Advanced Green Manufacturing Systems
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Lecture – 24
Fundamentals Techniques of Experimentation

Good afternoon students. Welcome to yet another lecture of Advanced Green Manufacturing Systems.

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Continuing on to the previous topics that we were discussing on the experimentation and we are discussed so far up to factorial experiments and let us take forward on the another major topic that we want to talk about, the Fundamental Techniques of Experimentation.

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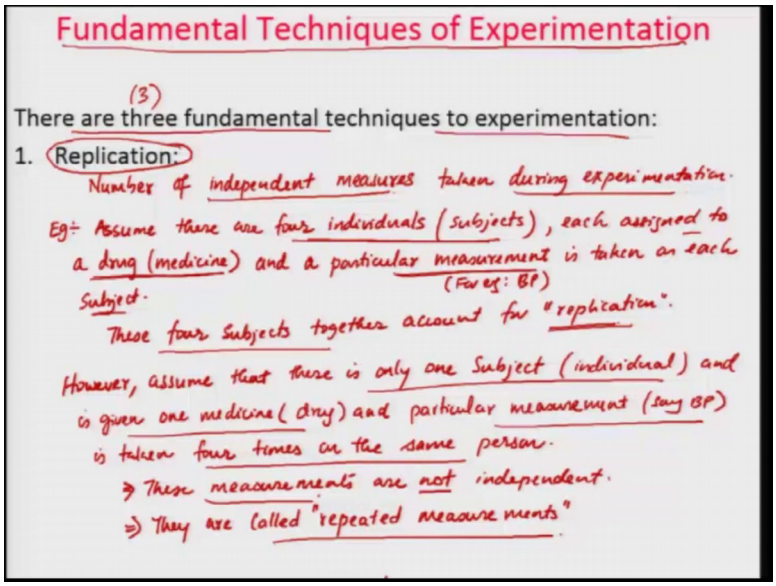

What the some of the major fundamental techniques associated with the experimentation. Ideally there are three fundamental techniques ok. There are three major fundamental techniques associated to the experimentation, the first one is called as replication ok. So what is replication? Replication is the, it is the number of independent measures. Independent measures, number of independent measures taken during experimentation ok so the number of independent measures. How many independent measures were taken during the experimentation is what we call as replication.

So let us take an example to explain this concept. Assume there are four individuals ok. Let us assume that there are four individuals ok, they are called as subjects individuals; each assigned a drug, each assigned to a drug is a medicine in this case ok. And particular measurement; a particular measurement is taken on each subject, is taken on each subject ok.

So assume that there are four individuals or four subjects ok. Four subjects in this each one of them is assigned a medicine or a drug and we are taking a particular measurement of the each subject. Let us say this is a blood pressure then we are taking the blood pressure of each the drug ok, these four subjects together account for replication . So, all of them are given a particular medicine a specific medicine and we measured their blood pressure ok. So then that measurement let us say in this case for example, BP.

We are considering the blood pressure and for these four cases, these four subjects put together will result in replication right. However, assume that there is only one subject or one individual and he is given one medicine or drug and particular measurement ok; say BP is taken four times on the same person ok. First part, these measurements, these Bp measurements, they are not they are not independent ok. They are called repeated measurements; repeated measurements ok.

So in the first case we talked about there are four individuals, four different human beings. Each one of them is assigned a medicine a drug and then we measure their BP or a particular measurement is taken on each one of them and these four subjects, these four measurements of the individual people put together gives you what you call as a replication. So, you are replicated it across four different individuals, but if you take there is only one subject only one individual is present and you gave the same drug, one drug to that individual once and then we take the BP measurement and then you take them four times on the same person.

Then the first thing is that these measurements are not independent they are no longer independent and they are not replication they are called as repeated measurements. So, what we are talking interested in the concept or this course is the first fundamental thing that we talk about is replication not repetition ok. So, the repetition is one individual the same drug given then take four different measurements on the same individual at four different time periods separated by maybe 5 minutes, 10 minutes or something like that is called repeated measurements. Same thing is you take four different individual same that give for the same medicine to all the four and measure their BP almost at the same time and that four recordings is what we call as the replicated measurements or replication ok.

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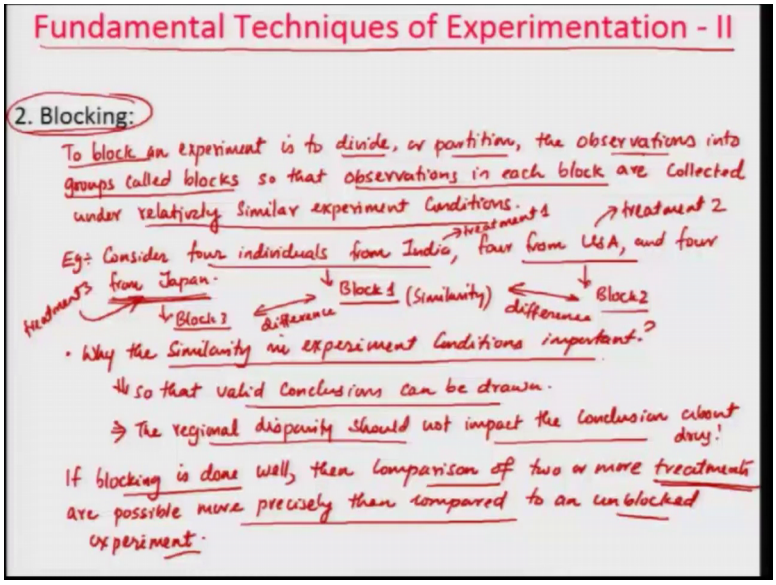

Now, let us talk about the second fundamental technique of experimentation. The second one, what we call us blocking ok; so blocking is, what is blocking right? To block an experiment; to block an experiment is to divide or partition or partition the observations into groups called blocks, groups called blocks so that observations in each block are collected under relatively similar experiment conditions ok.

So, to block an experiment when we say blocking of an experiment is to divide or partition the observations into groups called blocks. So you divide or partition the observations into various groups called blocks, and what is a reason? The observations in each block are having the similar experiment conditions. A classic example of this is, example, consider four individuals from India, four from USA and four from Japan and all these four cases we are giving them the BP drug that we discussed about.

So then, this is the first one this is block one ok. The people who are the four individuals from India they have the similar condition. Similarity ok, this is the USA is the block two, there are also the same conditions and from Japan this is the block 3. So, what we are doing is the results from the US thing is comparable same way the results from the Japan is comparable with the themselves and they say results from India will be comparable within itself. So, the blocking allows you to do so that the relatively similar experiment conditions can be created ok. So reason is why the similarity in experiment conditions important? Why is this important? why is why are we so particular about similarity in experiment conditions, why do we care about this too much ok? So that

valid conclusions can be drawn, we can draw valid conclusions from the system ok. So, that we can draw the valid conclusions can be drawn from the data right.

So, the most important thing is if you do not block it then the people between them. So, what happens is their difference and there is another difference, this difference can be physiological their living conditions food habits all of them could have differ from each other. So, how these difference also impact the drug? So the reason is, the regional disparity should not impact the conclusion about the drug ok.

So let us say for example, we only take the people from Japan who do not need that much of salt and all those kind of things so their BP would generally be good and then you try only the drug in Japan and say that oh look their BP has become normal. So then that is fine; and then you take that and put it in India and USA where BP is much more a complicated problem. Then the drug might be effective in Japan purely because of the fact that the people to begin with did not have that much of BP and in India and USA it might not have been that effective because the people had a much more serious case of blood pressure related issues. So to avoid that kind of regional disparity so preventing that region disparity impacting the conclusion that is why we do blocking ok.

So if blocking is done well, if blocking is done well, if you do a good job of blocking, blocking is done well then comparison of two or more treatments, two or more treatments are possible more precisely than compared to an unblocked experiment.

When we say the treatment, here the new word that we talk about is a treatment ok; one two or more treatments. So, this is your treatment ok. So, let say this is treatment 2, the India is your treatment 1 and Japan is the treatment 3 ok. So, what we are doing is each block individual block results in the treatment. So, what we are saying is if we do the blocking properly, in this case the blocking is done on the country as one reason then we can compare these multiple blocks or these treatments that we talked about. The blocks results in treatments or what is called as treatments as a technical term that is used it has been so that we can drew draw more precise comparisons compared to an unblocked experiment.

If he did not block this one then we cannot really say whether the impact of the health of the general health of the people in that region is also influencing the impact of the

medicine or success of the medicine. So, blocking this particular thing that we talk about blocking is one of the second most aspect of the technique of experimentation.

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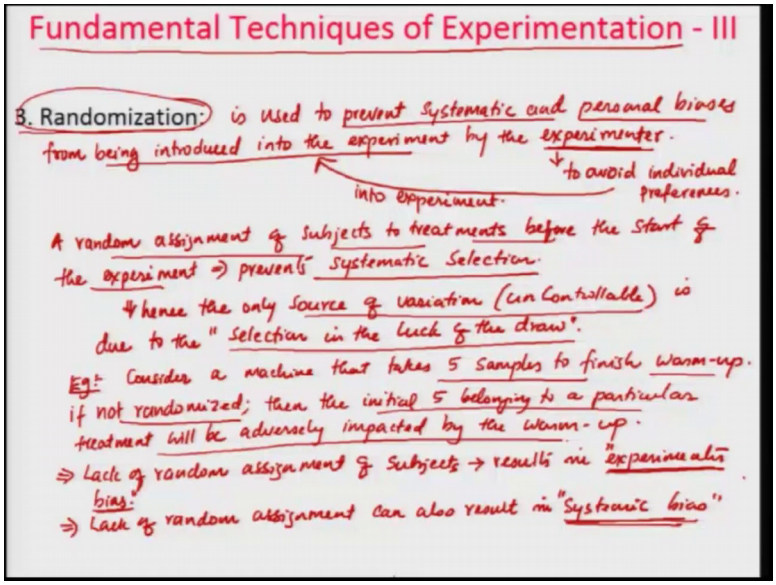

Then, we will get into the third aspect of fundamentals of experimentation today and the third most important aspect that we are going to talk today is something called randomization ok. So what is randomization ok? So randomization is used to prevent, is used to prevent systematic and personal biases from being introduced into the system or introduced into the experiment; introduced into the experiment into the experiment by the experimenter by the experimenter. So, what we are talking about it is, we use randomization to prevent systematic and personal biases being introduced into the experiment by the experimenter.

The individual who is do in the experiment the experimenter we do not want that individual preferences, to avoid individual preferences from being influencing the experiment or being introduced into the experiment; to avoid individual preferences into experiment. That is the fundamental reason behind randomization ok. So, what we saw is that a random assignment a random assignment of subjects to treatments ok. We randomly assign subjects to treatments before the start off the experiment; start off the experiment if we randomly assign subjects to treatments before the start off the experiment ok.

So, then prevents systematic selection systematic selection. If you randomly choose assign with a random variable if we choose the treatments and the subjects are assigned to each other before we begin the experiment then the systematic selection and the so, then; that means, what happens is this hence the only source of variation; only source of variation this is uncontrollable you cannot control this. Only source of variation uncontrollable source of variation is due to the luck of the draw; due to the selection in the luck of the draw ok.

So, an example, let me a give you an example, consider a machine that takes 5 samples to finish warm up ok. So, the machine is started and you put samples into the system and it takes 5 samples to finish the warm up. If not randomized, then the initial 5 belonging to a particular treatment will be adversely impacted by the warm up.

So, if you do not randomize, if you just take one set of sample and you shove it into the machine and the first one which belonging to the same category will all be adversely impacted by the warm up and your data you cannot draw valid conclusions out of it right. So, when we say lack of random assignment of subject results in experimenter bias ok. So, the lack of random assignments of the subjects can result in something called as an experimental bias. Lack of random assignment can also result in systemic bias ok. So, both these biases are important for us ok. The experimenter bias is the preferences of the experimenter.

So, let us say you are trying in an example of a farming procedure and then the experimenter is asked without randomization is given to it, then what the experimenter will do is the experimental will to select the crops that are favorable to the x individual. So, let us say that you are supposed to do experimentation on carrot, beetroot let us say rice and wheat. So, under say the experimenter likes carrot, so then he will start the experimentation with carrot to begin with.

So, you are sawing the you are putting the carrot seeds into a particular farm, then what happens is the initial crop that is planted will have all the benefits of the fresh nutrients and everything and so they will say that the carrots will grow better than all other tree crops. So, the entire country should grow carrots. That could be a conclusion that can happen on that bias is introduced because the experimenter was more favorable to our character ok.

Whereas, the systemic bias what happens is let us say for an example you are going to paint a room and in the room there are four different paints that are available. So, and you are painting one room and then you are trying to find out which paint looks better. So, if you start painting with the one particular and there are three samples of each individual paint. So you say I will finish with the paint number one. So, you painted one then you painted it again painted it again with the same sample and you say this is the one and then you change it into another one.

So, what happens is that instead of randomly varying those three samples of three individual paints by doing it in a systemic fashion you would really not be able to compare the difference between one paint to another. So that is called as something called as a systemic bias ok. So by doing randomization as I said earlier this third thing called randomization will help you to avoid both experimenter bias and systemic bias. So that you can actually do valid conclusions; so the selection is the luck of the draw. Only the luck of the draw is the one that is influencing the uncontrollable sources of variation right.

So, as I also give you an example of a machine that is being warming up in this regard ok. So, that the third one the randomization is also an important aspects of the experiment.

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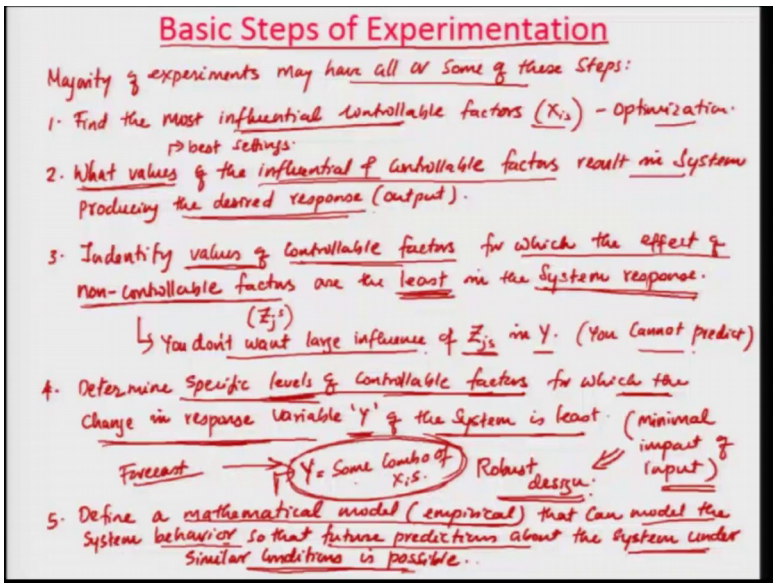

So, we come towards a conclusion of today's presentation and what we are talking going to talk today is about the basic steps of experimentation. So majority of experiments; majority of experiments may have all or some of these steps ok. So, we may have all or some of these steps. Number 1 first step, find the most influential most influential controllable factors, told you what are the controllable factors these are X is you can think about optimization is an example to do this. Find out which are the most influential controllable factors in this regard ok.

Let us see first part of it, second thing that you can think about it is what values what values of the influential and controllable factors result in system producing the desired output, desired response or output. So, there are many values of this influential controllable factors, you are more interested in what values which are those values that will give the result in the system producing the desired output that is the second most important step. Third one is identify values of the control factors, values of controllable factors identify values of controllable factors for which the effect of non controllable factors are the least in the system response.

So what we are saying here is that identify those values that particular values of controllable factors. Identify the specific settings of the controllable factors for which the effect of non controllable factors, the non controllable non controllable factors in our case are the Z j's ok. Remember they in the diagram they were the bottom ones this means you cannot control them and they are not controllable and their effect should be the least. So, it is the minimal in the system response or you are trying to find out what are the values of the controllable factors for which the non controllable factors exert the least influence in the system response because you do not want this. Why? Because you do not want large influence of Z j's in Y. If you have large influence of Z j's in Y then you cannot predict ok. So that is the reason why you don't want large influence of Z j's in Y because you are interested in building the empirical model that can predict the behavior of the system.

Four ok, the fourth one determine specific levels of controllable factors for which the change; for which the change in response variable Y response variable Y of the system is leased of the system is leased. So what we are saying is, identify the specific levels of controllable factors. Determine which are the levels of the controllable factors where the

change in response variable of Y is the least. This is what you are saying is minimal impact of input ok. This gives you something called as robust design.

So, we are interested in doing something called as a robust design. So, what for that what we are trying to do is we are trying to find out the controllable factors which are the specific levels of controllable factors that can result in the minimum, the change in the system is the least. The response variable the change in Y is the least for that particular set or particular specific level of controllable factors which gives you what we call as the minimal impact on the input which will result you in a robust design of the system or the process. Then the last, the fifth one which is important for us, the I mean I can tell you that all these five are important for us. There are so many other reasons or steps in experimentation, but these five steps are of more importance to us.

Define a mathematical model, a mathematical model which we say it as empirical. Mathematical model that can model the system behavior, the system behavior so that future predictions about the system under similar conditions is possible. So, what we are saying here is, let us define a mathematical or an empirical model. An empirical model is there in this case it's a Y equal to some combination combo of X i's ok. We are combining the variables Y the X i's the controllable variables to give a result to Y. So, that what we can do is, using this empirical mathematical model the system behavior in the future can also be predicted, if the similar conditions occur in the future. So when we say the similar conditions if they occur in future, then using this y, this particular y that we created we can use this y which is a some linear combinations of Xs can be used to predict the future of the system provided that the conditions are similar. As long as the system is under the similar conditions then this model can use be used for predicting. This is where forecasting can be used. Forecast the behavior of the system using this.

So as I said earlier, just reviewing the most influential factors of X i's we are trying to find out. That is the first thing that we need to do to a large extent we told it does optimization also is there. Then we also figured out what values of the influential factors result in the system producing the desired response ok. Which are those ident? So, this is the best settings which are the best settings that we are interested in right then the third one we said is we also want to find out those values where the effect of Z j's, the non controllable factors are least in the system response.

And we would like to have that settings where the Z j's are of minimum impact and then we also would like to find out this factors for which the changes in Y is the least or we want to do what he called as a robust design. Using all these things we would like to create a mathematical or an empirical model that models the behavior of the system. So that if the same conditions happen in future, then we can predict the system.

So with this, we come to the conclusion of what we call us our basics of the design of experiments for green manufacturing or the optimization of the green manufacturing process. So, we are just touched up upon the basics and the fundamentals of it. Now we will start working on simple examples of each one of this case. How do we do different treatment levels, how do we do randomization, how do we do blocking and how do we run factorial experiments. we work simple problems in the class and these problems will be solved in the class using excel mostly. But you can use any other software like R or something to do the same; but the idea is that this is a very important thing for us there is important skill for us to ensure that if you want to do some optimization on green manufacturing. Then this is what we need to do.

Thank you very much for your patient listening and hope that this course will help you in becoming better understand and master in the green manufacturing and please continue to read the assigned readings to the assignments and keep working on bettering your skills in this regard. I know these courses are slightly math oriented, but I will try to simplify it as best as you can. I will see you soon with more examples on experimental design.

Thank you very much.