Dynamic Behaviour of Materials
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Module No. #04
Lecture No. #12
Plastic Waves of Combined Stress

Hello everyone, in the last lecture, we have discussed about, the Plastic Waves of Uniaxial Stress. We discussed about, the simplest experiment, to generate Plastic Waves, developed by Von Karman and Duwez. So, this lecture, we will discuss, Plastic Waves of combined stress, that means, both, Shear and Longitudinal Plastic Waves. And also, we will discuss about, Taylor's experiment, that is, impact of finite length bars. And, another part of the Plastic Wave, that is the Plastic Wave of Uniaxial Strain, we will discuss later.

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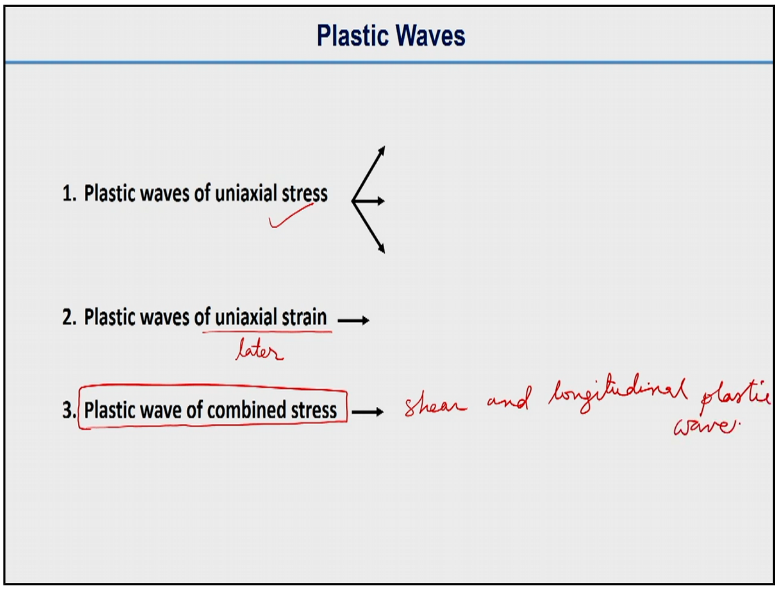

So, what we discussed earlier is, Plastic Waves of Uniaxial Stress. So, we have already discussed. And, so the Plastic Waves of Uniaxial Strain, which is like shock waves, so we will discuss, later. And, today, we will discuss about, the Plastic Wave of combined stress, that is, both, Shear and Longitudinal Plastic Waves.

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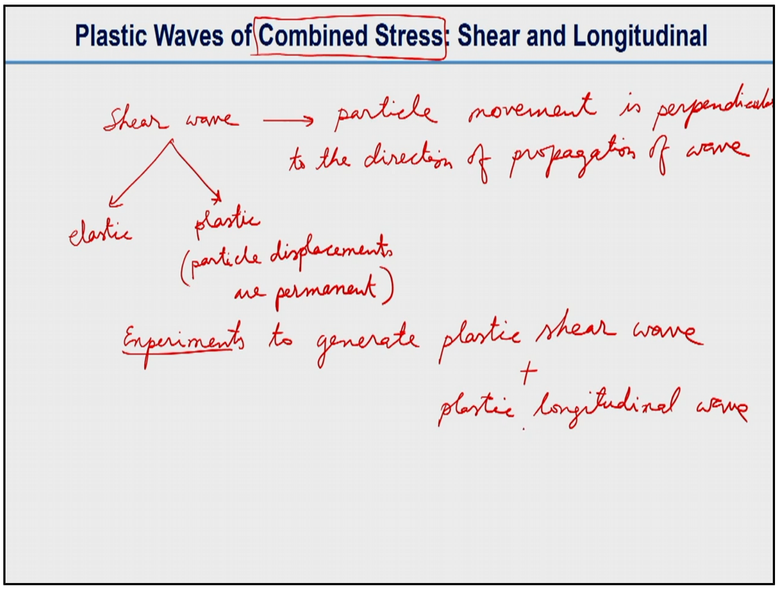

So, Plastic Shear Wave, like the Elastic Shear Wave, involves the particle displacement, in a perpendicular direction, or to the direction of propagation of wave. So, as we know, Shear Waves, the particle movement is, perpendicular to the direction of, propagation of wave. So, this is true for, both, Elastic and Plastic. But, in the case of Plastic, as we know, the particle displacement are permanent. This is a, permanent displacement.

So, the researchers have developed different experiments, to generate, Plastic Shear Wave. So, experiments, to generate, only Plastic Shear Wave, is not very convenient. And, then only the experiments have, both, Plastic Shear Wave, and Plastic Longitudinal Wave, combined. So, that is what, we have this title, the Plastic Waves of combined stress. So, we will have, both, Plastic Shear, and Plastic Longitudinal Wave.

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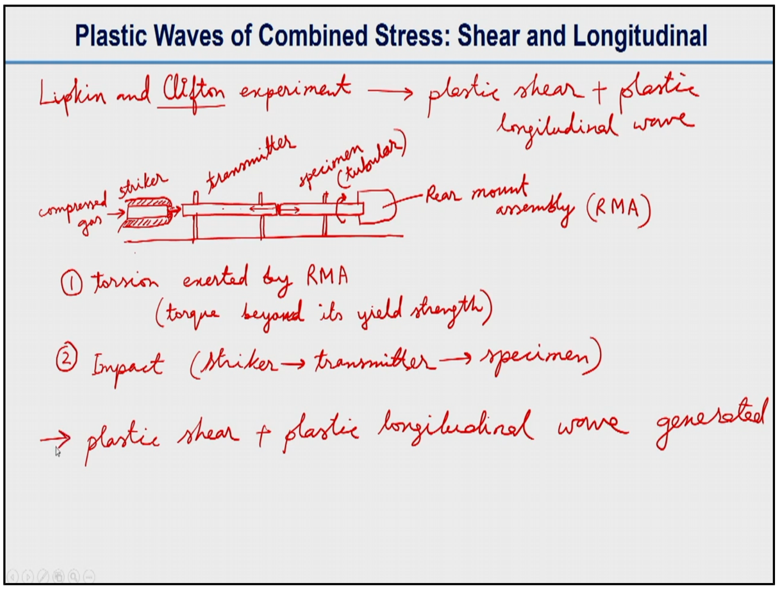

So, we will first talk about, Lipkin and Clifton experiment. This experiment, can generate, both, Plastic, Shear, plus, Plastic Longitudinal Wave. So, Clifton is from, the Brown University. So, the experiment, the setup, looks like this. So, we have a striker bar. Inside, this is the base of this experiment. So, this is the striker bar. I will write, just, striker. And, which will strike, a transmitter bar, which is connected to the base, like this.

And, this is a transmitter bar. And, there will be one specimen, which is tubular. And then, there will be one, the mounting assembly, to produce torque. So, this is the fixtures, that holds the transmitter, upon a specimen bar, with the base. And, this striker bar, will be inside a case, that is the barrel. So, that is probably the, gas gun barrel, with the help of compressed gas.

So, this striker bar will strike, the transmitter bar. So, this we call it a, Rear Mount Assembly. So first, torsion is exerted by, Rear Mounting Assembly, I will write, by RMA. So, that torque is beyond the yield strength, because we want to produce, some Plastic Shear Wave. So, this torque, beyond its yield strength. So, then, after the torsion is exerted, so we will hit the transmitter bar, with the help of the striker.

So, this is, we have a compressed gas. This is actually, a compressed gas gun, will move the striker, and that will hit the transmitter bar. This is the specimen is, already torsioned, and torque is applied here. So, and after this impact, second phase is the impact. So, striker hits the transmitter bar, and transmitter bar hits the tubular specimen. So, also this, the wave will reflect, from this transmitter specimen interface.

And both, Longitudinal and Elastic Wave will reflect, from this interface. But, it will also transmit, to the specimen, and producing the Longitudinal Wave, both Elastic and Plastic. Because, it is hit at a very, and the impact is at a very, high velocity. So, and then, this rear mount assembly, will generate, will produce, the torsion. So, that means, both, Plastic shear, and Plastic Longitudinal wave, will be generated, in this experiment.

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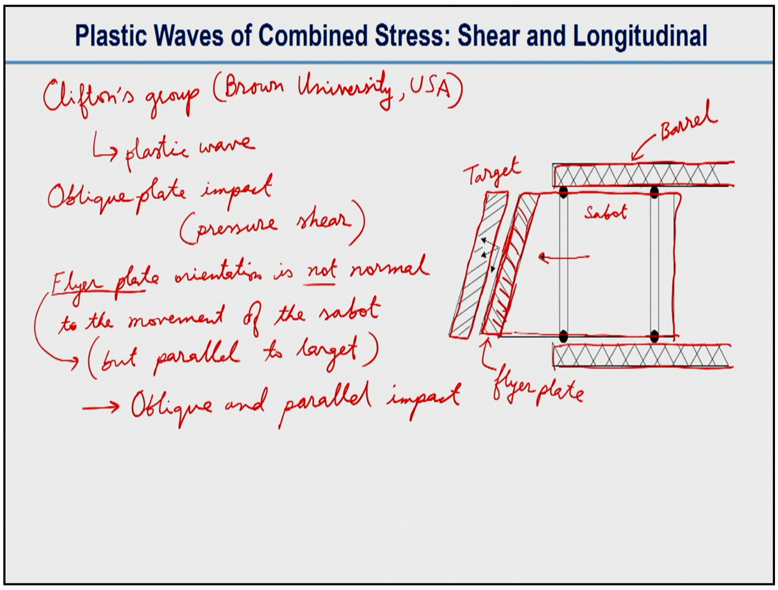

So now, we will talk about, one more experiment, developed by the same group, that is Clifton's group, from Brown University, Rhode Island, USA. So, here, in this case, this is a barrel. So, this one, a barrel, let us say, it is a gun barrel. And, the projectile, from the gun barrel is called a, Sabot. The entire, this portion, is called a, Sabot. You can see, the mechanism here, to move the Sabot, inside the barrel, at a very high speed.

So, this is moving, in this direction. And, this is the target. So, this is also an experiment to generate, Plastic Wave. And, this is called, Oblique Plate Impact experiment. Or, it is also known as, experiment of Pressure Shear Plate impact. So, the part of the Sabot, this part, this is called, Flyer Plate. So, that is the part of the Sabot. The Flyer Plate, will actually hit the target.

And, the Flyer Plate orientation is, not normal to the Sabot direction, support the direction of movement of the Sabot. However, Flyer Plate, is paralleled to target. So, this flyer plate is, the orientation is not normal, to the movement of the Sabot, but parallel to target. So, this is parallel to target. And, that is why, it is called, Oblique and Parallel impact.

So, anyway, it is oblique because, the Flyer Plate orientation, is not normal or perpendicular to the, say, Sabot movement direction. And, and another way is, it is called parallel because, this Sabot, actually the Flyer Plate, which is on front side of the of Sabot, is parallel to the target. So, this is called, Oblique and Parallel impact. So, upon impact, stress wave is generated, from that interface.

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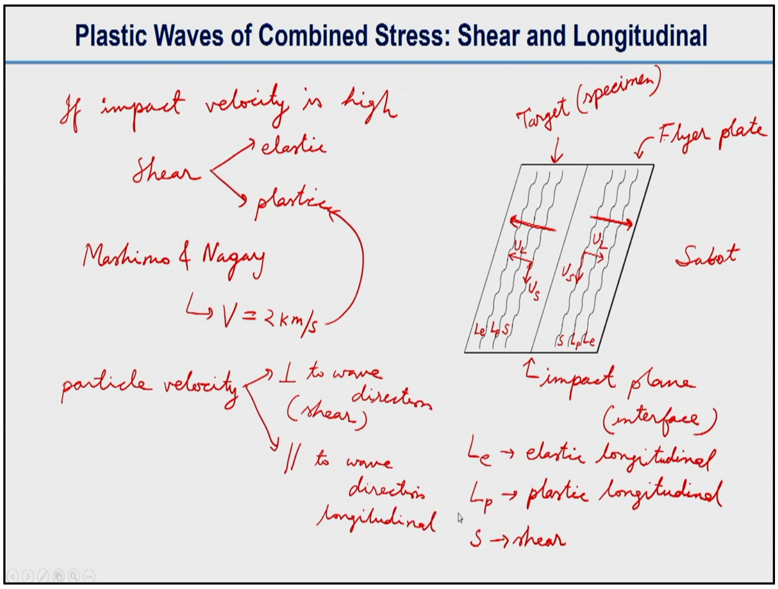

So, we will see, how these are generated. So, this is, let us say, target is nothing but the, actual specimen. Target is the specimen. And, this one is the, Flyer Plate. So, that is, as you can see, this is a part of the Sabot. Flyer Plate is the part of the Sabot. So now, this is the impact plane. As you know, upon impact, impact plane, or you can call, the interface, between the target, and the Flyer Plane.

So here, the wave, in both the direction, both in the target, and in the Flyer Plate, will move in that direction, that is, perpendicular to the interface. But, if we see different waves, the fastest wave, which will be ahead is the, Elastic Longitudinal Wave. And, the second wave will be, Plastic Longitudinal Wave. And, third wave is the, Shear Wave. So, similarly, in other side, in the Flyer Plane, as well. Sorry, this is Sabot.

So, in the other side, as well, the Longitudinal Elastic Wave will be ahead of, Longitudinal Plastic Wave, and the Shear Wave. So, Shear Wave can be, both, Elastic and Plastic. So here, I will write, L e is Elastic Longitudinal Wave. And then, L p is, Plastic Longitudinal Wave. And then, S is Shear Wave. So, if the Impact Velocity is very high, then the Shear Wave can be decomposed to, Elastic and Plastic.

So, basically, the impact velocity is high means, if the stress amplitude, exceeds the shear strength of the material, then the Plastic Shear Wave, can also be generated. Many researchers reported, and I think, by some researchers, it is mentioned that, Mashimo and Nakayama reported that, this impact velocity, is up to 2 Kilometre per second, which is very high, can produce, Plastic Shear Wave.

So, to generate Plastic Shear Wave, we need to have, very high impact velocity. And, as we know here, this wave propagates, in perpendicular direction, to the impact Plane or interface, for both, target and Flyer Plate. How and also, we know that, the direction of particle velocity. So, particle velocity direction, for Longitudinal Wave, it is perpendicular, this particle velocity.

And, for Shear Wave, it is parallel to the interface. So similarly, in this case also, these are, like this. So basically, the particle velocity, as we already discussed, this, the particle velocity, is perpendicular, to wave propagation direction, for shear, and parallel to wave direction, in the Longitudinal. That is, already discussed.

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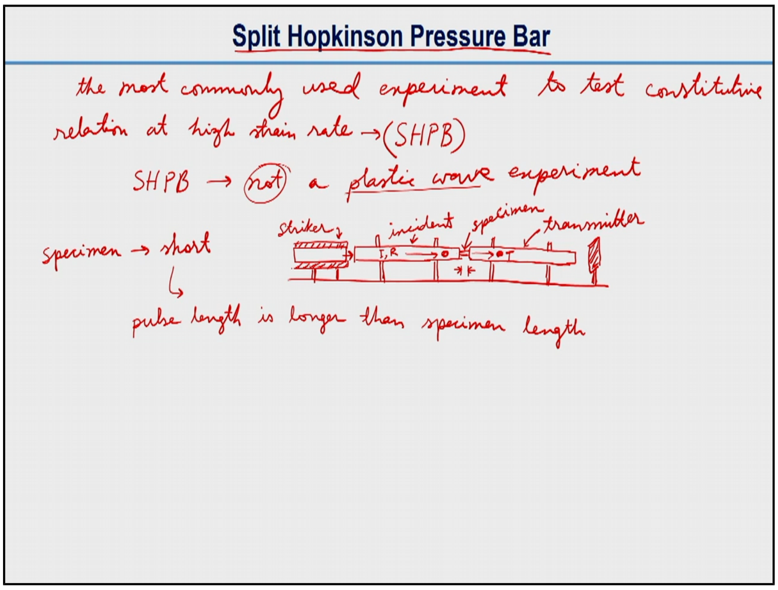

So, we have talked about, this Plastic Wave of combined stress, that means, both, shear Plastic Wave, and Longitudinal Plastic Wave. Now, we will discuss about the, Split Hopkinson Pressure bar, which is actually not known for Plastic Wave. But still, we will discuss that. So, this is the most commonly used experiment, to test the constitutive relations or material behavior, at high strain rate. So, the Split Hopkinson Pressure bar, as you can see, in the heading, is commonly written.

And, we also refer here as, SHPB, Split Hopkinson Pressure bar. So, but one should not consider SHPB, not a Plastic Wave propagation experiment. So, basically, the experimental setup is, like this. Or, whatever, we earlier have drawn, for another experiment, that is, to generate Plastic Shear Wave, and Longitudinal Wave, so it is similar, to that. So, here, we have first, the striker bar, inside a barrel.

So, this is called, striker bar or projectile bar. And, this is incident bar. And then, we have a small specimen. It is, small means, both the diameter, are even smaller, and the length, is very small. So, this is the specimen. So, this is incident bar, this is striker bar. So, and we have another bar, which is called, transmitter bar. And, there will be a, something we call as a momentum trap, to restrict the movement of the transmitter bar, out of the assembly.

So now, the specimen is very short, If you see, the length of the specimen is very less. So, specimen is short. And, you can understand from the figure, the striker will be exerted, by a compressed gas. And then, this will hit that incident bar, and the Stress Wave will travel, through the incident bar, and then, it will hit the specimen. And, some part of the wave will reflect back, and some part will go through the specimen, and it will, have been, enter the transmitter bar.

Now, this Stress Wave, the specimen will be plastically deformed. And then, this wave will continue to go, transmit towards the transmitter bar. But, although the specimen is plastically deformed, this is not considered as a Plastic Wave experiment, because the specimen length is very short. So, the pulse length, is longer than the, specimen length. So, we do not see, any Plastic Wave actually, traveling in this experiment.

Because, the Plastic Wave propagation configuration, in the specimen is, not available. It is a very short specimen. So, the Split Hopkinson Pressure bar, is not a, Plastic Wave experiment.

It handles only, the Elastic Waves, although the specimen is plastically deformed. But, this specimen, length is very short. And, the incident bar, and the transmitter bar, undergoes only Elastic deformation. The Elastic Wave propagates, from the incident bar, to the transmitter bar, through the specimen.

So, with the help of the strain gauges, what we can get that, we can have a strain gauge here, and the strain is here, where we can get the, transmitted wave. And here, we have, both, incident and the reflected wave. So, incident and reflected wave, that is, back from the, specimen and incident bar interface. So, we will discuss, the Split Hopkinson Pressure bar, in details, later. Now, we will talk about, the Taylor's experiment. So, that is, in Taylor's experiment involves, the impact of bars of finite length.