Design For Quality, Manufacturing And Assembly
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Lecture – 09
Design For Six Sigma – Stages, Design of Experiments

What are the different phases in 6 sigma?

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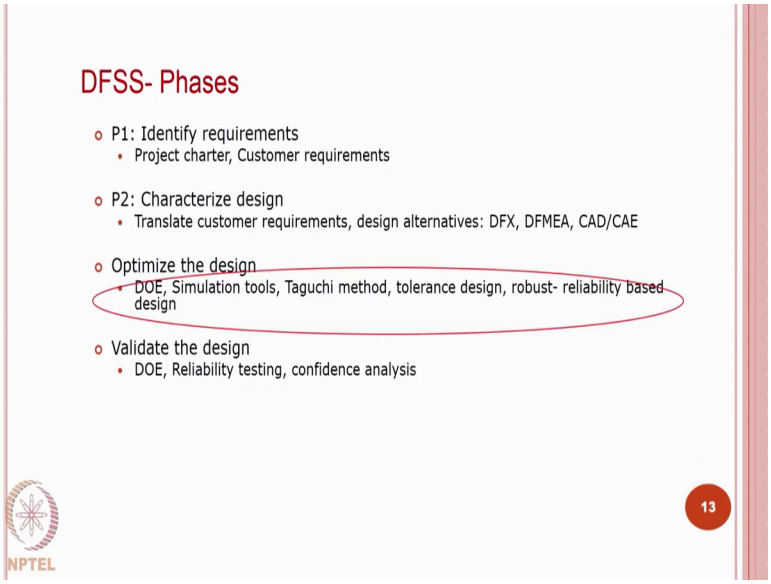

So, this P here stands for, the P here stands for the phase. This is see, this is not a comprehensive, this is just one way of looking at it, ok. So, P 1 is to identify your requirements. This is a regular product design phase. You no need assessment, requirement analysis, that is what is this identify requirements. From your customer requirements, you define your problem statements, that is what is project chapter and your customer requirements you collect that.

After you do that, what do you do? The phase 2 is to characterize the design. The customer will only say I want this to function better, they do not know what to do at the back end. It could mean a processor change. It could mean enhancing usability. It could mean enhancing user experience. That the user might not know. If you ask what kind of an improvement you want in this.

The user will say, let us say that there is a pen like this, and then you go and ask the guy. You can say oh this clip is made out of metal. They might not even say that; they might say that this clip sometimes it is very you know it adheres to my pocket. And sometimes when I remove it very fastly it might actually tare of my pocket that is a problem that is all.

They might not know a solution. The problem statement could be different looking at what your solution is. You might still want to live with this clip, you might entirely want to get rid of this clip, you might want to change the material of this clip, you might come up with the new way of holding your pen. There are different ways of looking at it and each solution will have a different problem statement.

So, when I say characterize design, what becomes important is, you need to translate the customer requirements into actionable items for an engineer. This is mostly engineering product. So, I am talking about that. And design alternators do you really need to have a clip? That is where you talk about design for DFX, DFMEA, CADCAE computer aided engineering, and today you can even talk about additive manufacturing. You can see whether it works at that level itself meaning at the concept level. Then you talk about this is actually product phase 3 and this is phase 4.

So, this you can think of as concept level, then you built cad models and you want to optimize your design. The moment we say optimize your design, you need more alternators, you need more designs. You cannot just save one design and I will optimize it unless, the word optimization itself means competition. So, there should be a competition, otherwise you cannot optimize, there is no need to optimize.

So, therefore, what you need to do is, you need to have more solutions, which roughly translates to having different design combinations. But where will I have these design combinations? How many design combinations will I have? You say, even for the form, I told you like 3 different cross sections. It could be a circle, it could be circular cross section, it could be a rectangular, it could be a triangular. And I am sure all of you have seen pens with or pens or pencils with such cross sections.

Now, you need to find out which one is good. Within that, you also need to find out what could be the optimal diameters. Is this too thin or is this too big? I cannot do all the combinations. I cannot build as many pens as I want. S 3 3D printing let us you do that,

but at a cost you cannot build as many 3D print and stuff. So, I need to sensibly choose some combinations, such that I can get maximum information out of these experiments.

That is governed by the design of experiments. We will see in details that is what the rest of the course is about. Then we can knew some simulation tools Taguchi has proposed orthogonal array, which is one of the design of experiments. Meaning he is proposed using orthogonal array to enforce robust design. Tolerance design plus or minus x plus or minus some data that is called a some value that is called tolerance design.

And robust are reliability based design. So, all this we can do with computer aided engineering, and are with physical experiments. Ones you do that this is an iterative process. Once you do this, what do you do? You go back and take a second look at the requirements, translate their customer requirements, accordingly and then you come back. You might want analyze it in d f x again. Then you come back you do this, you go back it could be iterative in that sense. Sometimes you might even want to go back and ask this question; is me requirements, right? Because whatever I do this is what I am getting you go back and ask the question and come back again, ok.

So, this itself is iterative in nature. Then finally, you have to validate your design. You do even for validating your design; you need to do a design of experiment. Finally, I have come with an optimal combination as diameter for my pen. How do you validate this design because not the people in my office are going to use it? The users are if not crores at least few lakhs of people. I will see what my target is in which regions of India am I going to sell it, or in which regions of the world am I going to sell it. In those regions I will select samples and I will ask them to use it.

And I will have to validate the design because if you have seen even for a pen, people hold it and write it in different ways. They will do it like this, they will write it like this, they can write it like this, left handers they have their own problem. I recently read an article, where a kid was not able to sharp, to sharp the pencil because a sharpener was predominantly design for right hand users. She was not able to do, ok, she has to do it this way, right.

You are not able to do the sharpener even she is not able to hold it and do it that way. We have not thought about it because we are our predominantly right handers. And they wrote it to a particular pencil company and through their research and development

board they have developed a special sharpener for her, and they sent 3 sharpeners they said thanks for letting us know giving us this feedback, and we have done that. See you have to validate your design you are all in a group with a certain exposure. Just because it is comfortable for you, does not mean that it will be comfortable for all the target audience that you will send.

So, you have to validate. So, it what I am telling now is more of a user experience. But it can also be from a performance perspective. I ask you to ride a vehicle, I am building a motorcycle, I am asking you to do a beta test. Sorry, beta test means, they know how do I under what conditions they will do, but I am asking I am asking you to write, you write and you say it is fine. But I really do not know where and how, who will write that vehicle when it is on the market.

So, you need to try to simulate all those situations, in what temperature, in what roads at what speed they will ride it, will it be a man, will it be a woman, if it is a man what will be the age group, how will they handle it, will they always be greater than 80 kilometers, are they will ride only between 40 to 80 kilometers, if there are always on the throttle mode what happens to my engine if it is heats up, where should I keep my foot rest, if it is too close to the engine it might it might the thermal energy might actually heard their food.

There are lot of this stuffs. So, you have to validate this is in, then that is why in the industry all these alpha test beta test, all these riders for instance in a 2 wheeler, they will come, they there designated riders. They ride across all the suit of motorcycles and the 2 wheelers.

So, they know what test they should do. You cannot visualize the variation in the tire. But you give to because that is all they do. They will say there is a small shake in the vehicle. You can you cannot visually see, but they will feel it. They will say there is a small shake in the vehicle; you will have to adjust the CG at this point, ok.

So, that is what is validation. But right now this validation in a research sense across the world there is something called verification and validation because the concept of digital twin has kicked in. What is the digital tin? The other day I told you, there is a car which is a physical car. And I have an equal and car in the computer. The physical car goes in crashes; I can also have the computer car go and crashed. It is likely to simulate the same

situation. If there is an person who is sitting inside the physical car, how the person will get displaced; to the top, to the front, the knee and the neck.

Similarly, a dummy will be simulated inside the meaning a computer dummy, even in that an original person will not be sitting only a dummy will be sitting in the physical car. A computer dummy will also be simulated to understand what will be they in.

But then what you should also understand is this computer is only a approximation of the physics. It is a numerical approximation. The computer is solving partial differential equations at the back. Partial differential equation comes under certain assumptions. It will hold good only for those assumptions. Reality does not care about all those stuff. Reality there is a crash; there is a crash that is all. So, you need to verify and validate that this is what will happen with the real car also. So now, there is a another word that I used instead of not instead of in addition to validate. I use a word verification, what is the difference between verification and validation?

Student: Verification is like a (Refer Time: 12:11).

Ok.

Student: So, validation is like (Refer Time: 12:18), I will see whether it is working or not (Refer Time: 12:22).

Not to the point. But I will give you just a single line explanation of that. It is not mine, someone I think over camp have defined this. To see whether yours you are solving an equation correctly, it is called verification. To see whether you are solving the right equation, it is called validation. How good this computer model represents my physical model is validation. After I validate, I have to verify how well this computer model is going to solve the; because a computer model is only a bunch of partial differential equations. How good is the solution are they converging, that is called verification?

So, verification v n v is what it is called now? It is called verification and validation is coming up in a big way, where in those conditions you have to use design of experiments, because you cannot used as many samples as you want. There you also physical reliability testing also happens. Just like your car crash, physically they will test. For that also you need to do? Design of experiments, and of course, you need to do

confidence analysis. This is the number that I say, what is a confidence that you have on that number. Number means the number on the performance. You say it will give 50 kilometers per liter, usually the engineers are supposed to answer what are their confidence, that under such a extreme conditions also this will give 50 kilometers per liter, that is a point.

Under this context, but even before that let me let me clear up one more thing. All these things we have talken we have spoken about is in a forward sense, when I am designing a new product towards a particular performance. After this whole thing is done, I might let the product in the market and the product might fail. Then you have to understand why the product as fail.

So, we usually there are these field test engineers they will go to the field they will see why it is failed. Then they will come back and simulate the same operating conditions. Either physically or on a computer and I want understand whether I observe the same type of failure, which will tell me whether it is a material failure or it is a design failure or it is due to operating conditions. I need to first answer that question.

But again you cannot simulate all the combinations in that. You left is only simulate certain combinations and how do you do that will be based on design of experiment. All of you would have done some kind of user input elicitation in your pd lab. How many of you had a pd lab? Pretty much, you have been had a pd lab?

Student: (Refer Time: 15:39).

Anyway, in a pd lab, if you have done user input elicitation, user requirement analysis, what I remember is many of you created Google spreadsheets and ask some questions to people and they entered in that. What do you think is an ideal way, do not do not tell me how you did. But let us say that you want to come up with the solution for the student population.

There is a problem that you know has existed and you want to solve that problem are, you want to come up with a solution for that problem. These are specific for the students at IIT Madras let us say. And you want to get their inputs on that, what are the problems that they are facing, and what type of solutions that they are expecting.

You know, the fact that you cannot reach out to 10,000 students. That you know for sure, for whatever reason. Instead you choose the way of going to specific students. You say I am going to go to these people. It is enough if I go to 100 people. I am just giving an example here. You have thousand rupees in your hand. And you believe that if you give 10 rupees to that specific each person, they will give you the input for sure. With 100 peoples input you can do the stuff.

But will you go and give this 10 rupees to the first 100 people that you see? Or how will you go about selecting these 100 people? What will be the criteria are the rational behind you selecting these 100 people? So, you will identify the different types. It could be gender, it could be years, it could be their background from where they are coming, it could be the language that they are speaking, it could be their food habits, it could be their departments and what not; depending on the solution that you are looking at or depending on the problem that you look at these numbers are these distinctions are these attributes could be less or more.

So, you are going to look at certain things. And you will have representations of each of this. If it is going to span across your going get a solution, you are going to develop a workflow for the students are access some information that everyone needs. Then what you will do is, this you will take a representation one each of these segments.

If there are 100 people and there are 50 such groups or attribute, then you will take 2 people from each of that; that is when you have a flat representation. There is contribution from each group. That is the basic idea of design of experiment also. You have to sample, you know, that you cannot get all the information. Someone comes to me; I do work on statistics. So, we wanted to get some data on height of students at IIT Madras.

So, there is a researcher who comes and says tells me; sir, can we go and measure the height of the students? I say fine, go and take about 40 people. They step out of my office, they go towards a hostel, they find the basketball court. They went and measured all the students at the basketball court, and they came back and presented. The result I told 40 and they got 40. Is that a good representation? That is not a good representation. Because at least to my knowledge short people like me, we do not play basketball, I do not know whether I would have played basketball if I am tall.

But one of the major criteria, major, it is not a sufficient condition. But one of the major criteria is you need to be tall. The moment you say tall your taller than the average. Then the sample is biased. I cannot make any conclusion based on the height of the basketball players.

I cannot make any conclusions about the student population at IIT based on that data. So, instead what I should do? I should go to the hostel zone, and I should select students from randomly, again it should be stratified across the years, across the hostels, across the gender, across the sports, whatever, whichever you can think of in terms of distinction you will have to do that.

Then only your sample is a representative sample of your population. In a similar way, if I were to conduct experiment, there are different design combinations, very simple. The pen design, take this into account, 3 designs, circular, rectangular, triangular, cross sections 3 different dimensions in each of them. You can also have combinations. Imagine the number of combinations that are going to be there. Or if you take a fixed design, ok. You take a circle with 3 different (Refer Time: 21:29) I mean 3 different measurements possible, you take a square with 3 different and you take a triangle with 3 different.

And if these designs are going to be correlating we are talking at least if not 27, at least 9 different designs you are talking about. You might not have the ability to do these designs. So, instead you want to do it in a smart way. Can I interpolate the data? Can I interpolate the response values? For that where do I run my simulations, are what of these combinations I will bill my products to understand what the response values are. These questions are answered by the concept of design of experiment.