Fundamentals of Gas Dynamics

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Week – 03
Lecture – 7.1
Discussion on Stagnation Properties

This is a tutorial on stagnation properties, how we can evaluate stagnation quantities. So, we will just to do few problems and try to understand what exactly (Refer Time: 00:29) mean.

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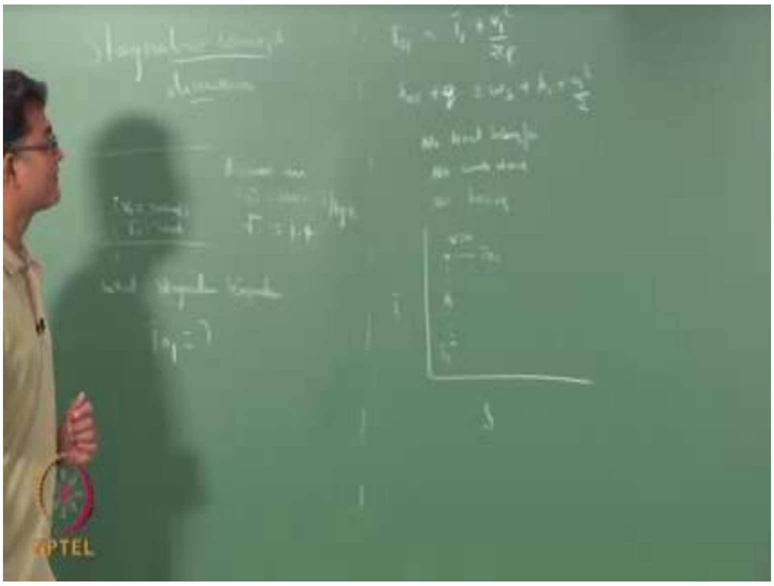

So if I have a duct, and at some cross section I have velocity V 1, which is around 500 meters per second. And, your T 1 is 300 Kelvin. Assume air C P is 1005 joule per k g Kelvin, gamma is one point four. So, what is the stagnation temperature? So, we need to find T 01.

So, we go back to the equations; T 01 is T 1 plus V 1 square by 2 C P. This, we obtained from the enthalpy equation, the energy equation q S equals w s plus h one plus v 1 square by two. So, the process is at any point we take the fluid to a location where the velocity is 0, the state where velocity is 0 isentropically without work. So, there is no heat in the process, no heat transfer, no work done. And, we are done this isentropically. So, there is no loss. So, there are no losses.

So, in the T S diagram we have state 1, which we take it to a state where v is 0. We know T 1 we need to find T 01. So, this is the imaginary process where it goes from 1 to 0. So, it is the mere substitution of this equation.

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So, your T 01 would be just 300 plus 300 Kelvin; 300 Kelvin plus 500 square by 2 into 105. This would be around 424 Kelvin. So, what we have done is we have taken the fluid which has some temperature, at what, are going with some velocity. We have isentropically reduced that velocity to 0 with no heat and no work transfer. And that state is the stagnation state. And, the temperature associated with that is T 01. We also know the difference between T 01 and T 02 is v square by 2 C P. So, if the fluid was moving with the different velocity, you would have got the stagnation temperature to be different. If the fluid is other than air, then again the stagnation temperature would have been different. That is what you get from this example.

Now, we will extend this problem. So, there is some duct. I have v 1 500 meters per second, T 1 300 Kelvin and say T 01 as 424 Kelvin. This moves to a new location two.

So, this is my location one and this is my location two.

So, this is question two; if no work done by the system or to the system and no heat transfer, what is T 02? That is the first question. What is T 02 and what is v 2, if I know my T 2. My T 2 is 220 Kelvin. So, the question is I have a flow in a duct with, at station one, the velocity is 500 meters per second and T 1 is 300, T 01 is 424 Kelvin what is my T 02 if no work, no heat transfer?

So, if no work, no heat transfer, I have T 01 h 01 equals h 02. How did I get? I get from the energy equation, where I assume this to be 0. So, I end up with h 01 equals h 02, which is nothing but T 01 equals T 02. So, my T 02 is same as my T 01. So in the T S diagram, all this assuming one d flow or quasi one d flow. I have 1, I have 2, it is some process associated with one. There is a stagnation state, which has T 01; because there is no heat and no shaft work, the temperature is the same. So, the delta S is this, which is entirely due to your irreversibility. So, here state one and state two has the same stagnation temperature or the pressure associated with this is different. So, how do we find v 2? Now, we know that T 02 is the same as this, which is 424, which is 424 Kelvin. This is also 424 Kelvin.

So, you have T 02 equals T 2 plus v 2 square by 2 C P. Now, you know all the values; T 02, T 2 v 2 and C P. Substitute this, you should get T 2 to be approximately v 2. We have to find v 2; 640 meters per second.

So, I repeat the process here. I have state one and state two. At state one, we have velocity 500; state two, we have velocity 640. Since, there is no work and no heat transfer, the stagnation temperature is the same. So, we have equated the enthalpy and obtained our v 2. So, this is nothing but your energy equation posed in a different way.

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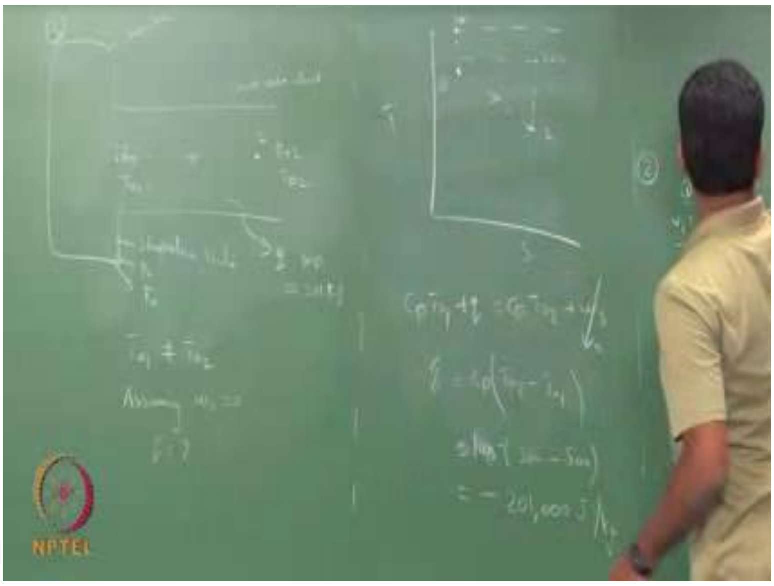

Now, I have a constant area duct. This is question three. This is connected to a large chamber where the fluids are all stationary. It is not moving around. So, the quantity you measure here is the stagnation quantities. So, the pressure I measure here is P 0 and the temperature I measure here is T 0. Now, this chamber supplies air to this particular duct. So, if I assume the station one has the same stagnation quantities as the chamber, I have T 01 and P 01, same as this. Now, the fluid flows through the duct. And, at location two I have P 02 and T 02. For some reason, your T 01 is not equal to T 02 because of your heat transfer. Assuming w s is 0, no shaft work associated with this fluid that is moving through the constant area duct. But, there is some heat transfer that is happening

So, what is the q to keep this constant? What is the q that you need to supply or what is the heat transfer that is needed to keep your T 01 same as T 02? So, what is the process in T S diagram. So, I have one. I have point two, the one has stagnation state T 01 and two has a stagnation state T 02, which is now different. So, from the energy equation C P T 01 plus q equal C P T 02 plus w s; now, w s is 0. So, your q is nothing but C P into T 02 minus T 01. So, depending on the values of T 01 and T 02, you would get your this thing. Suppose, if I assume T 01 T 02 to be, T 02 to be, say 300 and T 01 to be 500 multiplied by value of C P which is 1005. This is minus 201,000 joule per k g.

So, this is a minus sign; which means q is; in this equation, q is the heat supplied to the system. So, now it is a minus sign; which means, heat is a lost. So there is heat, that is q lost, which is approximately 201 kilo joules. So, lost heat is 201 kilo joule. That is why it comes with a minus sign. So, if I have a duct that which has these stagnation quantities at the beginning. Now, you are going to lose this stagnation temperature, if I do not account for the heat transfer. So, you need to insulate the pipe, if you want to keep the stagnation temperature same.

Now if I, yes, you can now reverse the question. I supply some heat here, what would be the velocity that you get gain at the station two?

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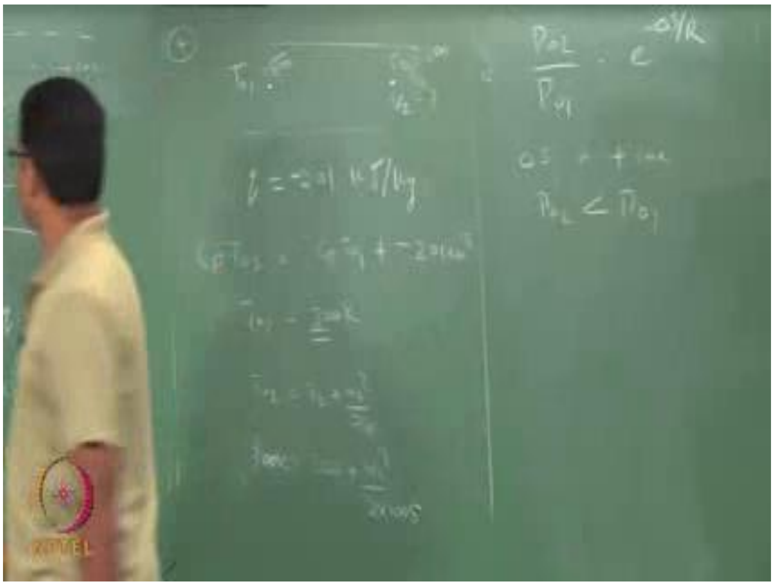

So, if I have the one and two. If q is; so, let us take 201 kilo joule per k g with a minus sign. So, I have T 01 to be 300. And, now what is my v 2? So, from this equation I can find.

So, this is my question four. So, from this equation I can find T 02, which would be; find your T 01 c r T 02, you can find your v 2, if I know my T 2. So, let us assume T 2 to be some value. T 02 is 300. So, let us put 200. So, you can find your v 2. T naught one is 500. T 01 is 500, T 02 you would get as 300, which is same as our numbers in the previous question. And then, q is this again the same number as from the previous question. You can find your v 2. So, there is a delta S that is happening between process 1 and 2. If the delta is there, then we have also seen the change P 02 by P 01 e power minus delta S by R. Since delta S is always positive, your P 02 is always less than P 01; which means in the P 0 here, P 01, this is P 02. P 02 is always less than P 01.

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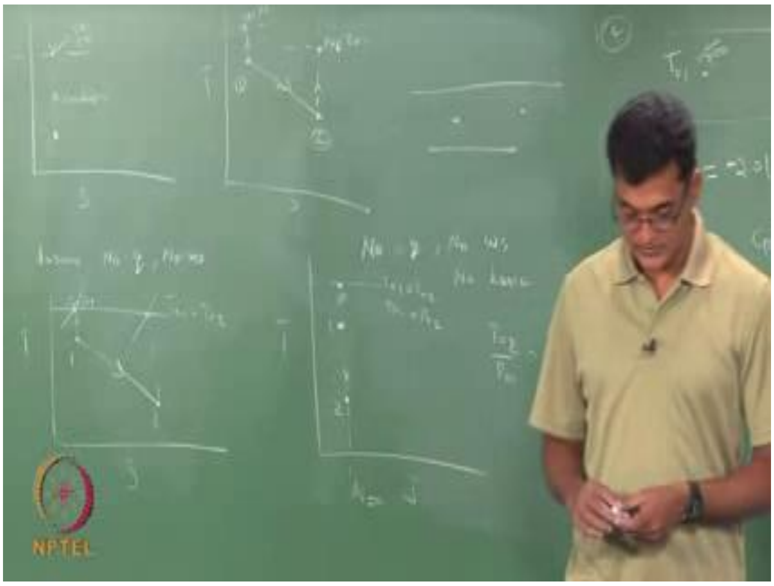

So, if I conclude today's lecture with the following understanding, so I have the T S diagram. For any given state, there is an associated stagnation state which is an isentropic process. So, you bring the velocity isentropically to an imaginary state, where the velocity is 0. And, you call that that as your stagnation point and associated with that you have T 01 and P 01 and the other stagnation quantities. Now for process 1 to 2 associated with 1, you have a stagnation quantity T 01 and P 01 associated with 2, you have an imaginary state where your stagnation quantity is P 02 and T 02, which need not be the same. But these process, this imaginary process of taking this point to these stagnation point, there is a isentropic process. But from 1 to 2, the state and states stagnation points are different.

Now, if I assume no heat transfer and no shaft work, then my one to two has same stagnation temperature. This is 1, this is 2. So, the imaginary process at which state one is taken to the stagnation point will have T 01 and T P 02. This is an isentropic process. Likewise, you have state two as with that you have a stagnation state, where you have T 01 and P T 02 and P 02. Since there is no work and no shaft work, your enthalpy is same from the equations which we have seen; h 01 equals h 02, where q and w s is 0. And because of that we have a temperature T 01 and T 02 same, but the pressures are different.

Now, if I also assume my losses to be 0, no w s and no losses. So, in the T S diagram, this all in the T S diagram. Process one will have a stagnation state is taken to a state two isentropically with no shaft work, no heat transfer and no losses. This state two will have the same stagnation point. So, the T 01 and T 02 will be same and my P 01 and P 02 will also be the same because my P 01, T 02 by P 01 is e power minus delta S by R, where delta S is now 0. If that is 0, then my P 01 and P 02 are same. So, this graph modifies to this. So, this is the stagnation process.

This is the process between two points where there is some heat, some work, shaft work and some irreversibility. This is no heat, no shaft work. But, there is some irreversibility that is associated with the process. And, here we have assumed even irreversibility to be 0. So, the process is, S, this with no entropy change. So if I have a pipe between point one and two, if I assume no losses, this is the process that is going to happen with no heat and no shaft work.

With that we conclude today’s tutorial and concept of stagnation properties. We will discuss stagnation pressures later. But, what we have demonstrated now is to find, how to find the stagnation temperature and the basic concept behind this stagnation process.