Product Design and Development

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Lecture – 13
Robust Design and Design for X (DFX)

[FL] friends, welcome to lecture number 3 in week 3. And we are today going to discuss the basic concept of robust design and design for X. But before we start our discussion a lecture number 13 overall and lecture 3 of week 3, let us have a brief overview of what we have discuss till today.

So, we have tried to understand the product design process as well as have tried to learn certain skills tools which are helpful to us in the design of a product. If you remember I or I can give it as an exercise that in the last 12 lectures name or list any 3 to 4 tools that you have learnt in the course of the lectures. So, we have already had twelve lectures and we have already learnt certain application based tools which are useful during the design process.

So, right from understanding the voice of the customer or the need of the customer and trying to relate it to the technical requirements of the product we can all technical functionality of the product, we can see that we can design a product using certain softwares which we have seen in computer added design. We have also learned that tool called value engineering in which we have learnt a specific technique called DFMA that is designed for manufacturing and assembly.

And if we go back we have seen in product development concepts that is the number one or product design and development concepts that is week 1 we have learned the product life cycle, we have learnt that what is the product design process, and we have also learned that what are the characteristics that we need to take into account when we analyze the product.

So, right starting from the market survey to the analysis point and finally launch of the product in the market there are different stages and at in every stage we need to understand that how scientifically we can think about the product, how logically we can think about the product, how we can think about the product a from economic point of

view, how we can think about the product from mechanical engineering point of view, how we can think about the product from production point of view.

So, it is a complete we can say overall total picture and we have to see it in bits and pieces and then combine these bits and pieces in the form of a successful product. So, it is not a one man job or a single person job who can design a successful product. It requires inputs from various sources, and when these sources in information combines together it is able to culminate into or the efforts of so many individuals are finally culminated into a tangible or a successful product. So, let us now see today another aspect that is the robust design.

So, some of you may be wondering that we are discussing. So, many different tools, but the overall objective of these tools is to make a sound design, to make a successful design, to make a design which is acceptable to the customer, to make a design which is acceptable to the market. So, our overall effort, for example we can say take an example from the value engineering background the fast diagramming approach, the computer aided design, the quality function deployment, the product life cycle, all these are tools which will help us in the successful design of the product. So, each of them is interconnected and this overall knowledge about the concept will help us to come up with the successful product design.

And in that series we can now think of discussing robust design that now till last 12 lectures we have seen that how the ideas can come, how to nurture those ideas, how to segregate those ideas, and then we have seen that how we can achieve the function we need to have different alternatives, then we will select one or two alternatives. When our alternatives are ready we will gave give them some shape that can be done using cad software in which we can do the geometric modeling or the drafting.

So, we have now a shape ready with us and we have to see that when this product will be launched in the market, what type of condition it is going to undergo. And then we have to see that its performance should not get affected because of certain factors. So, we will now see that how we can make our product robust that it is able to perform under different types of operating conditions. So, robust design basically is a design which is not influenced by the different parameters through which it is subjective, so we subjected.

So, when we are designing a product we have to insure that it is uninfluenced, it is independent of the various parameters that may affect its performance. And that we will try to understand with the help of example. So, once the design is ready we have to incorporate all these things that are relate to the performance of the product. Right now we were focusing on the functionality, we were focusing on the shape, the size, we were focusing on the colour. So, we have seen so many different parameters related to a product design.

But now we will focus our discussion will slightly move towards the second part that is once the product is launched in the market how it will perform. So, its performance we have to foresee and we have to design it in such a way that it is able to perform its functions properly or its able to deliver the requirements for which the customer is going to buy our product. So, for that we have to see that what are the tools and techniques that we should keep in mind so that the product delivers when it is called upon to do its intended job or intended function.

Moreover, we have also to ensure that when this product is fabricated it is assembled, it is manufactured the cost should not increase exorbitantly high so that the product loses its competitive advantage in the market. So therefore, we have to see that how all these parameters are important how to control this parameter so that our product is successful or is successfully launched in the market. So, all these things have to be taken into account during the design stage only.

So, this is the slight background that the our audience or everyone who is attending this course is able to correlate that we are not discussing topics independently all these topics are integrated into one common thread that is the product design and development. Now let us see that how we can make our product robust and what do we mean by a robust design.

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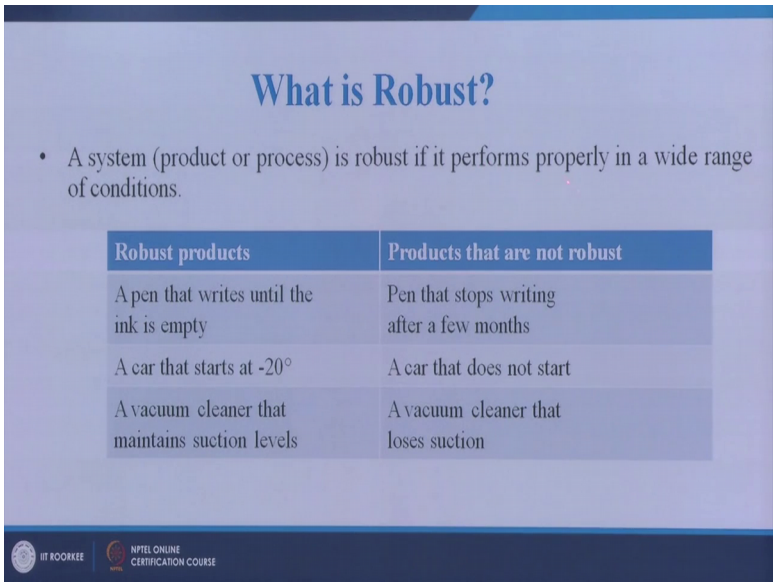

Now a system, in our case it is a product is robust if it performs properly in a wide range of conditions. So, robust means it should be able to sustain under different conditions. Usually we say is a I as got a very robust body which means that the effect of temperature and humidity and sweating and little bit of cold does not affect his body. It means, the body is insensitive to changes is in all these conditions or all these environmental conditions.

So, the robust body usually we say sometime for automobile also we say that that particular automobile has got a very robust body. So, robust word from we can say literal meaning is maybe strong and study and it is not influenced by the variations or changes in the parameters. So, a product is robust if it performs properly in a wide range of conditions.

So, let us take some examples of robust products. A pen that writes until the ink is empty is can be considered as a robust product. But if the pen stops writing after a few months still ink is there in the product we can also say that this product is not a robust product. This can also be related to the concept that we have already discussed during our product analysis stage where we have seen durability, dependability, reliability. So, these parameters can further be correlated to these parameters. Maybe this particular example can be given for durability dependability also.

A car that starts at minus 20 degree centigrade can be said as a robust design why, because it is not getting influenced by the temperature which is subzero temperature. But a car that does not start at this temperature we can say is not a robust design; because it is we can say influenced by the very low temperature. Then a vacuum cleaner that maintains section levels can be said as a robust design or vacuum cleaner that loses the suction can be said as is not a robust design.

So, these are just illustrative examples to understand that what we can call as robust. So, we can call up designed robust if it is not influenced by the parameters or the uncontrollable parameter. There will we some parameters which we can control, but our products should be such that it should be able to sustain different types of parameters. It should be insensitive to the variations in the various types of parameters in on a broader scale.

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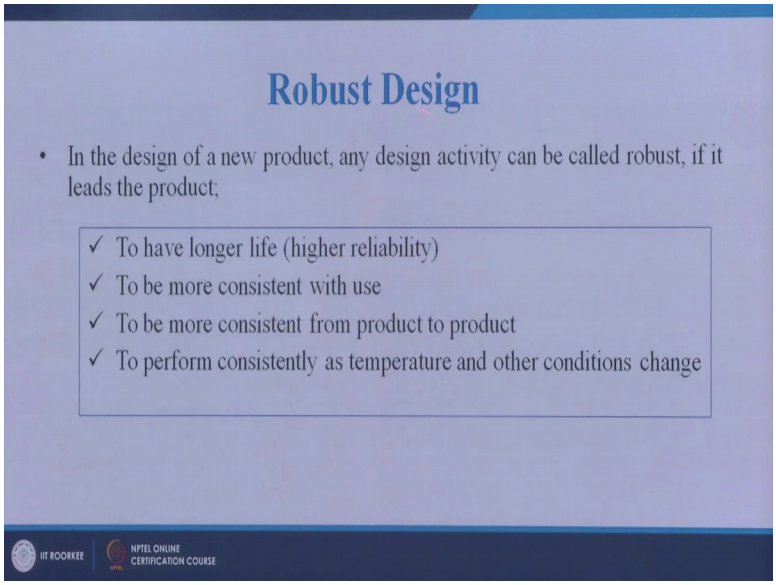

So, we will try to understand what do the robust design take into account. In the design of a new product any design activity can we called robust if it leads to. Now we have to see that how we can design a robust product, we have to ensure that it has a long life. As I have already told in the example of a pen it can also be related to reliability which we have already discussed in product characteristics.

It should be consistent with use it should not happen that maybe after a specified period or after a specific time the products starts to disfunction. So, that has to be ensure maybe

it has to perform consistently. To be more consistent from product to product, so there should be consistency level of performance for different product. For example, a company is manufacturing shoes. So, each product or each different product coming out from the company should be consistent in quality and performance.

To perform consistently as temperature and other conditions change; that example already we have taken of a car that if it is able to start at minus 20 degrees centigrade we can say yes it is a robust design. So, it is not getting influenced by the change is in the temperature.

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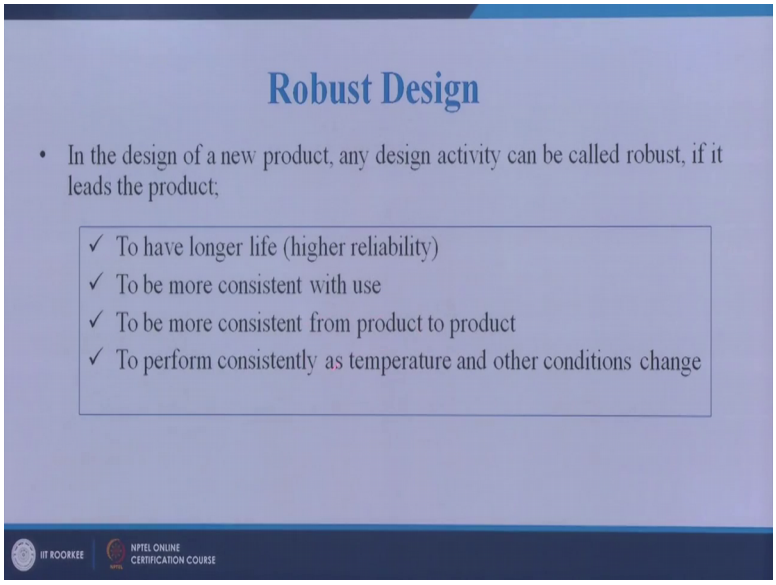

So, it should perform consistently under wearing condition. So, we can say we have to incorporate in our product all these characteristics. So, that the product performs robustly.

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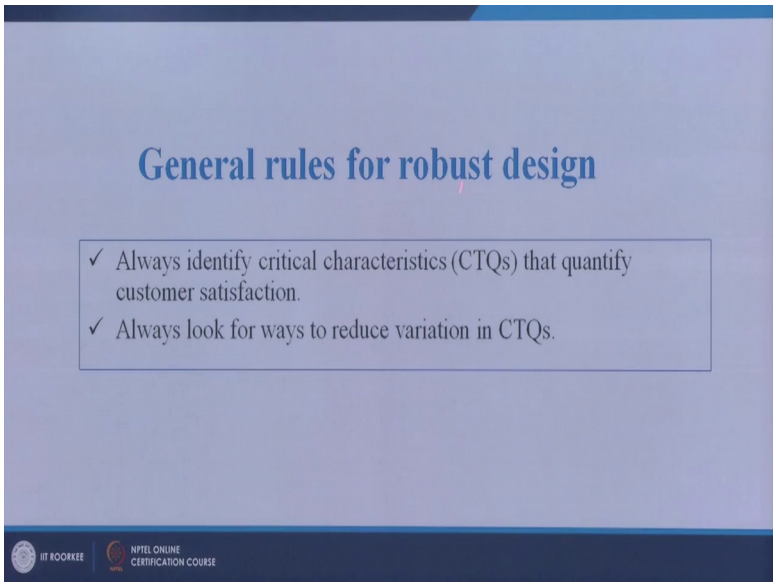

Now general rules for a robust then how we can ensure that the product will perform in a robust manner.

Now, let us see always identify critical characteristics that quantify customers satisfaction. Now let us take an example of a shoe. What can be the customer requirements from a shoe? First thing is it should be comfortable to wear, for some customers it can be it should we light in weight, then it should be pleasing to the eyes; so maybe these are the two or three important customer requirement from a pair of shoes. So, we have to identify that what are the critical characteristics and then we have to ensure that all these critical characteristics are met, so that the product is robust. So, always identify critical characteristics that quantify the customer satisfaction. And then always look for ways to reduce variation in these critical characteristics.

So, for our robust design point of view if I am buying a pair of shoes and my critical characteristic is that they should be comfortable to wear. Now maybe after 6 months or after 7 month suppose the I find them uncomfortable or maybe itching or there can be other problem that they have become loose, I will say no they are not very comfortable shoe and the designer has not incorporated the concept of robust design into the shoe. Why, because it is changing with respect to time. In many other cases there with the design may perform poorly because of the environmental condition, sometimes with respect to time, sometimes with respect to other factors which are beyond the control of

the customer. So, we have to ensure that the product that we designed should perform reliably with the duration for which it has been designed.

So, in order to incorporate that we have to see that what the customer wants and that think should not be compromised, maybe over a period of time or under a specific set of conditions. Like we have taken the example of a car in which we have seen the car should start even at minus 20 degree centigrade also and it should start at may be plus 47 degree temperature also.

So, this variation of temperature should not affect the ignition of the car or the starting of the car. And if that if the design ensures that it means it we can call it as a robust design.

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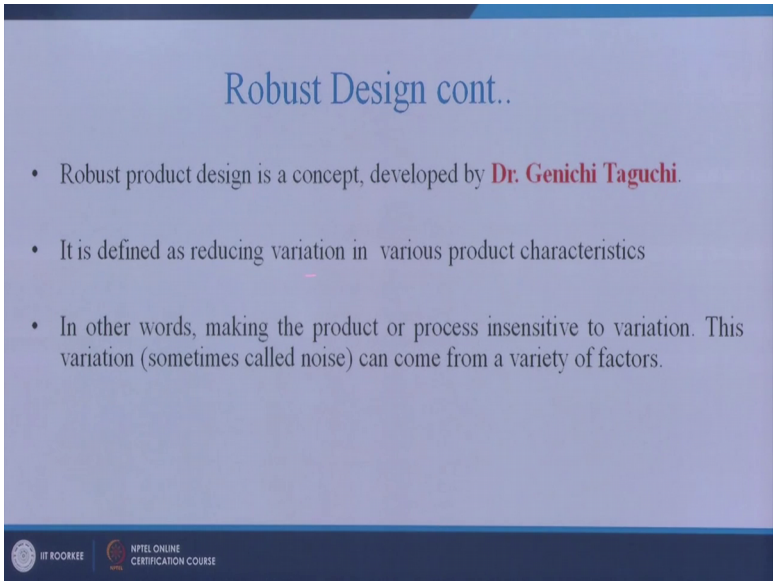

Now, let us see the robot design in detail. Robust design is a concept developed by Dr. Genichi Taguchi- Taguchi is methodology I think is important for every engineer. It is defined as reducing variation in various product characteristics. So, the variation because of which the product may become unusable that has to be reduced. In other words making the product or process insensitive to variation; so we have to ensure that at variation should we minimized or the product performance should be consistent independent or insensitive to the variations; that we have to ensure. This variation can come from a variety of factors, sometimes there are called as the noise factors also. We will see that what is a noise factor and what are the controllable factors.

So, let us further take the classification of the noise factor.

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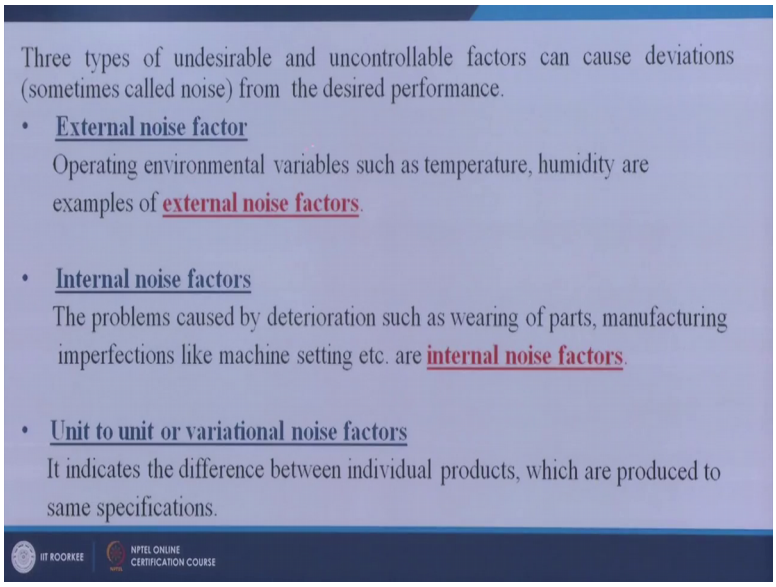

You can see three types of undesirable and uncontrollable factors can cause deviations from the desired performance. Now these are called different types of noise factors. Now first one is external noise factor, operational environmental variables such as temperature humidity are examples of external noise factors; example already taken. Internal noise factor the problems caused by deterioration, such as wearing of parts, manufacturing imperfections, like machine settings extra are internal noise factors.

Now, a in internal noise factors we can say that suppose we are machining a shaft and we are using a single point cutting tool to turn the shaft. Internal noise factor can be that over a period of time the work holding device and the tool holding device has worn out and there is little bit of movement between the two land the work peace which is spoiling the surface finish of the product.

Now, because of this wear and tear of the work holding and the tool holding fixture we are not getting the desired performance. Under ideal conditions or a new machine the tool and work piece would have been absolutely at their place and the performance would have been consistent and we would have got the desired level of surface finish, whereas with the worn out parts we are not getting the desired performance. But since the parts are worn out they may not be in our control why because this would be one of the outputs that a surface finish is not good.

And then we will see what can we the variations. And sometime this variation may not come to our mind also that the surface finish is poor because of the wear and tear of the machine elements. And therefore, we can say that they sometimes turn out to be the noise factor or the random variables or the uncontrollable factors.

So, I think external noise factor temperature example already taken, internal noise factors and unit to unit or vibrational noise factors it indicates difference between individual product which are produced to same specifications. Now suppose taking a simple example I have to travel from Roorkee supposed to Delhi by bus. Suppose I go ten times every time there will be a difference. The journey remains same, the distance is same, the mode of transport is also bus, but because of the parameters number of parameters like the traffic or the fog or we can say some traffic jams or some accident on the way; so because of so many uncontrollable parameters which are beyond my control the time will always be different.

And all those the type of variations can be indicated. It indicates the difference between the individual products. In my case it is a journey from Roorkee to Delhi which are produced at the same specification. Specifications remains same: I go by bus, I start at the same time, maybe 10 clock in the morning from Roorkee, but my reaching time at Delhi will always vary all other factors remaining same. So, that difference can be explained by the variations which are uncontrollable variations or noise factors.

So, basically as a product designer I should always or I must always ensure that the product is consistent in its performance and is not affected by the variations in the noise factors.

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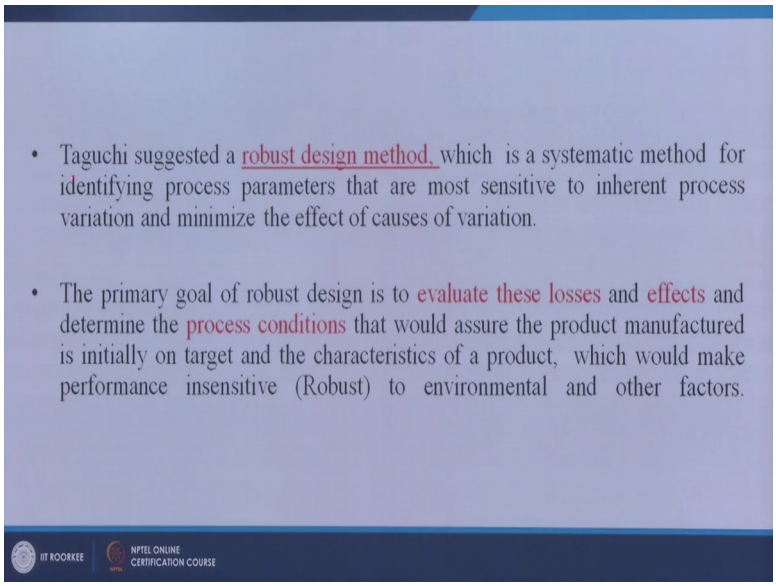

Let us see now Taguchi: doctor Taguchi suggested a robust design method. What is that robust design method? It is a systematic method for identifying process parameters that are more sensitive to inherent process variation and minimize the effect of causes of variation. So, we have to identify the process parameters that are more sensitive to the inherent process variation. And try to minimize the effect of these parameter. So, that the product is consistent in its performance.

The primary goal of the robust design is to evaluate these losses or maybe to find out these losses because of the noise factors, and determine the process conditions that would assure the product manufactured is initially on target. And the characteristics of the product which would made the performance insensitive to the environment and other factors. So we have to see, we have to ensure that the product manufactured is initially on target. So, first we have to ensure the quality of the product and the characteristics of the product we have to ensure which would make performance insensitive. So, the performance becomes robust, it is not sensitive to the variation of the noise factors. Those row noise factors can be environmental or other factors.

So, I think this I have already sentence or these two sentences I have already summarized in a single sentence only that as a product designer we need to ensure that our product is insensitive to the variations of the noise factors. And if we can ensure that then the

product becomes acceptable, the product becomes successful; the product is appreciated by the customers who are going to use that product.

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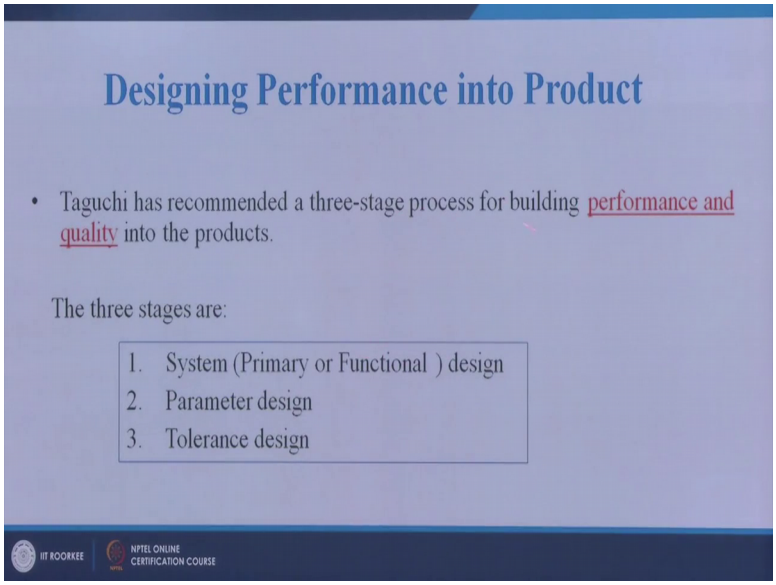

Now designing performance into product: we can see how we can ensure that the product can be made robust. Let us see the Taguchi is recommended three stage process for building performance and quality into the products, in totality making the product robust in its performance. The three stages are system level, parameter and the tolerance design.

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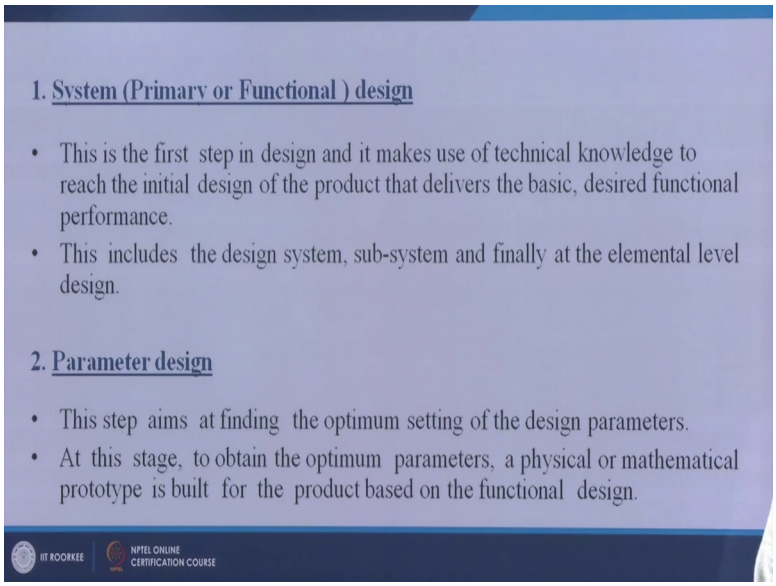

Now, let us just read this and then I will try to explain this with the help of an example. So at system level: already we have seen the functional design. We have already engaged week two one value engineering and functions we have discussed in much more detail. So, I will not go to functional design again, I will try to explain this with the help of an example. So, this is the first step in the design and it makes use of the technical knowledge to reach the initial design of the product. So, at this stage we will only go to the initial design of the product that delivers the basic desired function performance.

So, first thing is the basic functional design of the product. For example, the if you have use the table lamps which were used for studying during the orders or maybe when combine, there are roommate sharing a room, everybody live the table lamp to study. So, that table lamp a functional design was a simple design two links a holder and a bulb there, but now you see the design of the table lamps there are so many varied designs available we aesthetically well designed, functionally well designed.

So, first step is to ensure the basic functional design of the product. This includes that designs system subsystem and finally the elemental level design. So, this I have already told for example: the bridges that we see in India most of the bridges are the basic functional bridges only and ensuring that the traffic can pass over the bridge. But if you see at a higher level you will see certain bridge designs which are not only functional, but aesthetically also pleasing and maybe sometimes maybe having additional functional functionality also.

So, first design level is the elemental level design or the functional level design, second is the parameter design; this is step aims at finding the optimal setting of design parameters. At this stage to obtain the optimum parameter a physical or mathematical prototype is built for the product based on the functional design.

Now, next stage would be the setting up of the parameters: the specifications of the product, the size, the shape, and other parameters will be finalized at the parameter design stage.

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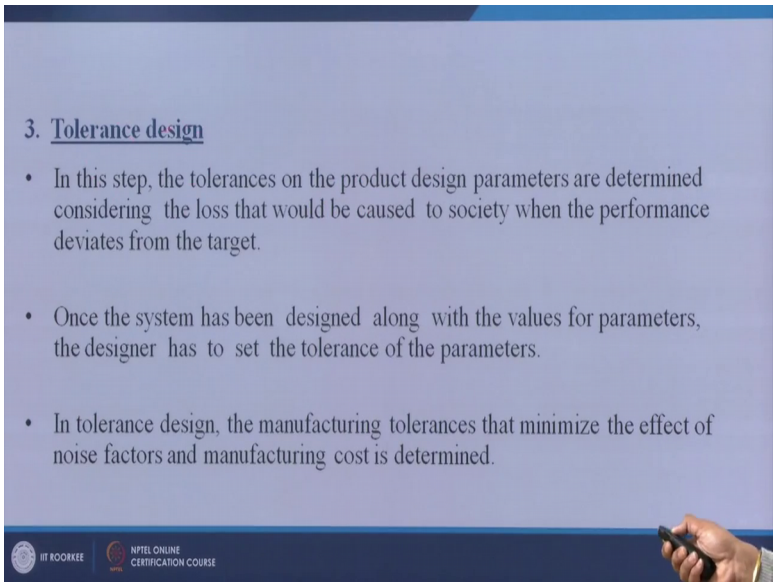

And the last stage is the tolerance design. In this step the tolerances on the product design parameters are determined considering the loss that would be cause due to society, caused to society when the performance deviates from the target. So, right going from the society because cause to the customer when the product will not perform its function reliably.

Once the system has been designed along with the values of parameters the designer has to set the tolerance of the parameters. So, we will see that at what range we have to set the parameters. In tolerance design the manufacturing tolerances that minimize the effect of the noise factor and manufacturing cost is determined.

So, there are two parameters here; manufacturing cost is one parameter and the effect of noise factors is a second parameter. So, when we are setting the specifications of the tolerance range we have to ensure that the design is insensitive to the noise parameters. So, insensitive maybe you know what is insensitive that it is not affected by the noise factors. So, these are the two things that need to be ensured during the product design process, when we are ensuring that the design is going to be robust. So, manufacturing cost as well as the noise factors.

Now let us take an example of a water bottle to explain these three points. That is system level, parameter level, and the tolerance design. Little bit confusing, but let us try to understand it with the help of a design of a bottle. At the first stage that is the systems

stage we will see that we have to design a bottle. What is a functional requirement of the bottle? We can say verb and a noun carry water or carry liquid it is not that only water velvet can carry maybe sometimes we use the same plastic bottle for bringing oil or petrol. So, we can say for a bottle the functional design is carry flute or carry liquid.

Now, the first part can be functional design. Now the second part that is the parameter design we need to ensure what will be the exact shape of the plastic bottle, what will be the colour of the plastic bottle, and then what would be the capacity of the water bottle or the fluid bottle. So, we have to ensure all these parameters for the design of the product.

So, first stage is concept design or the functional design that is it has to be able to carry the flute, second is that it should be able to carry a specific quantity of flute, it should be able to look good, it should have a specific shape, it should have a shape which can we held very easily. So, that is a parameter design. And at last stage that is a tolerance design we will see that if it is manufactured what can be the tolerance given to the mould in which it is being manufactured so that it is consistence with the performance. Performance means it is supposed now to carry maybe one liter of the liquid. So, it should not happen that the die is designed in such a way that it is only able to carry instead of 1 a liter it is able to carry less than maybe a 2 percent or 1 percent less liquid as compared to the actual design.

So, we have to insure second may be a tolerance design stage we have to see the when the bottle has to be closed by the cap the threads inside the cap and on the outer periphery of the bottle are consistent to each other. And follow the concept of interchangeability which means that this bottle any sample from the bottle and any sample from the cap should be able to assembled to each other. So, that is a concept of interchangeability. So, we have to set the tolerances in such a way that the performance of assembly of this bottle and the cap is done properly and there is no error in that particular thing.

So, from the functional design to the parameter design to the tolerance design this will ensure that the product is robust and it achieves its target for which the product has been designed. So, if we are not taking account at each stage the concept of robustness sometimes at a later stage the product may face a problem. Sometimes it may so happened the bottles that we are producing are not to the required size and in some cases

the quantity is more than 1 liter, and in some cases the quantity is less than 1 liter. And then your overall you can say authority or is challenged or overall authority in the market for that brand it gets challenged. So, it is always advisable that we should ensure robust design of the product.

Now, this is simple example very quickly I will go through this example.

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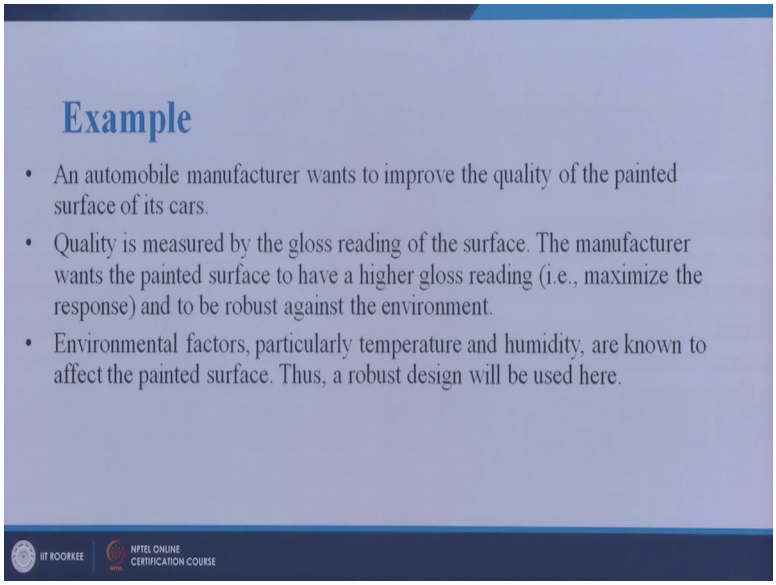

An automobile manufacturer wants to improve the quality of the painted surface on its cars. So, there is a automobile company, there is a paint on the car, the quality the manufacturer wants to ensure that the quality should we excellent. The quality is measured by the gloss reading on the surface. So, there is a instrument which measures the gloss reading on the surface. The manufacturer wants the painted surface to have a higher gloss reading; which means that the instrument that measure the gloss reading it is expected that the maximum gloss reading should come in order to ensure the quality of the painted surface. And to be robust against the environment; so it should be robust against the environment over a period of time it should not get influenced by the environment.

The environmental factors particular temperature and humidity are known to affect the painting surface. Thus, a robust design will be used here. Now you we have to ensure that even if the car is parked in the open or it is subjected to the temperature or direct sunlight the surface should not get influenced.

Now, what are the parameters that we can control? We can control few parameters.

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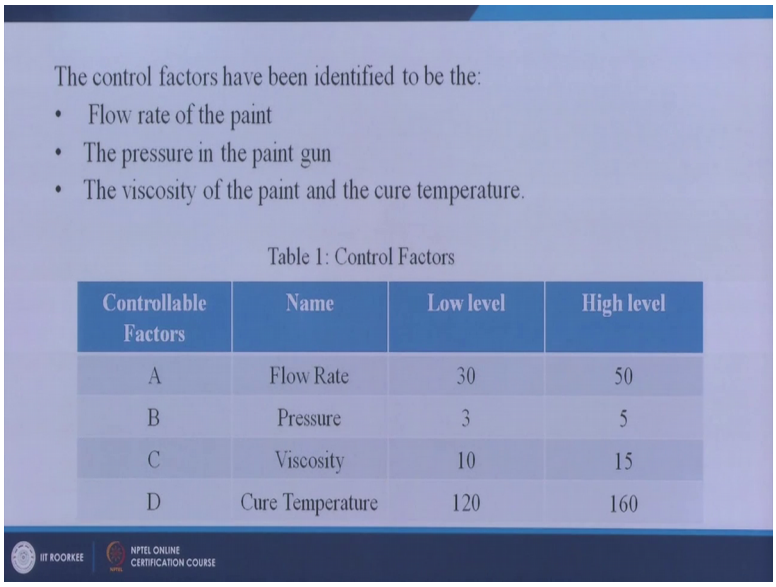

Now while depositing the paint on the surface or on the body of the car we can control the flow rate of the gun, flow rate of the paint, we can control the pressure in the paint gun, the viscosity of the paint gun and the cure temperature. So, these are the four parameters that we can control in order to deposit a paint which gives us the maximum gloss reading.

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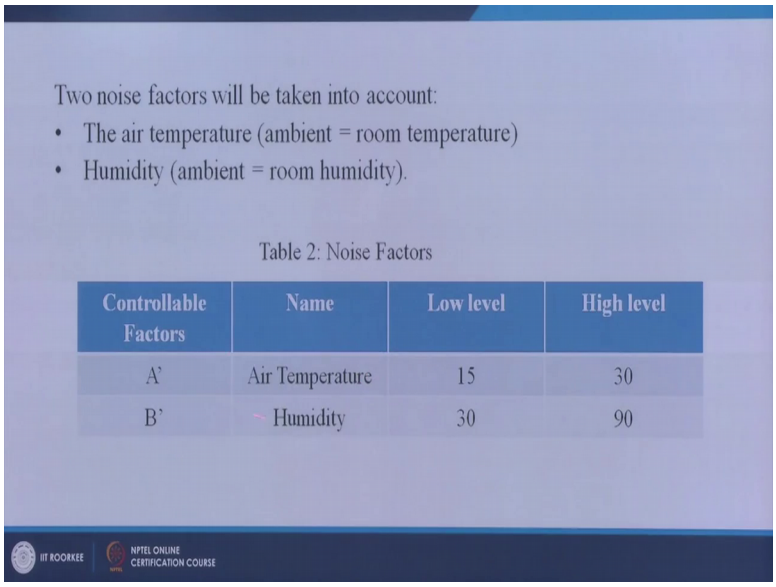

But there are few parameters which are out of our control that is the temperature and humidity for depositing the paint on the surface. Now, four parameters are within our control for depositing good quality paint on the surface of the car body, but there are two parameters during the process which are beyond our control. So, in order to improve our process what we can do? We can control these two parameters also by making our paint shop air conditioned, so that we can control the temperature also, we can control the humidity also, but currently maybe the manufacturer who is using a paint shop may not be able to control these parameters.

So, if the parameters are beyond the control we call them as the noise factors if it is a air conditioned room we can control air temperature and humidity also, they also become the controllable parameter. Then if there is a variation in the paint during service it can be because of certain other uncontrollable parameters which can be the bonding between thus paint and the body it can be certain parameters which are random in nature, which can be anything ranging from the skill of the worker to maybe the addition between the paint and the body.

So, different parameters can be there which are right now may be beyond our control, but if with proper investigation and results can be brought into control. But as a product designer my aim should be that I have to ensure a design which is robust in nature, which is insensitive to the noise factors and it delivers when it is called for to deliver the intended function for which the design has been put into place.

So, with this we come to the end of our lecture number 13. And I have tried to just introduce the concept of robust design with the help of an example. We have tried to understand that there are few controllable parameters which we can control, there are few uncontrollable parameters which we cannot control, and our product or process should be designed in such a way that it is insensitive to the uncontrollable parameters or the noise parameters.

In next lecture we will start our discussion from design for manufacturing and design for assembly. We will see what is DFX, and where do DFM and DFA fix into or fit into the concept of DFX.

Thank you.