

Course on Momentum Transfer in Process Engineering
By Professor Tridib Kumar Goswami
Department of Agricultural & Food Engineering
Indian Institute of Technology, Kharagpur
Lecture 38
Module 8

Problem on Pneumatic conveying Part-2

So if you remember we had been doing one problem and this was on typically trial and error type of solution, right? So when we had taken trial and error we had done first two trials you saw that it was not coming as the solution.

(Refer Slide Time: 1:05)

out pr. = 1 atm p_{in} ?

$$\frac{RT}{M} \ln \frac{p_1}{p_2} + (1+s+4\alpha f \frac{L}{D}) \left(\frac{GRT}{2M^2} \right)^2 \left[\frac{1}{p_1^2} - \frac{1}{p_2^2} \right] + (1+s)g(z_1 - z_2) = 0$$

$\frac{RT}{M} = 8.4 \times 10^4$; $p_2 = 1 \text{ atm} = 101325 \text{ Pa}$

$(1+s+4\alpha f \frac{L}{D}) = 137.8$; $\frac{1}{p_1^2} - \frac{1}{p_2^2} = 1$

$\frac{1}{2} \left(\frac{GRT}{M} \right)^2 = 3.48 \times 10^{12}$; $\frac{1}{p_1^2} - \frac{1}{p_2^2} = 1$

$(1+s)g(z_1 - z_2) = -3188.25$; $\frac{1}{p_1^2} - \frac{1}{p_2^2} = 1$

Trial 1, $\frac{p_1}{p_2} = 1 \therefore p_1 = p_2$
 LHS = -ve, < 0

Trial 2, $\frac{p_1}{p_2} = 1.2 \therefore p_1 = 1.2 p_2$
 LHS = -ve, < 0

Trial 3, $\frac{p_1}{p_2} = 1.5 ; p_1 = 1.5 p_2$
 $\frac{1}{p_1^2} - \frac{1}{p_2^2} = \frac{1}{(1.5 p_2)^2} - \frac{1}{p_2^2} = \frac{1}{2.25 p_2^2} - \frac{1}{p_2^2} = \frac{1 - 2.25}{2.25 p_2^2} = \frac{-1.25}{2.25 p_2^2}$

$2 \ln(1.5) \times 3.48 \times 10^{12} + 137.8 \times 3.48 \times 10^{12} \times \left[\frac{1}{(1.5 p_2)^2} - \frac{1}{p_2^2} \right] - 3188.25 = 0$

$34059 - 188.31 - 3188.25 = 30662 = +ve > 0$

1.2 & 1.5
 (-ve) (+ve)

$\frac{p_1}{p_2} = 1.2 \text{ \& } 1.5 \checkmark$

Now let us look into the third one, okay but to recapitulate because otherwise you have to go back to your previous lecture, that is difficult, so from where we started that let us write we wrote that the equation was $\frac{RT}{M} \ln$ of p_1 by p_2 plus 1 plus s plus $4 \alpha f \frac{L}{D}$, right? This into $\frac{GRT}{2M^2}$ square by $2M^2$ square, right? Into 1 by p_1 square minus 1 by p_2 square, right? Plus 1 plus s into g into z_1 minus z_2 is equals to 0 , right?

We found out in the previous class values of $\frac{RT}{M}$ is equal to 8.4 into 10 to the power 4 , right? We found out 1 plus s plus $4 \alpha f \frac{L}{D}$ this is equal to 137.8 we also found out $\frac{GRT}{2M^2}$ by M^2 square half of that, right? $\frac{GRT}{2M^2}$ by M^2 square half of that is equals to 3.48 into 10 to the power 12 , right? And these are the 3 and the 4 th one 1 plus s into g into z_1 minus z_2 this was at minus 3188.25 , right?

So we got trial 1 assuming p_1 by p_2 is equals to 1 that therefore p_1 is equals to p_2 and we got this left hand side of this whole equation was equals to less than 0, right? Is negative, right? That is less than 0, why? Because p_1 by p_2 p_1 was equals to p_2 so this went off this is ln of 1 that of 0 so first two terms 0 this was negative so it is less than 0. In trial 2 we had assumed that let p_1 by p_2 is equals to 1.2 that is p_1 is equals to 1.2 p_2 , right?

So if we write that we had written it, so instead of p_1 we had written 1.2 p_2 so here it was 1.2 p_2 square and here 1 by p_2 square so if we take p_2 square out, so 1.2 square minus 1 that became negative, so this term became negative this was positive this term negative so this value was very small, so left hand side again became negative so this is less than 0, right? Now, let us take the third trial.

So trail 3 let us take if it is 1.2 is less, than let p_1 by p_2 is equals to say 1.5, yeah say let us take p_1 by p_2 is equals to 1. something, maybe 4 or 5 so that this becomes 1.5 this becomes positive. So if we take this, this value we have found out to be RT by M 8.4 10 to the power 4 plus this value we have seen 137.8, right? Of course here 1 ln of p_1 by p_2 that is ln of 1.5 into this 137. this into we had this whole stuff to be 3.48 10 to the power 12, right? 3.48 10 to the power 12 and we took 1 by p_2 common and $(\)^{(6:49)}$ inside it becomes 1.5, right? 1.5 p_2 square minus 1 by p_2 already taken out, so 1.5 square divided by 1 minus we had this 3188.25, right?

So if we make this solution and see what is the value, so we get 1.5 square inverse, right? 1. square 1 by 1. square, okay so this value is 0.44 minus 1 is equals to minus 0.55 are we doing correct so 1 by p_2 1 by p_2 comes out 1 by p_2 comes out, right? So p_1 is 1 by p_1 is 1.5 p_2 , right? So if we write 1.5 p_2 square so 1.5 p_1 by p_2 goes out, so 1 by 1.5 square minus 1, right? So that becomes 1 by 5 square so that is minus 0.55, right? And this is 1 and let us see what about ln of 1.5, 1.5 ln is positive 0.40, right? So this is positive this is negative this is also negative, right? If that be true, so 1.5 minus this is that, though we had this GRT by this thing was 10 to the power 12, okay so it was 137.8 10 to the power 12 so 1 by 1.5 square minus 1 so this becomes ln of 1.5 into 8.4 10 to the power 5, so let us see 8.4 0.04 into 8.4 10 to the power 4 so that becomes 34059, right? So that becomes 34059 or 34059 059, right?

And this we have seen to be negative, okay that was negative that is 1.5 square inverse minus 1 is equals to that minus into 1.37 137.8 into 3.48, is it 10 to the power 12 or 10 to the power 9? It was 10 to the power 3.48 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 yes 12. So 3.48 into 10 to the power

12, okay then how come it becomes positive then 26 our this thing was GRT square by 2 M square, right? GRT square by 2 M square 1 plus s 4 α f L by D so that has become 137.8 this is 10 to the power 12 and this is minus of that 1.4 p_2 , right? And without the value of p_2 , p_2 is 1 atmosphere so if we take 1 p_2 , then 1.2, right? This is 1.5 so 1.5 square minus 1 this is minus and that became equals to minus 26641, so it is still a bigger number, right?

This still a bigger number 10 to the power 12 so how come it is then how come it is then it has become p_1 by p_2 1.5 so this is 34099 is okay, but how it has come so less our 1 by 2 GRT M square is this, so 3.489 10 to the power 12 is okay and this has become 3 minus 3.88 3188, fine so when I took \ln of p_1 by p_2 is 1.5, then this became this number, fine but how come this has becomes so low 26015 because in our expression it was GRT by 2 M square, yes 1 by p_1 square minus 1 by p_2 square, not cube 1 by p_2 square by 1 by p_2 square.

So if that is true, then \ln of p_1 by p_2 is 1.5 so it has become that 34059 or something and this value is 137 this value 10 to the power 12 this value has minus 0.55 something. So if so much and this is negative then how come then this has become 1.5 this 26016.236, right? So this has become so low 14308 in that first case 1.2 when we took it came like that, so it was 3.489 10 to the power 12 so it was 1 by p_1 square minus 1 by p_2 square, so p_1 p_2 so p_1 1.12 p_1 we have taken p_2 is 1 so we have taken the ratio p_1 by p_2 is 1.2, right?

So p_1 is 1.2 this is 1 and if it taken 1.2, then p_1 is 1.2 p_2 , right? So if we substitute here, 1 by p_1 and p_1 is 1 atmosphere, right? And if we take 1 atmosphere 101325, right? Pascal so that has to be taken then only this number will come so low. So 1 by p_2 square that is into this 1 by 1.2 square minus 1, right? So when we are taking p_2 p_1 no p_2 is given as 1 atmosphere, right? That is 101325 Pascal, right? That is p_2 so if we write the value of p_2 101325 square into 1 by 1.2 square minus 1, so if we look at that, then 1 by 1.2 square 1.2 square is this inverse of that minus 1 is equal to this, right? Okay divided by 101325 square is equal to so much into we had this value where this one 3.48 10 to the power 12 and 137, so into 137.8 into 3.48 into 10 to the power 12 is 14272, right?

So that is how it came negative for this case if we write it was for first time it was okay this term was 0, this term was 0 and it was negative this term is negative for the second one this has becomes 1.2 \ln , right? So this is some positive value this has become negative and negative is how much minus 14272 and this was 3188 and this was RT by M it became 8.4 10 to the power 4

this came 8.4×10^4 to the power 4 is equal to 84000, okay this into \ln of into 1.2 \ln is 0. So 15315, 15315 so plus 15315 minus 14372 minus 3188 was a negative value it is true, right? So we have to convert this 1 atmosphere to Pascal and substitute this into p_2 then only we can get in. So in that case this value we have got for p_2 , right? 1.5 that is if p_1 by p_2 is 1.5, then this value we got for the first term, second term we got let us look into again what is the value of second term, second term came out to be 1 by 1.5 square, right? Inverse minus 1 is equals to this divided by 101325 square equal to this into it was 3.48 into 10^{12} .

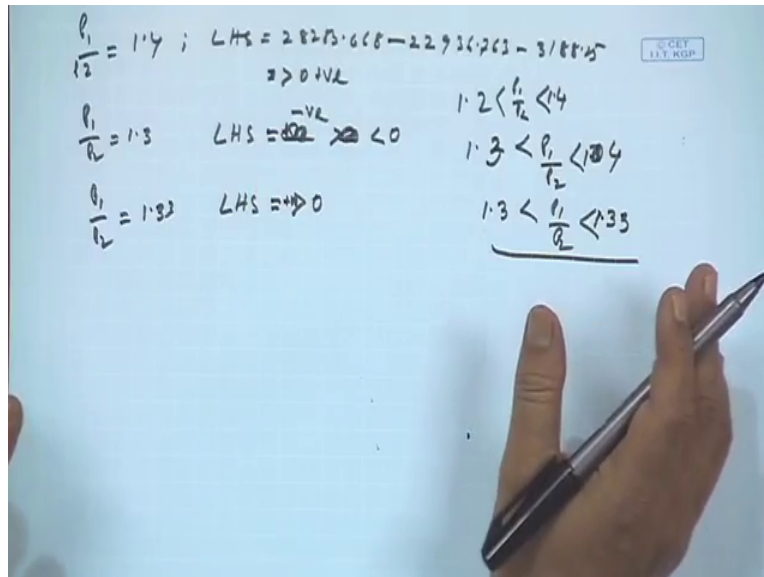
So it came to be minus 188, so our thing was 34059 minus 188.31 minus 3188.25 if we neglect that, then it became to be calculated as 34059 minus 188.31 if we minus 3188.25 this is equal to 30682, right? So that means this is a positive value, right? So this is a positive value, right? That means this is greater than 0, which means that the value is lying between 1.2 which was negative and between 1.2 which was negative and 1.5 which is positive this has become negative, this has become positive, right?

So it is lying between 1.2 and 1.5 that is the ratio p_1 over p_2 is between 1.2 and 1.5 it lies between that. So now we have to take 1.4 in a similar fashion we have to find out that is why I said these compressible fluid flow the calculations are very very big and that is why typically I have taken that with the help of the calculator let us also try online the reason being you also practice, right? Otherwise, we could have done outside and put the value then it would have become very difficult for you to understand.

For example, here we had said in the problem that outlet pressure was 1 atmosphere, right? And inlet pressure is to be found out, right? If we put 1 atmosphere in an atmospheric term, then this problem will have very difficult to solve and the units which we have so here atmosphere has to be converted into Pascal. So 1 atmosphere is 101325 Pascal, so the moment we took that 101325 Pascal we could realize that first trial when p_1 is equals to p_2 was there that time it was okay, but when it became p_1 is equals to p_2 other than that, 1.2 times p_2 , then it became negative first time also it became negative, right?

We found whatever we had done was not coming, so then we realized that no it should be converted into Pascal, the moment if you convert it into Pascal we found the solution it was like that and then we carried out for 1.5 we saw this is to be positive.

(Refer Slide Time: 28:12)



Now if we take the value of p_1 by p_2 to be 1.4, then by properly doing I am not because now we are running out of time. So if we do 1.4, then the first term left hand side first term is coming 28283.668, second term is coming minus 22936.763, third term 3188.25 and when it is coming like that if we add up then it becomes equals to greater than 0, right?

So it is positive, right? So this becomes positive so it is less than then that means p_1 by p_2 lies between 2 and 4, right? So p_1 by p_2 less than 2, but greater than rather greater than 2 but less than 4, right? So if that be true, now let us take p_1 by p_2 to be equals to 1.3 and left hand side we will see this is still positive, right? And that means it is greater than 0, so we can say 2 is less than p_1 by p_2 less than 3. So it is lying between 2 and 3, so now let us take p_1 by p_2 to be 1.33, right? And we will see that it is this is then not positive, this is negative so it is less than 0 that is this 3 rather 3 and 4 p_1 and p_2 lies between 3 and 4. So if we take 1.33 then we will see left hand side this is greater than 0, right? This is positive and greater than 0. So that means 3 less than p_1 by p_2 less than 3. rather 1.3 should have been p_1 by p_2 1.2, 1.4, 1.3, 1.4, 1.3, 1.33, right?

So it lies between 0.3 and 0.33, so this way if we how many number of digits, so it is 1.3. So how many number of digits you want accurate so you have to go on doing the trial and then find out whether it is 1.33 or 1.3, 1, 5 things like that, right? So this is a way you have to do the trial error and find out the value, right? Okay, thank you.