

**Structural Health Monitoring (SHM)**  
**Prof. Srinivasan Chandrasekaran**  
**Department of Ocean Engineering**  
**Indian Institute of Technology, Madras**

**Lecture - 39**  
**Part - 1: Non-Destructive evaluation - I**

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Module 2  
Lecture 12: Non destructive Evaluation

- (1) Non-destructive test (NDT)
- (2) Non-destructive evaluation (NDE)
- (3) Non-destructive inspection (NDI)

} for SHM scheme

- Inspection methods  
- continuous/intermittent health monitoring.

To detect the structural failure (damage - local)

- Ultrasonic inspection - most commonly practiced technique in SHM

Friends, welcome to the next lecture in module 2 this is going to be lecture 12. In this we are going to talk about non destructive evaluation, which is a vital part as far as structural health monitoring is concerned. There are three components or three major areas, which can do non destructive evaluation as far as structural health monitoring is concerned.

One is non destructive testing briefly known as NDT other is nondestructive evaluation briefly known as NDE third is non-destructive inspection known as NDI. All these are very vital for structural health monitoring scheme they become part and parcel of inspection methods sometimes they also become a part of continuous or intermittent health monitoring they are essentially used to detect the structural failure or in sense local damage.

The most important methodology being used is ultrasonic inspection, which is the most commonly practiced technique, in structural health monitoring.

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Basic principle

In a infinite solid medium, Elastic waves can propagate in 2 modes

- (1) pressure wave (P wave)
- (2) shear wave (S wave)

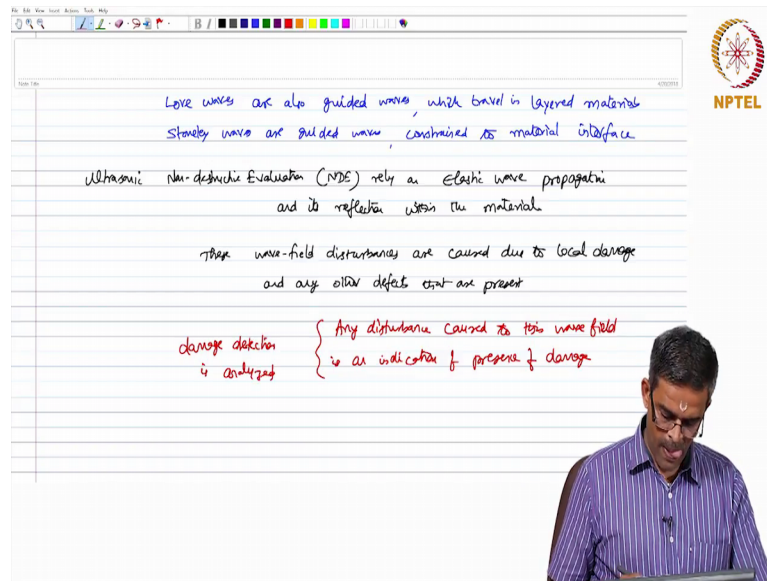
If the medium is bounded, then these wave reflect @ the boundaries to form a complicated wave pattern.

- Guided waves, which remain contained within the wave guide
  - Lamb waves are guided waves, travelling along the plate
  - Rayleigh waves are guided waves, constrained to the surface

Let us see what is the basic principle behind this? In an infinite solid medium elastic waves can propagate in two modes, namely pressure waves other ways called as P waves, the second is shear waves called as S waves. If the medium is bounded with the rigid boundary, then these waves reflect at the boundaries to form a complicated wave pattern ok.

Now, alternatively there are something called guided waves, which remain contained within the waveguide. For example, lamb waves or guided waves traveling along the plate, Rayleigh waves are guided waves which are constrained to the surface.

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The slide contains handwritten text in black and red ink. The text discusses Love waves, Stoneley waves, and Ultrasonic Non-destructive Evaluation (NDE). A red bracket groups the last two lines of text.

Love waves are also guided waves, which travel in layered materials  
Stoneley waves are guided waves, constrained to material interface

Ultrasonic Non-destructive Evaluation (NDE) rely on elastic wave propagation  
and its reflection within the material

These wave-field disturbances are caused due to local damage  
and any other defects that are present

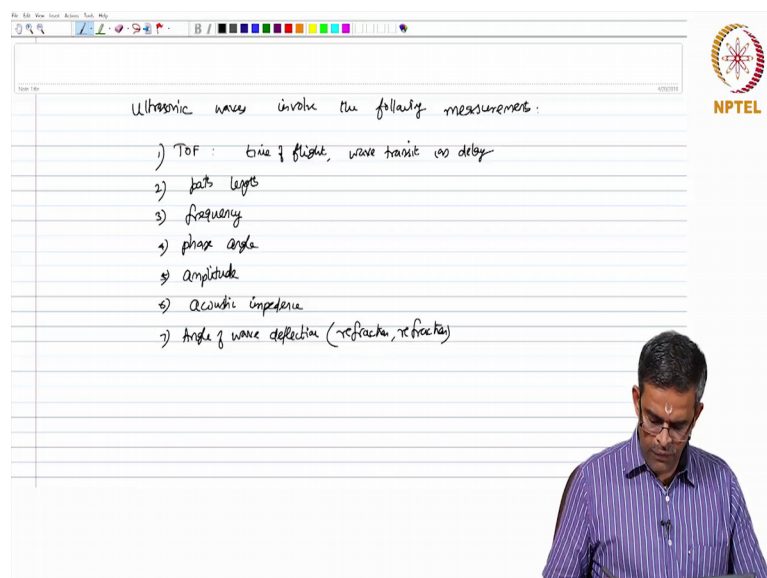
damage detection is analyzed { Any disturbance caused to this wave field  
is an indication of presence of damage

The NPTEL logo is visible in the top right corner of the slide.

Love waves are guided waves which travel in layered materials, stoneley waves are guided waves constrained to material interface.

Now, interestingly the ultrasonic nondestructive evaluation, which I refer as NDE essentially rely on the elastic wave propagation and its reflection within the material. These wave field disturbances or cost due to local damage, any other defects that are present on the other hand any disturbance caused to this wave field, is an indication of presence of damage that is how the damage deduction is done ok.

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The slide contains handwritten text in black ink. The text lists measurements involved in ultrasonic waves.

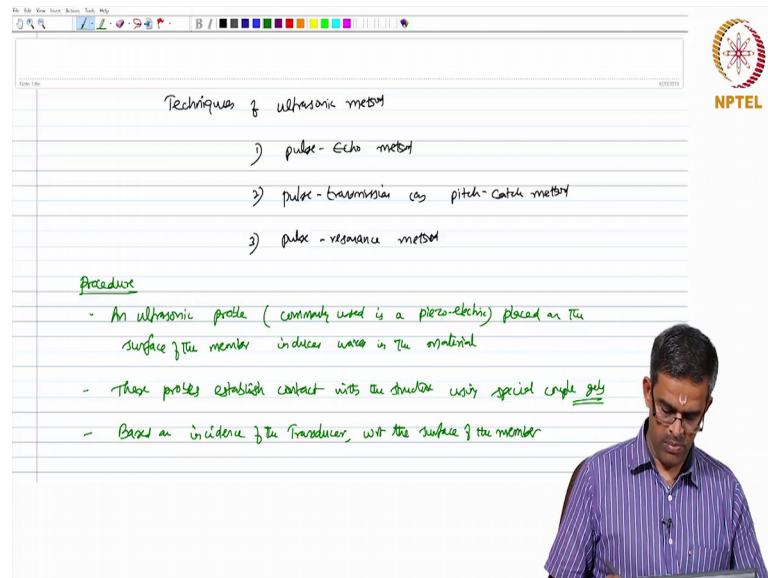
Ultrasonic waves involve the following measurements:

- 1) TOF : time of flight, wave transit (or) delay
- 2) path length
- 3) frequency
- 4) phase angle
- 5) amplitude
- 6) acoustic impedance
- 7) Angle of wave deflection (refraction, reflection)

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Now, ultrasonic waves involve the following measurements to which talks about time of flight wave transit or any delay in the wave transmission. Second will be the path length, third could be the frequency, fourth is the phase angle, five is the amplitude, six is the acoustic impedance, seven is the angle of wave deflection it can be reflection or refraction there are different methods and techniques of ultrasonic measurements.

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The image shows a digital whiteboard interface with a toolbar at the top. The main content is handwritten text in black ink. The title is "Techniques of ultrasonic method". Below it, there is a numbered list of three methods: 1) pulse-echo method, 2) pulse-transmission or pitch-catch method, and 3) pulse-resonance method. Underneath the list, the word "Procedure" is written in green. Below that, there are three bullet points in green: "An ultrasonic probe (commonly used is a piezo-electric) placed on the surface of the member induces waves in the material.", "These probes establish contact with the structure using special couple gels", and "Based on incidence of the transducer, with the surface of the member". In the bottom right corner of the whiteboard, there is a small inset video of a man in a purple striped shirt and glasses, looking down at a tablet. The NPTEL logo is visible in the top right corner of the whiteboard area.

Techniques of ultrasonic method

- 1) pulse-echo method
- 2) pulse-transmission or pitch-catch method
- 3) pulse-resonance method

Procedure

- An ultrasonic probe (commonly used is a piezo-electric) placed on the surface of the member induces waves in the material.
- These probes establish contact with the structure using special couple gels
- Based on incidence of the transducer, with the surface of the member

Commonly used is pulse echo method the other is pulse transmission or otherwise called as pitch catch method the third one is pulse resonance method. Let us quickly see what is the procedure followed in these methods. An ultrasonic probe which is essentially commonly used is a piezoelectric one which is placed on the surface of the element induces waves in the material.

Now, these probes establish contact with the structure, using special couple gels; now based on the incidence of the transducer with respect to the surface of the member.

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It generates P, S wave or its combination  
- These waves detect anomalies around the sound path.

- In pitch-echo method, defects are detected in the form of echoes

- In pitch-catch method, flaws are detected by wave dispersion and its attenuation due to damage

Major drawbacks of using ultrasonic method

- Sound path traverses only on a small portion of the material volume
- Hence, transducers should be moved, to cover a large volume
- This is time-consuming

It generates P S wave or its combination. These waves which are generated by the transducers, which is in contact with the structural member detect anomalies around the sound path. In pitch echo method defects are detected in the form of echos. In pitch catch method flaws are detected by the wave dispersion and its attenuation due to damage.

Now, these methods have a major drawback let us see; what are they. Let us see; what are the major drawbacks of using ultrasonic method. The sound path traverses only on a small portion of the material volume. Hence, the transducers should be moved to cover a large volume this is time consuming that is the first issue we have. One can use C scans, but they are expensive.

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Alternatively, we can use C-scan, but that is expensive.

- Ultrasonic waves cannot be induced normal to the surface of the structure.

Hence, cracks which are normal (to) to the surface cannot be detected readily by this process.

But guided waves can be used to detect such flaws.

Lamb waves are commonly used guided waves.

- They are used to detect damage/faults in sheet metal airframes, large containers and pipes.

The ultrasonic waves cannot be induced normal to the surface of the structure. Hence, cracks which are normal that is perpendicular to the surface cannot be detected readily by this process, but guided waves can be used to detect such flaws. For example, lamb waves are commonly used guided waves they are used to detect faults in sheet metal airframes large containers and pipes.