Design For Quality, Manufacturing And Assembly
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Lecture – 04
Introduction To Robustness

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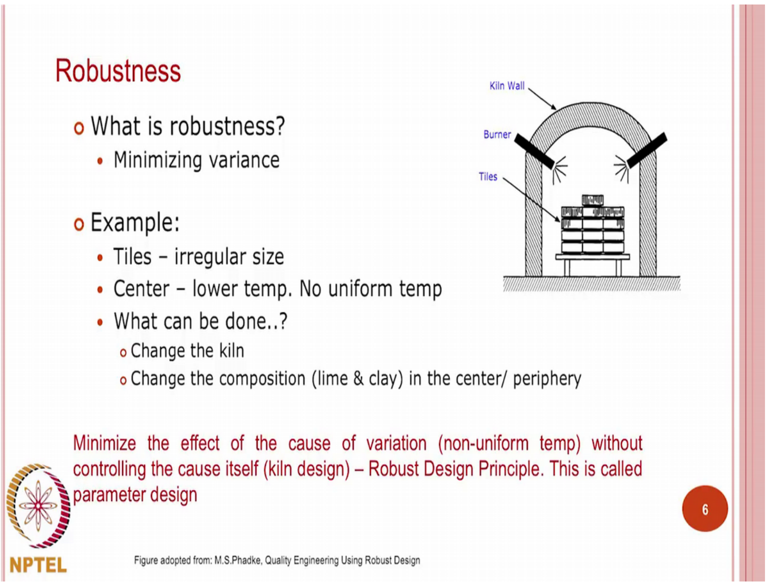

So, now in a discreet sense I am also going to talk about another quantity call the robustness, and then we will see how these 2 connect. Just hold on for a while we will talk about robustness if not today tomorrow we will see how they are connected. What is your opinion or understanding about the word robustness, because usually people let it be learner, not learner, engineers, scientists.

People usually use these words in exchange quality, robustness, reliability, durability. Actually as a matter of fact durability is under quality, that we will see what reliability is also under quality in one sense, under quality means it is a subset. What do you think robustness; your opinion, you are thought about? Someone was about to say.

Student: Strength.

Strength if someone is really sorry.

Student: A strength of product.

Strength of a product that is robustness fine, we will see strength of a product. If a product b is stronger than product a you think product b is robust than product a you think so, fine.

Student: (Refer Time: 01:41).

How the product is performing in the different environmental conditions, then.

Student: Efficiency.

Efficiency so, if b is efficient then a then you think it is robust than a, anything else?, it is it can be any of these 3 answers or it could be a combination of that, but the one because, but then you will have to alter what you told and you told to, but the one that he answered is very close to the actual perspective of what robustness. What robustness says is; irrespective of your variations in the input, my output can vary only this much allowed specification, allow tolerance. There are n number of variables and they are going to vary that we understand that is what we saw these are aleatoric uncertainty.

There is inherent randomness are it could be epistemic you might be able to control I do not know, that is different. There is uncertainty, they are going to propagate through the model, there is a performance. Irrespective of the variability in your input my output variability should be minimal or it should be within the limits that I prescribed. So, this goes back to our example; that if I am a 2 wheeler seller I am a dealer and then I sell a bike to you motorbike. And then I promise x kilometers per liter you drive it and then you figure out that it is x minus 15 kilometers per liter and then what will you tell when you come for the first service?

You are going to say that you guys cheated me. So, because it is heavily deviating from what we promised. So, the deal is then I ask you where did you drive it? So, you said that oh I actually drove it in Bangalore, then if I say no this engine was designed to operate in Chennai. So, you can only drive it in the roads of Vadiyare and Velachery, if you drive elsewhere we cannot promise this, is that an acceptable statement? It is not an acceptable statement. So, for whatever reason I just gave the example of Bangalore, it could be anywhere else it can be Kashmir.

So, irrespective of the temperature, irrespective of what kind of a rider you are irrespective of what roads you have driven, irrespective of where you went and pumped your petrol, irrespective of any input condition that would influence the efficiency are the mileage of my vehicle.

Your vehicle is expected to give minimal variation plus or minus of what I promised. I promised x kilometer per liter I understand plus or minus few kilometer is this is acceptable. If I give like 50 kilometers per liter and I am giving only I mean my engine is giving you only 35 kilometers per liter you are going to be a heavily disappointed person. So, that is the key idea of robustness, this is more from a perspective, but how do you achieve it this is conceptual right, but how do you achieve it. Irrespective of the variability in the input my variability in the output should be minimal or within the specification that I state that is one part of it.

The second part is you do not touch the cause for variation, you still live with the cause for variation, but you minimize the variation in the output, that is the important part. So, for instance the dealer understood the variation in the mileage was because of the roads in which you grow. So, can he say sir you cannot drive the vehicle in the gullies, you can only write the vehicle in the highways. He cannot say that, he should tune the engine to an extent that irrespective of whatever road you drive it should still give you close to 50 kilometers per liter. So, you cannot get rid of the source of variation, you have to live with the source of variation, but still make sure your output does not vary more than the specified limit.

So, we will discuss an example here, which will drive this point home. So, here is a Kiln, Kiln which means a furnace. So, you know these bricks, so something like a brick is being made here that is it is called tiles. So, there is a burner, and this is the wall of the Kiln and these are the bricks are the tiles that are being, you know how the bricks are usually done there is some molten mixture that is placed, you know cut into cakes and it is placed and then it is burnt. So, here is a furnace it is an advanced stuff right.

So, to make the problem little spicy, what I have done is; I say that this machine was bought out of Germany or any other country do not worry about it was bought out. And you cannot touch the furnace because the moment you touch the furnace touch, touch means you cannot make any changes in the furnace the moment you change it the warranty is void.

Now, there is a problem when people started using this furnace, what happened is; the output tiles that came out were of irregular size. If you see the tiles that we usually have is 1 by 1 one foot by one foot right. So, imagine you I give you 10 tiles to lay. One is 1 by 1 by 2 the other one is 1 by 0.8 the other one is point 8 by 1. So, I give you tiles of different sizes, you think you can lay it? You cannot. So, this is something that we might not have really realized all these days. So, if you get down to the floor and then you look at them they are all in a very straight line. Actually we observe them very closely there will be small deviations.

Very small deviations will be there that is why; they use the white color bonding material or whatever the tile color bonding material will be there. So, that you will not be able to see the difference, but there will be is minor the naked eyes when you stand and see you will not you will have to lay parallel to the tile and then you should see. So, the deal is this irregular stuff that we are talking about is much larger than that 0.8 and 1 is visual you can see in the naked eyes you can see the difference. There is a problem the tiles are coming out of different irregular sizes right, but I also know the cause for it. The cause is because the tiles in the central part you know the tiles in the central part here, they are exposed to a lower temperature compared to the ones in the outside.

.So, the ones in the central part experience lower temperature compared to the ones in the outer, which means; there is a temperature gradient there is no uniform temperature. There is a burner and all that within on stuff, but the way in which it functions is there is a gradient, there is a gradient of temperature it is not a uniform temperature it is a gradient of temperature. Hence, as a result the tiles when they come out they are of different sizes, what do you think can be done to address this problem? You cannot change the Kiln because it is very expensive and you were bought it from Germany. You cannot go and change anything part of the Kiln, because the moment you touch it is the warranty is void, these are the constraints yeah.

Student: (Refer Time: 10:32).

Ok so given the assumption that you know the gradient of the temperature, what he says is; let us remove this central one oh, let us remove this central portion. So, that the bricks that are exposed to the low temperature or not you know they are not exposed at all I mean they are not there. Yes, it is a potential solution, but also remember that this is only a representative figure. So, let us imagine I will make the problem slightly challenging. Imagine there are about instead of 3 there are about 9 columns, and then 9 columns from a projection and 9 columns deep also. So, it is about an 9 by 9 so you have about 81 and the central 3 represent the center.

So, you are talking about 3 times 9 27. So, let us say about 10 brick height or tiles high is what the each column is, then you are talking about 270 into 300 tiles less in productivity each time that you are you will have to open the furnace and close it, which that is why you have gone to Germany and what this it is a very expensive stuff, but it also gives you a very good productivity, but that answer is acceptable. But what I am saying is you still want the full productivity right. So, you do not want to remove this one, what else?

Student: (Refer Time: 12:06).

Sorry alter the.

Student: (Refer Time: 12:09).

Oh that you cannot do, see basically this is like baking. So, you open you put the dough inside you close it. You open and then you take the made out to bread you cannot just open it in between and put some cherries and then close no, once done put it then take it once it is done. So, I otherwise also it is not that easy to handle the hot brick and yeah then.

Student: (Refer Time: 12:43) so, you can (Refer Time: 12:46).

Tell me tell me.

Student: (Refer Time: 12:47) one kind of property (Refer Time: 12:50) can choose that rows and columns (Refer Time: 12:53).

And do what?

Student: (Refer Time: 12:56).

No no I know the results, I know that meaning; that is when I can do what he told right I know the temperature gradient that so that so; if you have noticed clearly I use the word assuming that we know the temperature gradient. I know that this is going to come out with 0.8 I know that will come at one that one I know. Before coming out you know that this is going to be 0.8, this is going to be 1, this is going to be 1.2 that I know, but how do you deal with the problem. Because I want all of them to be of the same size more or less.

Student: (Refer Time: 13:42).

Yes and yes or no, but what I am saying is let us say it is yes, it is already there and with that you feel this problem. So, if it is no finance no with that you find this problem; meaning you cannot change it now, if it is static it is static you cannot say let us go and rotate no you cannot touch the furnace.

Student: (Refer Time: 14:19).

Oh the other one will become even smaller, from 0.8 it will become 0.5, you want know whether it is a tile or it is a stone. You understand what I am saying right? When you increase there is a gradient, the gradient will go like this, the gradient will only translate.

Student: Is it time.

Time?

Student: (Refer Time: 14:45).

No it will not, that is what I am saying the gray it will maintain the gradient for our reason.

Student: (Refer Time: 14:53) same size; so, we can use multiple device and (Refer Time: 15:05).

That is one way of looking at it. So, what he is saying is; since we know what is going to be the output size why cut them all to the same size, why will you cut all of them 2.8 by 0.8. If you think that this guy is going to be larger than what you expect 1.2, then you cut it smaller so that when he instead of being 1.2 he will become 1. Similarly, the ones who which go in the center, you cut it of a larger size and then he will come to 1. That is an acceptable solution, but still you have to do some kind of a pre processing you need to understand you need to correlate and then you need to, but that is an accepted solution, what else? Yeah see in this whole thing the solution that you give is fine.

But I also want you to understand an important underlying idea about robustness, that is, that is; coming in terms of the constraint in another couple of minutes you will understand what I am talking about, but I want you to appreciate that well you are trying to give the solution anything else, any other solution that you can think of?

So, these are fair enough solutions that you have given from a data perspective because that is all I have told you right? But you can also go into the physics of the problem a little bit which I do not expect, but it is a trivial thing if you look at it. You know how these bricks are made what are the major components of the bricks, and why temperature is going to influence the size do you know? Because what I am saying is that is all right, the what is the problem here it says no uniform temperature, why should the uniform temperature or no uniform temperature influence the size of your type. What plays the role here? The temperature plays a role, what will happen if I am going to heat something; if I am going to heat something what will happen? They will they will contract and if you heat something they will contract is it.

Student: (Refer Time: 17:12).

Depends on the material right so, but in this material what will happen? Whether it expands or contracts there is a property of the material that will play a role, what is that material; no sorry what is the property, you told just now.

Student: (Refer Time: 17:33).

It is a coefficient of.

Student: Thermal.

Thermal expansion, there is some material that might expand this much there is some material that might only expand this much. So, how do I describe that; using the coefficient of thermal expansion that plays a role here. What it is saying is; there is a material this is the coefficient of thermal expansion, but what is happening is; there is a delta t that alpha delta t is what the term is right? The delta t is large in the ones that are in the corner compared to the ones in the center. Hence, they will expand more compared to the ones in the center.

One way to deal with that would be to check out what is the size and then do it, the other one will be to look at the material itself because the material that goes into it is your input it is not part of the furnace. So, what I do is if you know the physics of it basically line and clay are the material that go into it. So, what I will do is; I will play around with the composition such that; the coefficient of thermal because there are 2 materials right. So, the third coefficient of thermal expansion matches the gradient. So, it will have a large coefficient of thermal expansion and the center and it will have a less coefficient of thermal expansion towards the end in such a gradient that it will match the temperature gradient.

So, you can go ahead and do that, but this is also pre processing only, you should know you should do some experiments to understand how to do that. So, this is just an example to drive home the point on robustness. Now let me ask you the question, what was the source of randomness in this or source of uncertainty in this, source of the error in this?

Student: (Refer Time: 19:29).

Sorry.

Student: Temperature gradient.

The temperature?

Student: Gradient.

The temperature, the non-uniform temperature right. But did you go and change the non-uniform temperature. Because I told you that you cannot touch the furnace otherwise the first thing that you would have told us sir, let us go and fix the burner. You cannot fix that I told you that you cannot touch that. So, irrespective of the variation in the input, I expect my tile which is my output variation should be very less. I say 1 by one, but I will accept 0.98 to 1.2. I will accept that sorry not 1.2, 1.02 I will except. I cannot accept 0.8 and 1.2 I can accept 0.98 and 1.02.

So, the variation in the input temperature I have not addressed that at all it is still, with whatever solution that you gave and the one that I showed just now. The uniform temperature the non-uniform temperature is still there I am not address that problem, but still I am getting an output of my tiles which are 1 by 1. So, that is the idea behind robustness. You should minimize the effect of the cause, you cannot touch the cause, we did not go and change the non uniform temperature, but what you have done is what is the effect of the non-uniform temperature it is it created or it resulted in tiles that are off that did not adhere to a 1 by 1 size.

So, but; however, I have minimize the effect of the non uniform temperature which is the cause, without controlling the cause itself in this case it will be the Kiln design, I have not touched that. So, this is the robust design principle you have to live with the uncertainties or you have to live with the cause of the variation, but still you should be able to achieve your output, which in our case is a variation. Which is specified a variation or within the specification and this is also sometime called the parameter design or p design. Usually if you see there will be a block, and they will have some factors that come into it. And p meaning the factors are nothing but the parameter. So, the p stands for the parameter so it is called the p design. So, this is the underlying idea on robustness.

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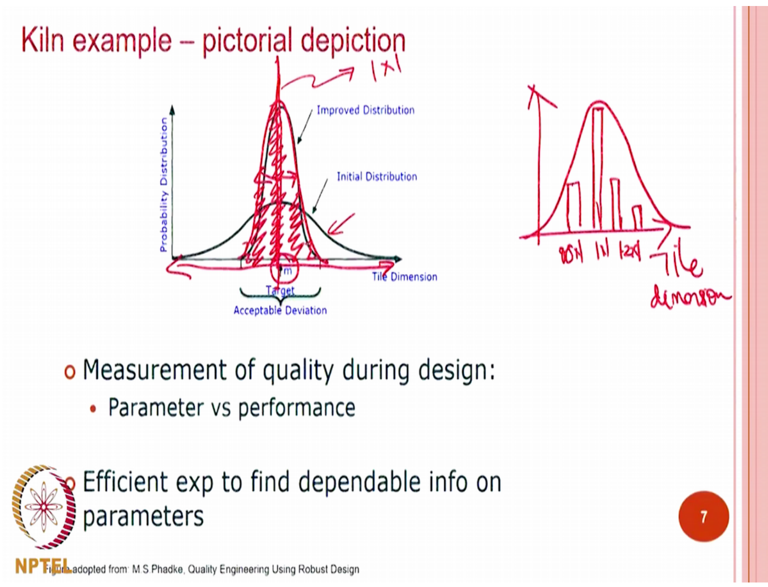

Now what I am trying to show you is a small pictorial depiction of the Kiln example itself. So, there are the first one is this initial distribution here. You see this guy, what it means is there is a mean average that we are talking about. So, this average that I am talking about is probably the 1 cross 1 that I am talking the area square meter or sorry square feet let us say, 1 by 1 square feet. What I am saying is; if I were to draw this here let us say, this is your tile dimension.

And then I am taking the first tile and then I am measuring what it was, it was this much, it is it is somewhere here, and then I went to the second one it was here it was here, it was here and then what does the height of this one mean?

It means there are multiple numbers at that level. So, if I did about 1000 tiles. It is likely that this the number of tiles might be about 500 or 600 in this level. And there might be some here liked about 200, this might be about 200 this might be like that and this is usually called the histogram. It is basically a frequency plot, how many times or how many tiles out of the total tiles measured about 1 by 1. How many of them measured 0.8 by 1, how many of them measured 1.2 by 1. Then you can kind of I mean it is not straightforward, but you can kind of come up with this, that is what we have plotted here. So, what it means is there is a larger variation; I have not given you any dimensions here the dimensions was just to motivate the example.

So, what it means is this m is what your target is this is 1 by 1 for instance is what the m is, this is what is the promised target but there was a deviation in the tile dimension before the solution. After implementing the solution again, it is not that it is going to be a straight line still there will be variation, but the variation is smaller. This is how you measure the variation how thin or how fat that is not the correct word, but for us to discuss here to enable the discussion this distribution is thinner compared to this distribution which is fatter. A fatter distribution means; there is lot of deviation from what is promised or what is expected.

Whereas in this there is only a smaller deviation from what is expected, which again means that there is more samples that is why this is a tolerant distribution when it is a thinner it is also a tolerant distribution, but let us say that you have a magic machine, which let us you produce tiles of 1 by 1 dimension; how will this plot look like, it is just this straight line if you had thousand products it will be 1000 by 1000 means 1 that is all.

Otherwise I am saying there are about 800 in here there are about 800 tiles, where here there are about 100 tiles in this area and there are about 100 tiles in this area and there are about 10 tiles here and there are about 10 tiles here.

They will come as close as possible to your promise, but still there will be some variation. So, the requirement in any manufacturing or product, so these are 2 different things when I say manufacturing is manufacturing of a product, but manufacturing ends by the time the user goes to the shop and gets it, until then is what the manufacturer has controlled the dealer has control. After that it is the performance that is why I said either in manufacturing or product, when I say product it is performance when I say manufacturing when it is with the dealer.

And this is also one of the subtle difference that people point out is until I sell it to you it is called quality. The moment you bought it from me it is going to be how well it performed to your expectations or to my promise then that is called reliability.

How well it performs with you is called reliability and how well did I meet the specifications until I sold it to you is called quality. That is that is a small distinction that people make it is a subtle distinction. So, from are you find with this explanation like. So, usually you can draw it from a histogram you can get these distributions if at all we are talking about that.

So, another part what becomes interesting is; when you want to measure the quality during design. So, all this time we were only talking about the geometry or the manufacturing tolerance and all that right. So, that is what is given here in terms of parameter versus performance. Now you need to talk about both performance as well as adhering to the specifications in terms of the geometric conditions right?

So, that is what is the parameter and then the performance is what the reliability that we talk about. And what are all the parameters that you need to worry about in this one for instance in this particular example that we are talking about there might be other parameter is also that will play a role. You can you can do further research to understand why there was a variation in this did not I make sure like after 5 days after 10 days you might get a better understanding of the composition, and you might be able to drive it even further or let us say that I relax one of the constraints like you can touch it you can touch the burners a little bit.

Then you might be able to bring down the variation even better. So, you need to understand what the parameters are which parameters play a role that becomes a very important stuff. And in order to do that you need to have efficient experiments this exp stands for experiments; to find a dependable information on the parameters. There are different ways or mathematical techniques or statistical techniques to do that, if you have a bunch of data today you can find out causal relationships, you can use something called the principal component analysis support vector singular value decompositions and things like that. These are all comes under something called factor analysis, they will tell you out of these factors out of the 10 factors that you taught only these 2 factors are very important, then you can do the study representing only those 2 factors.