Experimental Methods in Fluid Mechanics
Professor Dr. Pranab Kumar Mondal
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati
Lecture 40
Analysis of Experimental Data, Causes and Types of Experimental Errors

Good afternoon, I welcome you all to the session experimental methods in fluid mechanics.

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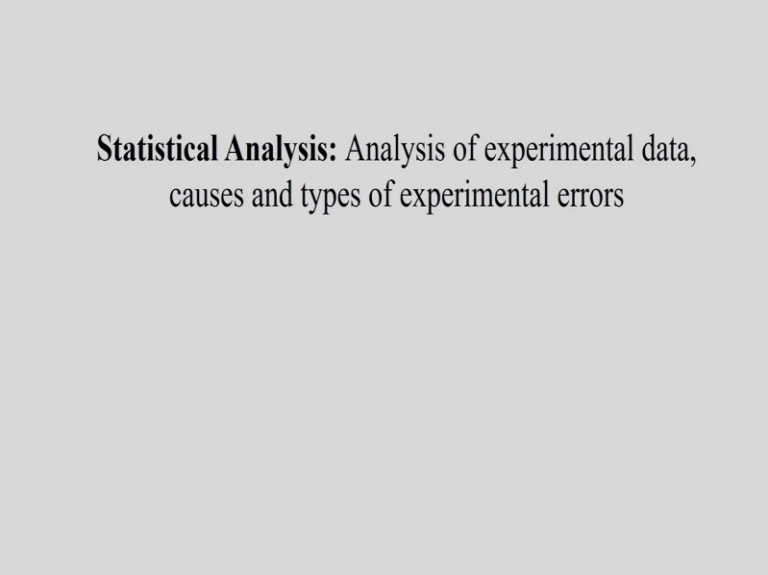

And today we will discuss about the statistical analysis of the experimental data. Now, this is an important module of this course, and if we try to recall we have discussed, you know several modules in this course and we have discussed about the you know, experimental methods in fact the operational principle of different instruments and of course while using those instruments, what are the precautions we need to consider and finally, you know that which is important that dynamic response configuration.

That means, if we are using any instrument or device or any system in measuring fluid, I can say flow parameters that means since the course is on the experimental methods in fluid mechanics.

That is why I am focusing on the measurement of flow parameter. In fact, we have discussed about, you know, several modules and in those modules we have discussed, you know, the measurement methods, working principle of several instruments, which are used to measure velocity, pressure, temperature.

So and in the context of this, we have also seen why we need to you know why you need to look at the dynamic response consideration and we have seen the effect of the, you know transient response and through the mathematical analysis by considering an example, we have seen how we can really design and why we need to model that and from the analysis we have seen that the you know from this exercise we can modify the design consideration so that that that the effect or issues which are you know associated with the transient response will be addressed.

Now, this is an important module as I said, this is not only for the you know experimental data which will be obtaining from the fluid flow analysis, but in general this analysis, this module is very important for this experimentalist. That means, whenever we are doing experiments we are collecting data, we are recording data and then the collected or recorded data should be you know analysed and while need to go for this statistic analysis that is very important.

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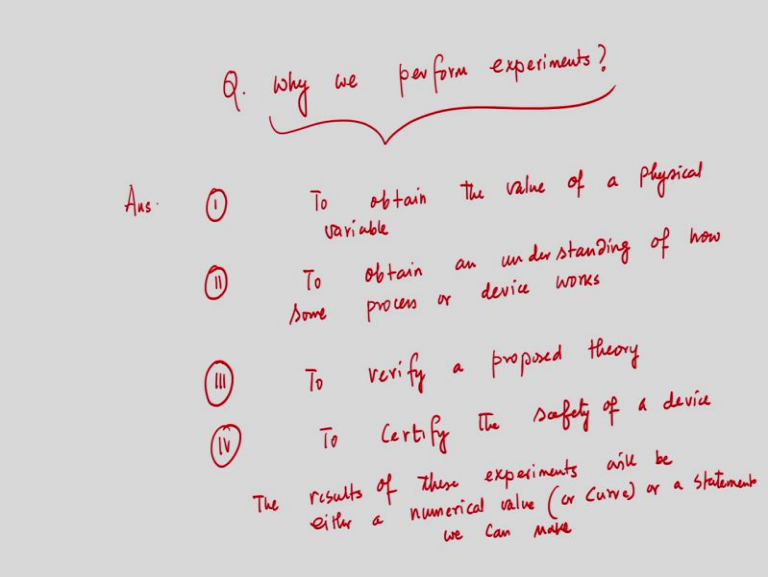

So, before I go to discuss this aspect, you know one question that I would like to you know address over here, is that why we need to go for experimentations. That means, why we perform experiments. So this is very this is very important question. So I am writing that, why we perform experiments? So this is an important question. If we know the reason behind the experiments then perhaps we will be in a position to address the in requirement of statistical analysis of the experimental data. So why we we perform experiments? There are you know, I

am writing that there are a few objects a few objectives rather and if we need to know, if we need to fulfil those we need to go for whether we should do experiments.

So the first question first answer is number 1. So if I write the answer number 1, why the experiments? We do experiments to obtain the value of a physical variable. Number 2, so the first objective is to obtain the value of a physical variable. If you would like to obtain the value of a physical variable then of course, we need to go for the experimentation.

That means, if I give you an example say where interested in measuring the pressure. So that means if you need to know the pressure of the, so when are fluid is flowing through fluidic confinement, then what is the pressure. So physical variable that I mean pressure, velocity, temperature these are the physical variables by which we can specify.

So when a particular fluid is flowing through a pipe then that is that is a flow condition. The flow condition will be specified by some variables like what is the velocity of the flow, what is the pressure inside the flow domain inside you know domain. What is the temperature of the fluid so? We need to specify, we need to know the physical variable. So if we need to know what is the velocity, what is the pressure, and what is the temperature of the fluid temperature of the fluid, pressure of the flow inside the domain and of course the flow velocity then we need to go for experiments.

So this is what to obtain the value of a physical variables. Number 2 is to obtain and understanding of how some process or device works. So, this is the second objective that means to obtain an understanding of how some process or device works. That means if you do not do experiments, we will not be in a position to know the working principle of a process or device.

That means if we say. if we now go back to the, you know previous classes then I mean the discussion of my previous classes then we will will be able to recall that pressure measuring device a temperature measuring instrument or if you would like to measure the flow velocity then you know, the working principle is very important.

That means to obtain the understanding the process working principle of a particular device and for that we need to go for the experiments. So, we we do we do not know priori, say if we considered the pressure measurement, we have seen that we need to take a tapping and from that

tapping process transducer is connected through a tube and then the then only you can measure the pressure.

So now, when we are planning when you are trying to measure pressure using this pressure transducer through this connection rather this system. So how we can measure pressure only we will be in a position to understand if we do the experiments. So that is to understand to have an understanding of how some device or process works. And number 3 you know is to verify a proposed theory.

This is another important point, that means if we I mean those who are doing theoretical work theoretical research. So when they are proposing any relationship, proposing any theory, then whether the theory, whether the proposed theory is correct one to predict the flow parameters if I talk about the, you know fluid mechanics you know domain of the fluid domain of fluid mechanics, then the proposed theories whether the proposed theories able to predict the data correctly or not. Whether the proposed theory can predict the, you know physical variable correctly or not, we need to certify you need to verify, then what we can do we need to go for experiments.

So by measuring the by measuring the physical variables or the data through the experimental process through the experimental technique, we can obtain we can verify the theory which is proposed. So this is another important topic and finally which is very important is that to certify the safety of the device. So this 4 are the important, so to certify this safety of a device. How can you know certify? That means, if we if we talk about the manufacturing unit say if we consider a you know manufacturing companies producing one product and before the product is used for the practical applications we need to certify. What to be the range of the measurement?

So we are considered the manufacturing companies producing one pressure vessel and if the pressure vessel is used in real life applications, then you need to specify, what is the internal pressure range for which the pressure vessel will be safe? That means, the inside pressure what to be the strength of the inside inside pressure that the pressure vessel can be stand without any problem.

And how we can certify that that means we need to certify the safety of a device that the pressure vessel should work if the internal pressure is from within this range. That means, and that we can

know only by doing experiments, so this is another important point. So these four important points are you know, you know, the reason behind doing experiments and that is why we are you know learning this throughout this course the experimental methods or in fluid mechanics.

So now, if you write that the results of this experiments will be either a numerical value or curve or a statement we can make. So, the results of these experiments will be either a numerical value. So if you do experiments will get either a value or a curve or a statement that what we what we can make. So the objective behind doing experiments, we have done. Now if we do experiments, we have seen that these are the different objectives and to satisfy or to fulfil these objectives we need to go for this experimentation.

And now if you do experiments, that is what I have written just now, that the results of this experiment should be either at the either a numerical value or data or it or a curve or sometimes a statement that we can make. Now, when we are getting data or we are recording data from the experiments, then we need to go for the statistical analysis.

Because if we do not go for the statistical analysis, then we are not sure whether the data that is recorded or sometimes you need as I said that if we need to if we try to have a plot a curve then accumulating all the data which are being recorded or which are already recorded may not be possible. So, we need to go for the statistical analysis, if I give an example say you are doing experiments and if we do experiments, we can collect you know a few number of data.

Now question is all the data if we use to generate a curve or plot, then all the data cannot be accommodated in a single line. If it is a straight you know curve, now that means what I would like to what I would like to say the a few data points will be outside the curve or now it will if we will discuss that it will it is seen that most of the data will be outside the curve and then we need to considered that should we ignore all the data which are outside the curve or we should not we should not ignore all the data and if you need to ignore then what what are the data we will be ignoring.

So that means, all the data should not be ignored to obtain the curves or even if when you are getting curve, since we have collected all of the data through out from the experiments and then while generating a curve or developing a plot then a few data points will be ignored and which

are the data set should be ignored from the measured value and for that we need to go for the statistical analysis.

That means, we should have sufficient basis for which we can ignore a few data points, which are obtained or recorded from the experiments and the basis by which we can ignore the data point is the statistical analysis. That means, we should have sufficient logics efficient argument to reject the data.

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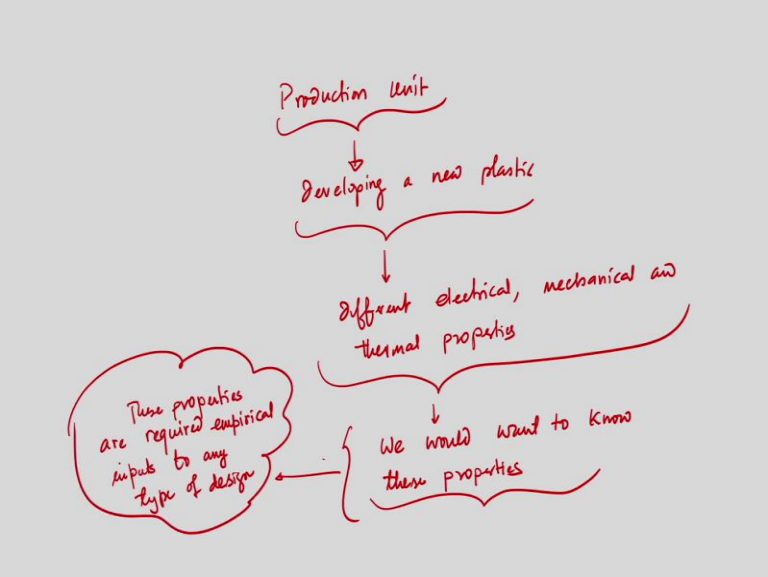

Now just I would like to give you another example, suppose a manufacturing unit or a product, you know, you know production plant is there and that manufacturing unit is developing a plastic. So just I am writing an example, so say a production unit and this production unit is, you know, developing a new plastic.

So when a particular, you know product is developed from our if from a unit, so for manufacturing unit, then this new plastic which is developed which is produced from the plant why we are now trying to develop a new plastic. So the objective is that from the manufacturing unit, when we are trying to go for a new product. Then obviously we should have of you know, our you know, planned objectives and only for that we are planning to have a new product.

So the objective is that if it is a new plastic, that means we are trying to we are trying to have you know, I can say different electrical, mechanical and thermal properties. That means, when we are

looking for a new plastic and if the plastic is used, you know as the insulating material then definitely we are looking for different electrical, mechanical and thermal properties.

So our objective behind the development of a new plastic is to ensure that the new products would have you know different properties. It is it is may be electrical or in may be mechanical. So the objective is completely different, that means the objective is to develop a new product. So whenever any production unit or any manufacturing plants is developing new products, there is or I can say the sole objective is to ensure that the property should be changed.

Now, that means this properties that we are looking for, now once the, you know, plastic is developed. Then you need to measure, otherwise we cannot ensure, so you need to go for the experiments that means our objective was to have different electrical, mechanical and thermal properties.

The product is produced, now, we need to measure whether the properties which you are looking for is really there in the new product or not. So that means, we need to go over measurement. So we would want to know these properties. Now, when we talk about new properties then this properties I am writing now then I will explain, these properties are required required empirical inputs to any type of design. That means, these properties are required empirical inputs to any type of design.

So when the new plastic is developed or objective is to obtain different properties. So the design that means this property, say if we looking if you are looking for the new electrical properties, definitely the property the different I mean a new electrical property will be required and empirical inputs to design.

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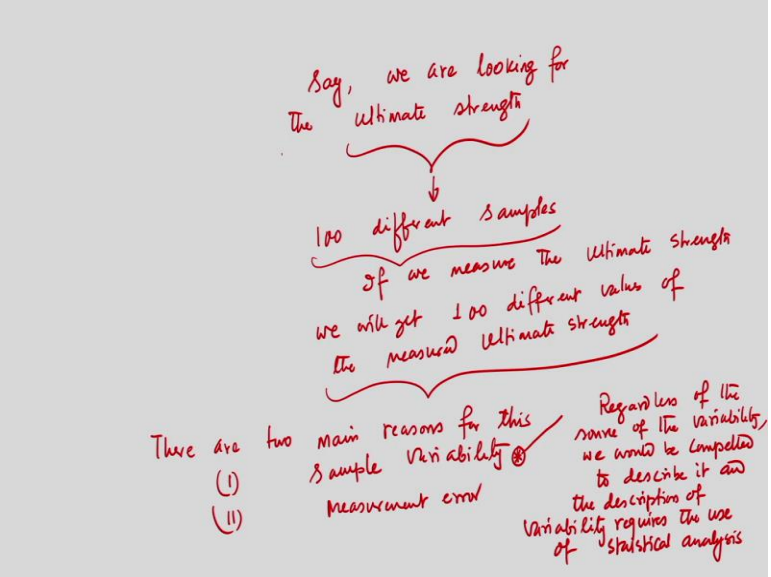

So now if I go to the next slide, say we are looking for the ultimate say we are looking for the ultimate strength mechanical property, so this is the mechanical property. So we are looking for the ultimate strength. Now our objective will be to ensure that the ultimate mechanical properties, that is a ultimate strength will be different, different and the new strength will be there in the new plastic which is being developed.

So, say is a production unit, there will be you know batch production and if we consider a 100 different sample, say you have considering 100 different samples and if we if we consider a 100 different samples because we need to ensure that the product which is being developed from the manufacturing unit will have new ultimate strength but before the product goes into the market goes to the market for the practical applications we need to certify that the product is having new ultimate strength.

And to certify that, we need to do experiments that is what I was talking about and if we take 100 different samples randomly if we take a 100 different samples from these manufacturing unit and if we measure the ultimate strength using, you know mechanical system or device, so if we measure the ultimate strength of these sample, what we will get ultimate strength. So, this is our common experience.

So for our common experience, we can say that if we take a 100 different samples and if we measure the ultimate strength of all 100 samples, we will certainly get 100 different values of the

ultimate strength, this is quite normal. We may get, I mean maybe we may get equal value of two different samples or three different samples, but it is about you know, it is accepted and it is about experience that we will get a 100 different values of measure ultimate stress, why you are getting so?

So this is very important question. So if we consider a 100 different sample samples, and if we measure the ultimate strength from our experience we can say that will get a 100 different values of measured ultimate strength. Why you are getting so? So now, while get there are two main reasons, there are two main reasons for this, number one so we will get whether we have seen this this is not our expectation that I will get it.

So we will get 100 different 100 different values of the measured ultimate strength because of the two because of two different reasons. What are those? Number one is sample variability which is very important because I will discuss this issue and number two is the measurement error. So, we have seen that there are two different reasons for which we will get this will get different values. One is the sample variability other is the measurement error.

Measurement error that is that will be there because we cannot eliminate it, but other important reason is the sample variability, what is this? So if we now consider this point, which is important that regardless of the source of the variability. So sample variability so maybe the product plastic which is being produced which is developed, we will have I mean if we take sample, so sample within when a particular plastic may not be equal.

So sample variability will be there because of what we may get different values of the measured ultimate strength, but regardless of the source of sample variability would be compelled to describe it. So we know that there will be you know, the source of variability sample variability knowing that or regardless of the source of you know, variability would be able to compelled to describe it and if you would like to describe it we need to go for the statistical analysis.

So and describe it and and the description and the description of variability requires the use of statistical analysis. So, this is important, that means again I am repeating if you take 100 samples randomly will if we measure the ultimate strength will get 100 different values two different reason that if we take two different plastic samples, may be the sample variability will be there the composition may not be equal.

Now, sample variability will definitely leads to the different values of the ultimate strength. On the other hand, we might we might have the measurement error. Measurement error will be discussing and for that we need to go for the statistical analysis, that is what I was talking about that if we get a 100 values, 100 values on with the correct one. So, some you know data will be you know, significantly or distinctly different from the other data points.

But when you talk about sample variability, regardless of the source of sampling variability, we even if we do if we know that there will be sample variability, we would be compelled to describe it we will described it what will be would be compelled to describe the, you know, why the different values of uncertain measurement strength we are getting. And for that if we need to describe it and for that description of variability recovers the understanding or the analysis of the of the use of the statistical analysis.

So with this, I stop my discussion today and we will continue our discussion in the next class. Thank you.