Quality Design and Control
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Lecture – 56
Robust Design and Taguchi Method

So in this session, that means the 12th week session, we are going to discuss a very important topic related to quality control and quality improvement of production processes. And this topic is referred to as the robust design and the Taguchi method. Now there will be a 5 session during this week. And the lecture wise let me first tell you; what are the topics we are going to cover. And when you learn all these topics you will be basically learning the fundamentals of Taguchi method.

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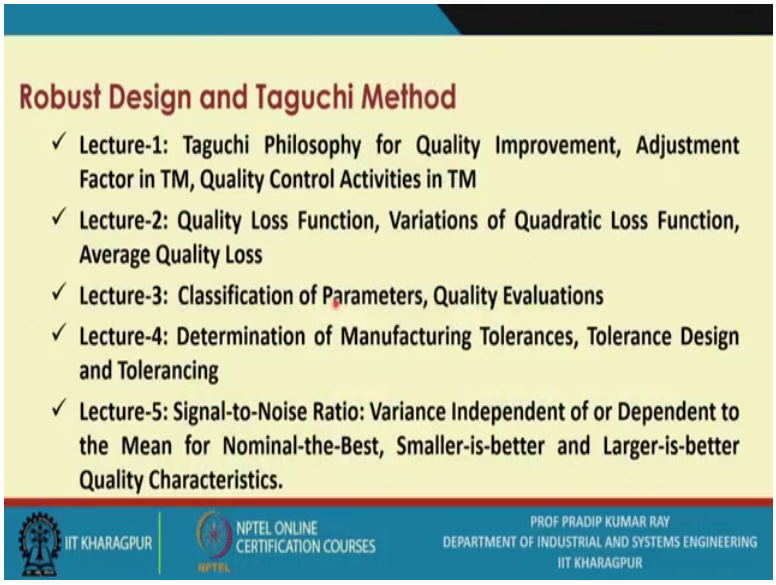

As we have already mentioned during the week 2 lecture sessions that the Taguchi method is used for quality improvement. So, the fundamentals of Taguchi method which we are going to discuss: if these fundamentals are applied what you expect that the product quality will be continuously improved.

In lecture 1: we are going to discuss Taguchi philosophy for quality improvement. The adjustment factor in Taguchi method, so you must have a very clear cut idea about what is this adjustment factor and how identification of this adjustment factor is related to quality improvement, quality control activities in Taguchi method. In the next lecture

session lecture 2; we are going to discuss the quality loss function, variations of quadratic loss function and how to compute the average quality loss under different conditions.

During lecture 3 we will be referring to the classification of different kinds of parameters that we come across and we will be discussing the topic called quality evaluations, with a number of numerical examples. In lecture 4, we will discuss the determination of manufacturing tolerances tolerance design and tolerancing 1 us the 1 of the key aspects in Taguchi method. And in the last lectures that is in lecture 5 will be referring to the signal to noise ratio as a performance measure, variance independent of or dependent to the mean for nominal the best smaller is better and larger is better quality characteristics ok, so this will be our coverage.

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Now, let us first discuss the Taguchi philosophy for quality improvement adjustment factor in Taguchi method and quality control activity. So, we will be very very specific in identifying the quality control activities in Taguchi method.

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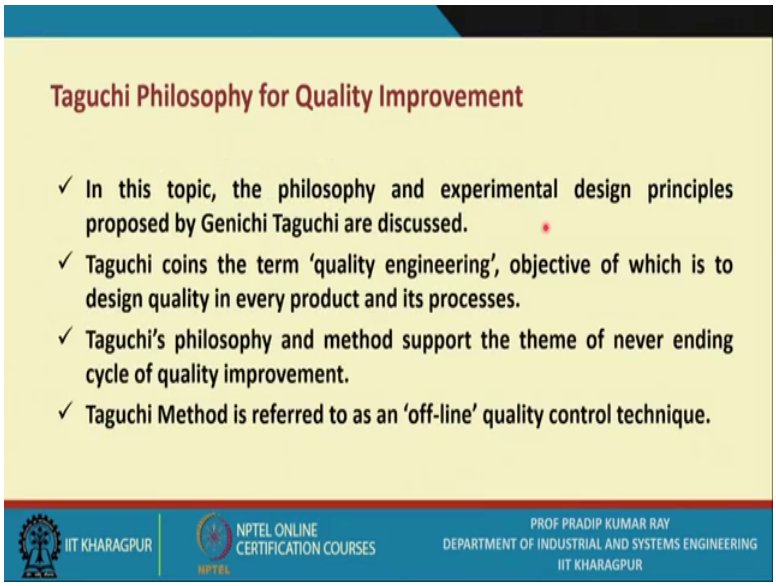

Now, so let us again go back in discussing the Taguchi method, certain the references we have given in lecture 2 as well as in lecture 3. So, I ask my students my learners to refer to the lecture you know the week 2 lecture sessions and by this time you know that how or the quality has been defined by Taguchi.

So, we will restrict ourselves to the definition of quality given by Taguchi and as you all already you are already aware that the Taguchi method or the philosophy proposed by Taguchi, Genichi Taguchi a Japanese engineer, was proposed by Taguchi to improve the quality of a product as well a the process. Now this the tools and techniques under Taguchi method they referred to as offline quality control technique; that means, it is expected that all these tools and techniques you use during the design stage.

Now, when you refer to this particular topic the philosophy and experimental design principles proposed by Genichi Taguchi are discussed. In fact, you know as it is referred to as an offline quality control technique, so obviously you know that these techniques or these method is supposed to be used at the prototyping stage.

So, while you were referred to a prototyping of a particular product, now obviously you have to follow certain say experimental design principles because, you need to carry out a lot of experiments at the prototyping stage and so that you must know that under what conditions, the product is supposed to provide the best possible performance ok.

So, this is the first point we remember that whatever the methods, he has proposed these are to be you know experimentally verified. Taguchi coins the term quality engineering we have already defined what is quality engineering objective of which is to design quality in every product and these processes. So, not only we are referring to the product, we are also referring to the processes ok.

So, it is a total systems approach you can say and so you want to say incorporate the quality features in your product, so there must be you know by the separate approach it is not necessarily only through the design effort you are assured of the quality. So, they separate approach called quality engineering approach you have to apply. Taguchi philosophy and method support the theme of never ending cycle of quality improvement, like we never say that the design has been design of a product or a process has been fully matured you cannot conclude that.

Similarly, you will never say that the quality of the product has reached it is final level ok, so always even we say that even if you say at this time that the quality is best; but we believe in the philosophy of the best can be bettered. Taguchi method is referred to as an offline quality control technique this point already I have mentioned.

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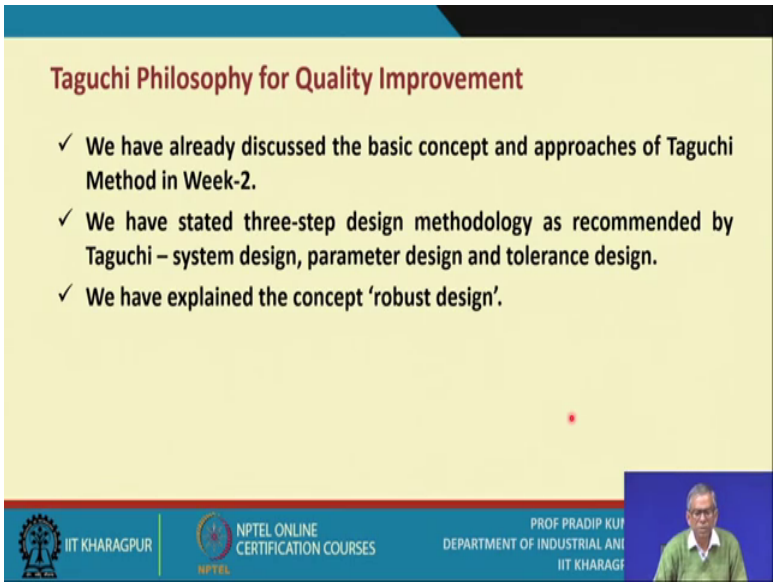

We have already discussed the basic concept and approaches of Taguchi method during week 2. So, I i suggest that you refer to week 2 the lecture sessions we will get an idea about what is Taguchi method and what is the basic objective of using Taguchi method.

Just I will tell you at this point that the main objective of Taguchi of applying Taguchi method is to create a design which is referred to as the robust design and if you are successful in creating a robust design then we will say that the Taguchi method has been applied. There are numerous examples of Taguchi of robust products and directly or indirectly the method you need to apply for creating a robust product directly or indirectly you are referring to the Taguchi method.

We have stated 3 stave design methodology in Taguchi method as recommended by Taguchi, what are these 3 steps the first step is the system design we have already defined what do you mean by system design, then you go for the parameter design and the parameter design is referred to is the is the is the main aspect of the Taguchi method. So, many a time know the system design is already there what do you need to do you whenever you start applying the Taguchi method essentially, you will be referring to the parameter design.

So, it lives at the heart of the Taguchi method and then once the parameter design is over then you go for the tolerance design, so this is referred to as a 3 step procedure. So, we have already explained the concept of robust design, now what is robustness let us again define robustness.

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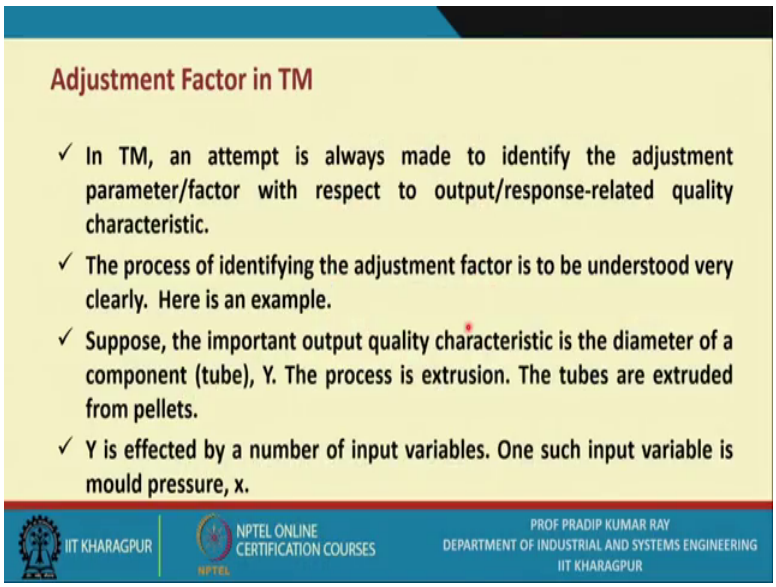

That means you say a product is a robust only when you create a situation you create a condition, in which the product performance or the product quality is virtually not

affected or you can say that even if there is an effect this effect is minimum and the defect of what that means, effect of external as well as the internal noise factors.

So, once you say that the product has been designed in such a way, that the effect of internal as well as the external say noise factors uncontrollable noise factors the effect is minimum on the performance of the product, then you say it is a robust product and the design methodology which you apply to create such a condition is referred to as the robust design.

So, in Taguchi method and attempt is always made to identify the adjustment parameter or the factors; that means, any exercise or any assignment or any project is given under Taguchi method, that is the first objective we will be whether you are able to identify the so called adjustment parameter at the factor or not and these adjustment parameter and the factor you need to identify with respect to the output or response related quality characteristic is it ok. So, you have a product so from the product you need some kind of output and output maybe you know 2 or 3 kinds of outputs and how do you define this output that means, with respect to the output quality characteristics. So, sometimes they are also referred to as the response variables.

Now, you have to create or you have to identify, but the process parameters and their values, in such a way that that the value of the output related quality characteristic is acceptable to you and it should be acceptable as well as it should be the best value. The process of identifying the adjustment factor and that is the thing you have to do, that means you have to identify the adjustment factor and once you can identify the adjustment factor possibly in 99 percent of the cases you will be able to you know the apply the Taguchi method.

So, the process of identifying the adjustment factor is to be understood very clearly I will give an example. So, here is an example suppose the important output quality characteristic is the diameter of a component say tube diameter and how do you specify it is output quality characteristics that is y; that means, Y is a variable the process is suppose the extrusion process or where drying process.

The tubes are extruded from pellets, so this is the process. So, before you start applying the Taguchi method you must know what is the process the process details; that means, what are the output quality characteristics, what are the input variables, what are the

external noise factors, what are the parameters all these details you must know and you must be able to create the boundary line.

Now, what do you find that Y is affected by a number of input variables? So, this is your knowledge base you must have this knowledge, 1 such input variable that you have identified is the mould pressure x. So, the mould pressure is also a variable that is why we say that it is it is referred to as X square now what do you do.

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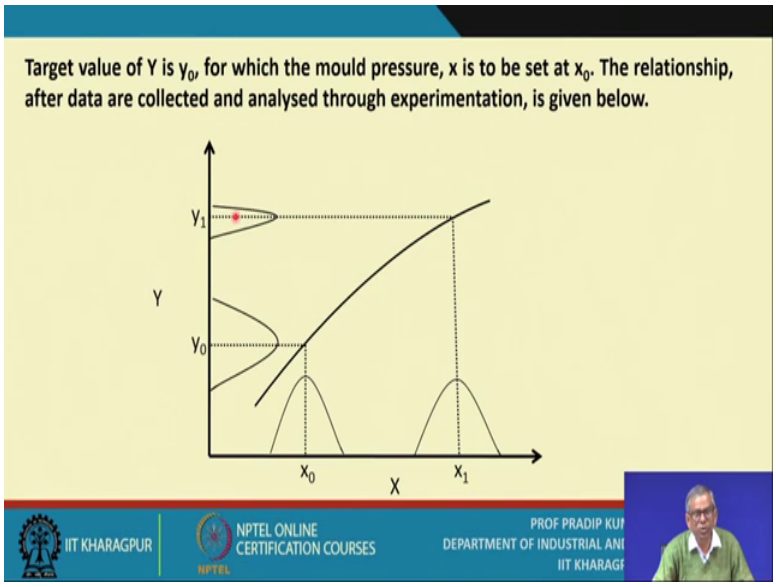

Now you start collecting data and what do you find that you are the target value of Y is Y0 there is a target value and this value you get against a value of x, that means the mould pressure that is X0. So, whenever you use a kind of for the press and the mould pressure you get and when the mould pressure is X0, then you get a value of Y0 fine.

So, far it is but what happens that is always you cannot you know they get the value of X as X0 all the time there will be variations. So, this is the variation, that means X0 plus minus delta X0 you cannot avoid this, so with respect to the variability across X0 you will be also be getting a variability of Y across Y0.

Now, what do you find in this particular case that these variability is very high ok. So, that is why it is not acceptable, even if you get Y0; but in most of the time the values will be values of X will be say either less than X0 or greater than X0 within this zone

definitely, but what do you get that means, you know excessive variability around Y0 is it acceptable to you definitely it may not be acceptable to you is it.

So, now the question is how do you control these variability in Y0, 1 way you can do like say you use a better quality press or you know you replace the existing say the press with a new 1 and obviously, you know you may find that this variability gets reduced that is 1 solution. But the question is that these the new press maybe the state of the art technology press this may be very very expensive but most of the cases.

So, you have to think of alternative that means, to what extent the existing process you can use and you can reduce this variability or the effect of variability you can reduce is it getting my point; that means, whenever you try to use the Taguchi method again you go back to your basics, that means as I have been telling you that any exercise on quality is essentially an exercise on variability. So, if the variability is the reduction is there then you say that yes that the quality exercise we have been carrying out.

Now, the alternatively what do you find that if the value of X is X 1 there will be variability across X 1 this is acceptable, but surprisingly you get a value of Y as Y 1 fine, but across Y 1 the variability is very very less is it. So, as far as variability is concerned definitely you can (Refer Time: 16:42) X 1 fine, but then this Y 1 which you get it is far off from the target is it ok. So, you can control variability by changing say X0 to X1, but in that case you will be getting Y 1 not Y0 now as we have been telling you that if you apply Taguchi method, what do you try to do you try to produce the output quality characteristics to it is target value.

So, it is far off from the target value, so this is the problem you face, target value of Y is Y o Y0 for which the mould pressure X is to be set at X0 the relationship after data are collected and analyzed through experimentation is given below. So, this is the relationship and in majority of the cases the relationship is non-linear.

So, the problem I have already mentioned now the question is that what you need to do; that means, you have to by using the same process you need to get the value of Y0, as well as you need to will reduce the variability from this level to this level ok. So, that is the challenging assignment given to you, so how to do that?

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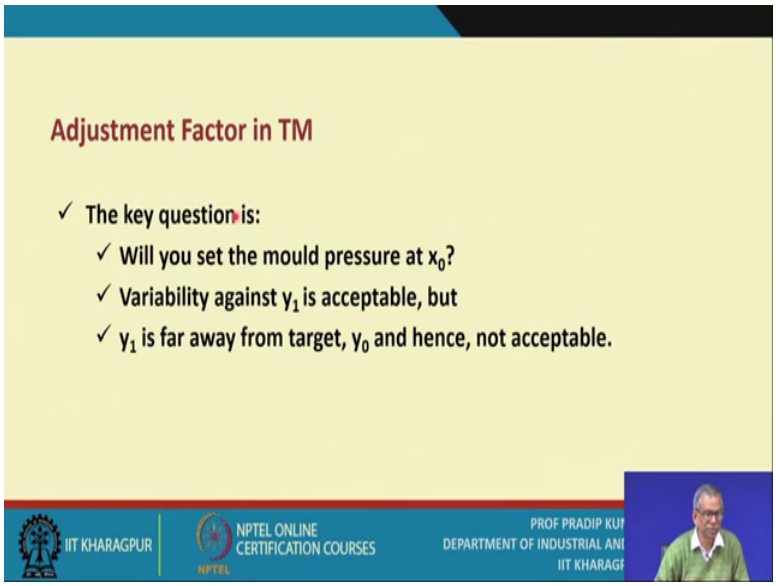

So, here what do you need to do that means, the first thing you have to thoroughly study the system or the process and you have to identify the adjustment factor. So, but before you start identifying these adjustment factor there are certain key questions, will you said the mould pressure at X0 variability against Y 1 is acceptable fine, but Y1 is far away from target Y0 and hence not acceptable, so these are the key issues to be deal with.

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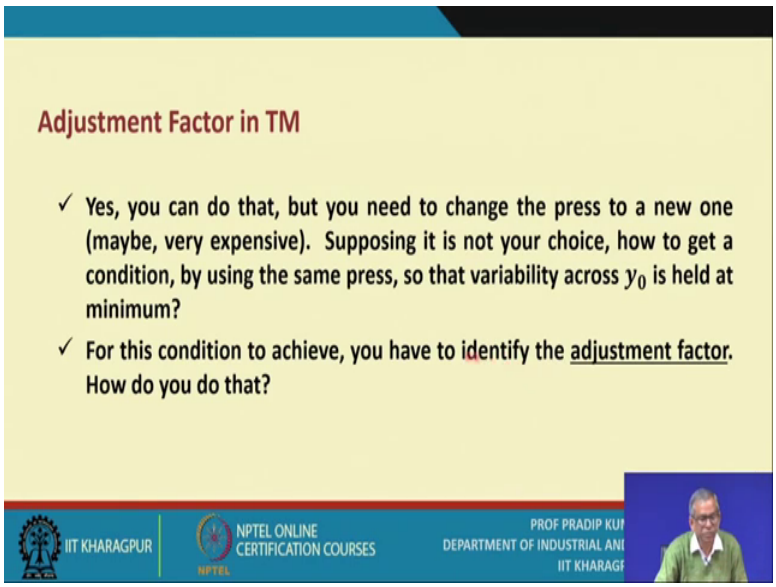

So, what is alternative yes you can do that, but you need to change the press to a new 1 may be very expensive is it ok, you can restrict yourself to X0 fine, but then make sure

that around X0 the variability is very very less and if you can reduce the variability around X0, what do you expect that the variability around Y0 also may come down.

Now, in order to reduce this variability around X0, what you need to do you need to in majority of the cases you need to go for replacement and the replacement cost would very very expensive and that that is why it may not be preferred, supposing it is not your choice in majority of the cases how to get a condition by using the same press. So, that the variability across Y0 is held at minimum, so this point I have already elaborated; for this condition to achieve you have to identify the adjustment factor how do you do that ok, so how do you do that? So that process I am going to explain.

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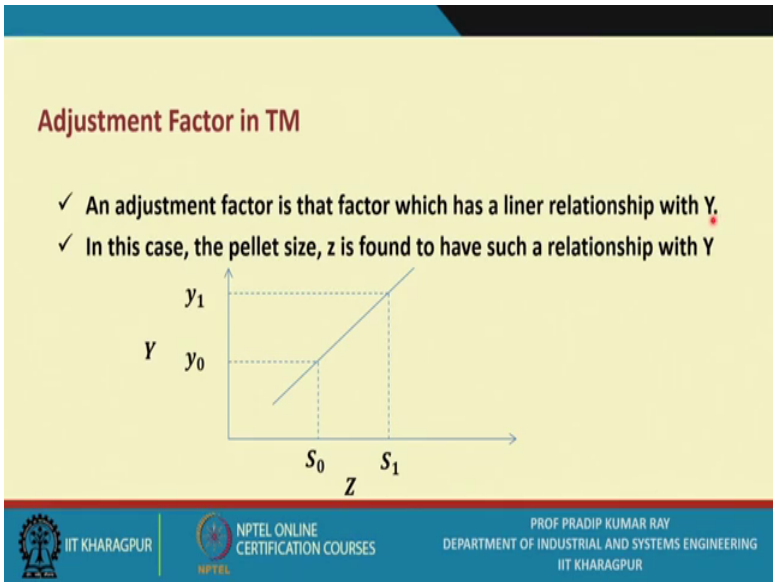

Now, what is an adjustment factor, an adjustment factor is that factor which has a linear relationship with Y, usually we will find that Y is a function of it is a n number of Xs in n maybe you say the 10 n maybe 7 in certain cases n maybe 20 even in certain cases in n maybe the value of n could be as high as 100 ok.

So, so in this case particularly the suppose 3 or 4 factors most you know what you can say that the critical factors, you have you have identified and you find that out of these factors which are affecting the value of Y, 1 factor has a linear relationship with Y ok; that means, what you need to do you have to collect data you have to plot those data points between the relevant the variables and then you say that which particular factor

has got has a linear relationship with Y and that factor you may define it at the adjustment factor.

In this case the pellet size z pellet size z is found to have such a relationship with Y is it ok. So, value of z like say suppose S0 that is the pellet size. So, it has got a linear relationship. So, you get a value of Y0 and then if you change the pellet size from S0 to S1 and if you use a pellet size of S1 is the exclusion process where drying process, so you get a value of say Y1 so your target is Y0 is it ok.

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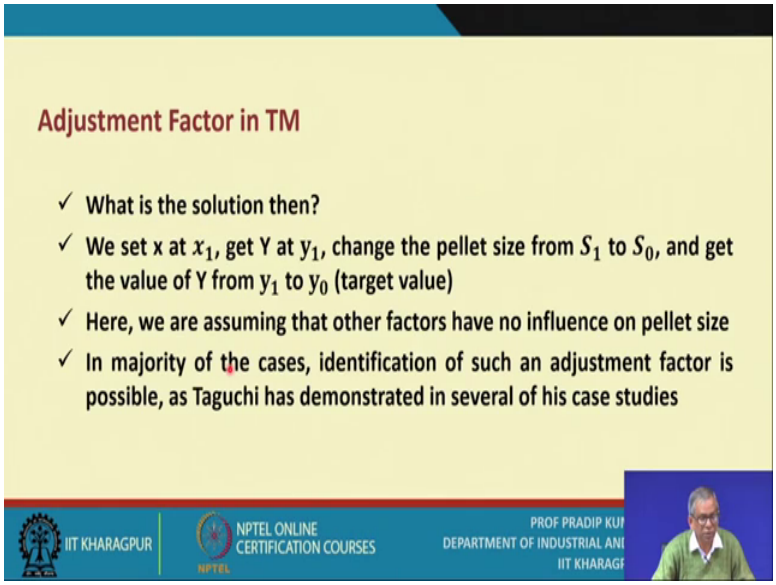

So, with the help of this adjustment factor how do you get the solution, so we set X at X 1 get Y at Y 1 change the pellet size from S1 to S0 and get the value of Y from Y 1 to Y0 ok. So, I repeat we set X at X 1 get Y at Y 1 change the pallet size from S1 to S0 and get the value of Y from Y 1 to Y0 ok, so we are getting the target value.

Here we are assuming that other factors have no influence on pellet size. So, this is this is the rule we follow and what we have found, if you go through the case studies on Taguchi method, what do you find that in majority of the cases identification of such an adjustment factor is a possibility majority of the cases maybe 95 percent of the cases. But what is the basic condition that basic conditions you must have a thorough knowledge about the about the behavior of the process; that means, what are the factors affecting the performance of the process and you must know how the process has been designed.

So, all these knowledge regarding you know the process performance, regarding process design you must have this knowledge and then only identification of an adjustment factor becomes easier. So, the Taguchi has demonstrated; so these applications in several of his of his case studies.

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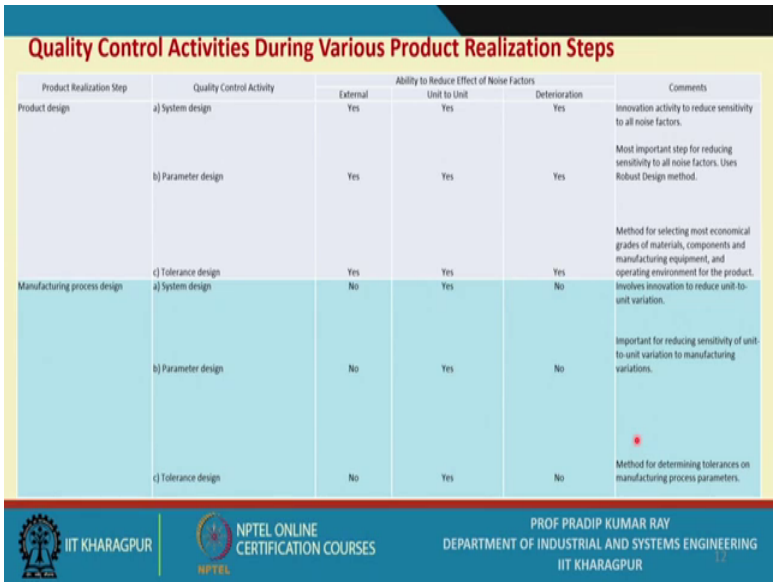

Now, before I conclude this session, now I will referring to the quality control activities during various product realization steps. What do you have basically in the product realization steps. You know what is this product realization stage; that means, first use the product design we have already mentioned, the second stage is the manufacturing process design ok, the third one is the manufacturing and the fourth one is the customer related activities ok.

So, these are the 4 you know the product realization steps we have, what we need to identify that related to a particular product realizations step like say product design, how do you define the quality control activities how do you identify the quality control activities related to system design, related to parameter design related to tolerance design. That means, this is these are the 3 steps one after another you have to follow if you if you apply Taguchi method ok

So, ability to reduce effect of the noise factors whether at the system design these external noise factors, whether you can reduce these effect you say yes countermeasures is possible, unit to unit variation this is another kind of a nice factor unit to unit variation

that is a yes and what is the deterioration effect, that means it is a product deterioration yes; that means, countermeasures at the system design you can take against those you know external as well as the internal noise factors.

Let me explain what is this unit to unit variation what do you find that supposing you purchase say 1 product say a TV for a particular brand and a your friend has also purchased the same brand is it ok; that means, with the same company the same model at the same say the TV he has also purchased, now there is a possibility that regarding the performance of this model of a particular TV brand. Now you may have one opinion your friend may have another opinion and both are you are also correct and he is he or she is also correct. So, now obviously I say that the performance is very good whereas, my friend says for the same model he is using the performance is not that good.

Now, what how do you explain this difference in opinion, obviously there has to be some unit to unit variation. So, unit to unit variation unit will to reduce and this unit to unit variation is due to some internal noise factors. So, at the system design level you need to take care of these aspects.

Innovation activity to reduce sensitivity to all noise factors these we talk about innovation. So, the innovation activity you must encourage most important steps for reducing sensitivity to all noise factors uses robust design method; that means, I have already mentioned that the parameter design is the most important step; so here also against all these noise factors you can take the you know the countermeasures. So, the product design similarly the tolerance design stage you can have the countermeasures; that means, method for selecting most economical grades of materials components and manufacturing equipment and operating environment for the product, this you do at the product design stage and similarly when you refer to with the next step we go to the next the realization step product realization step, that is the manufacturing process design.

Again you know as far as system design is concerned at the process stage; that means, the external noise factors there cannot be any countermeasures against noise factors. Whereas, unit to unit variation internal noise, so there could be some you know by the countermeasures right and the here, but the product deterioration you cannot take any countermeasures. So, involves innovation to reduce unit to unit variation only, similarly

when you reach the parameter design stage against external noise factors no curve this is no countermeasures.

A similarly unit to unit variation there will be some countermeasures, but against product deterioration there is no countermeasure. So, important for reducing sensitivity of unit to unit variation to manufacturing variations and when reduce the tolerance design again you have the same you know the conditions you have, against taking preventive measures to control the effect of, so the external as well as the internal noise factors.

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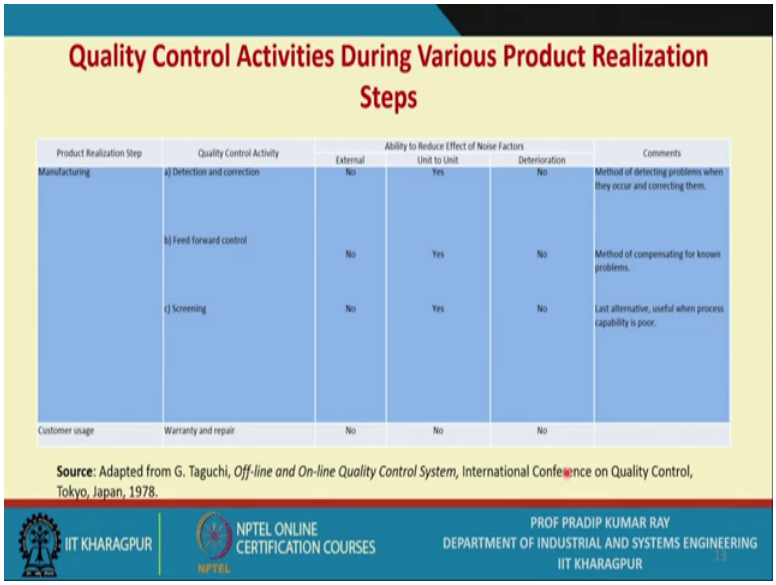

Now, then we move to the manufacturing stage; obviously, we will find that there will be at the detection or the correction stage is it quality control activity. So, you have unit to unit say against unit to unit variation you have some the action you can take, feed forward control there is a part of the system again unit to unit to unit say unit to unit X external the noise factors internal noise factors, you can have the countermeasures and for the screening say you can have the countermeasure against unit to unit variation and when you talk about the customer uses warranty and repair.

So, that is very important aspect warranty and repair we are referring to the quality loop. So, please refer to the quality loop and you will find that the customer uses, when you reach at this stage nothing you can do; that means, as far as controlling of the external noise factors you cannot do at the customer use a stage is it ok.

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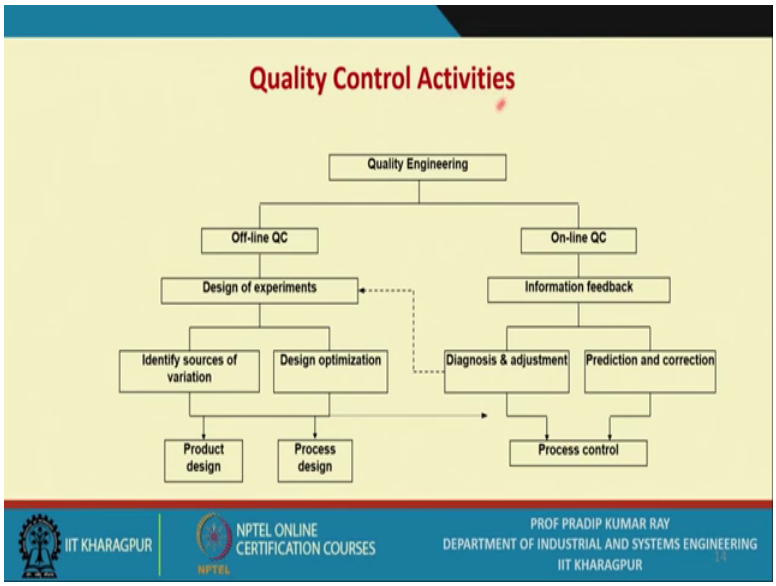

So, this is the approach and what are the quality control activities related to quality engineering offline quality control, online quality control. Online quality control based tools and techniques we have already discussed as far as offline quality control is concerned. We say that we refer to the design of experiments then through design of experiments you identify the sources of variation and we opt for the design optimization and then we refer to the product design again we refer to the process design. So, here on this the domain will be using the Taguchi method, and obviously when you refer to the online quality control we refer to the process control.

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So, we conclude these sessions. We will be referring to the next topic in the next session.