Fundamentals of Gas Dynamics

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Week - 10
Lecture – 37
Discussion on Moving Normal shocks

We will continue with Moving Shock. We have used the notations for a moving shock in the previous lectures.

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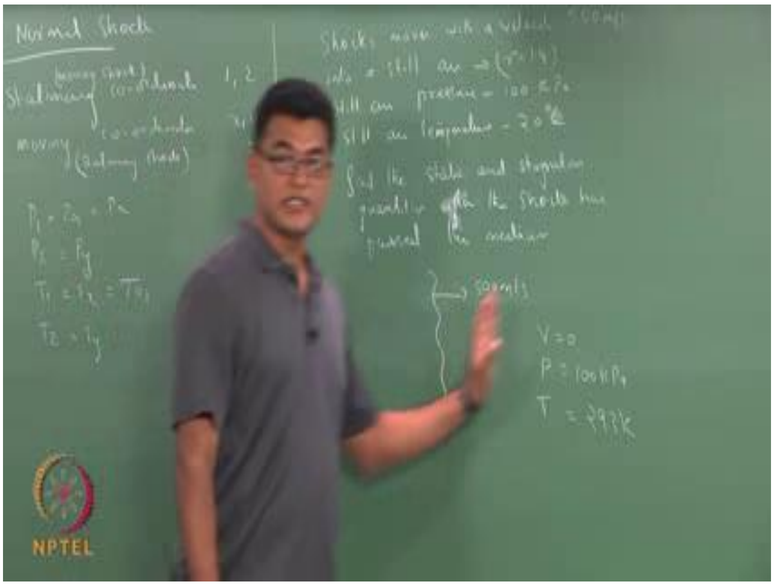

The notations are for stationary coordinates we have used 1 and 2, correct. And for moving coordinates is x and y, before and after the shock, in stationary coordinates means it is also your moving shock. And if I travel along with the shock that is a moving coordinates and that is a stationary shock. So, it match with the stationary shock notation that we have used before used x and y and this thing.

So, we have seen how the static quantities are seem for your moving as well as stationary coordinates because their measure static quantities are measured while travel along with the fluid and hence the static quantities same stationary coordinates as well as your moving coordinates are the same. Now, we will understand the problem better if we do a numerical problem.

So, I have a problem here which shock moves with velocity 500 meters per second into a still air fluid is gamma 1.4. So, the still air has pressure as, let us take it as 100 kilo Pascal and still air temperature is whichever is around - 20 degree Celsius. Find the static and stagnation quantities after the shock has passed the median or at some locations even the shock has moved what is the property, the static property and stagnation properties (Refer Time: 04:25).

So, I have a shock that is moving with velocity 500 meters per second. It is moving into still air and still air property is given P is 1000 kilo Pascal and temperature is 293 Kelvin. So, as it pass it changes the properties here, so what is the property after the shock has passed. So, we will do the problem the way we know.

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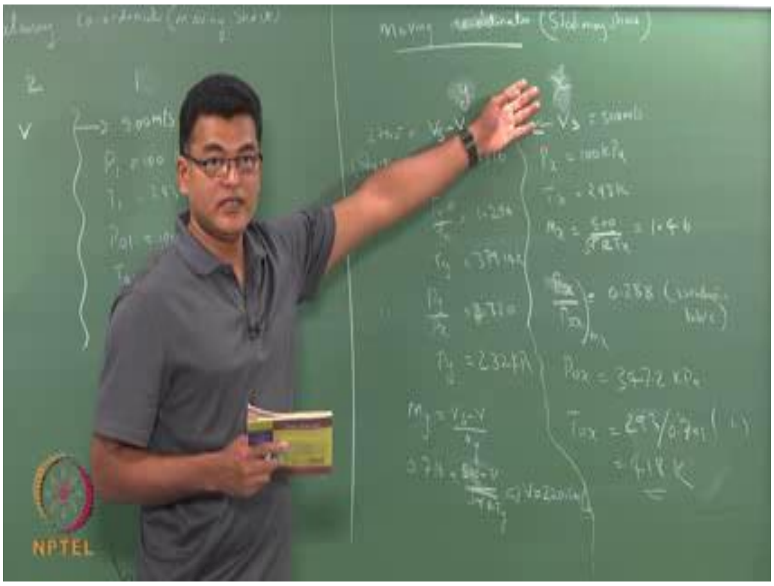

So, I have stationary coordinates here, I have a moving coordinates here. As I told is stationary coordinates also means we observe where is stationary which means it is moving shock, this is a stationary shock. So, I have a shock here is 1 and 2, I have a shock here with x and y. So, the shock is moving this way. So, the shock is moving this way or maybe I will write it the way we had better it is 1 and 2 the other way. So, we say this has 2 and 1. The shock is moving with some velocity and this is y and x, both should be same. So, here this is x and y.

We will do from the information we know, first is the velocity of the shock is 500 meters per second which is our vs. So, in the stationary shock I will be freezing the fluid which is moving at a velocity vs and I would see the fluid receiving me with vs minus v. So, the velocity here is v. Now, we know the pressure and temperature and the stagnant fluid which means this is my P 1 is 100 kilo Pascal, T 1 is 293 Kelvin. We know that this static pressure and temperature would be same as in the coordinates whether it is moving your stationary. So, this is also our P x and T x.

So, P x is 100 kilo Pascal, T x is 293 Kelvin. So, this is stationary as coordinates or moving coordinates or stationary wave, stationary shock wave we have the static quantities the same as what is written here. But we also know that this is for velocity 0. So, this is also my P 01 because the velocity is 0 and my T 01 is 293 Kelvin. Vs we know as 500 meters per second. So, my M x is vs by A x which is 500 by gamma R T x which is.

Student: (Refer Time: 09:49).

1.46, this is a stationary shock wave. Now, I know my M x from which I can find my M y from shock tables because now the wave is shock wave is stationary I can use the shock wave tables, I would get M y to be or gamma equals 1.4, I will use shock tables to get 1.46 on my M y is 0.716, 0.716. So, now, I know my M y, I will also get T y by T x again from shock tables. So, T y by T x is four point 1.46, T y by T x is 1.294, and likewise my T y by T x is 2.320 and hence my P y is.

Student: (Refer Time: 11:39).

379.14 Kelvin and T y is two kilo Pascal. Now, I know these values from which my M y is vs minus v divided by ay, now since I know my T y I can find my A y. So, M y is 0.716 equals’ vs minus v divided by gamma R T y. So, vs also we know as 500 from which I can find my v 220.5 meters per second. So, my v is now 224. So, I see a fluid shock that is coming and the relative velocity after that is 220, v is 220 point this, the relative velocity is 500 minus 220 as 279.5. So, the fluid is reseeding with a velocity 279.5 meters per second if the fluid is coming and heating with the shock waves, standing shock wave with this. I can also find my P 0 x from this; since I know my M x. So, all this are from shock tables. Now I can use isentropic tables to find my P 0 P x by P 0 x for M x. So, I use the isentropic tables M x is 1.46 M x is 1.46 this ratio is 0.288 from isentropic tables. So, my P 0 x is.

Student: 347.2.

347.2 kilo Pascal, likewise I can find my T 0 x to be from the ratio P T x by T 0 x this 0.70 multiplied by this is.

Student: (Refer Time: 15:18).

30 yeah, is again from isentropic tables which is.

Student: (Refer Time: 15:46).

So, these are the quantities in the stationary wave or moving coordinates. If I move along with the shock wave these are the changes I would feel. Now we are to find what is happening in be moving wave. So, the static quantities are going to be the same, since I know my T y and P y I can write this as.

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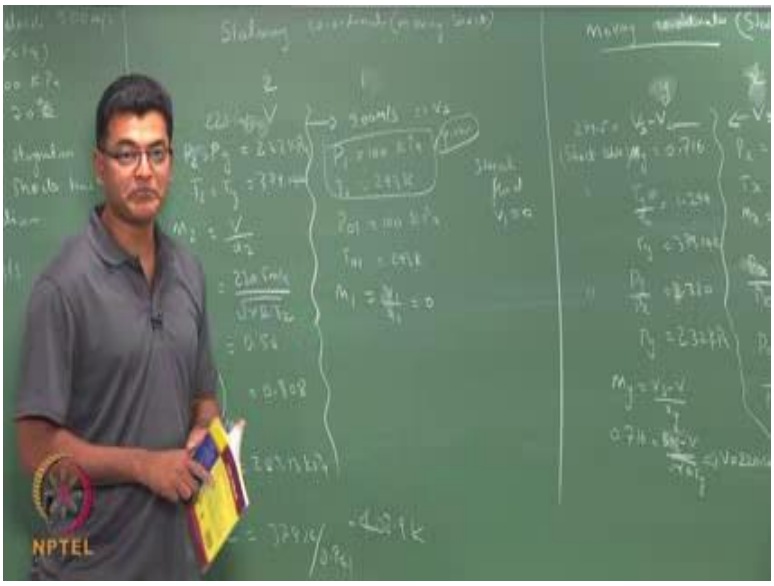

P 2 as same as my P y which I can copy it from that it is 232 kilo Pascal and T 2 is same as my T y is equal to 379.14 Kelvin my v is calculated to be 220.5 meters per second. So, these things we have obtained from the other value from which I can find my M 1 is 0 because my v is stagnant fluid here, so my v 1 as 0. So, v 1 by a 1 is 0, but my M 2 is v by a 2, v is 22.5 meters per second divided by gamma R T 2 is T y is 375 this is 0.56. So, a stagnant fluid is there, a shock comes and moves, it gains this much velocity 0.56. So, if I know my mach number I can find all these stagnation quantities P 0 by P 01 for M 2I look at the isentropic tables 0.52.

Student: (Refer Time: 18:23).

Sorry P 2 by P 02 for 0.56 is 0.808. It gives me a P 02 of 287.13 kilo Pascal; likewise I can get my T 02, T 02 is 0.941 divided by 0.941. Again from isentropic tables this ratio, this is 402.9 Kelvin. So, now, we have the answer. I have a stagnant fluid the shock is coming in movie into this pressure and temperature. So, this pressure and temperature if the shock is moving with a velocity 500 meters per second I am going to increase my stagnation pressure into this much, stagnation temperature by this much and my fluid which is 0 velocity here, gains a velocity of 220 meters per second by which the mach number is also different. Mach number has changed from 0 to 0.56.

The shock wave brings this much change in your fluid. So, we have obtained this by transforming the coordinates computing of properties across the shock from the moving coordinates, where we assume this shock to be stationary and obtained all the properties and then map it to this particular coordinate system where we know the static quantities are not going to change with respect of the coordinate transformation.

With this I think you can do any kind of problem, even when the fluid here even if the v here is not stationary except that you cannot equate P 01 equals P 1. So, if the fluid velocity, if we have a finite velocity here then P 1 and P 01 cannot be equated and T 1 and T 01 cannot be equated, otherwise I will think else are same.

That brings end to the small discussion on moving shock; now, we will proceed to oblique shock waves.