Fundamentals of Gas Dynamics
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Week - 09
Lecture - 34
Discussion on Normal shocks – 2

We will continue with the Discussion on Normal shocks, I have a numerical problem here in which I have a CD nozzle.

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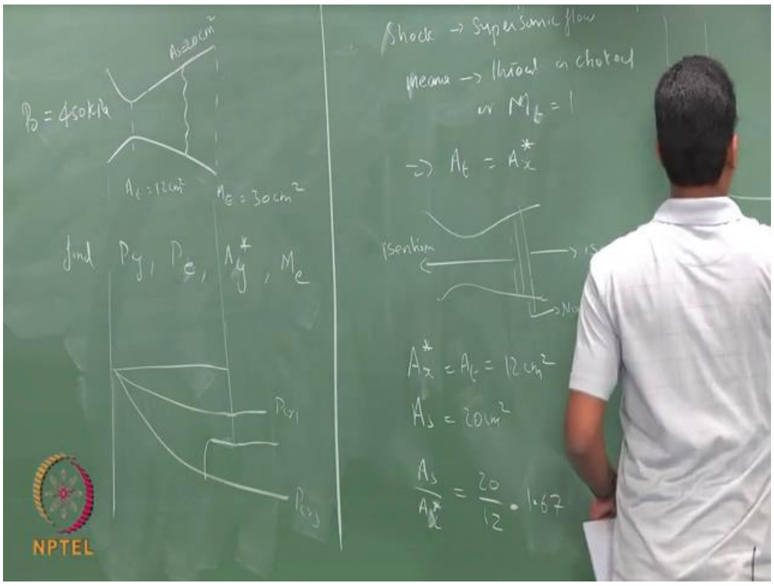

So, this is supplied from a chamber where the pressure is 450 kilo Pascal. There is a normal shock somewhere which is 20 cm square; area to exist is 30 centimeters square, area at the throat is 12 centimeter square and the shocks happens at area where it is 20 centimeter square. Find Py, Pe, Ay star and mach number of the exit?

So, I have nozzle there is P 0 that is being supplied. So, we have P 0, nozzle comes there throat area is given, exit area is given and there is a shocks that is sitting at the location where the area is 20 centimeter square. This is some case where what we had seen which we are going to discuss in next week lecture. It is going to some back pressure between P critical 1 and P critical 3. So, the back pressure is somewhere here. So, that there is shocks that is happening here.

The question is to find the exit pressure P y that is after the shock and this. Now in this question we know that shock is going to happen only for a supersonic flow. So, that is the first question first information we have from here shock for a supersonic flow, which means throat is choked or mach number at the throat is 1. Which implies your A throat is your A star. So, this is before the shock so I will also use the suffix x. So, just before the shock I have isentropic flow, after the shock I have isentropic flow only the shock has been none isentropic flow. So, I will use isentropic tables up to this, just before shock and isentropic tables just after this shock and in for the properties across the shock I will use shock table which is non isentropic process.

So, I have the throat Ax star equals At equals 12 centimeter square. Shock happens at location 20 centimeter square. So, I can find As by Ax star which is 20 by 12. So, As by Ax star is 1.67. This as we know is going to give me 2 mach numbers M and A by A star. I will take a supersonic mach number because the flow is now supersonic, it is stopped.

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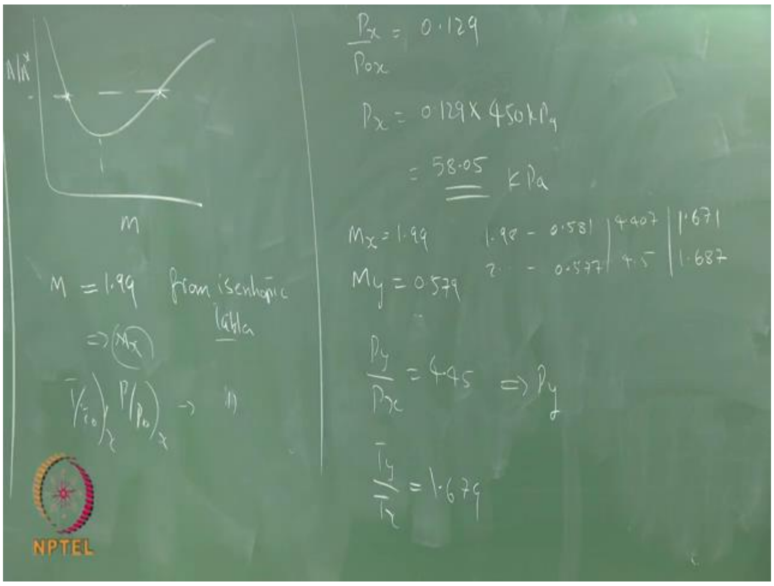

So, the mach number is associated with is 1.99 from isentropic table. So, I look at the tables I get A by A star of 1.67 to be 1.99 from the isentropic table. So, this is the mach number here just before the shock which is my M x. So, I can get all the properties at M x using my isentropic table. So, I take the isentropic table 1.99 will give me T by T 0 P by P 0 or at x before the shock from isentropic tables.

Now, the question is to find the properties across the shock. So, my P by P 0, P x by P 0 x is P x by P 0 x is - I take the table 1.99 P x by P 0 x is a 0.129. So, my P 0 x already given, so my P x is 0.129 into 450 kilo Pascal that is my P x.

Student: 58.05.

How much?

Student: 58.05.

58.05 kilo Pascal. Now I have M x which is 1.99. So, I look at my shock table to get my M y which is 1.99. 1.99 is not given in the shock table here, so I have values at 1.98 and 2 the M x is 0.581, 0.5771. Ideally you need to interpolate this. So, now, let us take the average, this will be 0.579; that is my M y. Now the moment I have my M y, I can also get the pressure jump P y by P x, P y by P x is again the pressure value or pressure jump value or 4.407 and 4.5. So, the average is.

Student: (Refer Time: 10:06).

Four point

Student: (Refer Time: 10:10).

Yeah, approximately this, OK.

Again T y by T x is 1.671, 1.687 to the average is around 1.679, OK. From this we can find P y and then I can also find P 0 y where is that. So, we have (Refer Time: 11:09) so I rub this.

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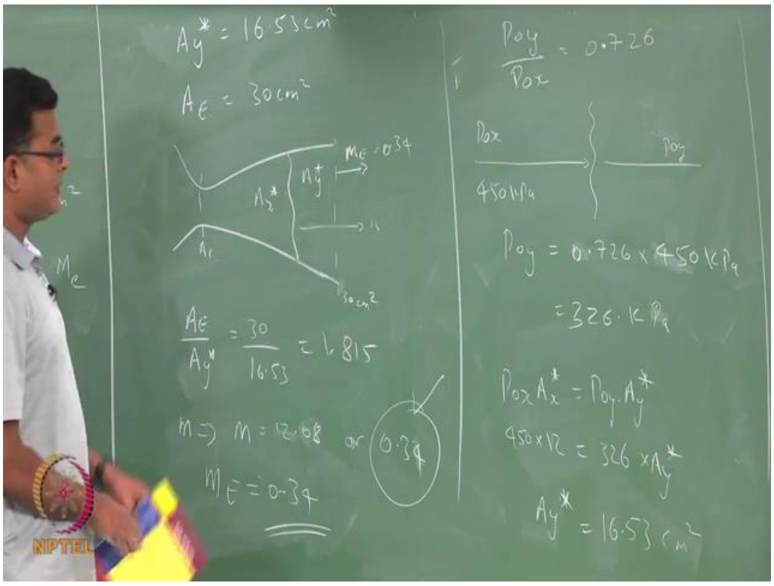

So, M y P 0 y by P 0 x is again the average of these two values here. So, it would be 0.726. So, I have shock here there is a P 0 x that is coming, it would be constant up to the shock after this I again have a P 0 y. So, the jump P 0 x, P 0 y is given here P 0 x is already given as 450 kilo Pascal. So, my P 0 is 0.726 into P 0 x in P 0 x is 450 kilo Pascal.

Student: (Refer Time: 12:42).

3.

Student: (Refer Time: 12:44).

326 point something kilo Pascal. Now we also know that P 0 x Ax star equals P 0 y Ay star for non isentropic process. We know P 0 x is 450 kilo Pascal Ax is (Refer Time: 13:15) A throat which is 12 centimeters square P 0 y is again in kilo Pascal, it is convenient to write this into Ay star. So, my Ay star is.

Student: (Refer Time: 13:39), 16 point (Refer Time: 13:41).

16 point?

Student: 5.

5.

Student: (Refer Time: 13:47).

16.53 centimeter square. Now we know your Ay star as 16.53 centimeter square, we know our A exit to be 30 centimeter square. So, in the nozzle I have shock here there is Ax star associated with this which happens to be our A throat and this after the shock we have reduction in, increase in our A star value which is a new A star. Now there is a area that is given here, A exit. So, up here again is isentropic, this is isentropic. So, all I need do is this area ratio find the corresponding mach number. So, A exit by Ay star is 30 centimeter divided by 16.53 this is.

Student: (Refer Time: 15:10).

1.815.

So, the mach number associated with this is 1.815. This one m is approximately 2.31 or, no I have looked at wrong table A by A star 1.85, 1.85 is 1.81 is around 2.08 or around 0.34. Now the question is which one you will pick. So, now, I have strong normal shock after which I have a sub sounding shock. Now this sub sounding shock I still have a diverging section.

Student: (Refer Time: 17:08).

Sub sounding flow yes; I have a supersonic flow, I have shock after which I have sub sounding flow and the sub sounding flow faces a diverging section. So, it continuous to be a sub sounding flow, your answer would be this.

So, your m exit is going to be this m exit is this. So, that is p mach number is here. Now the moment you have the mach number, you already know your P 0 y which is your stagnation pressure here you can easily find your P exit, P exit from the look at the isentropic tables find the associated values of P exit. So, your P exit is.

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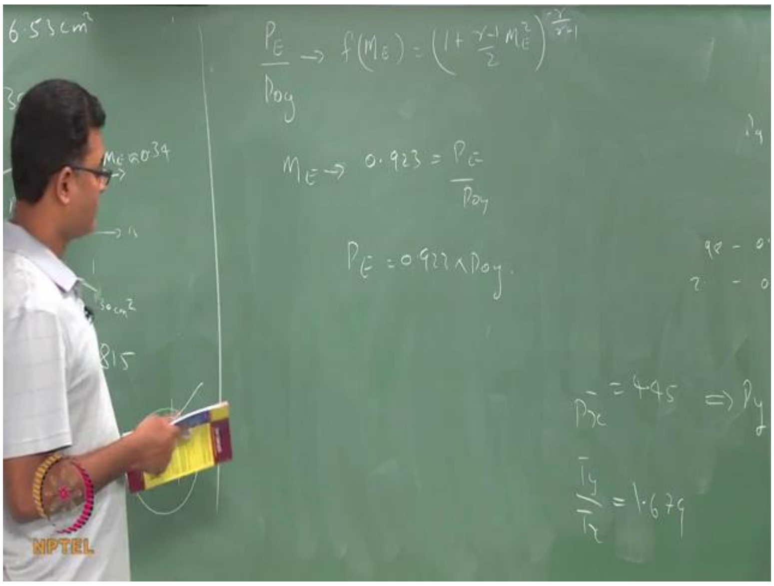

So, you look at the isentropic tables and get the fraction which is M x, it is 0.34 - 0.34 P by P 0 is 0.92, 0.92, this is an approximate value because you have to interpolate it and get it. So, you get this ratio as P exit by P 0 y. So, you have P exit is 0.923 into P 0 y which we have obtained it before, you get your P exit. So, the original problem we had supposed to find P y, P exit, Ay star and Me. So, we have obtained all those quantities. If one temperature or velocity is also given you could find other temperature quantities also.

So, for that we need at least one temperature or one velocity because a mach number is already given. We will end with one more problem on say Pitot tube and then.

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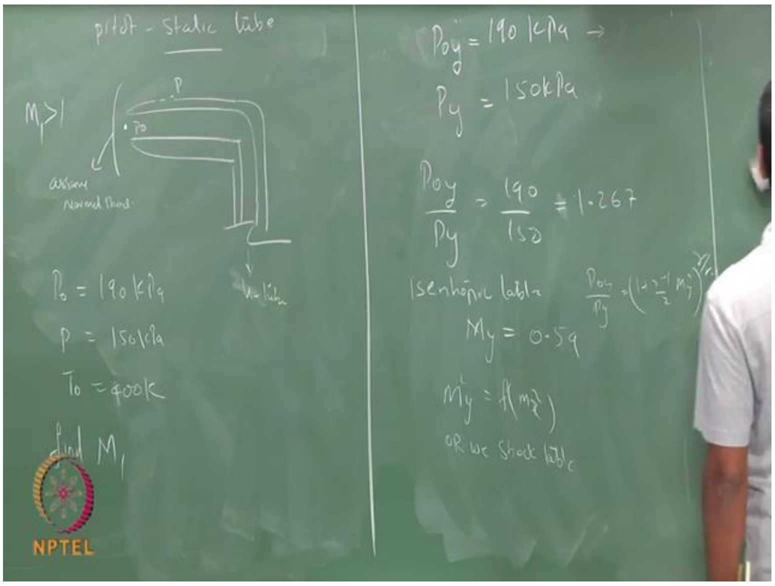

I have a shock that is (Refer Time: 20:59) before Pitot tube some measuring device. Go to sometimes user or YouTube or some quantity, say let us take YouTube some instrument. So, this is going to pressure my P 0 this going to pressure my p static. But the flow is, oncoming flow is greater than 1 you are going to have a shock in between assume normal shock. So, what is measured here is P 0 is 190 kilo Pascal, P static is 150 kilo Pascal, your T 0 is 400 Kelvin, find the mach number? So, let us say M 1, find M 1.

So, a supersonic flow is coming and you have measuring device is here pitot static tube because it is supersonic this bluff body will create shock. So, those shocks are standing in front and let us assume this to be a normal shock and because of which you have compute M 1 in terms of the properties that jump across the shock.

So, your P 0 y is 190 kilo Pascal because that is the stagnation pressure after the shock; that would be this, after the shock. So, your static pressure after the shock is given as 150 kilo Pascal. So, your P 0 y by P y is 190 by 150 kilo Pascal, kilo Pascal - kilo Pascal cancel. So, this would be around.

Student: (Refer Time: 23:40).

1.267. So, you look at the isentropic tables, find your M y. So, for this particular ratio this is from your P y by P 0 y by P y is 1 plus gamma minus 1 by 2 M y square to the power gamma by gamma minus 1 or use your isentropic tables to find the mach number

M y that is after the shock. So, M y for this particular ratio is what - 0.59, so that is your mach number after the shock. The moment you know mach number after the shock you know the relation in terms of mach before the shock or you use your shock tables. So, using the shock tables for M y is equal to 0.59 gives me a M x of M y 0.59, 0.59 M x is 1.96.

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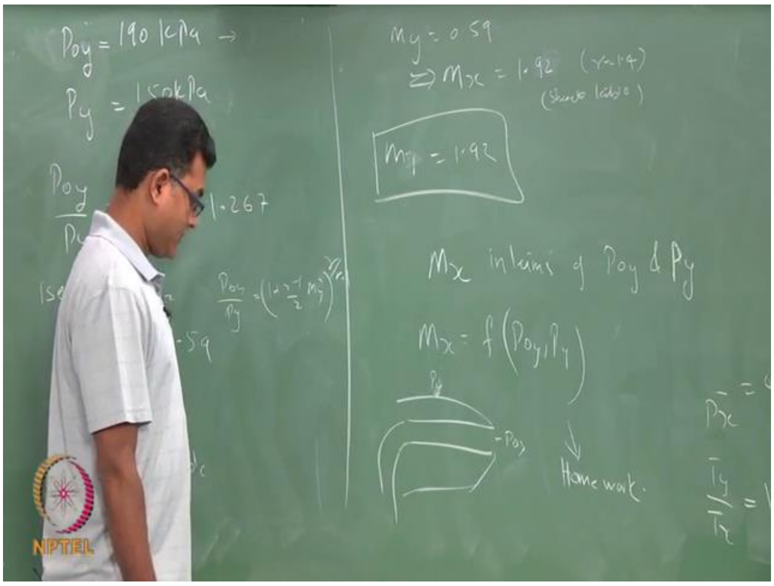

I have looked at wrong gamma wrong table. So, 0.59 is 1.92 for gamma equal to 1.4 shock tables. Now, if I have this mach number that is the question. So, your M x is or M 1 is 1.92.

So, technically you can write your M x in terms of P 0 y and P y. So, your M x is a function of P 0 y and P y. So, if I have Pitot tube, pitot static tube I measure P 0 and P y I can directly get P x if I know this function, that you can try it out write your M x in terms of P 0 y and P y. In fact, that is something called ranking rally equation for Pitot tube where your mach number that is to be measured or the mach number of the oncoming flow it in terms of the values that is been shown in the Pitot tube, pitot static tube. Pitot static tube the value that is shown in pitot static tube is P 0 y and P y from which you can directly get your mach number of oncoming flow.

With this, for time being we will end normal discussion. Next class we take up CD nozzle and do the same analysis, see what happens and also do some numerical problems involving shocks in the diverging section of a CD nozzle. We will also discuss over expansion and under expansion of nozzles.