Dynamic Behaviour of Materials
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Lecture - 23
Complex Problems of Shock Waves and Temperature Rise under Shock Wave

Hello everyone. In the last lecture we have discussed about equation of state of shock waves. We discussed little bit about porous materials and alloys and mixtures, that equation of state of those materials. And today we will discuss a little bit about the temperature rise during shock wave and also we will talk about some complex problems of shock wave and also shock wave attenuation, interaction and reflection.

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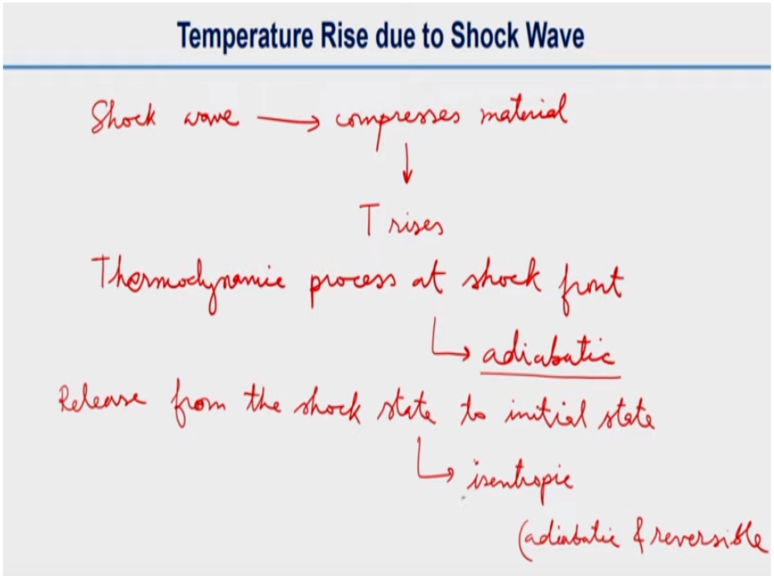

So shock wave compresses the materials, shock waves compresses material and so that increases the temperature or temperature T rises. So the thermodynamic process at the shock front process, at shock front is considered to be adiabatic. So this thermodynamic process at the shock front is adiabatic. So you know what is adiabatic. Adiabatic is no heat or mass transfer from the system to the surroundings.

The release from the shock state to the initial state that means when a shock wave passes through a material so after the shock front then the material will after some time come to at the initial stage, no higher pressure, the pressure will be zero. So that release from the shock state, that means high pressure state to initial state, initial state that means mostly it is without pressure. That process is isentropic.

So this is assumed to be isentropic. So isentropic means an idealized thermodynamic process. This is that is both adiabatic and reversible.

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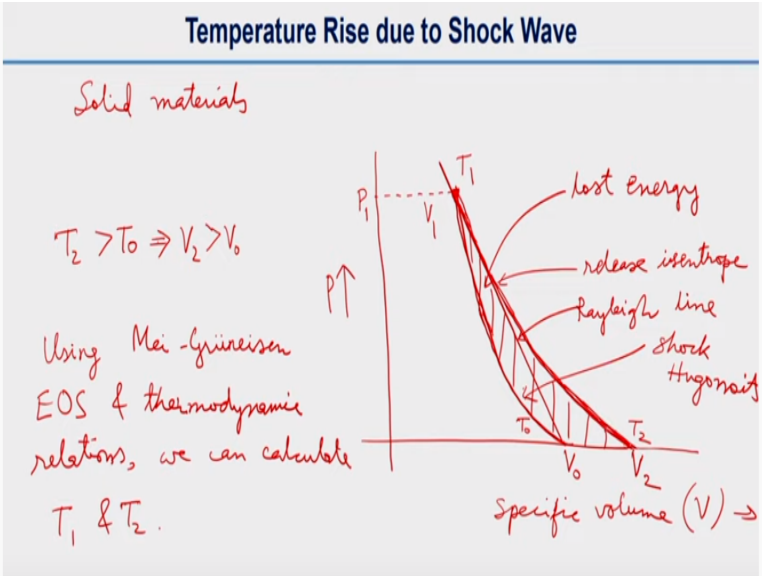

So for solid materials these shock Hugoniot curve and the release curve that is released from shock state to initial state actually they are very close to each other. So if you draw the pressure versus specific volume curve v, so what we will see that there will be shock Hugoniot which we can draw like this, it is a curve. And then we can have this release curve something like this.

So let us say this pressure at this point is P 1, temperatures is T 1. So this curve, first this curve is the shock Hugoniot of the solid material, shock Hugoniot. And then this is the release curve or we can say release isentrope because it is isentropic, isentrope okay? And we can even draw a Rayleigh line; we know that the Rayleigh line will be a straight line, will be from this point connected to this point.

So this will be, the straight line will be Rayleigh line. So this part is the, the hatched part is the lost energy. So basically what we saw in the shock Hugoniot curve is this one and then so we have the release curve that is assumed to be isentropic. So this is the release curve. And here you have volume is V naught because it starts from here and then here you have volume V 1 and then volume here we have volume V 1.

So here the specific volume here is a V 2 and then the temperature will also be here T naught and T 2. Because T 2 is greater than T naught. That means, this V 2 will be greater than the V naught. So because that is T naught is the initial temperature and we know the temperature will rise in this process even after the shock state comes to the initial state.

So using Mie-Gruneisen equation of state and thermodynamic relations we can calculate T 1 and T 2. T 1 that is the peak point, peak pressure point and then T 2 is the point temperature after it comes back to the initial state. Okay and that is all for this temperature rise. So let us talk about now little bit some complex problems here. So in the earlier chapters we discussed about the Rankine-Hugoniot conservation equations.

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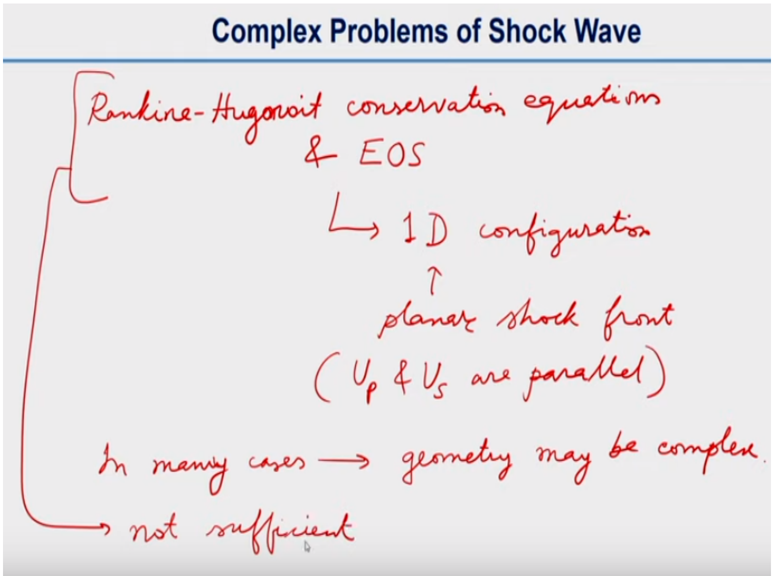

Rankine-Hugoniot conservation equations and the equation of state. So that can describe the propagation of shock waves in basically 1 D configuration. So we what we discussed earlier is that is 1 D configuration. 1 D configuration is a planar shock front, planner shock front. That means this particular velocity U p and shock velocity U s are parallel. So this is 1 D configuration.

But there can be some complex problems. So in many cases this may not be so simple. This may not be 1 D configuration. So the geometry may be complex. So complex geometry basically we are talking about the geometry of the projectile here.

And then this, those simple equations in this case not sufficient. They are not sufficient for these complex geometries.

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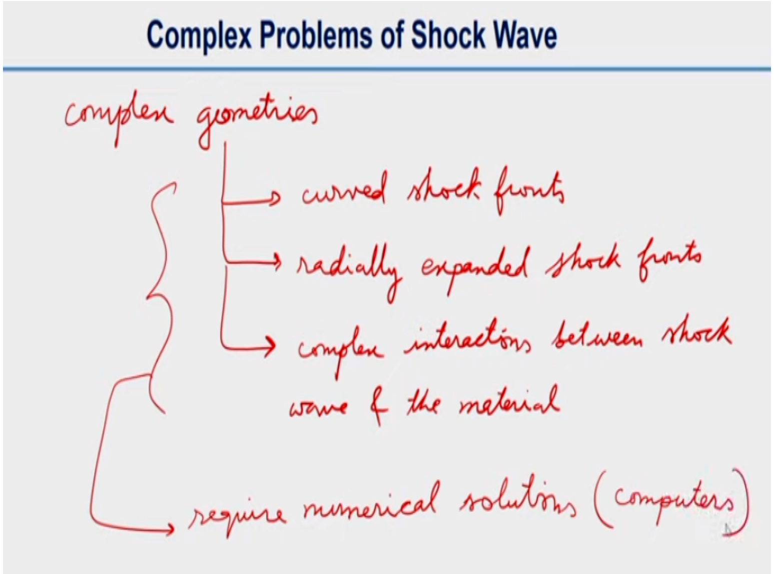

Because the complex geometries will result number one curved shock fronts and number two it is, it may have radially expanded or we can call spherically expanded shock fronts and also complex interaction between shock wave and the material, shock wave and the material. So these are the main features, main aspects of complex geometries. So these type of problems will require numerical solutions which can only be, its only possible using computers.

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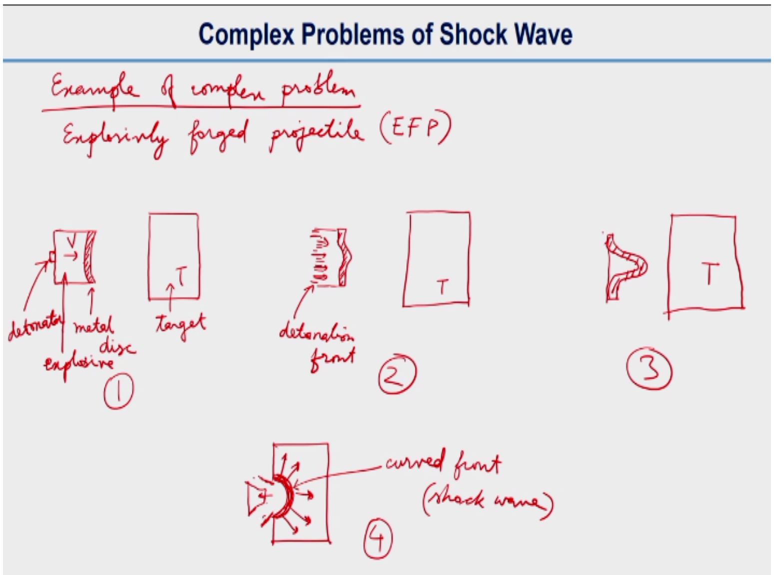

So let us have an example of complex problem. We will have an example of this one of the complex problem that means complex problem of shock waves. So this is nothing but the explosively forced projectile. So we discussed about that in one of the initial classes. So we can call it as EFP. So we talked about shaped charges and we talked about even explosively forced projectile.

So what happens is suppose, we will draw this step by step. So this is the target, this is the target and we have a projectile which is a metal disc. This is the disc, metal disc with explosive here, explosive with a detonator at that point, detonator. So what happens will be there will be the velocity will heat the metal disc. So what will happen is again we will draw the second step. This is our target.

I will write target is T, this is our target and our metal disc will take a shape like this when the detonation detonator will detonate the explosive. So this is let us say or we can draw some arrows. This is a detonation, detonation front. So and finally, okay we will draw two more steps. No this is not the final one, this is target. So this is step number 1, this is 2, this is 3. So this projectile will get a shape like this.

Projectile means the disc, metal disc got a shape like this and so what will happen is in the final step what we can draw is this is the target, this is the target, this is number 4 and what will happen the target will be better we will not write T here. So target will be defeated and then the remaining part of projectile will thrown away. This some material will be thrown out.

So this is the penetration and then what I wanted to show is this shock wave, this is the direction of the shock wave. So this is the front of the shock wave. So if you see this front is curved front. That is shock wave, shock wave front, curved. And also you can see that the radially expanding and the shock waves are going moving propagating and along the radial direction.

So this is now, the problem is complex. Its not like a planner impact where this is we can have like one dimensional system which is that means the particle velocity and the shock wave velocity are parallel.

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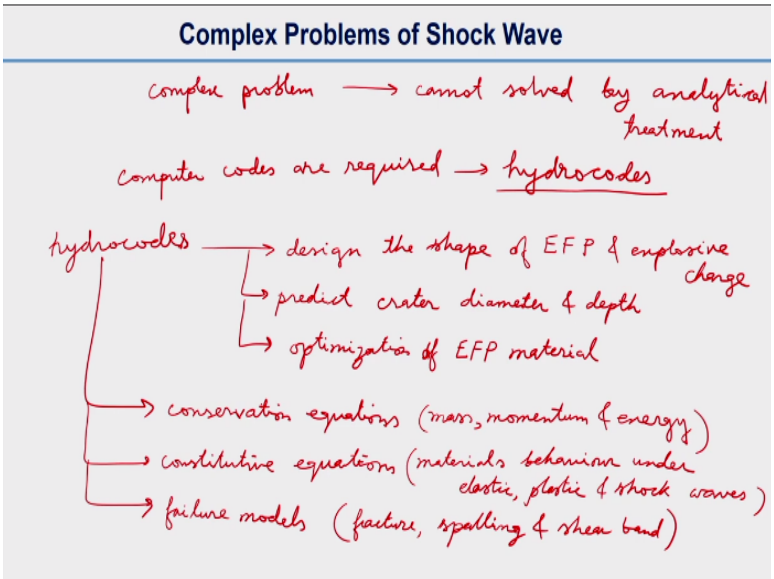

So this type of problems, the complex problem, this type of complex problems are difficult to solve by analytical treatment. That may not be realistic or not accurate. Cannot solve by analytical treatment. That means, we need a computer. We need to do some use some numerical methods to solve this. So we need some computer codes, computer codes are required.

And these codes are generally known as hydrocodes because as we know it will have hydrodynamic treatment. So these are known as hydrocodes. Hydrocodes are so they are complex and then we are not going to discuss details about this hydrocodes. We are leaving it for you if you are interested you can study this chapter number 6 of Mark Myers book.

So we do not have that much time to cover all those and this is I feel this is little bit advanced. So that is why I am leaving this part for you, if you are interested really interested in this subject, then you can follow it up from that textbook. So with the help of these codes, what we can do is we can design the shape of, shape of explosively forced projectile and also the explosive charge that we will be using.

And also we can predict the crater that means the impression made by the projectile, crater diameter. That means the impression made by the projectile on the target diameter and depth and also optimization of EFP explosively forced projectile material. So your projectile material, what should be your projectile material that we can optimize from these using these hydrocodes.

Also these codes contain first the conservation equations and constitutive equations, and failure models. So conservation equation as you know mass, momentum, and energy. And the constitutive equations means materials behavior under elastic, plastic and shock waves. And the failure models that may include fracture. We will talk about dynamic fracture later, spalling.

That means fail of the material after tensile reflected waves. That we discussed and shear bands. That also we will discuss later. So these hydrocodes and these conservation actually equations deal with the conservation equation of fluid mechanics and also there are the areas like fluid dynamics and gas dynamics are used here in these type of complex problems.