Transport Phenomena in Biological Systems
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Lecture - 37
Macroscopic Aspects: The Engineering Bernonulli Equation

Welcome back. Today let us start looking at macroscopic aspects. And what we are going to do is we are not going to worry too much about the depth the rigor and so on and so forth. I think I also need to mention at the stage this course is not a mathematics course you need to understand the physical reality far better we need mathematics to it. So it is I means to an end I sure this course is concerned.

So that means to be clearly kept in mind. So far we had looked at very rigorous aspects starting right from macroscopic aspects very recent definitions then we build things up we got a lot of insights we could use that for design probably operation by extending things and so on and so forth. And basis was a complete picture of the system. And then when we came to turbulent flow and other aspects we realized that we do not understand things clearly.

However those are things that are useful turbulent was very useful. Therefore we need to be able to handle turbulent flow we need to design based on turbulent flow and so on and so forth, some means of starting from a basis was given in the previous lecture. Here we are going to look at some formulations which are very useful which may not be based on highly rigorous aspects will there will be some hand way example but they are very useful, definitely useful for design and operation.

So the remaining part of this chapter is going to look at such aspects and the first aspect that we are going to look at is called the engineering Bernoulli equation. I am sure you would have seen Bernoulli equation in your high school higher secondary school or in the early parts of your engineering curriculum okay that probably was a simplistic Bernoulli equation physics courses and so on.

Here that would have been an ideal Bernoulli equation which does not consider losses.

$\frac{\Delta p}{\rho} + \frac{\Delta v^2}{2} + g\,\Delta x = 0$

if you recall that however this is a practical situation ideality does not exist. So this is the engineering Bernoulli equation and we need to understand the standards non idealities only then can we design devices processes overcome, so those aspects. Let us see this in some detail.

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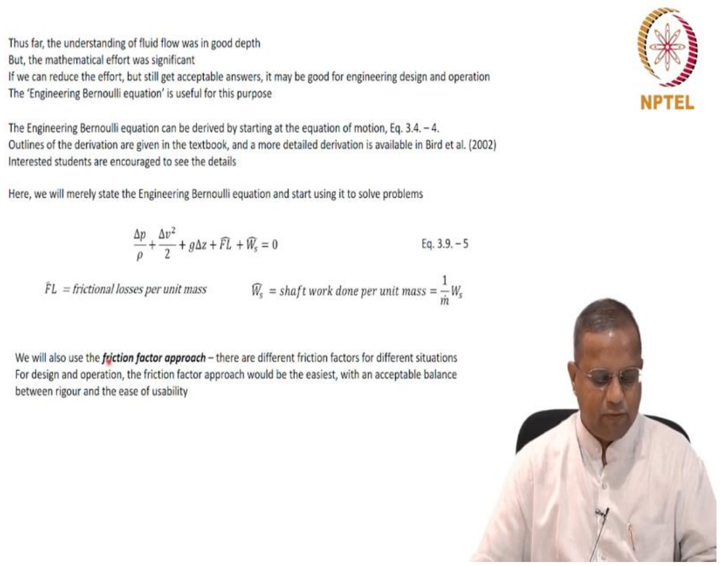

Let me repeat this it is worthwhile repeating this thus for the understanding of fluid flow was in good depth. But the mathematical effort was significant. We need mathematics it is no doubt about it. How was this is not a mathematics course? If we can reduce the effort but still get acceptable answers it may be good for engineering design and operations and engineering Bernoulli principle is useful for this purpose.

The engineering Bernoulli equation can be derived by starting at the equation of motion you started the equation of motion momentum balance you can get to this. And such a derivation is available in other textbooks and detailed textbooks it is the outlines of the derivation are given in your textbook, more detailed derivation is available in advanced textbooks and papers written on this in the 60's may be.

In fact Bird the first author of the paradigm shifting paradigm changing book transport phenomena. He had written a paper on this derivation in the Korean Journal of chemical engineering way back in the 1960's. And I may have mentioned this earlier I am very privilege to I am happy to tell you that professor bird Russia Robert Bird he wrote the 4 word for your textbook for my book the nice story about this.

This of course transports phenomena was a book that we all used to look up and Bird was one of a rock stars if you could if call it that. And when I wrote this book but for biological systems width you know the charge aspects and so on and so forth. Bird book does not have the charge aspects. When I wrote that and this book is very thin it is about 240 pages. Bird book is thick about 700, 800 pages of course it is a lot more comprehensive in terms of whatever it covers.

So when I wrote this book of mine and I thought it would be or in fact the publisher suggested that it would be good to consider people to write forwards. I said why not write to professor Bird himself. Then I wrote to him I sent him a sample of the book and waited. I think I sent it on friday, the email on friday and then of course the weekend saturday sunday although I was excited, I had to wait. And then monday came no response, tuesday came no response.

Then I said maybe I expected too much expecting Bird to write a foreword is really too much and so on it was the Bird. And but wednesday I got a response, wednesday morning I got a response. It said you know this book transport phenomenon was written in 1960 1st edition. And it was Bird about 10 years ago. Yeah about 10 years ago was 88 years old. And he wrote saying are about 10 years ago, he was 88 years ago.

And he wrote back saying and the first few lines said you know I am 88 years old I am revising my own book with the help of others. And I said maybe it is a polite and then the next paragraph said but I like your book and therefore I would like, I would write a 4 or 5 word. I was very excited that person Bird agreed to write 4 word for my book. And when we were discussing the various aspects I have to send him the entire book and he had looked through out in three days flat. And he even pointed out errors between C_p and C_v in that book.

And that is fixed level of familiarity understanding of the material. And coming back to this I had derived the engineering Bernoulli equation from a different point of view. He specifically said do not do that do not propagate this method of derivation. It is wrong. In a certain sense I have written a paper on this and it is in the Journal of Korean Journal of chemical engineering. And so please do not do that. He at least if give the outlines of the derivation based on the momentum balance equation that should be fine.

And I took his advice and I give the outlines of the derivation in the textbook and then he wrote the 4 word which I am very grateful for. And for this reason I am not going to derive the engineering Bernoulli equation in this course if you are interested in the outlines please see the textbook. If you are interested in more detailed aspects please see the journal article written by professor Bird in the Korean Journal of chemical engineering in the 60's.

Here I am just going to state the engineering Bernoulli equation we are using it for a utility purpose anyway we are not looking at the basis. So however be assured that it can be derived from fundamental principles. So it is definitely valid. So the engineering Bernoulli principle states that

$$\frac{\Delta p}{\rho} + \frac{\Delta v^2}{2} + g\Delta x + \widehat{FL} + \widehat{W_s} = 0 \qquad (3.9\text{-}5)$$

where

$$\widehat{FL} = -\frac{1}{\dot{m}}\int (\tilde{\tau} : \vec{\nabla}\vec{v})\, dV$$

$$\widehat{W_s} = \frac{1}{\dot{m}} W_s$$

Equation 3.9-5 is a useful form of the engineering Bernoulli equation.

Also what we are going to do is we are going to use something called a friction factor approach. We will determine the friction factor for different situations and that friction factor allows us to do very many design aspects and also take care of some operational aspects. So our main aim in this particular approach would be to find the friction factor for various different situations. And you have a different friction factor for each situation we are going to define a friction factor first.

And then find the friction factor for different situations once they find the friction factor then everything else falls in place. That is the way this is going to be and that is the way the remainder of this chapter is going to be we are going to find friction factor for various different practical useful situations. So just re emphasizes for design and operation the friction factor approach would be the easiest with an acceptable balance between the rigour and the ease of usability. This equation of course is from fundamental basis from the momentum balance equation.

So there is no difficulty with this as to how we use this. You know you need the friction factor for each case.

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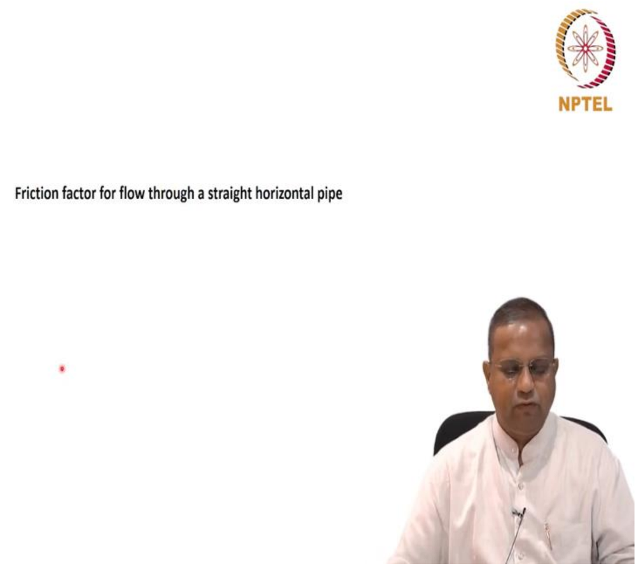

Let us start with the case at we are most familiar with the friction factor for flow through a straight horizontal pipe. Should we take a break? Yeah why do not we take a break? You have been introduced to the turbulent flow approach or the engineering Bernoulli equation approach. I have introduced the engineering Bernoulli equation to you. And Let us take a break. Then we will be starting the next class. We had look at the friction factor for flow through a straight horizontal bye see you.