Design for Quality, Manufacturing and Assembly
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Lecture - 10
Introduction to Design of Experiments

The Design of Experiments primarily serve two purposes; one is it allows you to get the statistics of the response.

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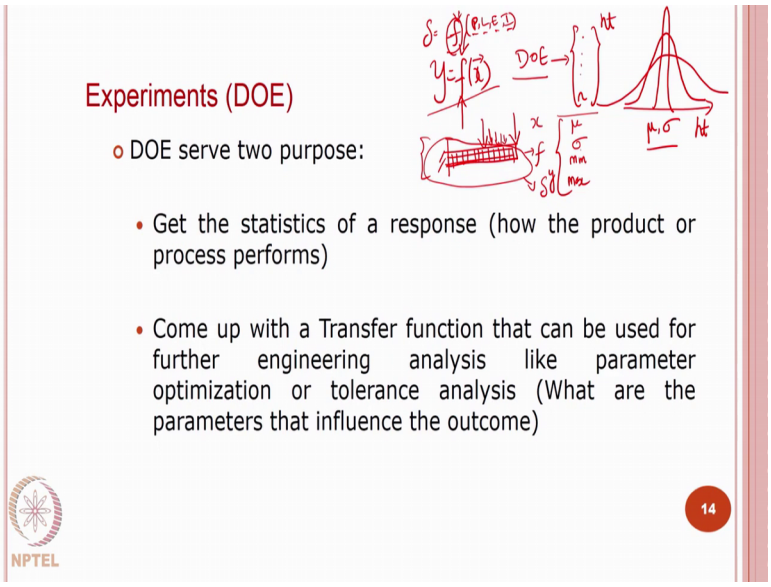

If you go back to our discussion on the probability distribution or your quality loss function, one underline thing that you have to understand there is I need data to construct all these stuff. A priori no one is going to give you those information. What is the likely distribution of the height of the students that I (remembered as?

Student: (Refer Time: 01:02).

Is that information good enough? I have asked a question. They follow normal distribution correct, what other information will I need? Why would my student want to go and measure, so, that.

Student: He can get a information from the.

What information?

Student: (Refer Time: 01:51).

I do not know this is also normal, this is also normal, this is also normal. I do not know which of this is your height distribution. So, I need to know my mu and sigma, I need to know my parameters, how do I know my parameters?

I need to go and get the data, I need to sample. So, every time I wrote this, I need to have the data. How do we get the data? I have to experiment, I have to go and interview, I need to go and measure, I need to build a design. In order to create this data and take the parameters is nothing but your statistics; design of experiment can let you do. Because from the design of experiment, which means I have selected the candidates. I said go and select 5 candidates from first year, 5 from the second year, 5 from the third year from each department.

So, 16 times 5; imagine there are 16 departments; 80 students from each year you do over 5 years 400 students you collect; that is the DOE, then I come here I collect all these details. What I do after that is a different story, but what design of experiment let us you do is collect this information and then you can get your mu sigma statistics, you can say minimum maximum all that information it can let you do that is one stuff.

The other stuff is it lets you create a transfer function. What does a transfer function mean? This DOE is a function of the attributes. In our example it is something about the year, the department, the gender, the features whatever it is and output. So, when I have an input x and I can have an output y, then one natural thing as an engineer want to do is find the relationship between x and y.

If I can write y equal to f of x, it is very interesting for me to find this f because for a new x, you do not have to go and repeat your experiment. I will just plug in this f plug in the value of x into that and it will give me my y.

So, often times it is very important and very interesting to find f and it is not straightforward because we are I am just writing as y is equals f of x, but this x itself could be a vector. So, I am talking about n dimensions; the moment it is n dimensions it is a surface it is a hyper surface. This f you do not know the non-linearity what order it is or can it even be represented in a polynomial sense, it could be anything, it could be

highly non-linear function. So, that part is not straight forward, but you can come up with the transfer function.

Transfer function means what? It relates my output to my input. You need to have this for any design purpose. For instance, consider a finite element model, consider a CFD model, consider a Simulink model, what are they? They are nothing but your f. You have a cantilever beam, it is a complex cantilever beam otherwise you know it is just PLQ over 3I and I am also having a different kind of loading whatever loads that I want to apply.

This I am modelling it with a finite element model. What it means is you just need to only model this chi, you can change this input on whatever you want, but it will give you a deflection output. So, this is your x, this is your y and this is what is your f. So, you change your x, the f is the same, you are plugging it in and then you will get your y. Sometimes it need not even be as complex as a finite element model; it could be a simple equation.

For instance, if I knew this for a tip load, if I knew my displacement is PLQ over 3 I then this displacement is what this chi is, equal to f of it is a function of L load length, E Young's modulus, I moment of inertia. The moment you change any moment of inertia, I can tell you what the deflection is, you change the load I can tell you what the deflection is, but the deal is other than cantilever beam or simple geometries you cannot come up with this function directly, that is why you go to finite element model to solve such kind of problems.

Sometimes even the finite element model becomes expensive. So, you cannot run it as many times as you want. Then you need to choose at what design combinations of PLE and I will run at, that is what design of experiment will let you do or in an approximate sense, design of experiments will let you construct this f which is nothing but your transfer function that relates your output to your input. Get it?

Once you do that you can do multiple things, that is what we call usually in the optimisation area as design space exploration. What is design, what combination of excess will you give the best y that is an optimal design. Design space exploration is can you give me an idea of y for different axis, so that depending on my application I might have different requirements, you have you see the video on what a 500 rupees can do for

different people. So, 500 rupees is one design combination, but what it can do for different people is different, a particular motor bike is a design combination.

One might look at it as high fuel consumption, one might look at up at as high power, one might look it up as a very nice design, one might look it up as a nice beat noise. So, it depends the one with the fuel consumption we will go for another bike, it is it might still be the same cost, but they are trading of something else, they are trading of the power, they are pay they are trading of the pickup, but they will get a good mileage.

For the same cost for the same pick up someone might have a seat that is good for a teenage, that is good for a young person, but might not work for a family person. So, these are trade-offs, that is called exploration; can you give me different combinations and also the responses because what is optimal for one is not necessarily optimal for the other.

I need to be able to make that decision unless I have the information on the platter I cannot do this, in one sense that is the idea behind your electives. I will think as a product design engineer, you need to learn probability and statistics without which how can you design it reliability? You might have a totally different perspective on it you might say, why will I am worried about reliability? I want to worry more on data at the user experience level and I wanted to know how artificial intelligence can be used or I want to use virtual reality to increase user experience.

So, what we do is what is optimal for me or what is exciting for me need not be exiting for you. So, we give you a series of courses from which you can select, in one sense that is also a design of experiment.

Similarly, when you go to a shop to buy something, they do not show you one, at the same rate combinations or for a different rate combination, different feature combination, different rates, they lay you a series of cell phones that you can look up. What works for me might not work for you might choose for whatever reason you might like the other phone, in one sense that is design of experiment. So, we will look into the details.

Before we get into the how to use design of experiments and to choose design of experiments, you need to get used to some language, terminologies.

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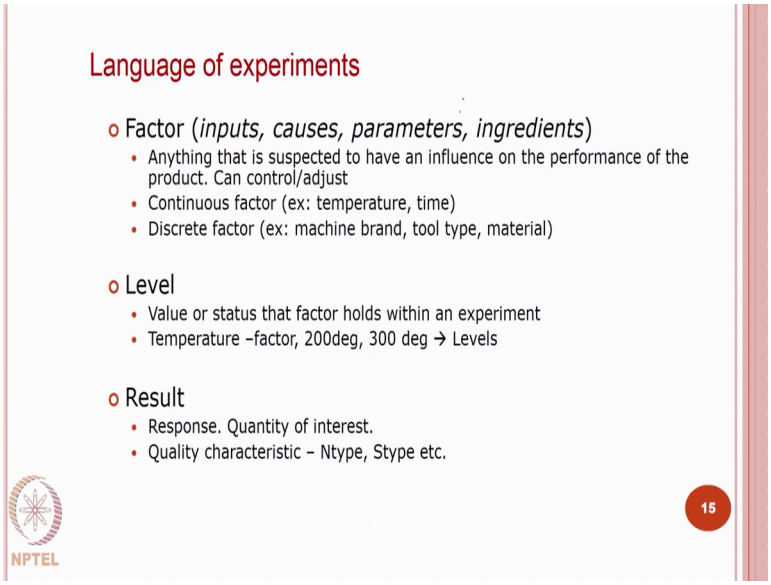

The first one is called the factor; factor is nothing, but your attributes, your inputs, your parameters, your ingredients, anything, it can be anything that you suspect to have an influence on the performance.

Importantly, this makes a lot of distinction; this statement, you should be able to control or adjust it. If you recall, what are the different types of uncertainties we discussed in the first class. We discussed the two words called aleatoric and epistemic; the second one the epistemic uncertainty comes from the fact that the model is not fine or there is limited data, whereas, the elaterid uncertainty comes from the inherent variability, you cannot do anything about it is variable.

Just because we were born to the same parents, does it mean that me my brother younger brother, elder brother all of us will the same and we will have the same attitude we will? No, there is a inherent variability between us. So, is the case with the product; car engine number 1, car engine number 7 coming out of the same shop floor. Do you think that they are going to be they will be identical, they will look similar? Their performances will differ.

But, I need to be able to control those factors then only this is considered as a factor. The reason I told the aleatoric and epistemic uncertainty is, in the epistemic in the aleatoric uncertainty for instance the wind speed is the example that I gave you, you know that it

is random; you know that it is a variable, but can you do anything about it? You cannot do anything.

What you can do is you can choose a different site may be you can say oh this motor is for a less RPM. So, I will choose a different that is a different thing, but you cannot control the wind speed, you can argue that you will put all those diffuser and all that that is not what I am talking about. In general what I am saying is you cannot control the speed of the wind. So, a factor that you can control or adjust is called a is just called the factor, there is something else that we will talk about at a later point that is called noise.

So, there are two types of factors; one is a continuous factor and the other one is a discreet factor. What is continuous? The number is continuous 25.2 mm, 26 mm, 23.8 mm you can do all these things, but can you say 1.2 machines? 2.3 Vamshi's? You cannot say that, it is either 2 machines, it is either 2 students, it is 3 faculty, you cannot say 3.2 faculties, it is either 3 faculty or 2 faculty; that are called discrete. Certain variables are continuous, certain variables are discrete certain variables for discussion purpose are continuous for practical purpose they are discrete.

For instance, take thickness gauge thickness; practically, if you build products, you will know have you bought any sections in terms of steel from anywhere.

Student: Yes sir.

How are they specified? Where did you get them from?

Student: Local vendor.

Local vendor, fine. So, they will give the one that you ask for?

Student: Yes sir.

They will give. So, if I ask you to go 12.2 mm can you get it?

Student: No not basically, will be in normal way, they will give up to the what are the equipment they have. So, based on that they will be like 10 mm 10 feet they will give you the 10 feet or 20 feet.

You go and ask the gauge thickness is you can have is 12 or 14 mm, sheet if you are talking about. You go and ask can you give me 12.3 mm, may be Tata can give you, but you need to place an order for few crores then they will give you, but otherwise it is only 12 or 14. So, theoretically you can see it is a continuous variable thickness, but for all practical purposes you have to buy it only in a discrete sense. So, we will have to be careful about that in a design perspective.

The next is called the level. The values that the factors can take is called a level; let us say that temperature was a factor, this temperature you are trying to study the preserving the quality preservation for an ice cream, you can control the temperature inside the refrigerator. So, you are able to control that. But what combinations am I going to do that? 35 degrees and no 35 is not cold; 20 degrees, 15 degrees, 0 degrees, minus 2 degrees that 0 degree that minus 2 degree is a level.

In our pen example circular cross section is a level, rectangular cross section is a level, triangular cross section is a level ok. And the factor is cross section, you get the point right the factor is cross section and these are the three levels that the factor can have. If it was time, 20 minutes, 25 minutes, 30 minutes, I want to understand what is the attention span of the students? I need to do the tests, I need to lecture to you for 10 minutes, I need to lecture to you for 2 minutes, I need to lecture to you for 5 minutes.

Then I can tell I will have to record everything and I will have to see what is your attention span or I will have to keep your EEG on your head and then figure out how far I am able to retain your attention. Is it for 2 minutes, is it for 5 minutes or is it for 10 minutes? So, time is my factor and the time set which I test that is your level.

The last one is your result that is nothing but your response. This is your quantity of interest and the quality characteristic because we are going to see all these things from a quality perspective. So, what is a quality characteristic of the response? Because that will allow you to define your sn ratio. Is it n type?

Student: Yes sir.

What is n type, Vamshi?

Student: Normal.

Normal the better? Nominal the better.

Student: Nominal.

Nominal the better s type is? Imran?

Student: Smaller.

Smaller the better, smaller the better, l type is larger the better. So, you need to define what type of a problem it is.