the component or using the product the actual value of say the quality characteristics will be within m plus delta and m minus delta, is it ok. So, this is idea.

Now, because of some reasons suppose some manufacturing deficiencies or say certain kinds of manufacturing losses or manufacturing defects or you know the unreliable the performance of the manufacturing systems or a machinery it may so happen that at the time of shipping the component you find that the value the actual value of the quality characteristics has crossed m plus small delta maybe somewhere here or it has crossed the value m minus small delta.

That means, somewhere here; that means, what do you try to do; that means, do not send the component immediately to the customer; that means, do not sell it, before you sell it, what do you take some you know the preventive measures the corrective measures and. So, that those manufacturing defects or the manufacturing deficiencies you take care of and then you spend a little more.

But what do you gain; that means, you will not have you know the excessive say you know the societal loss is it ok. So, it is better that you spend certain some extra amount of money for correcting the errors within the manufacturing system its better than to without making, this is you know the expenditure or some corrections, you do not make and you send it to the customers assuming that whether if the value is you know even if it is cross m minus small delta or m plus small delta, if you feel that it is within m plus capital delta or m minus capital delta. So, in all likelihood the societal loss will be more and the customer will have you know will have a value which is which is beyond the customer tolerance range.

So, there exists a breakeven point in terms of loss between the manufacturer and the customers ok. So, at this point in time this is the loss you get and when it goes to the customer's level the loss which you expect permissible loss; that means, up to this one, is it ok. So, it is B, capital B that is the loss whether when it reaches the customers level the acceptable the loss that is capital A.

So, there is a breakeven point figure shows the manufacturing tolerance for the case in which the target is best or the nominal is the best case, is it ok. So, always when you when you start you know say reading the concept of say manufacturing tolerance, you must have in your mind this particular diagram ok.

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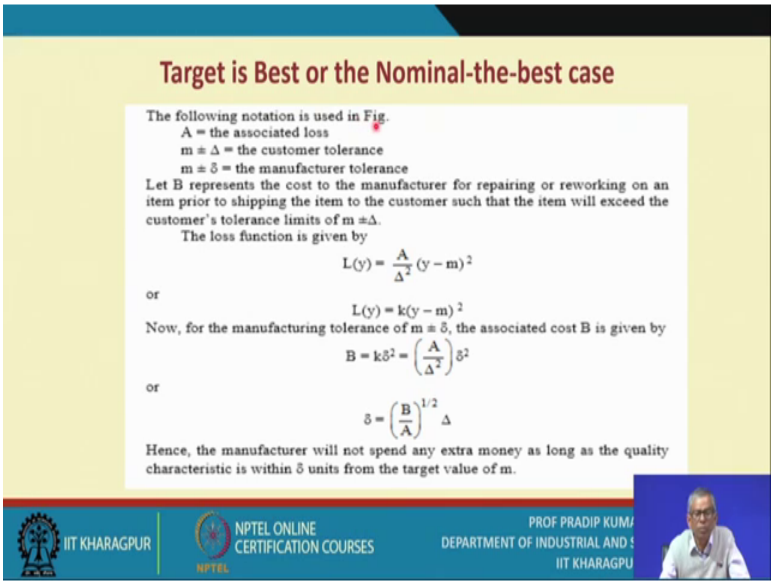

Now, how do you compute the value of small delta; that means, capital delta is known m is known what is unknown that is small delta and when small delta is known; that means, the manufacturing tolerance will be known. So, I will just briefly explain the procedure of determining small delta the following notation is used in figure you just refer to the figure capital A is the associated loss against the customer tolerance m plus minus capital delta is equals to the customer tolerance already we have specified m plus minus small delta the manufacturing tolerance.

So, what is the unknown? Unknown is basically the small delta and you must have an expression; you must derive an expression for this small delta in terms of the known parameters and the variables.

Let capital B represent the cost to the manufacturer for repairing or reworking on an item prior to shipping the item to the customer ; that means, already you know such an item you have come across one unit and you find that this has a crossed that m plus minus small delta the range. So, what do you do immediately you must take some corrective measures? So, that the value is brought back to m plus minus small delta.

The item will exceed the customers tolerance limits of m plus minus capital delta the loss function is given by this is the loss functions already we have determined this loss function that is capital A by capital A by small capital delta square this is basically the proportionality constant small k y minus m square, is it ok. So, y is a particular value of the quality characteristics and m is the nominal dimension.

So, this is the expression. Now, for the manufacturing tolerance of m plus minus small delta the associated cost capital B is given by B equals to k into delta square small delta square and capital K is capital A divided by capital delta square into small delta square. So, from these expressions you get an expression for small delta that is B upon a square root into capital delta.

Hence, the manufacturer will not spend any extra money as long as the quality characteristic is within small delta units from the target value of m; that means, he feels comfortable; that means, even if he does not if he finds that the actual value of the quality characteristics at the last stage of the manufacturing system, he is within plus minus m plus minus small delta; that means, he can send it to the customer, is it ok.

So, this is the procedure you use to determine the customer tolerance.

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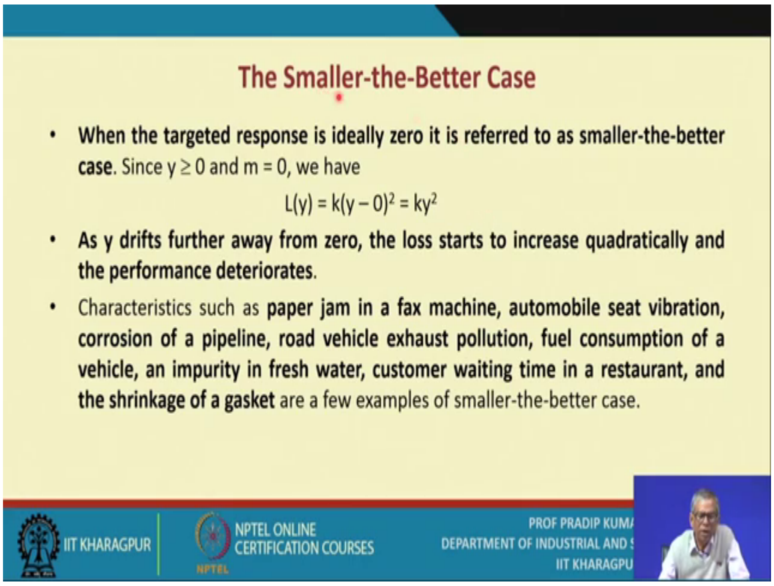

For the quality characteristic smaller the better, how to determine the manufacturing tolerance is the same approach you employ when the targeted response is ideally 0, it is referred to as the smaller the better case this point, already we have elaborated in the previous you know the lecture sessions.

So, since y is greater than equals to 0 and m equals to 0 that is the target value, we have the loss function as k into y square as y drifts further away from 0, the loss starts to increase quadratically and the performance deteriorates. So, this is our observations this is our assumption characteristics such as paper jam in a fax machine. So, these are the examples. In fact, of such a quality characteristic referred to as the smaller is the is the better quality characteristics.

So, the first example is paper jam in a fax machine automobile seat vibration should be as minimum as possible and ideal value is 0 there must not be any jamming paper jamming corrosion of a pipeline, he should be ideally 0 road vehicle exhaust pollution, is it ok, your target value is 0 fuel consumptions of a vehicle, is it ok, always you try to minimize this the fuel consumption rate and impurity in fresh water ideally, it should be 0 customer waiting time in a restaurant he should be immediately you know the given service without any waiting time that is the ideal case and the shrinkage of a gasket are a few examples are smaller the better case is it ok. So, I am citing several examples in this case.

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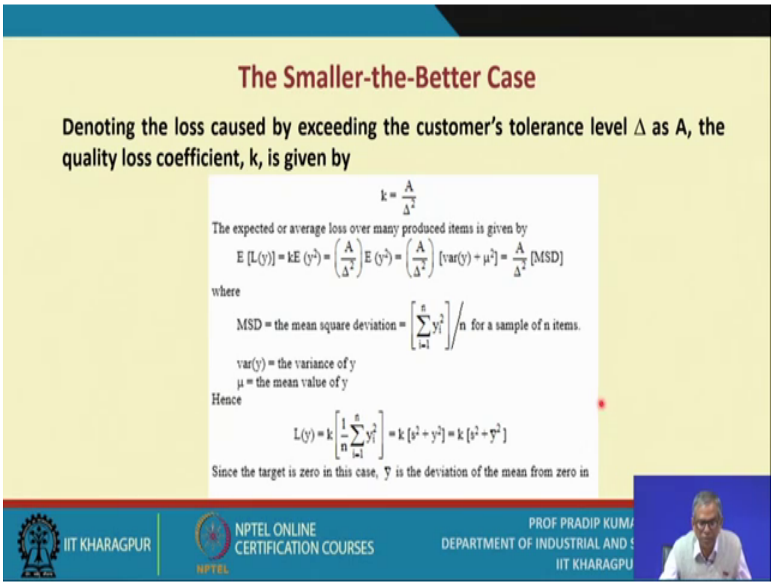

So, how to compute this the customer the tolerances denoting the loss caused by exceeding the customer tolerance level capital delta as a the quality loss coefficient k is determined by this one already we have determined this one. So, expected or average loss over many produced items is given by; that means, when you start producing n number of such units ok.

So, n number of units you produce. So, you use this expression that is the value of k is capital A by small capital delta square the expected value of y square and then you have this manipulation. So, this is variance of y plus mu square is it actually this is the squared bias and. So, this is essentially this term is referred to as you know. So, the mean standard square deviations MSD mean square deviation.

So, the mean square deviation when you get say n number of y values is it ok. So, each value are specified as y i. So, how many such values you have; that means, n number of values n could ten it could be 15, it could be 100 you get all these values from a continuously say running production system. So, you compute MSD with this formula; that means, sigma y i square sigma i equals to 1 to n divided by n for a sample of n items. So, this all already we have specified, what is mu; mu is the mean value of y and variance of y that is notation is this 1 var y.

Hence the loss function is given by this is it k times for a specific sample; that means, this is mu is replaced with y bar square and sigma square is replaced with the sample variance the notation is small s square since the target is 0 in this case y bar is the deviation of the mean from 0 n, ok. So, that is 0 that is it there is deviation case.

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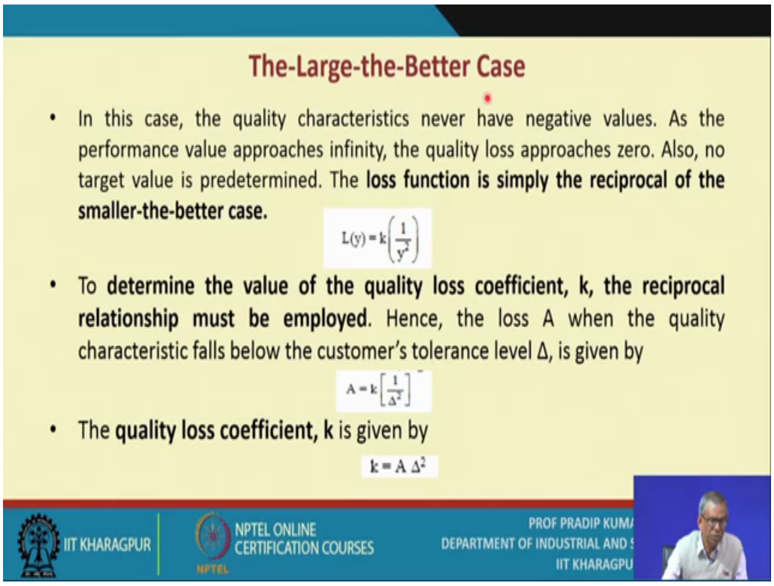

For the larger the better case the quality characteristic never has negative value it is always positive as the performance value approaches infinity the quality loss approaches 0, is it ok, already you know we have derived the expressions for quadratic loss function also the target value is predetermined the loss function is simply the reciprocal of the smaller the better case.

So, what is the express of the loss function that is L y y is the quality characteristics of this type larger the better case k into one upon y square to determine the value of the quality loss coefficient k; that means, essentially the proportionality constant the reciprocal relationship must be employed hence the loss a when the quality characteristics falls below the customer tolerance levels delta is it just from the opposite side.

Now, this loss a is given by capital A is equals to k times one upon you know the capital delta square so; obviously, the loss coefficient k is given by this; that means, small k equals to capital A into capital delta square ok.

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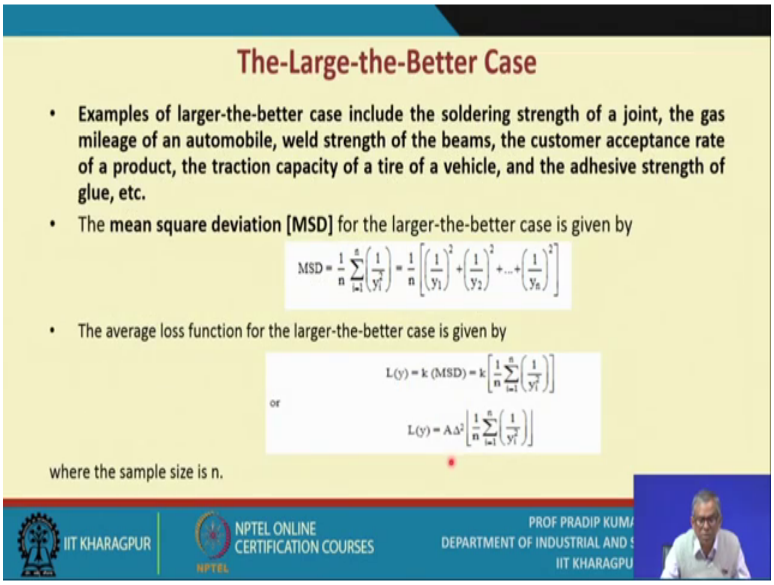

So, this is very very simple. So, what are the examples of such a quality characteristics, there are many like the shouldering strength of a joint, you should be as high as possible the gas mileage of an automobile, it should be as high as possible weld strength of the beams, it should be as maximum as possible the customer acceptance rate of a product, it should be very high acceptance rate the traction capacity of a tire of a vehicle, is it ok.

So, these are the examples of the quality characteristics for which we say the larger the better and the adhesive strength of the glue etcetera.

So, there are many examples. So, I have I am just citing few important examples which you come across. So, how do you compute this mean square deviation for the larger the better case that is this 1 upon n sigma i equals to 1 to n 1 upon y i square; that means, these value you collect; that means, when you have to collect data on y i n number of the data points you collect and then you compute these expressions, is it ok, up to n values.

So, the average loss functions for the larger the better case is this one that is L y k into MSD already we have you know the computer the expressions for k that is capital A into capital delta square already we have computed into these expressions, is it ok. So, in a typical the problem these values will be given; that means, 10 values of y will be given or twenty values of y will be given and you compute these summation and then you get the value of the loss, is it ok, so; that means, this is the expected or average loss you have computed.

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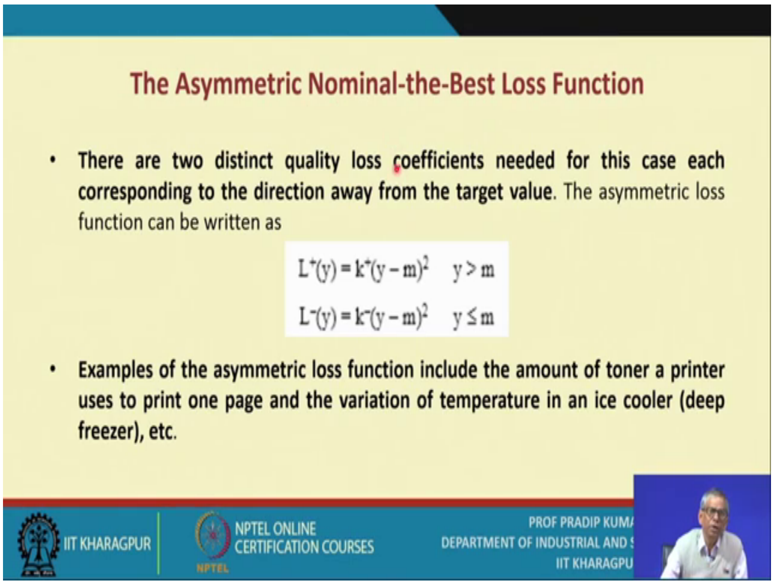

If the quality characteristic is of this type; that means, asymmetric nominal the best loss function. So, this point also we have we have mentioned and we have derived the expressions for the quadratic loss functions. Now here in this case as already we have pointed out, there are two distinct quality loss coefficients; that means, instead of just having one expressions for k you have two expressions for k 1 is k 1 and the second one is the other one is k two

So, are the two distinct quality loss coefficients needed for this case each corresponding to the direction away from the target value, is it ok. So, it is asymmetric case. So, asymmetric loss functions can be written as; that means, this is the positive deviation, is it ok, all the y values are greater than m. So, that is one case and on the other side when each y value is less than m on the equality case; obviously, you can consider either here or here, is it ok.

So, here I have considered the equality case when with this one; that means, when y is less than m and I also consider equality case over here is it ok. So, the entire loss function is split into two. So, examples of the asymmetric loss function what are those examples like the amount of toner a printer uses to print one page, is it ok.

So, if the toner is more, then the amount of toner is more than the what is required or the target one; obviously, you will find that the you know the quality of say the print will be very high and if the quality of the print is better; obviously, the loss will be less right whereas, on the other side if the amount of toner is less you will find definitely quality is affected and the loss will be very high.

So, the variation of temperature in an ice cooler, deep freezer, etcetera. So, what are my suggestion is that the from the manufacturing systems from say other service systems can you just identify 5 to 10 say such quality characteristics. So, during the assignments we will come across such cases or such examples more precisely.

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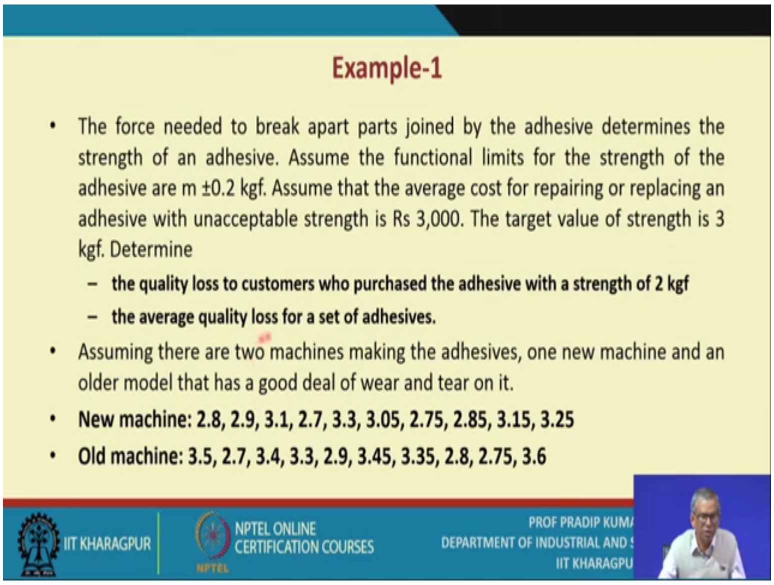

Now, here is an example the force needed to break a break apart parts joined by the adhesive determines the strength of an adhesive I repeat the force needed to break apart parts joined by the adhesive determines the strength of an adhesive assume the functional limits for the strength of the adhesive are m plus minus point two k g f assume that the average cost for repairing or replacing an adhesive with unacceptable strength is rupees three thousand is it ok. So, these estimate as I have already pointed out that usually this loss or the cost must be you know converted into monetary terms.

So, the target value of strength is three k g f determine the quality loss to customers who purchased the adhesive with a strength of 2 KGF and the second question is determine the average quality loss for a set of adhesives assuming there are two machines making the adhesives one new machine and an another older model that has a good deal of wear and tear on it, is it ok. So, here we are using a new machine as well as you can also use the old machine.

So, when you use the new machine. So, these are the values you get right and when you use the old machine. So, already this old machine is having a good deal of wear and tear. So, the values will be like this one. So, how many such values you have you have collected data points from each of these two machines 1, 2, 3, 4, 5, 6, 7, 8, 9, 2, ok.

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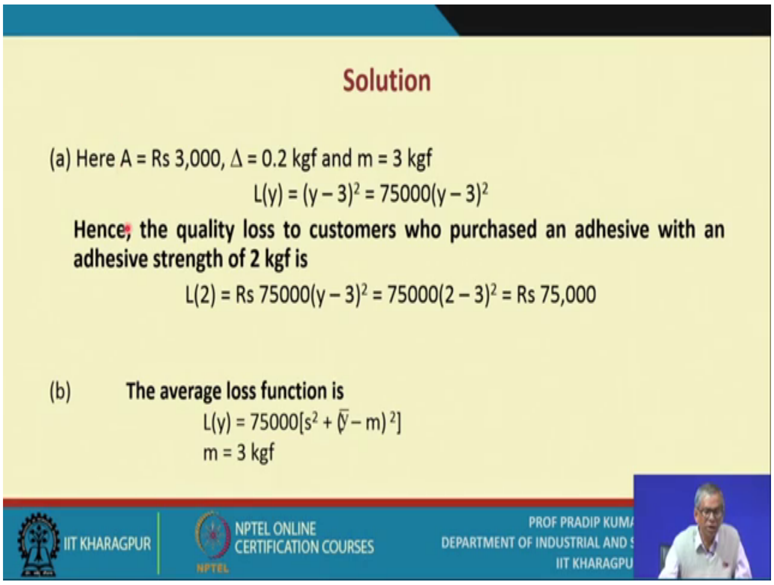

Now, so; obviously, you know in the first case you determine capital A that is rupees 3000 capital delta is small 2 kg f that is the customer tolerance and m what is the target value that is 3 kg f. So, what is the loss against a particular value of y that is y minus 3 whole square that is seventy you known, this one is 3000s in 2 to 5. So, y minus 3 whole square hence the quality loss to customers who purchased an adhesive with an adhesive strength of 2 kgf is this one. So, this is the value of small k into y minus 3 ok.

So, this is rupees 75,000. So, that is when someone get a value of 2 the average loss function is; that means, you have this MSDs, this is MSDs, you compute MSDs m equals to 3 kg f the value of k is 75,000 and now you determine s square and you determines y bar, is it from the given the set of data and m is already known.

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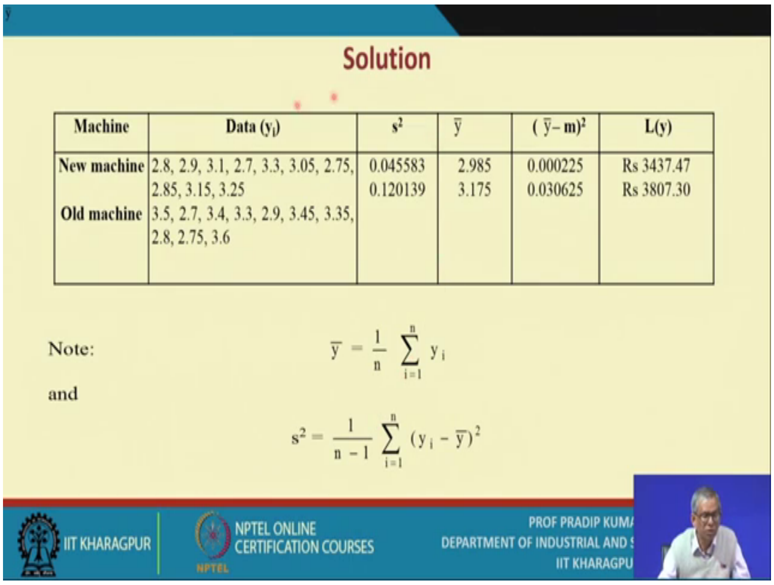

So, for the new machine these are the data points you have for the old machines, there are the data points n is ten both the cases. So, you compute for this one, this is the sample standard deviation with these values and this is the sample standard deviation values. So, for with all these ten values over here.

So, in y bar for the new machine is 2.985 whereas, for the old machine it is 3.175. So, then you compute this expression that is yy minus minus m whole square y y bar minus m whole square and ultimately you compute the loss expected loss with the old machine that is 3437.47 and for the this is the new machine and for the old machine which is 3807.

So, these are the expressions, you have when you compute the sample standard deviations; obviously, it must be an unbiased estimate that is why you use n minus 1 not n and this is the expressions for the average everybody knows.

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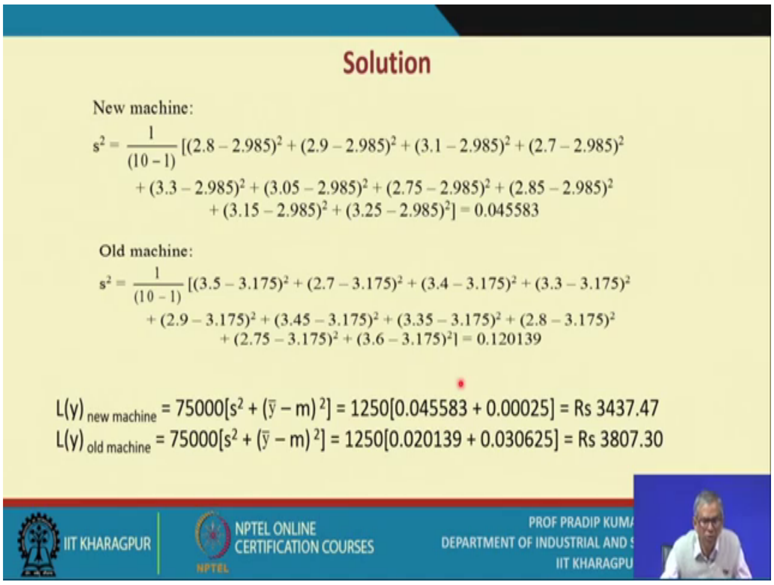

So, the this is the computation say s square we have computation, we have computed s square for the new machine with the given data points like this one and similarly for the old machine.

So, this is in the calculations we have made only; that means, the expected loss for the new machine is this one and expected loss for the old machine is this ok. Now what you can conclude that; obviously, you know that the old machine the loss is more; that means, significantly more than this one.

So, what we suggest that how do you say that this old machine loss is significantly more then the loss in the new machine. So, that you have to prove later on.

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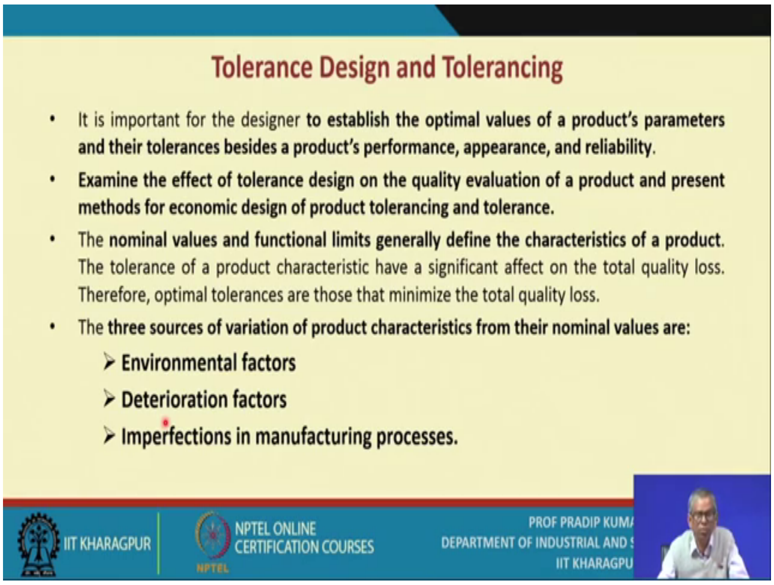

We will come back to these conclusions now; obviously, you know we are referring to the tolerance design and tolerancing and the there are three sources of variation of product characteristics from their nominal values.

So, this point will be discussing in your in our next session.