Fundamentals of Aerospace Propulsion
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Lecture - 08

Let us start this lecture eight as usual with a thought process from WF Hilton, who made this statement in 1951 who happens to be a scientist in Naza.

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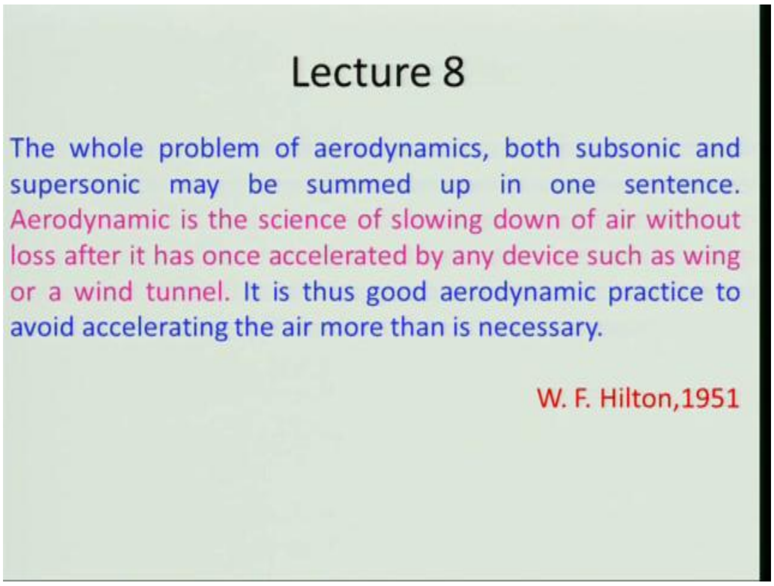

He says that whole problem of aerodynamics both subsonic and supersonic may be summed up in one sentence aerodynamic is the science of slowing down of air without loss. After it has once accelerated by a any device such as wing or a wind tunnel, but I would suggest that whether a wing flow where a wing or a flow through the propulsive devices. And it is thus good aerodynamic practice to avoid accelerating the air motion air more than is necessary it is a very important statement. That means we should not really accelerate the flow to the extend what is not require and that is the basic thing what we will be doing while designing a propulsive device. And so also analyzing we need to look at compressible flow.

And I had already initiate discussion on the last lecture on the compressible flow and if you recall, I ask a question whether a fluid will be compressible or a flow will be compressible. Then we define a term known as compressibility factor we are using a symbol K, but there might be some other symbol for compressibility factor and also I told you that it will be change in density divided by the change in pressure. In other words change in density per change in the pressure per unit density that we call it as a compressibility factor.

And we also talked about there are other definition as well because this is a more general, but to be more specific right one has to talk about the compressibility factor for isothermal flow condition or for an isentropic and considering the flow to be isentropic. Then we use those definition to derive equation for what for speed of sound and I also tried to give an idea about what is a sound, how it behaves what are the mechanism of the sound propagation going to the microscopic effects or the molecular label. As I told you yesterday that by using the kinetic theory of gases one can derive an expression for average molecular velocity, which is equal to root over 8 phi t divided by sorry root over 8 phi RT divided by K some constant.

And which can be related to the speed of sound and if we look at the speed of sound we have derived for an ideal gas that is A is equal to root over gamma RT. If you look at this root over gamma RT that means it is a function of the temperature and also the fluid properties, you remember I had taken you know example of air and helium I so that at same temperature it is having different speed of sound. And keep in mind that R what I am using that equation or expression is basically specific gas constant, which is ratio of universal gas constant and molecular weight.

When I talk about molecular weight then molecular weight of particular gas and this speed of sound will be different in different material. For example, solid for example, water will it be different or it will be same it will be actually different because it depends on the properties of the fluid. And based on this speed of sound which is very essential to delineate whether the flow is compressible or incompressible, we define a term known as Mach number which is a ratio of velocity and speed of sound.

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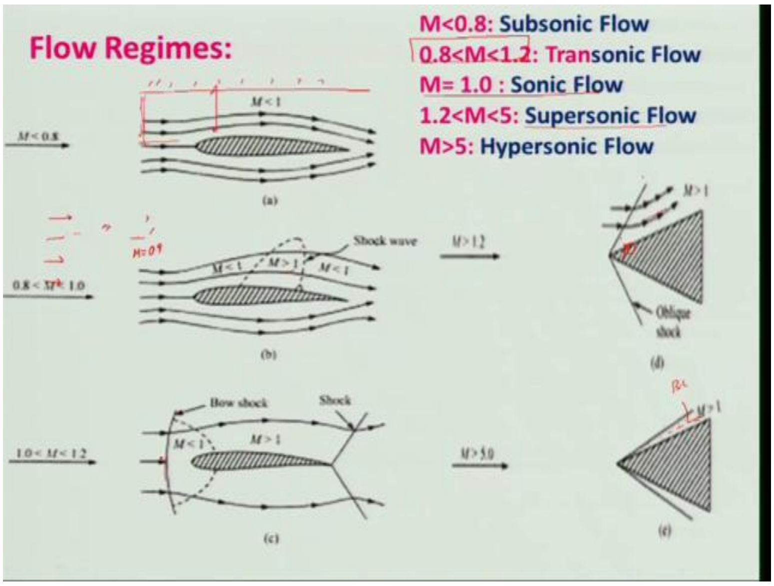

And based on this Mach number we can divide the flow into various regimes and what are those regimes one is of course, you can call it as a subsonic flow. When Mach number is less than equal to 1 because Mach number equal to 1 we call it as a basically what you call we call it as a sonic flow. And when it is less than 1 we are supposed to say it is a subsonic flow when it is greater than a 1 we should say it is supersonic flow as usual right one is subsonic other is sonic other is supersonic.

However, people like a person Theodore Von Karman right you know him he is a great fluid dynamist you were aware about Von Karman's streets where this vertex streets will be shaded downstream of the flow over a cylinder or a anybody. So, you might be aware if you are not aware just look it he is a very he gave the you know idea of transonic flow. That is the flow when it is between 0.8 to 1.2 you know and this regime it is which it call as a transonic flow, question is what really happens it you know in this subsonic flow and what happens in transonic flow which we are going to see.

And beside this like when the flow is between the Mach number of 1.2 and 5 or less than 5 we call it as a supersonic flow and when Mach number greater than 5 we call it as a hypersonic flow. Now, what is a difference between this supersonic and hypersonic similarly, transonic and supersonic and subsonic and transonic this we need to look at because it will be helpful for us to appreciate the flow in general. Of course, we will be mostly dealing with the subsonic flow and supersonic flow. In our analysis and hypersonic we would not be really looking at it during our what we call this course or discussion on this course and question is what is the difference when we can call it as flow to be subsonic.

For that let us consider a flow over a an aerofoil this is basically cylinder body and if some mach number which is coming which is less than 0.8 that means it is subsonic according to this regime. Now, what will happen if the flow is uniform velocity here you can see this arrows has showing it is uniform velocities and if it will move it will move in this way giving a state something very smooth stream line around this and aero foil. What it indicates here it will be subsonic if it is subsonic throughout this region then we call it as a subsonic flow, but I am having a doubt why this stream lines are moved you know is like this if flow is coming.

For example, if flow is coming over here you know something like this uniform flow lets in a wing tunnel kind of things because uniform flow in nature is difficult to get. So, and then what I will do I will put a body like a slender body or a aerodynamic or aero foil right if I do that what will happen the fluid will be moving. You know if I take this is coming over here and it will be impinging and then there might be another one, I can loop it goes this way, why does it go is it a intelligent like us that fluid element will take a path and how does it know that there is a body which is existing.

For example, I know like just now I was coming to attend to take your class in a cycle I found that in a police post one young person was just going in the other way around that is surround circle. He just went in the you know just cross that is take a short cut route he is intelligent enough, but he is not knowing that the if he will go he will meet an accident but, whereas if we look at the fluid flows if it is coming it changes its path or the steam. These are the basically steam lines or path and moves that means it is smart enough to say that the yes there is a body I need to go in such a way that I would not bump into it.

For example, if it is goes this way for example, if I say this is fluid is going here directly heating the body you will get hot am I right is it so that means the fluid element is intelligent like human being. Whereas, when I see our traffic and other things we are not intelligent enough we just get bumped into it we do quarrel we bumped into the people that means fluid element is smarter than us or intelligent than us am I right.

Then how does it do there is no police man to say that look go follow this traffic rule or go this way there will be problem you know is there anything nature has given no, are you sure it is nature is given. That means if there is a body here and if the fluid is there then it will be coming of course, some fluid will be coming in the beginning. Suppose there is a fluid and I put a body then it will give a sound wave and it will be moving with the speed of sound. And it will make the aware the fluid element to say look there is a body you should take moment or change your path properly, otherwise you will hit on it are you getting my point this is very important point I am talking about.

Therefore, the speed of sound is very important when you talk about Mach number right I could have put any other ratio therefore, the Mach number plays a very important role to define or to divide the flow regime whether it is compressible or incompressible that will learn as you go along. There is one thing and other thing is that if the fluid element is moving here so then what is happening to this stream lines this stream lines are coming, but if you look at there is a here there is a curvature of this body if it is there the whatever in figure these stream lines are drawn is it right.

For example, if I put a line here this is my boundary you know then what will happen if I take this cross sectional area, but simple argument I will say and if I take here what will happen this there is decrease in area right decrease in area what will happen you know from your previous learning. There will be acceleration if there is acceleration of the flow what will happen to stream line it will not only deviate, but it will be crowded it will be coming through you know closer coming closer to that. I would suggest that you please read something about the stream line stream tubes you know if it is a circular one you know what will be dealing with our propulsive devices right.

And this mass because mass has to be same mass has to move into so whatever the mass is flowing in this region I have taken half of that and say mass has to be move into in the same smaller area. Therefore, there will be decrease in velocity and the stream line will be coming closer to each other, but however it is not drawn here and if it is drawn then or it is that means the fluid velocity will be here more than the what is the fluid stream velocity at this point are you getting my point.

So therefore, it is very important then there will be increase in the fluid flow here and as I told you that there will be also deceleration here in this region there will be change in the Mach number. That means local Mach number in this region will be changing am I right if this is 0.8 will it be 0.8 throughout it will be somewhere higher somewhere lower done the 0.8 if I take or if it is 0.5 then it will be different. That means this region a local Mach number have the fluid which is moving around it will be different.

Now, if I increase my free steam Mach number to in the range of 0.8 to 1.2 what happens for example, let say my Mach number is around 0.9 that means here it is 0.9 this is the free stream I can write down this is 0.9 let us say. And fluid will be moving there will be you know a acceleration of the flow also, but it will be less than 1 and there is a regime where it is greater than 1. And if it is greater than 1 there will be a shock wave which will be discussing about this basically there will be discontinuities in the flow properties. And discontinuities means, what it would not be the stream line would not be that smooth if you macroscopic it will look at why shock is being formed that we will see whenever we are discussing.

And therefore, at the downstream of these there will be Mach number will be less than one keep in mind that I have shown only one shock wave on the upper portion of this stream, what to call aero foil. What happens to the lower one will it not be there in this figure it is not there right will it be there or not there would not be isn't it am I right

Student: For symmetric it will be there.

But, non-symmetric it would not be there.

Student: But positive angle of attack it would not be there.

Angle of attack that will be dependent on and here we are assuming the flow is not separated if flow is separated then this stream lines whatever I have shown here would whole good depending on whether where it is separated all stream lines has to be changing. So therefore, we are not considering what you are talking about we are considering whether in this case flow is not separated. That means angle of attack is not small and there is no angle of attack here you can look at it this figure does not show that it is a angle of attack it is a just angle of attack is 0 in this case.

Therefore, what will be whether the shock wave will be there this region or not if it is there, there will be if it is there then where it will be located will it be located exactly symmetric in this region or it will be here or it will be there it is quite difficult to say, but however one can guess that it will be little downstream because of this region you can look at this surface. There will be the when the Mach number will be greater than 1 will be attaining little bit down right because if you look at this surface and this one you know you can see that. So therefore, you please think about it and then you know have a feel for it is very important.

And now, let us look at a flow you know here we have consider the Mach number range of the flow between the 0.8 to the 1 right however the transonic flow it is one region that means we are considering something 0.8 to sonic condition. You can ask me a question why you are so particular about 0.8 is it something you know so sacrosanct for magical number that it will be the same time for all the time or is there any basis is it that question coming to your mind or not because it is written in book that is why we will have to take am I right. There is nothing sacrosanct about it, it is just be a thumb rule which is being done it may be different when you conduct experiment.

Suppose in case of what you call stream line body if I take a black body naturally this you know numbers what is given here like 0.81, 0.25 may not to be the same it will be generally. For example, when you go for this subsonic flow regime it will be much lower than 0.8 when you talk about a flow over blab body or some people call it as a blend body. So, please you should develop a feel for it do not just remember the number, but you need to remember the number, but, you should know what is the limitation.

So, coming back to this that then we need to understand what happens when the flow is between the 1 sorry 1 to 1.2 that is the transonic regime what will happen if the free stream here you know is not really it is greater than 1, 1 what will happen. There will be there will be shock where there will be shock it will be leading age nearby leading age or it is away from the leading age or it is somewhere down stream you know of the leading age. Where it will be it will be you know before the leading age away from the leading age towards the you know flow or the main stream up stream rather. That means my shock will be like this and this is consider as a bow shock because it is like a bow shape of the bow right.

And then when the flow is let say Mach number which is greater than 1 then the downstream of this bow shock Mach number will be less than 1 right why it is so we will see may be when we will discuss about the shock. And then after that it become accelerated and in this region the flow will be what you call supersonic M is greater than 1 right Mach number is greater than 1. And then there will be also a shock which will be here at the liter ling age right both the upper portion and the lower portion and it looks like what can anybody tell me this two shocks looks like what have you never observe what.

Student: Expansion.

No, this is shock it is not expansion wave, but I am asking you what is the shape you can have, have you never seen a fish did you look at the fish shape is it not like a aerodynamic body or aero foil similar to that right it is having a tail right. So, this shock we call it as a ((Refer Time: 23:19)) when you look at nature you should have a good observation power and try to late what you learnt and what they are having. If you look at most of the science whatever we are using has come from the nature so nature is a great teacher to us we must observe the nature as closely as possible/

As I always say that we need to learn how to leave with the nature not leave against the nature because he is the you know our mother right sustains our all activities without any grudge in mind. This feeling is very important to when you are doing the science technology or life any other thing. So therefore, we need to learn this is known as fish tail shock right of course, there is little complex it is here involve we would not discuss at this moment, but however some of you were interested you can look at it and keep in mind that in transonic flow we get the flow subsonic, supersonic and combination which is quite difficult to solve mathematically as such.

And you will see that here also in this regime the Mach number less than 1, Mach number greater than 1 we says that it is basically supersonic flow, sub sonic flow and therefore, we call supersonic subsonic combination is known as the transonic flow. So, if I will increase this Mach number beyond 1.2 what will happen if I use this here in this what you call a an aero foil or a cylinder body then the shock will be similar to your bow shock. And what will happen to the shock strength it will be much higher as the Mach number goes it increases what do you mean by shock strength we look at it little later on, but generally people use a wage in this case it is wage or sharp nose you know where it which the shocks are being attach and this shocks is attach and makes an angle.

Therefore, we call it as an a oblique shock we which will be discussing little later on how to handle the oblique shock how to analyze oblique shock and how we can use later on we will see particularly in case of supersonic air intake. You know we need to use this relationship for the oblique shocks under the things right and how we can design how we can avoid the pressure losses and other things. If you look at what is happening here Mach number greater than 1.2 as shown any number between the 1.2 to the 5 you can see that fluid is going over here and across the shock it is taking a turn.

If you look at this stream lines, if you look at this stream line lower one what it indicates it indicates it is the curved one right that means this is air wage or it is a cone right you think about it we will come to that later on. Therefore, if I am increasing this Mach number what happens to the shock location I am having one question to ask you and there is another question if this angle this cone or wage whatever you call. Let say this is angle theta if it is increasing what will happen to the shock position will it come closer to the surface of this or we will go away it will go away.

Of course, that depends up on several conditions like how for it is and what is the Mach number then it can be a bow shock if it will go certain limit values which all those things will be discussing when we are discussing about oblique shock and its relationship and how it behaves. Now, if this Mach number goes beyond the 5, 5 is a number you know and then what happens the shock this is the shock right will be coming closer to the this surface of the wage or a cone whatever you call. And then what happens there what will happen the temperature across this shock will be much higher that is the one important aspect beside this as it is closer to the solid surface it will be interacting with the bound layer.

And if the Mach number is more than 5 the temperature attain by in this boundary layer and shock the region you know there will be boundary layer here right in this region shock will be interacting. So, that right this is your basically boundary layer and it will be closer to that and the thickness of the shock will be also very, very you know thin or it is reduce drastically and the gradient will be very high, temperature will be very high. As a result ionization will be taking place and chemical reaction will be taking place there will be quite complex in nature. And as a result this has to be burnt right and we need this thing whenever we are taking about the space vehicles reentry.

For example, ICBM intercontinental ballistic measles or the Apollo lunar you know vehicle which is when is returning right that is at that time when you design you need to take care what will be the effect of that on the body. So, that it would not melt at out due to the temperature and it is quite difficult to handle also this is the chemically reacting flows we need to consider. And you know like in case of Apollo lunar you know vehicle while returning what could be the Mach number they where a might be experience it will be quite very high what will be order it will be around 36 kind of thing.

ICBM you know like intercontinental ballasting missile will be experiencing around 25 even I am saying you do not go about exact number you know, but it is the range what we are talking about number order is more important or the kind of things. That means you know like what will be there is a quite complex things and we would not be discussing about it except you know when you are talking sometimes will be just mentioning about. So, this is the flow regime which you must understand and we will be revisiting and rather in detail about oblique shock and there will be a normal shock here in this some region that we will talk about and how to handle may be expansion shock expansions and other things.

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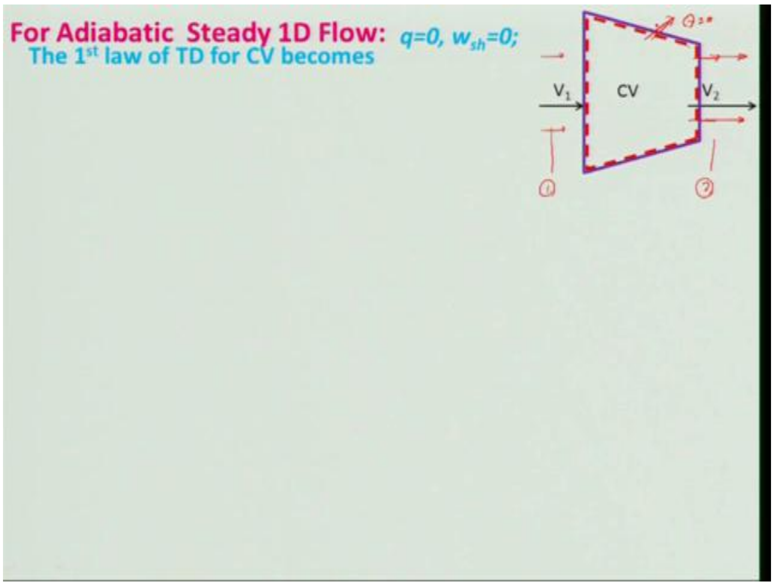

So, let us look at you know adiabatic steady 1-dimensional flow and apply some of the equations for that and let us consider a nozzle like let say the station 1 is here and we are saying this station 2 and flow is coming in this region and flow is leaving at certain velocity. If you look at this itself is source it is the you know vector source is the higher velocity now I want to analyze this thing and as the name it indicates this is the adiabatic flow. Therefore, there would not be any heat interactions or heat is not going out and steady for that we can consider it as a what we call as a steady 1-dimensional flow.

And for the analyzing we can take a control volume so control volume as usual it will be adhering to the surface of this you know nozzle and also inlet if you look at this is the fixed boundary this is the imaginary boundary. And then we will have to look at this what you call apply this first law of thermodynamics for control volume and what are the condition we will be looking at we will be looking at that the adiabatic q will be 0. That means this no 0 I am like you know q or small q, q is the specific you know it interaction and shaft work. There is no shaft work as such, but can I consider this as a 1-dimensional flow is it possible or it will be 2-dimensional flow or it will be 3-dimensional flow.

Student: 2-dimensional flow.

It will be 2-dimensional is it so.

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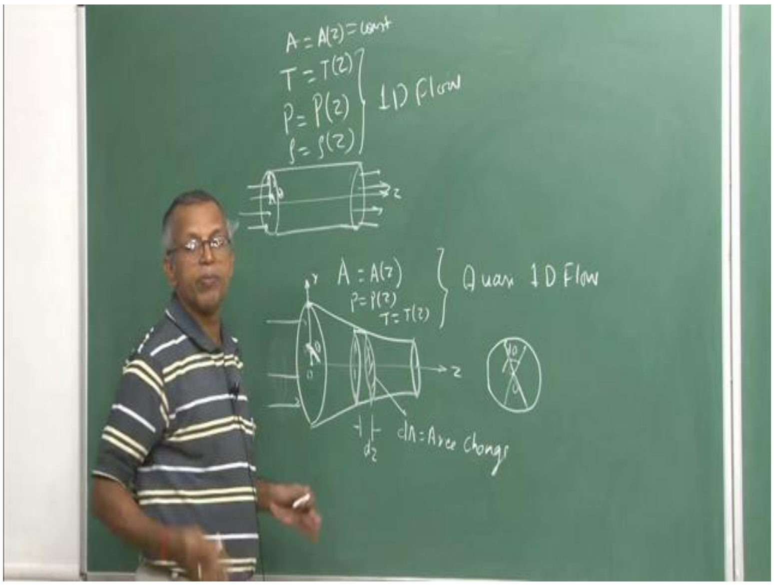

For example, if I take a pipe flow simply in a constant area rho is taking place here and I can say this is my z direction and this is my r direction of course, this will be my theta direction right. And similarly, I will take another one let say my z direction, r direction and this is my o and theta direction right. In this case if I look at flow properties and I will assume there is no bound layer on the surface that is also important one or I will assume it is a fully developed flow means flow is already developed here there is no change that means there is another portion which I have not drawn.

Then what will be the properties let say pressure at each point will be function of z rho is a function of z similarly, temperature is a function of z and what about area in this case area is a function of z or not it is not a function of z its constant. It is constant area is constant cross sectional area is constant, but in this case what I will be in reality this flow will be not 1-dimension like this I can call it as a 1-dimensional flow can I call this flow as a 1-dimensional. If flow is taking place this way can I call I cannot in principle it will be 3-dimensional, but I say that theta you know if I draw this and if I take this as a O. You know like any theta directions, any cross section theta if I take d theta you know kind of things it will be same.

Therefore, this symmetric is there and everywhere flow is in then I can say it is 2-dimensional, but if I will assume this is symmetric in the theta direction. Therefore, I can call it as a 2-dimensional one is your z direction other is your r direction, but if will say this area which is changing because cross sectional area is changing or along with the z, but if the change is very, very small. If I take an element over here you know keep in mind this is a circular and this is rate at which it is change is taking place is very very small. Then I can assume to be quasi 1-dimensional that is p is function of z similarly, T is function of z and all other properties then we call it as a quasi 1-dimensional flow please this is a very important concept you must understand.

Here, the rate at which along the z direction area is decreasing is very, very small such that the properties not changing if you take a small element like this, this is my element you can say d z in z direction however you can say in area wise it will be dA area change. If I take this this will be basically like this kind of things cross section so this change in area in comparison to this it will be you know very, very small. So, this is a very important concept you must appreciate this and here we are doing the similar thing as well. However it is not very obvious from the equation we will be looking at in little detail later on.

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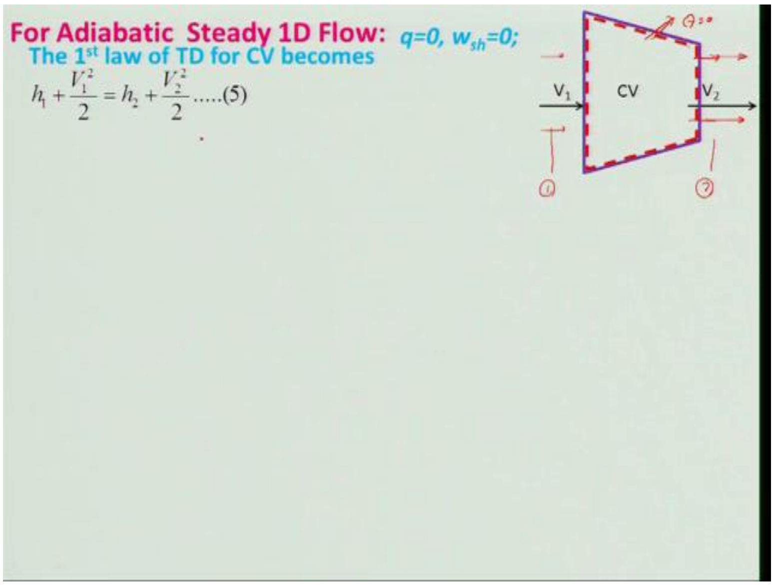

Here, I am considering this as a you know equations of first law of thermodynamics for control volume which state that h 1 plus v 1 square divided by 2 is equal to h 2 plus v 2 square divided by 2. Now, this equation I have just written do you agree with this how it has come from where it has come h 1 plus v 1 square divided by 2 is equal to h 2 plus v 2 square divided by 2 from where it has come.

Student: Energy equation.

Energy equation, so if I want to write down energy equation what it would be I must know that right then I will have to make this what you call make the assumptions whatever that q is equal to 0 shaft work is 0. Then I will have to do that and there is no gravitational you know or the potential energy change I want to write down for you let me do that.

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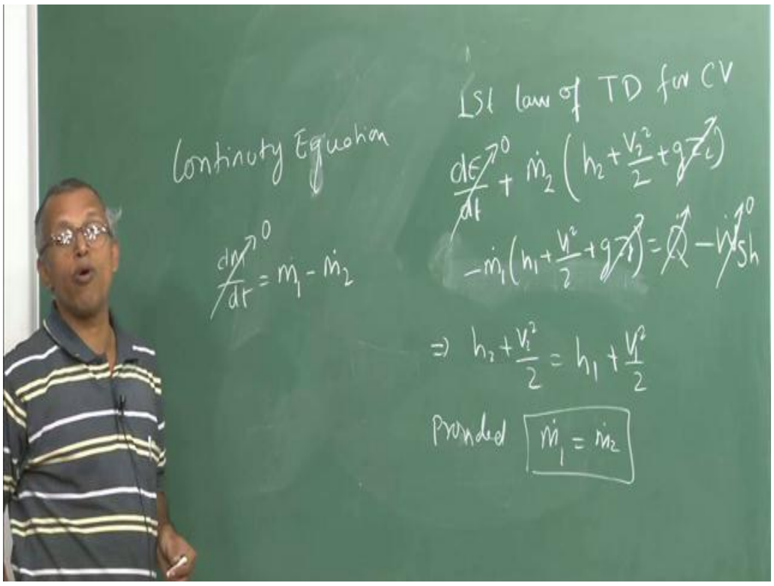

So, if you look at this equation thermodynamic for a control volume and keep in mind that we are considering what you call 1-dimensional flow that is very important. Generally, you know flow is uniform across this a cross section what we are considering so I can write down dE by dt is equal to is plus m dot 2 if I take a station 2 and it will be h 2 plus v 2 square 2 plus g z 2 minus m 1 h 1 plus v 1 square by 2 plus g z 1 is equal to dot minus w shaft.

Now, in this case what is happening we are not considering this potential energy terms and this is a steady flow and there is adiabatic flow this is shaft work. Then I will get h 2 is plus v 2 square 2 is equal to h 1 plus v 1 square by 2 provided what, provided you know provided m dot 1 is equal to m dot 2 is it true because if I apply the continuity equation 1-dimensional continuity equation. What it would be d m by d t is equal to m dot 1 minus m dot 2 this is 0 because of steady flow therefore, m dot is equal to m 1 and then we arrive at this. And this is the energy equation for what you call the 1-dimensional flow under steady state condition with of course, no shaft work and adiabatic in nature.

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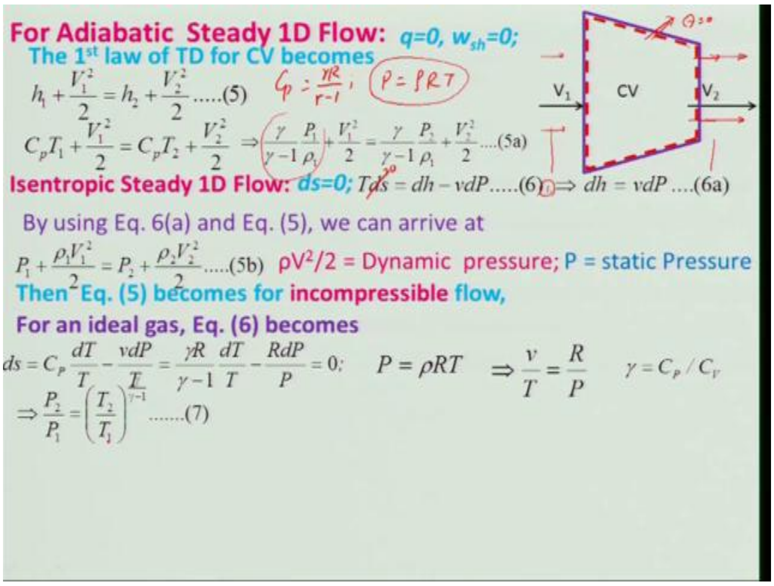

So, if I convert this equation in terms of what you call temperature what I will do I can write down in place of enthalpy I can write down Cp T 1 plus v 1 square divided by 2 is equal to Cp T 2 plus v 2 square divided by 2. How could I write this under what condition I can do this can anybody tell me we are assuming as an ideal gas right what kind of ideal gas it is. It will be calorically perfect gas because the Cp is a function of temperature, Cp is also a function of kind of fluid.

If it is oxygen it will be different if it is helium it will be depend different right if it is carbon dioxide it is different what are the difference between three examples I have given one is mono molecule di molecules and tri molecular structures automatically. So therefore, it Cp will be different and here we are assuming that specific heat or the c p is also a function of temperature. In this case we are assuming that Cp is not changing with temperature when it will be valid if the change in temperature is not much, but in case of combustion we cannot really do effort to do that.

Of course, we will be doing, but will be makings lot error in that therefore, you keep in mind we could do this conversion for that caloriphically perfect gas. Now, what we will do we will put this in place of Cp we will express in terms of the gas constant that is specific gas constant that is R what we are saying what we will be doing we will be in place of Cp. You know I will be using Cp is equal to gamma R divided by gamma minus 1 and keep in mind that ideal gas equation is equal to P rho RT.

So, if I write down in place of Cp as C gamma R gamma minus 1 it is here and in place of R and T if you look at this T 1 RT 1 it will be p 1 divided by R 1 from this equation of from this equation of state for an ideal gas you can write down p 1 divided by R 1. Of course, v 1 square divided by 2 is remains and similar thing for the right hand side can you recognize this equation what kind of equation it is all of you are expose to the fluid mechanics earlier and even what kind of equation this is can anybody tell me what it says.

It says basically ratio of pressure and density right this says is the velocity particularly you can think of in terms of kinetic energy and what is this can you say anything about this term I mean I am expecting an answer.

Student: P by rho 1.

P by rho 1 p 1 by divided by rho 1 what it indicates physically what do you mean

Student: Speed of.

Speed of what

Student: sound.

Speed of sound where is speed of sound comes into picture here right. So, if you look at this is of course, what he has told it is similar to that, but however you know it is different physically if you look at it will be like making a flow what will make the flow to happen it is the pressure. If I look at in that terms, but this is applied basically and if you look at can I call it as a Bernoulli's equation right and generally people call it as a Bernoulli's equation for compressible flow right and, but however in some of people dispute they say that you know like Bernoulli's equation would not be there for an cannot be applied for an for compressible flow.

But however it will be convenient because it is similar to that let us see that whether we can derive a Bernoulli's equation considering the flow to be isentropic in steady 1-dimensional. When I say that isentropic it is basically change in entropy is equal to 0, change in entropy is equal to 0, then what will happen to this first Gibbs law or expression sometimes people call it as a Gibbs expression. That is T ds is equal d h minus v dP I think I had discuss in the last lecture is a combination of first law of thermodynamics and second law of thermodynamic together we will get this expression. Some of you might have looked at and see that how it is derive and what is its implication.

So, if the it is an isentropic flow then I can make you know it is 0 so what it indicates this expression equation six it indicates that d h is equal to v dP. And then if I you know use this equation six in equation five which is nothing but what energy equation for adiabatic flow but, it is not isentropic. Then what I will get, I will get an expression is equal to p 1 plus half rho 1 v 1 square divided by 2 is equal to P 2 plus rho 2 v 2 square divided by 2 which is very familiar to with you right. What is this equation this is your Bernoulli's equation, what is the validity of this equation and what it indicates to you if you look at this terms this basically says what the first one is your pressure.

That means this is the pressure work or the pressure the work will be done on the fluid so that it can flow as a result there will be kinetic energy right change in energy. That means what its saying if pressure increases what happens to the velocity decreases, but we know that you know in the pressure gradient is more than velocity will be more there is something contradictor am I right. Then how will interpret this, but from these it says if I take session one P 1 I mean and the pressure P 1 and then at the station same place at 1 it will be velocity is V 1 if pressure is decreases here at the station two. Here you know what happens to a velocity, velocity will be higher because the total is remaining constant.

That means total energy is remaining constant at between the station one between the station one and station two am I right of course, there is another term which is there due to the elevation kind of things which we have not consider what we call it as a potential energy. That means what it indicates, it indicates that the energy equation that is the equation five is same as that of the equation five b which comes from what momentum equation. You can derive that and this is valid for what steady incompressible equation five b and then isentropic flow and whether it is rotational or irrotational.

Student: Irrotational.

Why I did not talk about it because if it is rotational then entropy you know has to be changing particularly when near the bounder layer you know. So, and also it will be dissipated kind of things therefore, it is valid for 1-dimensional steady irrotational flow.

And therefore, we call it you know flow along a steam line right where mass will be remaining constant. That means if you take a stream tube that mass any section is remaining constant therefore, continuity is valid.

So therefore, you know like one has to consider that along a steam line it will be valid so and I have already told you that rho v square is a dynamic pressure and P is a static pressure right. What do you mean by static pressure can anybody tell me what do you mean by static pressure is there fine go ahead

Student: When it is accepted by molecule ((Refer Time: 53:30)) brought to rest.

Brought to the rest right how I will get it if I say that I want to measure how can i measure it is it I will make the fluid to come to the rest.

Student: Isentropic ally.

Isentropic ally is it possible I can do that, that means what it is can you people think about you imagine that you are hoping over a fluid element or a may be a sensor which is hoping on a fluid element that fluid element is moving at certain velocity. That means it is there is a fluid element and I am having a tiny center of course, it is quite difficult imagine that and then it will be experiencing certain pressure due to what as it is moving right a element will be having certain velocity. As it moves different places it may be experiencing different velocity that is a different thing, but then what it will be experiencing it will experiencing a pressure or a force the force is due to the molecular interaction that means molecules will be coming and bombarding each other.

That means that pressure which you will be fell due to the change in the what you call momentum change that you will get the pressure we call it as static pressure. So, for an ideal gas equation six becomes you know I can write down d s in Cp dT by T minus v dP by T is equal to gamma R divided by gamma minus 1 dT by T and minus R dP by P is equal to 0. Are you getting this, this what we are getting we are basically equation six I am taking and looking applying this you know changing the Cp values and putting this equation of state and we are getting P is equal to RT if I apply this ideal gas law.

Then I can get into v by T, R by P and then if I say gamma is basically ratio of Cp by Cv then I will get this expression p 2 by p one is equal to t 2 by t 1 gamma, gamma minus 1 keep in mind that is not visible, but look at it right. That means this is the expression for an isentropic flow relating the pressure and temperature with this I will stop over it, but let me ask a question before stopping over. Why we need to look at this isentropic flow equations or expression which is being use rough usually and we will be using it you know left and right in our analysis why it is so we will discuss, we should think about it. So, I will stop over here any questions.

Thank you very much.