Fundamentals of Gas Dynamics
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Week – 11
Lecture – 42
Reflection of Oblique Shocks

We are going to extend the discussion on Oblique Shock to something called Shock Reflections.

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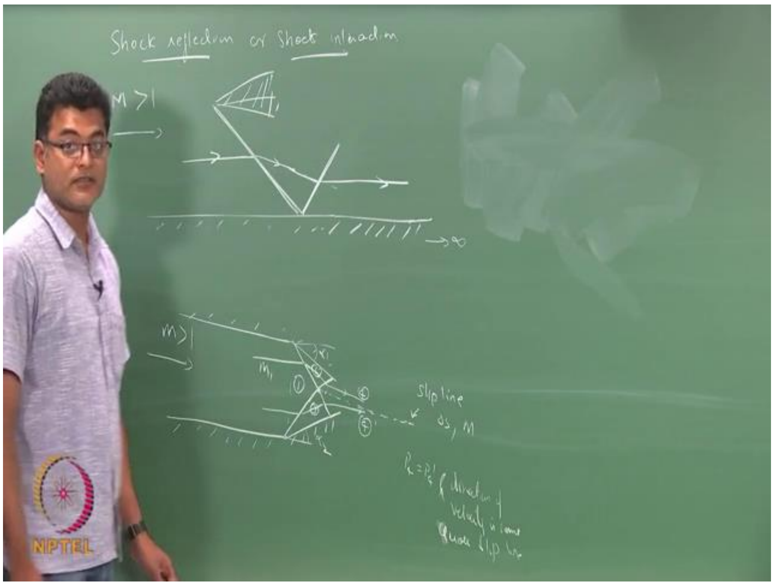

What is going to be reflections or shock interactions, so what do I mean by shock reflection? Suppose I have a plate here and I have a flow which is greater than 1, and somehow I have a oblique shock here this may be due body that is kept here at some angle or due to whatever. Let us forget about the reasons why we have a shock here we just have a shock here. So, there is a shock here. As we know there will be a velocity vector that is coming, stream lines that is coming because of the shock there will be a turn.

Now somehow the flow after this, if this is infinitely long plate the flow somewhere has to turn towards to the inline with your surface. So, if there is a flow that is at an angle this goes and hits the surface, so to avoid that kind of scenario the flow would take another shock wave which is the reflected shock wave from the surface. The flow comes here and make a turn like this so that the stream lines are parallel with the this thing

Now, this happens because we are doing an inviscid flow analysis we avoid separations here. In reality there may be a region where you can have a shock that is going like this within the boundary layer and it can reflect like this, so there will be region here which can have separations which are typically called as shock induced separations. So, you can have oblique shock that as going to take you this way or you can have stream line that is going this within the boundary layer, if you consider viscosity it can you can also have separations and other things. Let us not discuss that rather we will discuss the first case which is weight inviscid flow and we will restrict to a flow like us which is regular reflection from the surface.

So, I have the reflection from the wall and then I get it or if I have a channel which suddenly reduces in area. So if I have a channel like this, the incoming mach number is greater than 1. So, because of this there will be a oblique shock that is formed here, and because of this top surface there will another oblique shock that forms here. This can interact at some position if these angles are same they will interact at the center line, otherwise there will be different location in which they interact depending on this angle say alpha 1 this angle alpha 2. And once this reflects there will be another oblique shock that is formed out of this again the flow direction you can get it; so if you know the reflection angle from our theta beta relation you can further get the angles at which the out coming flow is.

So, can have m 1 greater than 1 here and then you have a region here, so this is region 1 this is region 2 this is region 3 and this I call this as region 4 and region 4 dash. If these angles are same then I can have 4 and 4 dash of same kind, otherwise the mach numbers here at 4 and mach number here at here 4 dash can different depending on the angle at which these shocks are reflected. We are going to do some problems related to this. So, all this because this uniform constant area duct suddenly deflects at two different angles and there are shock reflections that is happening here and the stream lines are going to do these kinds of phenomena.

Now, the point to note here is that I have drawn a dash line here, so there is a region where demarcates 4 and 4 dash, the properties in 4 and 4 dash namely the mach number or the pressure or a entropy change everything depends on the angle at which these shocks are reflected within 3 and 2. So, if the angles are same 4 and 4 dash would be seen, otherwise the entropy change across these the top shocks are different from the bottom shocks. So there is a sudden entropy change at 4 and the entropy change in the region 4 dash is different.

So, there will be a discontinuity of entropy change in 4 and 4 dash and that happens at this particular dash line which is called as Slip Line, where my entropy change is discontinuous, my mach number is discontinuous except the pressure P 4 is same as P 4 dash across the slip line and the direction of velocity is same across slip line. All other properties can have a sudden jump, temperature can have a sudden jump or all those quantities densities can have a sudden jump, everything can have sudden jump.

So, if you take a pressure contour of this you are not going to visualize this slip line. Whereas, if you plot the mach number contours you will see a slip line according to this particular configuration.

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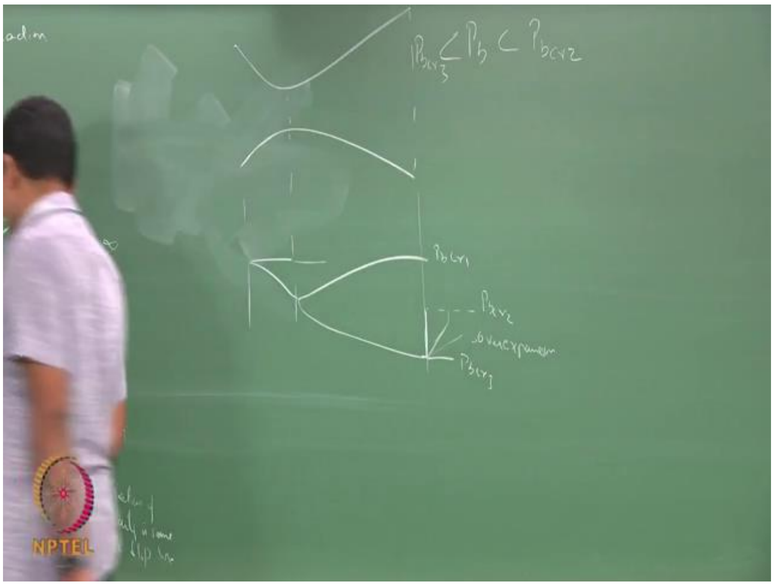

Now, same thing is happening at a flow in a nozzle, say if I have a 3 d nozzle. If my P b is between P b critical 2 and P b critical 3 which means my shock is; so if I have isentropic solution like this, so this is my P b critical 3 and this is P b critical 1. Now if my shockers outside the nozzle, so if I have a shock here I have a P b critical q. So, if my back pressure is between these two values I would have a shock that is happening outside the nozzle. So, in that scenario also you would see these kinds of flow, the schematic of which is what I have it here.

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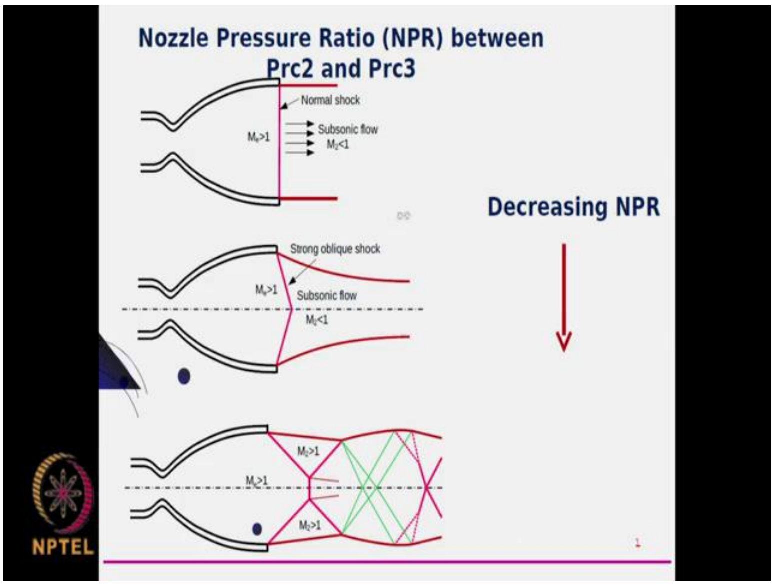

So, in the slide what you have here is the P b critical 2 which is some mach number where the shock is sitting at the exit of the nozzle. Now if I reduce my P b further this shock is pushed down stream and hence you would see a strong oblique shock setting outside the nozzle, and you mach number after the shock are typically less than 1. But if keep reducing the pressure ratio pressure; ratio is P b by p 1 then I have reflection shock like something like this, so your shock is pushed further down. So, you have a shock reflection and this straight normal shock kind of a thing is called the mach reflection because this normal shock reflects with the oblique shock here.

So, these kinds of a shock interaction are also possible and we are going to analyze few of these kinds of these. These green lines are called expansion fans which we will deal it in the next week lecture, we will try to do. So, this is a power expanded nozzle what this scenario is, so when it goes further down if the back pressure is further down and lower than P b critical thing you will have the under expansion. This over expansion happens here and this phenomena what we have drawn here happens in a power expanded nozzle.

So, what we will do is we will try to evaluate, we will do a numerical problem to see what happens further with these kind of analysis.