Fundamentals of Gas Dynamics

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Week-07

Lecture-27

Discussion on C-D Nozzles-2

We will do few more problems related to C-D Nozzle.

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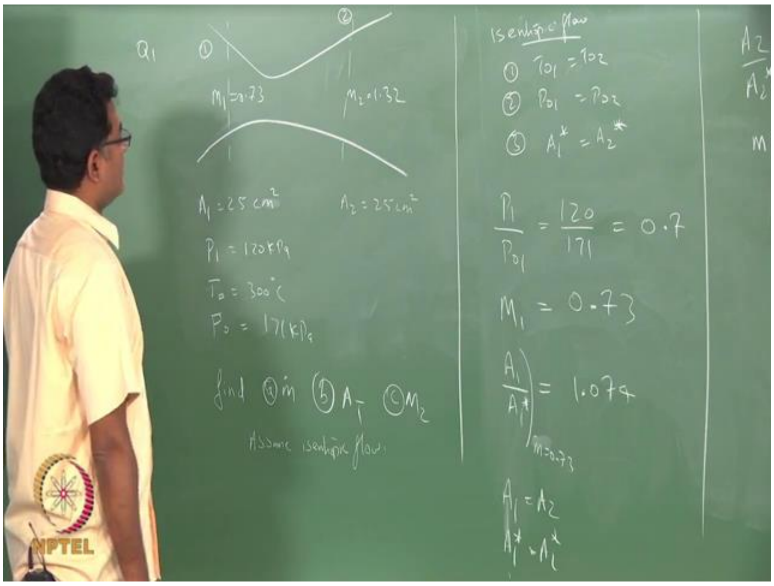

So, the question 1; I have a C-D Nozzle, I have 2 sections; section 1 and section 2, A1 is 25 centimeter square, A2 is also 25 centimeter square, P 1 is 120 kilo pascal and my stagnation temperature is 300 degree Celsius, P 0 is 171 kilo pascal, find M dot area at the throat M 2? Assume isentropic flow. So, the moment you know, it is isentropic flow you know 3 things, T 0 1 equals T 0 2, P 0 1 equals P 0 2 and A1 star equals A2 star.

So, these three things are implied when you say isentropic flow, we will use this information to do the problem. So, first we have P 1 by P 0 1 which is 120 it is 120 by 171 which is 0.7. The mach number 1 less than. So, I look at the tables gamma, 1.4, P 1 by P 0 is 0.7; 0.7 is mach number, 0.73 which has A1 by A1 star which is at M equals 0.73. So, I look at the tables M equals 0.73 my A by A star is given as 1.074, but my A1 equals A2 and we also know A1 star equals A2 star. So, my A2 by A2 star is also my A1 by A1 star which is now which is now 1.074.

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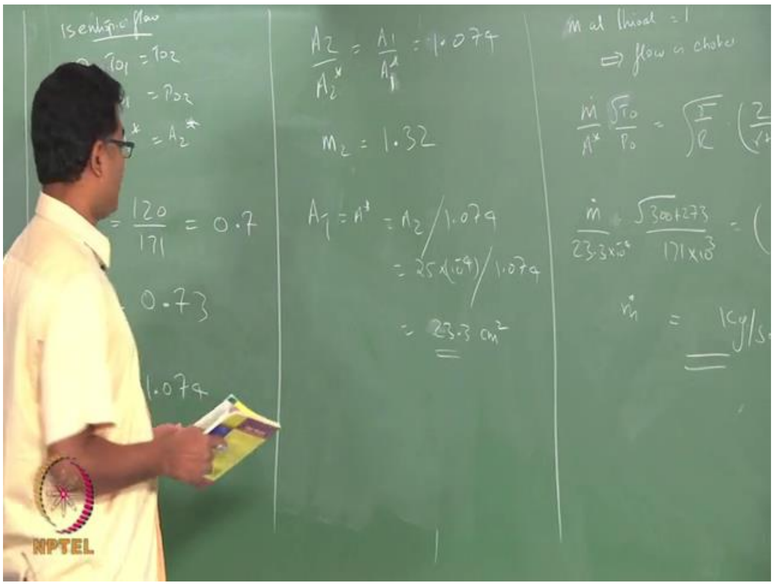

So, this A by A star has 2 mach numbers. So, 1 is already here, 1.74, the other mach number is, you look at how the supersonic solution of this area ratio 1 point 0 1.074 1.074 will give me mach number of 1.32. So, my M 2, the fluid that comes here M 1 0.73 reaches a mach number of 1.32 for this area ratio, somewhere it is crossing 1 which is happens at the location where A is 0, which is your throat. So, your A star is your a throat. So, your throat value a throat is your A star is A2 into 1.074 A2 is 25 centimeter square which is A2 by point. So, 25 by 1.074 it will be around 25. So, it is 24.

Student: 23.

23.3 centimeter square, so that would be my throat area given this condition. Now, also need to find my M dot, now M at mach number at throat is 1 implying flow is choked or the nozzle is choked. So, if it is choked the maximum flow rate a by A star into root of T 0 by P 0 is a constant, which again is given here in the gas tables which is gamma by r square root into 2 by gamma plus 1 to the power gamma plus 1 by gamma minus 1 into 1 by 2. So, your M dot you can find it A star is known A star is 25, 23.3 into 10 power minus 4 root of T 0 is known 300 plus 273 divided by P 0 is known 171 into 10 power three equals this particular constant. So, we can find your M dot in kg per second.

So, this is all because the flow is assumed to be isentropic. So, somewhere here between station 1 and 2 the flow is isentropic. So, somewhere across the mach number reaches 1 which happens at the throat, which since it is mach number is equals 1 the A star is here a throat. So, we have computed our A throat and then obtain this particular relation. So, if your A2 is not same as your A1 then you cannot write this, but you can still find your A2. So, give if you are given A2 you can still find the ratio and obtain your M 2 just that it may not be the same ratio as this it would be some other solution which has to be supersonic solution because we have said this would be at M equals 1. Now, we go to the next question.

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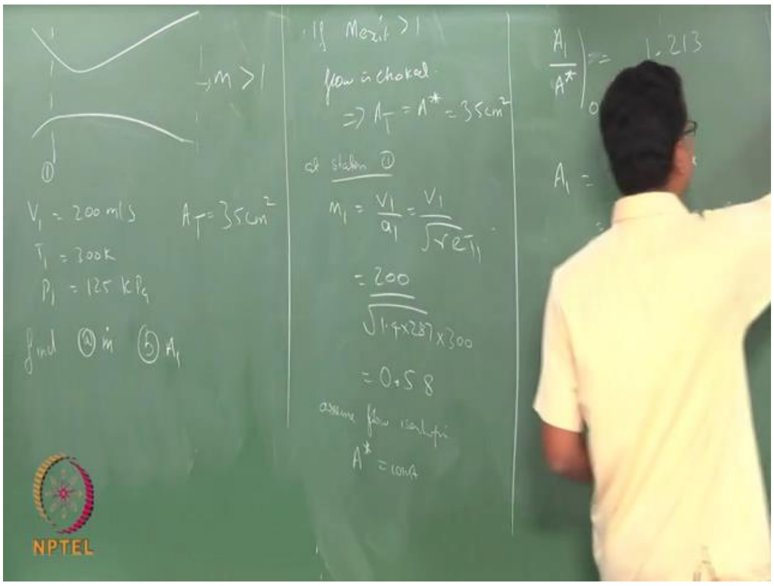

Again a C-D Nozzle, at some section 1 my v 1 is 200 meters per second, T 1 is 300 kelvin, P 1 is 125 kilo pascal, M is M exit is greater than 1, find M dot A1 if the throat area is 35 centimeter square? So, the C-D Nozzle flow is coming in at section 1, we have the values static values, the exit mach number is greater than 1 implies, exit is greater than 1, flow is choked; this the nozzle is choked implies your A throat is same as your A star which is same as 35 centimeter square.

So, at station 1, my M 1 is V 1 by A1 which is V 1 by gamma r T 1. So, V 1 is 200 root of 1.4 into 287 into T 1 is 300. So, this gives me a mach number 0.58. So, for this mach number assuming flow to be isentropic A star is constant. So, if my A star is constant now A1 by A star at mach number 0.58.

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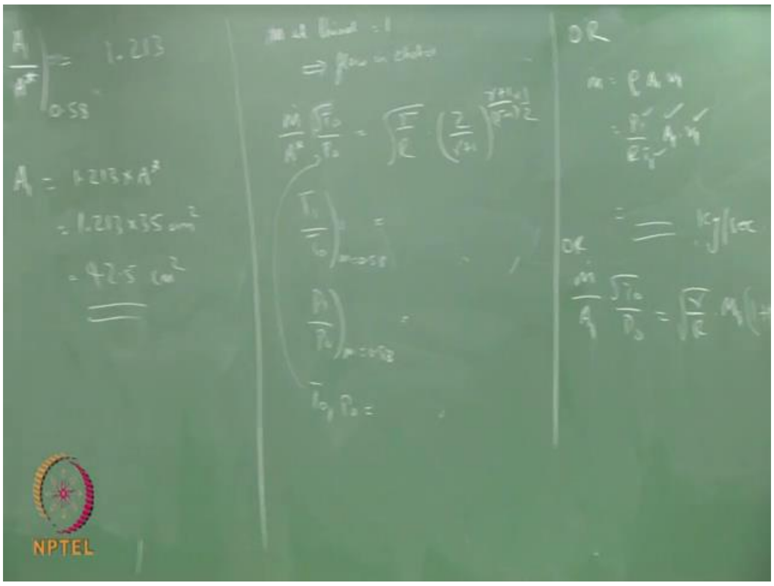

I look at the table’s mach number 0.58 as on A by A star of 1.213. So, my A1 is 1.213 into A star which is 35 centimeter square. Now, you need to find M dot? So, M dot since M at the throat is 1 or the M at the exit is greater than 1 your M at throat is 1 and the flow is choked, you use this relation, find your M dot, but what about T 0? You have T 1 by T 0 at M equals 0.58, P 1 by P 0 at M equals 0.58 from this you can find your T 0 and P 0 substitute that here A star is already known. So, you can find your M dot.

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You can also find it from the throat value or from the inlet value or M dot is rho 1 A1 V 1, rho 1 is P 1 by r T 1 into A1 into V 1. So, V A1 now we have found V 1 is given P 1 and T 1 is given is again. So, you can check whether this is same as that. So, this is under assumption flow is choked, otherwise you use since the mach number at station 1 is known that also can be used. So, M dot by A1 into T 0 by P 0 then you have a relation for r M 1 one plus gamma minus 1 by 2 M 1 square gamma plus 1 by 2 gamma minus 1 x.

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Minus of gamma plus 1, so your A1 is known, M 1 is known, we can find your M dot?

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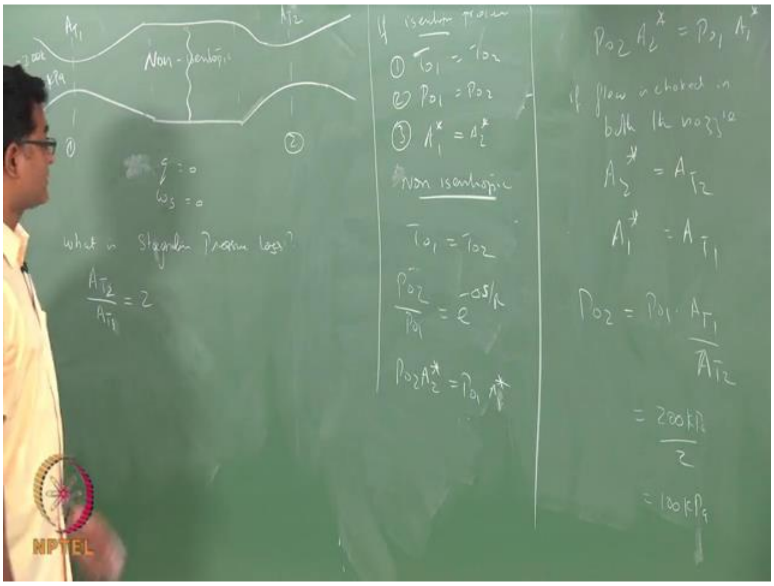

Now, we will do a different problem. So, I have 2 nozzles; 2 C-D Nozzles we took them as 2 different throat area and there is something that is connected here, which is the typical case of a supersonic wind tunnel. So, there is some shock or some non-isentropic process that is here. So, the process is non-isentropic, but no heat transfer no shaft work and this is supplied from a tank kept at T 0 and P 0. So, I have A throat 1 and A throat 2.

So, my temperature here is 300 Kelvin temperature here is some 200 kilo pascal. So, what is this stagnation pressure loss T 1 by a T 2 is given as 2. So, what is this stagnation pressure loss? So, if it an isentropic process, we know T 0 1 equals T 0 2 or T 0 stagnation temperature is constant and stagnation pressure constant and our A star constant, but here it is non isentropic, since there is no queue and no shaft work you can still write this, but P 0 2 by P 0 1 depends on your entropy change. So, this is your drop in your stagnation pressure. So, this is a non isentropic process you also know this A1 star. So, we will use this relation now, since the flow is non-isentropic we will use this relation defined our drop in pressure. So, your throat area, assuming the throat area is choked A2 star is your A throat 2 A1 star is your A throat 1 to again find my P 0 2 to be P 0 1 into A T 1 by A T 2.

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So, my A T 2 by A T 1 is 2 because your second throat should be larger than your first throat. So, the process is you have ayou are generating a supersonic flow and at the exit you have a supersonic flow, that supersonic flow remain constant in your constant area duct and then it is reduced by a supersonic diffuser. So, this would act as a diffuser andit would eject into the atmosphere slowly. So, there are no back pressures from the nozzle. So, your second throat would be larger. This ratio is A to A T 2 by A T 1 is two. So, which is P 0 1 is 200 kilo pascal by 2. So, this would be 100 kilo pascal.

So, this is your reduction in your stagnation pressure. So, there is some loss of your stagnation pressure along the non-isentropic process. We are going to do the shock analysis and you will see that this has some implication in the flow. So, your string this stagnation pressure is your strength of the, or the power of which you have the flow. So, this is a measure of the strength of the flow and that is lost due to your non-isentropic process. So, it iscoming at full steam with P 0 1 then suddenly it encounters a non-isentropic process and loses all those things that is what it typically means.

So, we will discuss that in the next week and the examples on over expansion and under expansion we will take it up when we discuss shocks and oblige shocks. So, we will come back to these examples again at a later stage to do some more problems involving shocks and expansion waves. The diffusive part or supersonic diffuser also we will come back and take it up after discussion on shocks and oblige waves because supersonic diffuser is also an important part. So, we will take it up that as well as at a later point in time.

Thank you.