Design for Quality, Manufacturing and Assembly

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Lecture – 08
Linking Quality and Robustness

Welcome back to the lecture on Design for Quality. So, in the last class, we spoke about how to quantify robustness. So, no one of the matrix that we discussed was SN ratio. SN stands for Signal to Noise. As I pointed out in the previous class, the idea of SN ratio emerges from Electrical Engineering and the one who introduced it is Taguchi. Usually in Electrical Engineering, you need to compare two different signals. The way signals are seen, there is a mean signal and there is a noise around it.

So, if you want to compare two identical signals, then you will look for the noise information in that and it is usually delta as a ratio. So, the signal becomes the mean value and then, the noise is nothing, but the standard deviation or the rate at which their signal is varying. So, if you want a signal that has minimum variation in that, it means the denominator in the SN ratio will be less. This translates to the SN ratio being more. So, if you are comparing two different signals and your criteria is to have less noise, then you are looking for a larger SN ratio. So, that is the same concept that we are trying to use here to quantify robustness. One simplest way of looking at robustness in a single phrase that you would like to say is mminimize sstandard ddeviation.

So, we are trying to use a ratio as signal to noise. So, that noise is nothing, but your standard deviation and the principle of standard deviation is to, sorry the principle of robustness is to minimize the standard deviation which means for the same mean if you are going to have a lesser standard deviation then your SN ratio will be large. So, the idea of robustness would be to maximize my SN ratio. That is the whole idea of using SN as the metric for robustness.

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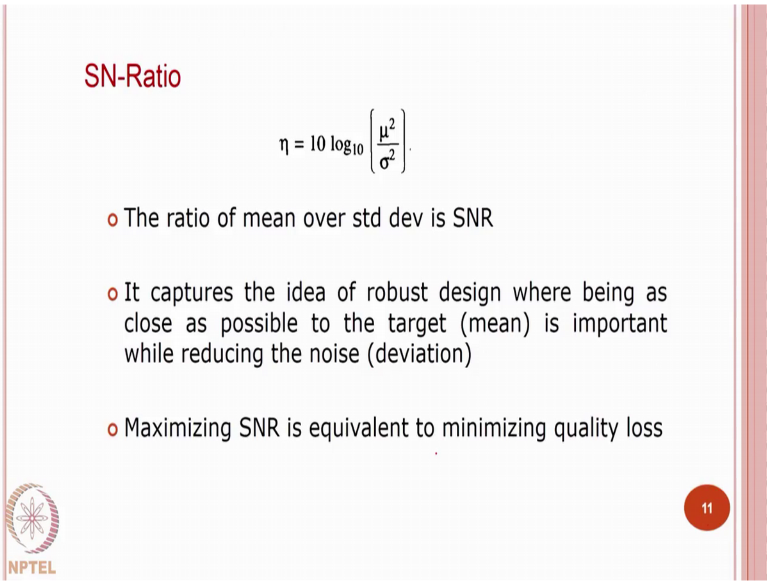

So, as pointed out here, the maximizing SN ratio is equivalent to minimizing quality loss.

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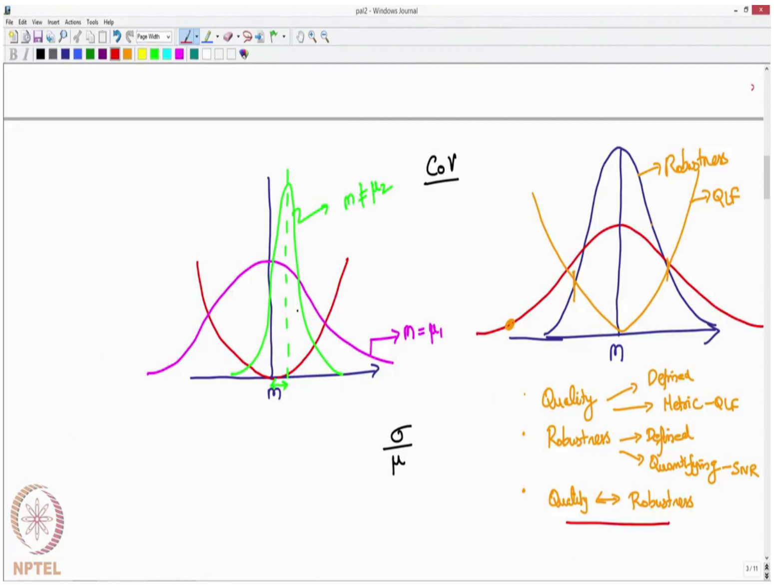

So, the other day we also started to look at how this quality loss function is related to robustness. So, you remember the Sony TV example? So, this is my target, M is my target and I would like to have my distribution as close as possible to this guy ok, compared to a fatter distribution.

So, imagine your loss function is like it is a quadratic function, right. So, what the loss function says is tries to stay as close as possible to your target value. The moment you deviate from your target value, the loss is, correct y axis for the loss function is the loss. So, the moment you deviate from the target, the loss is going to increase and the way in which it will increase is quadratic in nature, but there could be applications where the loss could be exponential as we have discussed nuclear power plant, golden jewellery, ok.

It could be in an exponential sense, but what Taguchi says is most real life applications you can use a quadratic loss function. So, the other way of looking at it is if you want to minimize your loss, you need to be as close as to your target, do something in your design variables, such that you stay close to your target and so is the story for robust design also.

What robust design says minimize your variants. If you are talking about these two probability distribution function, the red and the blue, you would prefer the blue under the assumption that the mean for both of them is same because the blue has a lesser standard deviation than the red so, you would prefer that. Are you able to visualize the fact that the blue which has a lower standard deviation directly translates to a lesser cost meaning quality loss compared to the one with the red, because I am going to only utilize this region you know maximum like this region is what I am utilizing with respect to the blue curve, where as I am really utilizing you know if you see like for instance this data you know data at this point is very far away from this target which means it is a huge loss for me, ok.

So, this is a direct overlapping of your quality loss function and this is a concept of your robustness, ok. This is where we are mapping quality and robustness if you remember, ok. The other day I told you the first thing that we will talk about is quality. We will define quality verbally and we will see how to quantify quality. The second point that we told is we will also discuss about robustness which we have done. We will define verbally what robustness is and we will see how to quantify robustness, how did we see, verbally how did we see robustness means.

Student: (Refer Time: 06:50).

Correct; irrespective of your variations in the input, the output variation should be minimal or within the specified element that is what robustness is. That is a verbal description how do you quantify that is using a standard deviation. So, if you are going to reduce the standard deviation of a given process, the process is supposed to be more robust that is what is robustness right. So, we have defined and we also discussed on quantifying it.

Now, we also need to bring about a relationship between quality and robustness. This is that relationship because right now I have only discussed the concept of robustness and I have talked to you about the verbal description of quality and then, we also discussed on how to or what is the metric that can be used for measuring quality. What is the metric? It is the quality loss function. And robustness the matrix is SN ratio. You see the idea and you can see that these two are in principle related because by assuring a robust design, I can say the product has a better quality, but there is one assumption that goes into it. What is that? It is not an assumption it is a given condition also which I stated when I drew these two graphs and the quality loss function. I stated that?

Student: The mean has to be same.

Very important, very important observation the mean has to be the same. Usually we say the mean of the process and the target that is important, because with respect to the quality loss function, there is a target and irrespective of the target, your process has a mean. So, when you use the word target, it is usually for the quality loss function. I have a target and how much did you deviate from the target on either side or on one side depending on what type of problem you are discussing at target and how much I am deviating from the target holds good for the quality loss function.

So, be your target, but I have a process and the process has a mean. Yes you can bring the process mean to match my target and that is a different discussion ok, but the terminology that is used target for quality loss function mean essentially refers to process mean that will be for the robustness discussion in our context. Please understand this is not in a global context in the course of this particular offering we are using these terminologies, ok.

When I use mean, it is usually the mean of the process and when I use a word target, it is used for referring your quality loss functions target. So, sometimes there could also be a situation like this that brings us to this discussion. I have a target m, it is a straight line. I am not able to draw a straight line on this interface. I have a target m and of course, I will define my lost function also based on that. The moment you deviate from that should be a mirror, ok. I did not mean to draw an asymmetric, but let us assume that it is an asymmetric loss function in this case, but I could have a process that runs like this. So, let us say for this green, sorry this pink let us call the word mu 1 let me call it, my target mu is the average of this rose or pink probability distribution function.

This is the process variabilityy, but I am looking at these loss for these conditions and then, I say this is not acceptable. So, what I do, I use some robust principles or the concepts for robust design and I end up reducing the variation. So, in this case specifically the mean does not overlap on your target; it might still satisfy your quality conditions. The green is a robust design over your pink design. There is no doubt about it.

But however something that has happened here is there is a mean shift. I have done something in my process that the mean of the process itself has shifted, however during the process, the standard deviation has reduced. The standard deviation compared to the pink one, the green one is better it is less in the sense. One thing however you need to note is you always need to look for this. What is this? I do not know whether you always need to look for this term. What is that?

Student: Coefficient of variation.

Coefficient of variation so, it is basically sigma over m. So, if you call sigma 1 for the rose and sigma 2 for the green, then you have to have sigma 1 over the mean and sigma 2 over its mean. In this particular case, we might not have that kind of a difference with respect to the mean of the small shift, but still it has shifted. Hence, one small update to our perspective on robustness rrobustness does not only involved reducing the standard deviation, but it also has to account for the mean shift. You cannot say I have a close to a straight line performance, but then my mean is away by about 10 meters. Every time you punch a whole, it give you 10 mm. Yes it is great, however my requirement is 7 mm. Your machine cannot adapt to 7 mm there is no use. You do 100 million punches every time, it will give you 10 mm sir good no use for me because my requirement is 7.5. So, unless you shift your process from 10 to 7.5, there is no use to me per say and on top of it, you can even have little leverage. You can make some errors that is the advantage of this design paradigm rather than saying you have to design in such a way that the design will never fail. You understand, do you understand the concept?

This is a very nice paradigm. You accept to the fact that the failures will be there. You just try to make sure that the failures are less in number rather than saying you cannot fail, you are saying it is to fail, but let us figure out the ways in which we can minimize the failure. So, the more practical perspective it is a new, it is a very interesting paradigm from design.

Because there are a lot of parameter attribute factors that contribute to a particular design and not all of that are under our control. This is where the concept of robustness kicks in. You might not be able to control all the factors. In spite of that your product is expected to perform with minimal variation or within the specified bonds, hence you need a framework to carry out such a design and that is what is a robustness design ok.

So, this is the whole idea. This robustness and QLF loss function. So, the QLF is a metric used to measure quality and robustness is a concept and just now we see how you can use robustness as a tool to achieve quality. So, that is the relationship that we wanted to establish. If you recall the title of the book, The Fat Case reference book for this particular segment is that it involves both quality and robustness. So, the concepts from robustness are used to drive quality.

So, there is necessarily a difference between quality and robustness and the other day we also discussed what reliabilities are. So, as we have discussed so far quality is predominantly used and refers to a product at the manufacturing phase. The moment manufacturing is over and as a manufacturer I sell it to the user, the performance of that with respect the performance of the product with respect to the user is called the reliability. How well the product lived up to its expectations or the promise that the manufacturer made is called reliability. That again is nothing, but a ratio it says I sold 1000 products in about 998 products were fine.

So, what is your probability of failure?

Student: 2 over 1000.

2 over 1000 that is what is my probability of failure so, your probability of success is just 1 minus that ratio or 998 divided by 1000. That is what 998 products work fine, but you cannot apply this concept for everything that you design. For instance, aircraft how

reliability is taken care of in an aircraft is by introducing redundancy. All aircraft's can fly with one engine. Why do they have two engines because

Student: (Refer Time: 19:24).

If the one fails gone; so the second can get in they can actually manage to fly there will be some unbalance issues because the other one is not rotating, but still they can land. So, the redundancy is used as a way to ensure reliability. In a similar fashion for medical devices, there are certain medical devices that you cannot afford to talk about reliability numbers. They have to work every time what ever might be.

So, they use redundancy in our computer centre. There are three levels of backup; there are backup for UPS because certain data cannot be lost. So, they have to be preserved and whatever may the case be, there will be pressure. So, this is one way of ensuring robustness and reliability, but the other classical way of looking at reliability is to do is to do what?

Redundancy is as good as saying I will carry two phones. If one fails, I will use the other one. If one charge is over, I will use the other charge, correct. That is what usually these travel executives do. If you see their bags are really heavy sometime, but their laptops are very small, very thin.When you look into their bag, they will actually carry a additional battery because they have a long flight and I might not be able to charge their laptops on the flight. So, they will carry a charged battery with them. Once this battery drain down, they will put the other battery and then, they will start working. So, that is a redundancy mechanism, ok.

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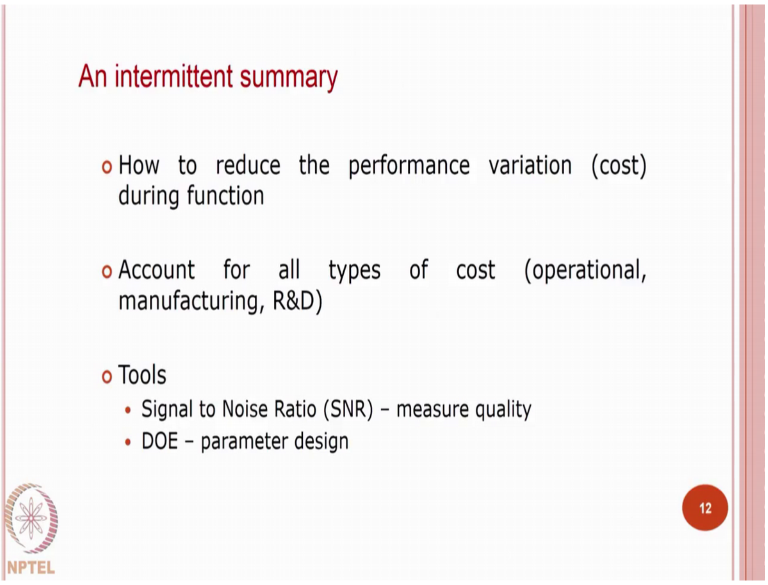

So, an intermittent summary on the 3 bullets that we saw as learning outcomes of this particular segment the first one was about the definition of quality, how to measure quality, the second one was about robustness, how to quantify robustness. The first bullet here kind of combines those two how to reduce the performance variation during functioning. When I say function, it is functioning that is something that we need to talk about how to reduce, but how it can be measured is something that we have discussed and it should also account for all types of cost whether it is operational cost, manufacturing cost, R and D cost.

The third one is the tools for instance signal to noise ratio is a metric, it is allowed to use, it is allowed to measure robustness and you can use quality loss function to measure quality. In a similar fashion, we need to now learn about design of experiment that will lead to parametric design.

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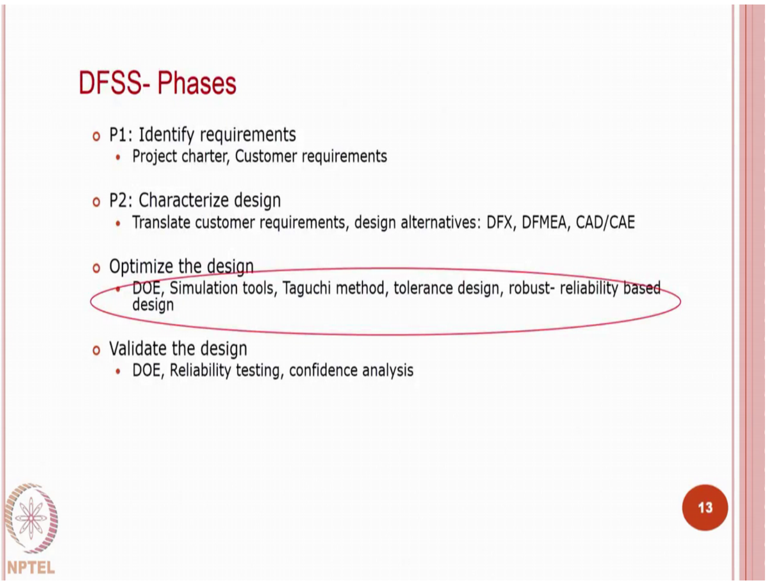

Before going into design of experiments, we will step back a little bit and try to look at this entire discussion as a design for six sigma. If you look at it how the design over the years has evolved, if I am not wrong, we have discussed this already. First getting the performance was important. Get it to work that is what we say in our product design lab first get it to work because form follows function.

We need to first show me that it will function. If you designing car, you show me in goes from A to B, then let us worry about what is the color of the car. First you need to tell me whether the device can take you from point A to B. So, the function then comes the form, form follows function. This is a pen what is the function of the pen?

Student: Write

It should write. Who will write? Human beings will write. How will they write? Using their hands and fingers ok. How are they going to use their fingers? They need to hold it. They will use predominantly these 3 fingers and some people might use their 4 fingers, ok. If that is the case, how am I going to hold it? I am going to hold it like this. A pen has to have certain dimensions and shape, so that the holding becomes easier for me, it becomes intuitive for me that is a form. Can I design a pen like this? Yes I can always design a pen like this. I can design a pen like this, but the problem is I am going to use the same 3 fingers, but it is not as comfortable as. Can I design a pen like this, like a ball you can design why not. You can design a pen like this where you use all your 5 fingers to hold it and then, be able to write it, but we all know the most easiest and intuitive way to do that would be this. Hence, first you need to if you are designing a pen, you need to make sure that it is writing, then you need to worry about oh should it be a triangular cross-section, should be a rectangular cross-sectional or it should be a cylindrical cross-section, how big should it be because form follows function. So, in the design theory, the evolution of the design itself people were first ensure function, then comes form.

So, if you look at it, lot of decades ago people were worried only about the performance it has to do that, but once the device itself has been in the market for a while, you need to ensure that it does the function every time you wanted to do the function. You cannot say I sell about 100 times and 80 times it will work that is a very bad ratio. At least in paper 100 of them should work. 100 of them will work to begin with, but that is why they give you the warranty period.

I know that there could be errors, but what I can guarantee you is for 5 years my power train will run without any problem. That is a confidence that I have in almost all my engines, all my engines only 5 years there is a chance that 1 out of 1000 engines might fail after 5 years, one of the house is a very good number for man-made products.

So, first it is about ensuring function, then the second is ensuring it functions every time that you wanted to function, that is sometimes called reliability, durability and the concepts of quality and robustness also come with the same time, ok. They can be discussed in the same frame. Now, that is where the design for six sigma comes into picture. So, what the concept says is today if you are designing a product, not a single company when most of the products, not a single company does all the components.

You go to a sub contractor, you have a vendor who will supply some parts to you, but you cannot ensure a six sigma product without ensuring a six sigma component. There can be variation in the component performance, but it cannot fail. Often if it fails let us say that there is a component supplier who supplies 100 components, out of which 50 will fail and these components go into a larger product which a company manufactures. If that component fails, the product will fail. 50 percent of the times the product will fail, you cannot afford to do that.

So, if the product needs to be at six sigma level, almost all the components that feed into it should also be six sigma at least theoretically there are criticality issues. Not every nut and bolt needs to follow six sigma stuff there failure levels, low risk, high risk, medium risk. Obviously, for high risk you need to be in a six sigma let us say that you are supplying a part to the break you are supplying a part to the airbag. You have to be maybe not even six sigma some higher sigma guy.

It cannot afford to fail whereas, you are just supplying in audio system can afford to fail. It is not going to be a very critical failure. Even if it fails, the user experience guy will come and blast you, but from a criticality from an occupant safety perspective, that is not that very critical. You can go for a less sigma manufacturers if you want.

So, depending on the criticality, the sigma can be increased or decreased. So, I just wanted to tell you in a design sense people first did design for performance, then design for reliability currently we are talking about design for sustainability. Right now, the idea is only it is called the reactive design we have used our electronic products for instance our printer cartridge. That is the one that is used widely in the discussion.

We have bought it, we have put it inside the printer, we have printed thousands of pages then one day it shows the printer cartridges over you need to replace it. We have brought the next printer cartridge also. We have removed the whole printer cartridge and we do not know where to throw it because we have read somewhere that this is an electronic stuff that you should not dispose just like that. There is no system that says come and deposit all your printer cartridges here.

So, this is called reactive design. After usage we worry what to do and so is the case with our water. We have depleted all the water resources and now, we are saying I am not sure how do we manage water. Now, instead at least for the sustainability perspective what people have now started advocating is you need to enforce an active design, not a reactive design. Do not respond after the function is over, after the performance is done at the concept level.

You should ask these questions on if you are going to use this material after its usage, what are you going to do with that, how are you going to dispose it safely? You need to bring that yes if you use an alternate material, it might influence a cost, it might put, it might burn a hole in your wallet. That is fine, but you need to make that decision at an early concept stage. So, it is called designing for sustainability.

Now, people are coming up with matrix for sustainability and including it at the design stage. We need to choose material or you need to choose design methods that are sustainable in nature. So, like that from a manufacturing perspective, people spoke about design for six sigma. You cannot say I will buy my components from wherever I want, but then my product has to be six sigma you cannot say that you will have to ensure as many as possible.

All the components that come also follow a six sigma process, and then it is relatively easier for you to ensure a six sigma. So, six sigma if six sigma is required for the product, then it also has to be ensured at the input level. That is what six sigma design for six sigma means.