Manufacturing Guidelines for Product Design

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Lecture-11
Robust Design

Namaskar friends, welcome to the 3rd week of our discussion on the course on manufacturing guidelines for product design. Just to have a brief review of what we are covered in the 1st 2 weeks, in week 1 our focus was primarily on understanding the need for such a course and understanding the various terms that made the course that is manufacturing, then guidelines.

In context of the product design we have tried to see that how this course is different from the courses which are already under way or the courses of the books which are already available. So we have tried to understand that a product designer must have fundamental knowledge about the manufacturing processes and therefore this course was conceptualized and is being afford to the participants or the learners or the students who wish to become product designers or who are studying the course of product design.

So that they are able to equip themself with the fundamental information or the parameters that they must keep in mind while they are designing their products or they are coming up innovative ideas regarding products. So we have tried to understand the basic concept related to manufacturing, the classification of manufacturing processes, we have tried to understand the process capabilities of the manufacturing processes.

Then in week 2 our focus shifted to materials because the product is going to be made up of the materials. So the material basically we have classified them, we have tried to see the special characteristics of the materials and then we have tried to understand that what are the major applications for the engineering materials. We have tried to understand the material from different perspectives like from the application we have seen that where polymers are use.

What type of products can be made by polymer, what are the special characteristics of the polymers, then we have seen ceramics, we have seen composites, so basically we have by

now understood that materials and manufacturing play a vital role in the life of a product designer or in the life an engineer, so therefore there is a need to further discuss that once you have an idea how to realise that idea.

What are the various parameters that you have to keep in mind when you are designing a product and in that line today our topic is robust designs, so let me give you a brief overview of the discussion for week 3, as we already revised in week 1 we have covered related to manufacturing and the fundamental aspects of the course. In week 2 we have covered materials, in week 3 we will try to learn tools and techniques.

The guidelines, the procedures that are used for designing a product and then there after our focus will primarily be on the specific guidelines, special guidelines which have to be taken into account when we are designing a product. So these guidelines are related to manufacturing, that once you decide that the product has to be made by machine then what are the various guidelines.

What can be the maximum length to the in relation to the diameter, what can be the fillet radius that you can easily give. So those kind of guidelines we will try to establish already they are establish they are available in the book but we will try to compile from different sources and present them to the learner. So that you have an idea that is the product is going to be made by machining.

What are the guidelines to be taken care of during the design stage, if the product is to be made the casting process, what are the guidelines that we must take care of while manufacturing as well as while designing. So while designing we can design the product and then during manufacturing whatever special characteristics or whatever special needs requirement or we can say procedure that must be adopted must be outlined at the design stage only.

So while designing we may suggest that during manufacturing these are the special things must be taken into account, these are the special needs and requirements that must be taken into account in order to make a good quality product. So basically in this week our target will be to learn the various tools or to understand the basic concept of robust design. We will try to see that when we are designing a product.

And the product has to be made manually or the product is made in different parts and it has to be assembled together then what are the guidelines in context of the product design which must be taken care of. We will try to understand the very basic concept of design for manufacturing and design for assembly and in general I must say design for x or design for excellence.

We will try to see design for manufacturing and assembly guidelines as well as towards the end we will try to understand the concept of ergonomics. Now this week will be giving us a nutshell maybe 2, 2 and half hours of discussion related to the various tools and techniques that we must keep in mind when we are designing our product. Now what is the relevants of these topics in context of our title.

Our title is manufacturing guidelines for product design. So these topics are important because when we are going to make a product we need to understand that how the product is going to be assembled. Now assembly is a manufacturing process it falls under the broader umbrella of manufacturing. So we must know that when we are designing a product how it will be assembled.

We must know that when we are designing a product how it will be manufactured in general or how the manufacturing cost will be calculated, what are the basic principles of design for manufacturing, what are the basic guidelines or basic we can say steps for design for manufacturing, what are the basic guidelines for design for assembly. So what are the DFMA guidelines.

Although I must admit here that there are full fledged courses available on design for manufacturing and assembly, but for our course also when we talk about product design and we talk about the manufacturing guidelines for product design these topics are equally relevant why because in order to ensure a good quality product all these tools and techniques must be known to the product designer.

And if you, some of you may have done our earlier course also on product design and development where we have already discussed all these points because the course was dedicated towards the topic on product design. So here we will try to see the similar

presentation only but wherever possible we will try to address that how the materials and manufacturing is going to play a role in the decision making process during design for manufacturing during design for assembly.

There is a design for manufacturing and assembly and in today's session our target is robust design. So how we can input or how we can include or how we can put the concept of robustness in our product design and how manufacturing a materials are important or how manufacturing and material selection is important in ensuring the robustness of the product design that we are going to understand today.

So let us quickly now rush through the presentation whatever I think the basic concept is here that this week our focus will be to learn the important tools and techniques in context of a product design and try to relate them or try to relate them with the manufacturing as well as the materials. So let us quickly go through the presentation, let us first try to understand the word robust.

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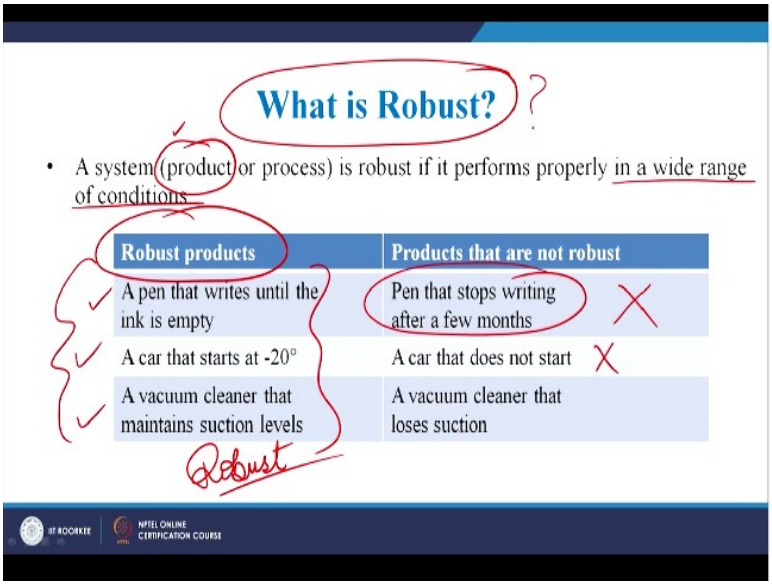

Now what is robust, let us try to see that, we will try to see the word robust first, what is robust?, question mark is already there. A system what we are talking about is here is the product, a product is robust if it performance properly in a wide range of conditions**,** so normally if you ask in a class that how you will define a robust product.

Many of the students will try to relate it with the strength, with the toughness of the product, that is the product has good strength it is called robust, no that is not right definition of the

word robust, robust means that the product is insensitive to the variations or it is not sensitive to the variation or the wide range of conditions. Examples are given, what are the robust products let us see.

A pen that writes until the ink is empty, now suppose we have bought a pen, it has got ink cartage and then we are using it by the time the ink is over, the pen is still writing, we change the ink again it starts writing. So we say a pen is robust, but a pen that stops writing after few months the ink is still there in the pen but it has stopped writing there is some problem with the may be the point of a pen or it is sensitive to the temperature the it.

Because of the extreme cold the ink has got frozen and n number of reasons it has not performed the desired function reliably, therefore the pen stops writing after a few months we will say the product is not robust. Similar examples are a car that starts at -20 degree, a car that has not start. So this is not a robust design because the starting of the car is sensitive to the variation.

Variation can be extreme cold condition, if it is insensitive that we will say product is robust, a vacuum cleaner that loses the suction, a vacuum cleaner that maintains the suction level, we will call all these products as the robust products. So how do we include this degree robustness in the products.

Now that will depend if I should take an example now whatever examples we have taken, materials and manufacturing will definitely will be an integral part in ensuring the robustness of the product because a pen that writes until the ink is empty. That means the nib or the point has been designed in such a way that it has lived the life for it which was designed. The material that was used for making that point or able to sustain that service conditions for the designed life.

So therefore we will say the selection of material is very very important in order to ensure the robustness of the product design. Similarly the manufacturing processes that were chosen we able to ensure that the product will perform its intended function till its designed life. So the manufacturing or the manufacturing process that is what that was used for manufacturing the product also will affect the robustness of the product.

So when we are designing a product we must be very very careful while selecting the manufacturing process as well as the materials that are going to be used for making or fabricating the product. I think the basic difference between robustness with a robust design and a normal design is now clear to all of you. Now on your screen you can see in the design of a new product.

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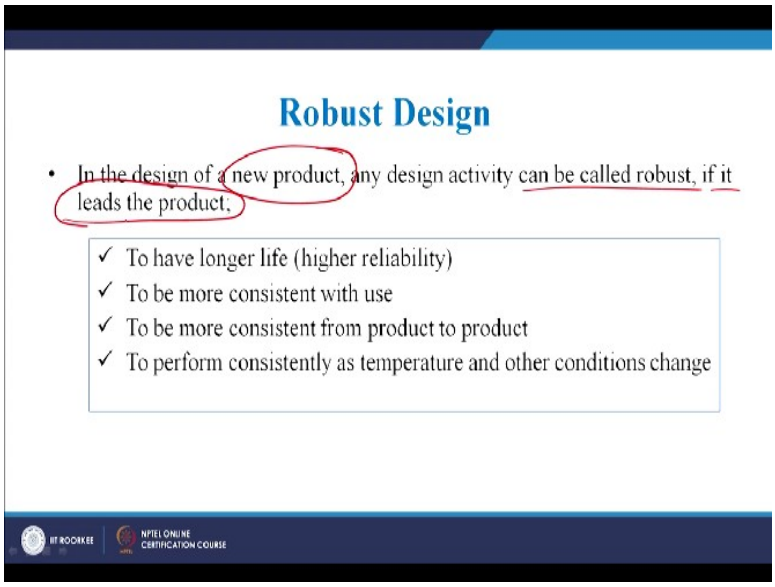

So as our course is related to manufacturing guidelines or new product, so when we are designing a new products any design activity can be called robust, if it leads the product. Now what is required in the product when we say that our design is robust, it must have longer life which was already the pen performs till its designed life to be more consistent with use it must not change the performance with time.

So it must be consistent the product performance must be consistent with use to be more consistent form product to product, so product to product variation must be minimum, for example suppose I am using x car or a x model of a particular company the other person has also bought the x model of a particular company. So the both models must be similar in performance.

So the product to product variation must be minimum to perform consistently as temperature another conditions change which we normally have seen in the previous slide also that the product performance must be insensitive to the variation in the conditions. So here the example is given as temperature and other conditions change. So if the conditions change the product must not detoriates in its performance.

So the performance must not detiorate and as we have seen in example that the car starts at -20 degree temperature also which means the product is a robust product is this not affected by the change in the conditions. So this is the basic we can say category or for basic criteria which must be taken into account when we call any product as a robust product.

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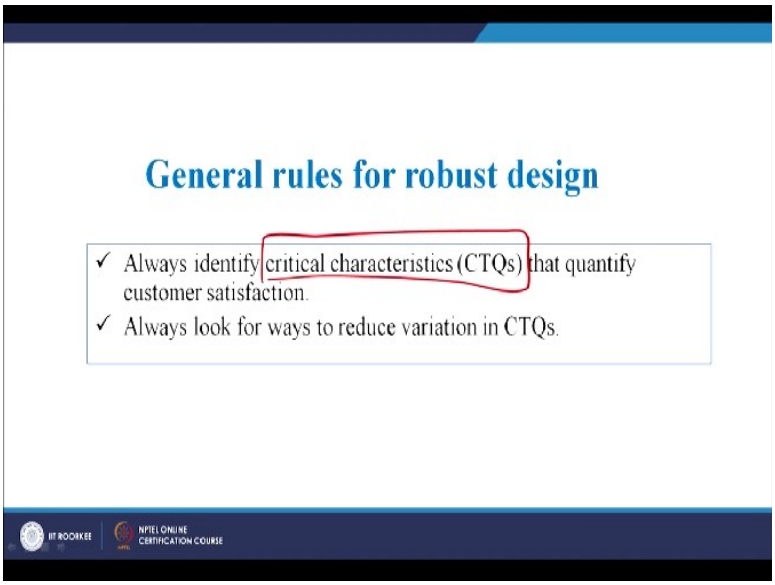

Now general use for robust design always identify the critical characteristics that quantify the customer satisfaction. So we need to identify the critical characteristics which will satisfy the customer for his needs and requirements. For example suppose I buy a new motor bike I wish that it must start all kinds of environmental condition or climatic conditions or we can say all kind of weather.

Now suppose it is extreme cold I want to start my motorbike and it is not starting I will say no the main critical characteristic for me was that the product must start or a motor bike must start under all kinds of conditions and it is not starting, so I will say no the product design is not a robust product design. Always look for ways to reduce the variation in the critical characteristics.

So we must try to maintain the critical characteristics of the CTQs that quantify the customer satisfaction. So if I have bought a product for a particular or to satisfy a particular function the product must satisfy that function reliably for the designed life it must not fail in-between and that has to be ensured by the product designer he must include or her must put into the product a fair degree or a high degree of robustness.

So that the product is not sensitive to the variations or the changes which are beyond the control or which are usually called as a noise factors. So let us see general rules I have already told that we identify the critical characteristics and try to maintain them.

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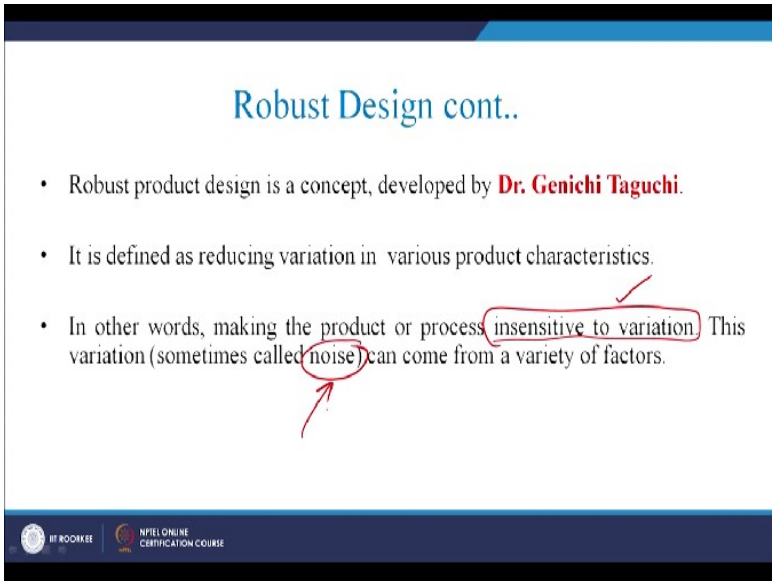

The robust design just a historical perspective is a concept which was developed by Dr. Taguchi it is defined as reducing the variation in various product characteristics, in other words making the product or process insensitive to variation. This word many times you will see in any good book on robust design if you read. We will say the product must be insensitive to the variation.

This variations sometimes called noise in the previous slide I have introduced the word noise also. So this variation is often termed as noise can come from a variety of factors. So difference products if you take the example different types of noise factors may be there. So it must not or the product must not be sensitive to these noise factors, it must perform its desired function reliably with minimum variation or I must say with no variation in its performance.

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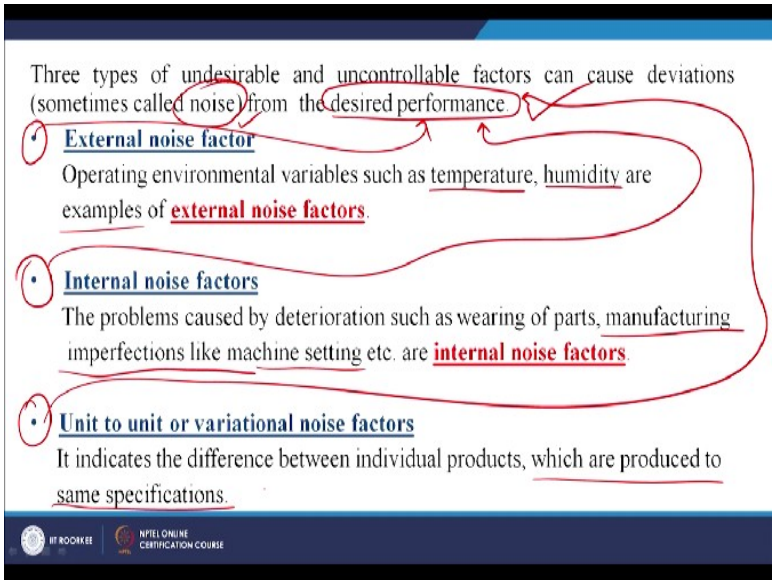

Now 3 types of undesirable and uncontrollable factors can cause deviations, in the previous slide we have seen that there are certain noise factors, which may vary form product to product. So 3 type of undesirable and uncontrollable factors can cause deviations and this is again the word noise is coming into picture here from the desired performance. Now desired performance is something which is designed into the product.

For every product there is a designed performance or for there are design specification. For example I am using this pointer for making of this stylus for marking on the screen. So therefore some performance indicators are there for this. Now suppose I have I move it and half of the time it is not pointing out at the text that I want to highlight I will say no this is not giving me the desired performance.

So 3 types of undesirable and uncontrollable factors can cause deviations. Now what are these factors, these can be external factors that affect our desired performance, there can be internal factors that affect our desired performance and there can be unit to unit variations which affect our desired performance. So all these factors affect our desired performance. Now what are the external noise factor.

The external noise factors like operating environment, variables such as operating, variables such as temperature, humidity are example of external factors. If you see example in the very second slide of our today's session a car does not start at -20 degree centigrade the product is not robust, a car that starts at -20 degree centigrade we will say the product is robust.

So what is the external noise factor, the noise factor is temperature, the temperature is affecting the desired performance of automobile. So that is external noise factors that there can be internal noise factor, the problems caused by deterioration such as wearing a parts, manufacturing imperfections like machine settings etc. are internal noise factors. So again you can see the word manufacturing imperfections is coming.

And the machine settings is coming into picture, wear and tear of the machines is coming in to picture. So therefore the manufacturing or the process of manufacturing is definitely going to affect the noise factors and these noise factors are going to affect the performance of the product. So the internal noise factors will also affect the desired performance and another thing is if you remember the robustness is not only in the product, in the previous definition we have seen a process also needs to be robust.

So this wear and tear sometimes may affect the process performance or the desired process performance. The process may be designed to produce the parts with certain degree of accuracy, certain degree of precision, but the wear and tear of the machine or the components of machine may affect the accuracy and precision of the process therefore affecting the desired performance.

So therefore the external noise factors may affect the desired performance of the product, the internal noise factors may affect the product performance as well as the process performance then the unit to unit or variational noise factors which I have already taken an example of a car 2 people buying the same model of same company there must not be any variation from unit to unit or from product to product.

It indicates the difference between individual products which are produced to the same specifications. Products are produced to the same specifications, so there must not be any variation between the product produce to the same variation. Although there is a concept of inherent process variability but that concept is a different concept from robustness point of view we do not want any variation from unit to unit or from product to product.

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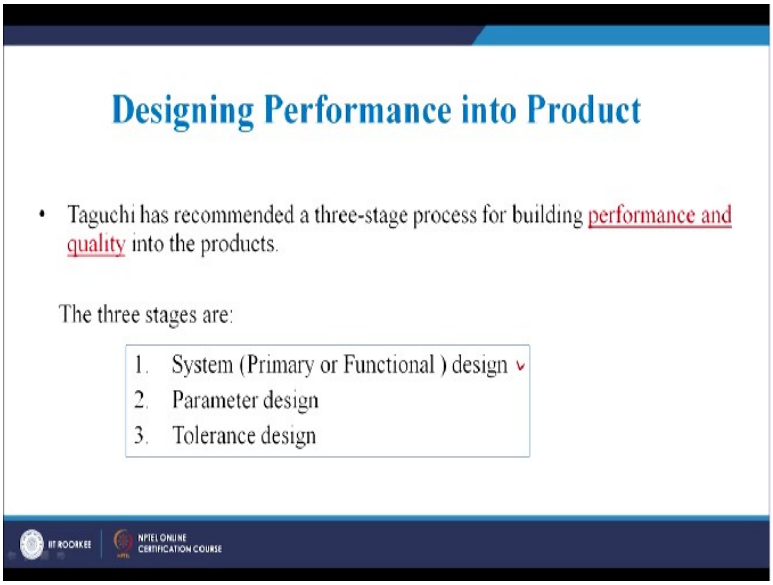

So Taguchi suggested a robust design methods which is a systematic method for identifying the process parameters so for any manufacturing processes or a fabrication process, process parameters that are most sensitive first thing is identifying. The process parameter that are most sensitive to the inherent process variation and minimise the effect of causes of variation. So the first part is we have to identify the parameter which are sensitive to the process variation.

And then we must try during our robust design methods to minimise the effect these causes of variation. The primary goal of robust design, the primary goal of robust design is to evaluate these losses and effects and determine the process conditions that would ensure the product manufactured is usually on target and the characteristics of the product which would be at the performance insensitive to the environmental and other factors.

So that has the primary objective or goal or aim of the robust design that we have to evaluate these losses and effects and determine the process conditions that would ensure the product manufacture is initially on target and the characteristics of the product which would make performance insensitive to the environment and other factors. So this is the basic objective or aim. So we must first identify it is given identify the process parameters which are most sensitive to the process variation.

Then we must determine the conditions, we must find out the conditions that will ensure that the product is giving us the desired performance or it is manufactured to the desired specifications which would make the product insensitive. So we have to find out those

conditions which will make the product insensitive to the variations because of the noise factors or the environmental factors.

Now how we can design performance into the products, now let us try to understand that as you have you seen the previous slide we have to identify the causes of variation, we have to determine the conditions which will ensure that the product is manufactured right at the very first time as per the specifications. So that it becomes insensitive to the noise factors or it becomes insensitive to the variations in the conditions.

So Taguchi has recommended the 3 stage processes for building performance and quality into the products. Now the 3 stages are system design, parameter design and tolerance design. So these 3 things must be taken into account for building the performance and quality into the product. Now let us try to see one by one what is a system level design, what is the parameter design and what is the tolerance design.

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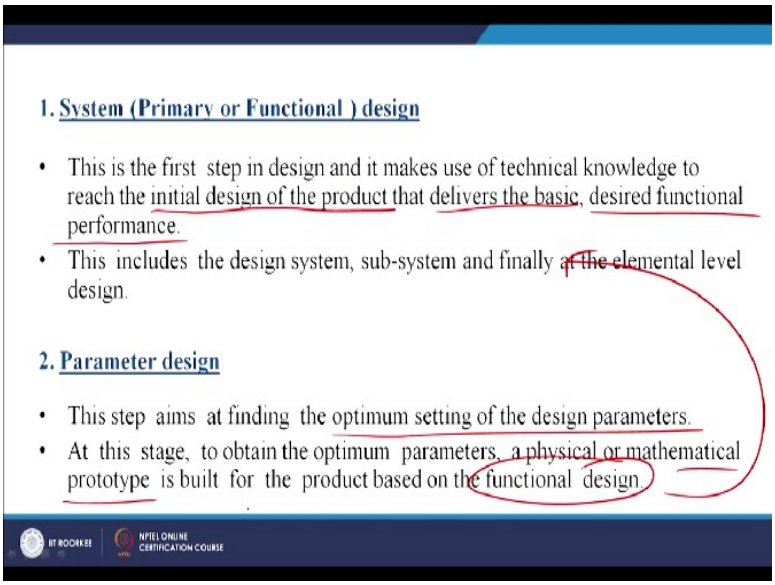

Now the system level design you can see primary or functional design, this is the first step in design and it makes use of a technical knowledge to reach the initial design of the product that delivers the basic desired functional performance. So that is the very first you can say type of analysis or types of design that is the initial design the functional design.

For example I must try to explain the word functional design, if you see the kind of bridges is that we have the basic function of the bridge is to provide a passage way of over up river or over up rivulet. Now you will see that the bridge mostly has a functional design only. There

will be on the 2 sides there will parapets and then may be at the centre you will have a span on which you can cross the river.

So that is the functional design of the bridge. Therefore in the system level design we will this is the first step in the design and we will use the technical knowledge to reach the initial design of the product and which will deliver the basic function or the functional perform, basic function is to provide a passage over a river in case of a bridge. This include the design system, sub-system and finally at the elemental level design.

So we offers the overall system design then the elemental design, the thickness and the height of the sideways and all those things or maybe there can be a side passage for the bike people who are driving the bike. So that those kind of elemental level design is done. So first one is the system level basic functionality design. The second one is the parameter design. This step aims at finding the optimum setting of the design parameters.

Now second is the optimum setting of the design parameters. First system level then we go to the optimising the design parameter, at this stage to obtain the optimum parameter a physical or mathematical prototype is built for the product based on the functional design. So the functional design already is done at the system level. Now we are trying to make a mathematical or a physical prototype for the product based on the functional design which is done at the system level.

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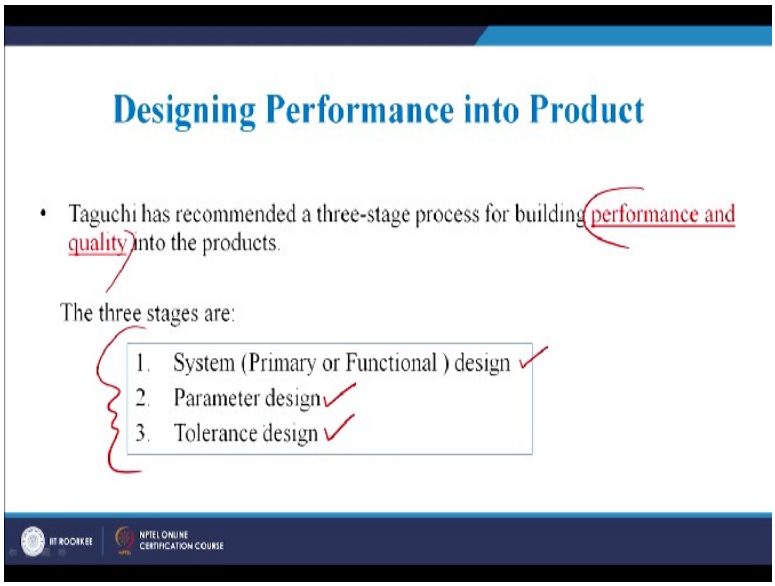

Then the tolerance design, in this step the tolerance is on the product design parameters are determined considering the loss that would be caused to society when the performance deviates from the target. And this is the most important point performance deviates from the target, this is what we have to avoid. So in this step in tolerance design step we will the tolerance is on the product design parameter determine considering that if the product deviates from the performance.

What kind of losses can take place, once the system has been designed along with the values for parameter the designer has to set the tolerance of the parameters. In tolerance design you can very easily see the importance of manufacturing. The manufacturing tolerances that minimize the effect of noise factors and manufacturing cost is determined.

So we will see the manufacturing tolerances and the manufacturing cost with an objective that we have to minimise the effect of the noise factors. So we will try to set the manufacturing tolerances that minimise the effect of noise factor and the manufacturing cost is then determined. So we can 3 level of analysis or 3 steps that we have to take again we can go and see that 3 levels are there.

So 3 stages are in order to ensure or in order to build performance and quality into the product, 3 stage process is there, the system level the parameter level and the tolerance design, the system design, parameter design and the tolerance design, that we have already see, so let us quickly have a example on automobile manufacturer wants to improve the quality of the painted surface of his cars.

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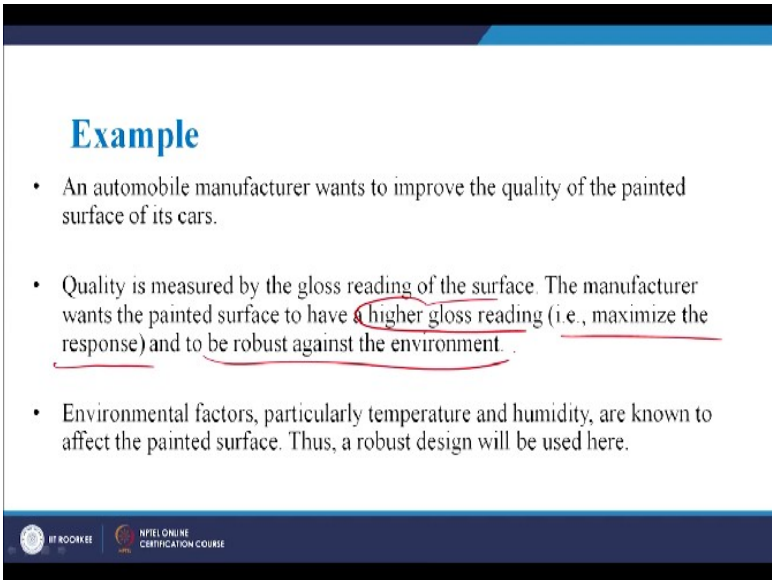

Quality is measured by the gloss reading of the surface. The manufacturer wants the painted surface to have a higher gloss reading that is maximize the response. So higher gloss reading which means you want to maximize the gloss reading and to be robust against the environment. So this the paint that the manufacturer wants must be robust, it must not affected by the environmental condition.

For example temperature, extreme temperatures or humidity, environmental factors particularly temperature and humidity are known to affect the painted surface. Thus a robust design will be used here. So we have to now ensure that how the product can be made robust that is insensitive to the environmental conditions in this case and environmental conditions are identified as temperature and humidity.

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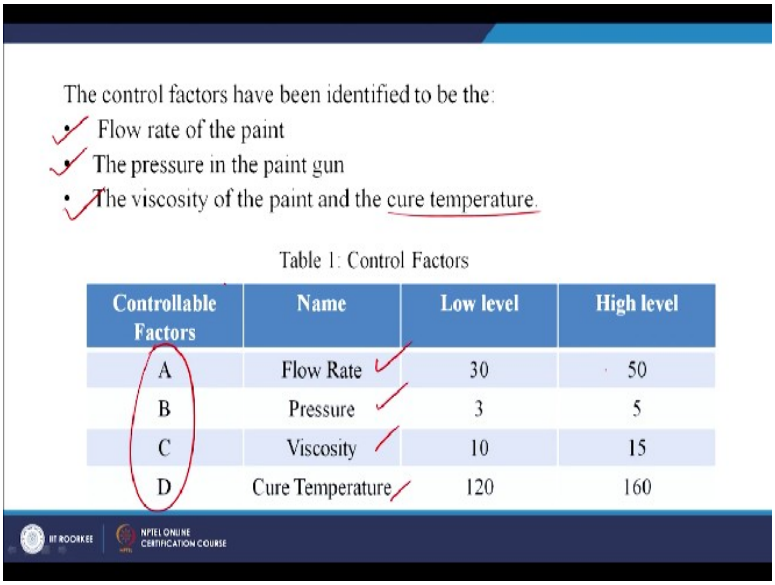

Now we have seen that what are the critical parameters that need to be taken into account as we have seen in the beginning of today's session, the control factors have been identified, so we must optimally select the flow rate, so we have seen that we have to select the parameters in order to ensure the desired performance. So that it is unaffected by the noise factor I think this sentence has been used 10 times in today's class.

So what are those bar crosses parameters the flow rate of the pain, the pressure in the pain gun, the viscosity of the paint and the cure temperature. Now all these parameters have to be optimised in order to deposit or in order to paint the surface of the car in such a way that it become insensitive to the variation in the noise factors that is a temperature and humidity in this case.

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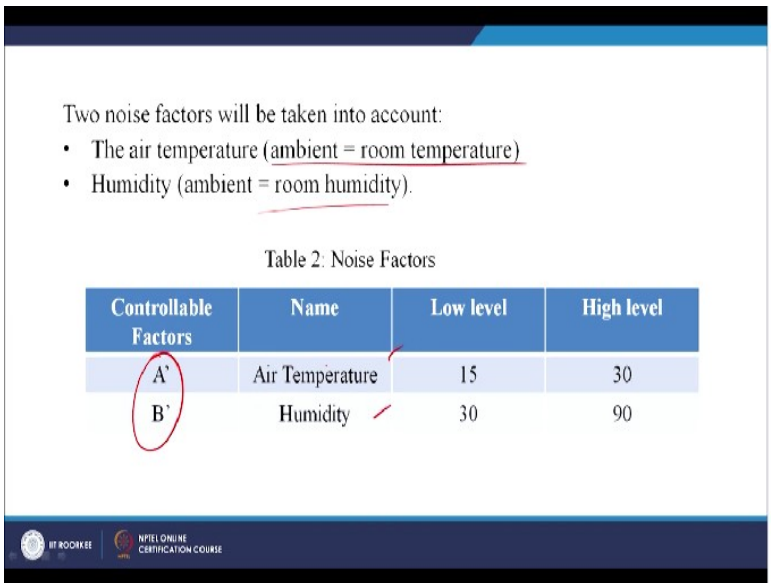

So these are the controllable parameters A, B, C, D flow rate, pressure ,viscosity and cure temperature and the values are also given sorry the units are not given here and then there are few noise factors also the air temperature which is must be room temperature, humidity may be the room humidity. So the the controllable factors A and B, air temperature and humidity must also be maintained.

So we have to ensure that when we are designing the parameters when we are selecting a parameter we must select the parameters in such a way that the products or the performance that is desired is not affected by the noise factors which are beyond the controls. So here these noise factors are there temperature and humidity. During the processing or during the putting up of the paint on the surface.

So that also we can we must control in order to minimise the variation when the car will be outside when it will be in use, when it will be in-services. So there are few control parameters, few noise parameters we must try to minimise this variation in the noise factor. So that the desired performance that we want to achieve is better achieved and the product that or the process that we are making robust or that we are trying to make robust is robust in context of variation in the various environmental factors or the noise factor.

So here we are trying to focus on whatever we can control, whatever difficult to control if difficult to control during the painting process that also we must try to control in order to minimise the variation that will lead to the change in the painting or the paint of the surface when the car will be in use. So these are the we can say basic concept of product design and here also you see painting is also manufacturing process.

So here how it is related to the robustness here we the example taken is that we have to select the process parameters, now here the example was the painting in some other case the example may be of machining in any other case the example may be of joining. So when we are selecting the parameters we must select the parameters we must categories the parameters it to controllable and uncontrollable.

And try to select them in such a way that whatever product or process that we are trying to design or to develop is insensitive to the noise factors or insensitive to the external conditions. So with this we come to the end of our very brief discussion on robust design, I think the basic concept of robust design is clear to all of you, in case of any doubt you can always write on the discussion board, we will try to answer the queries to the best of our abilities and in this week our target will be to learn all such concept that must be kept in mind while we are designing a product.
Thank you.