IMPULSE EXCITATION TECHNIQUE, IET

Submitted by: Tuğçe SEVER
Date: 21.04.2011
Outline

- What the impulse excitation technique is used for
- The principles of the IET
- High performance IET devices
- The measurement systems of the Grindosonic and RFDA software
- Devices according to temperature
- Application fields
- Advantages of IET
- Disadvantages of IET
Impulse Excitation Technique,

- measure the dynamic elastic properties of materials
- detect defects
Dynamic methods of measuring:

- Introduced in the mid 1930s
- Not sufficient progress until late 1950s
- The first ASTM (C623) in 1969
The Principle of Impulse Excitation

- Figure 1. A method for supporting a rectangular bar to induce the flexural mode of vibration. The sample is supported on two knife edges placed at the standing wave nodes, which occur at 0.224 of the length from each end. The bar then flexes freely in and out of its plane, as indicated by the vertical lines.

- ASTM standards E1867 and C1259
Step 1

- Microphone
- Nodal points
- Automated tapping device
High performance IET devices,

- **1) The Grindosonic**
  Frequency range 100 Hz - 50 kHz (limited by microphone)

- **2) The RFDA-software**
  Frequency range 100 Hz - 250 kHz (limited by data-acquisition card)

- **3) The air-furnace**
  Temperature range 20°C - 1100°C (limited by suspension wires)
  Heating rates < 5°C/min, recommended value 2°C/min
  Maximum sample length = 160 mm, recommended length between 40 and 100 mm

- **4) The graphite-furnace**
  Temperature range 20°C - 1750°C
  Heating rates < 5°C/min, recommended value 2°C/min
  Maximum sample length = 160 mm, recommended length between 40 and 100 mm
Measuring with GrindoSonic

1. Touch

2. Tap

3. Read

9.472 KH
Measurement Systems

In RFDA software calculates,

- Young’s modulus
- Shear modulus
- Poisson ratio
**Young’s Modulus**

![Diagram of Young's Modulus](image)

Elastic Properties of Selected Engineering Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (kg/m³)</th>
<th>Young’s Modulus $10^9$ N/m²</th>
<th>Ultimate Strength $S_u$ $10^6$ N/m²</th>
<th>Yield Strength $S_y$ $10^6$ N/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel $^a$</td>
<td>7860</td>
<td>200</td>
<td>400</td>
<td>250</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2710</td>
<td>70</td>
<td>110</td>
<td>95</td>
</tr>
<tr>
<td>Glass</td>
<td>2190</td>
<td>65</td>
<td>50$^b$</td>
<td>...</td>
</tr>
<tr>
<td>Concrete $^c$</td>
<td>2320</td>
<td>30</td>
<td>40$^b$</td>
<td>...</td>
</tr>
<tr>
<td>Wood $^d$</td>
<td>525</td>
<td>13</td>
<td>50$^b$</td>
<td>...</td>
</tr>
<tr>
<td>Bone</td>
<td>1900</td>
<td>9$^b$</td>
<td>170$^b$</td>
<td>...</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>1050</td>
<td>3</td>
<td>48</td>
<td>...</td>
</tr>
</tbody>
</table>

$^a$ Structural steel (ASTM-A36), $^b$ In compression, $^c$ High strength, $^d$ Douglas fir

Data from Table 13-1, *Halliday, Resnick, Walker*, 5th Ed. Extended.
Shear Modulus;

- deformation which takes place when a force is applied parallel to one face of the object while the opposite face is held fixed by another equal force

\[ S = \frac{\text{shear stress}}{\text{shear strain}} \]
\[ = \frac{F/A}{\Delta x/L} \]
\[ = \frac{FL}{A\Delta x} \quad \text{(units are Pascals)} \]
Poisson Ratio;

is the ratio of the relative contraction strain to the relative extension strain in the direction of the applied load.

\[ \nu = \frac{-\varepsilon_t}{\varepsilon_l} \quad (1) \]

where

\( \nu = \) Poisson's ratio

\( \varepsilon_t = \) transverse strain

\( \varepsilon_l = \) longitudinal or axial strain

Strain can be expressed as

\[ \varepsilon = \frac{dl}{L} \quad (2) \]

where

\( dl = \) change in length

\( L = \) initial length

For most common materials the Poisson's ratio is in the range 0 - 0.5.
Rectangular bar

**Young’s modulus**

\[ E = 0.9465 \left( \frac{mf_f^2}{b} \right) \left( \frac{L^3}{t^3} \right) T \]

\[ T = 1 + 6.858 \left( \frac{t}{L} \right)^2 \]

- \( E \) is Young's modulus
- \( m \) is mass
- \( f_f \) is natural frequency in flexure dimension
- \( b \) is width
- \( L \) is length
- \( t \) is thickness

The above formula can be used should \( L/t \geq 20 \)

**Shear modulus**

\[ G = \frac{4Lm}{bt} \left( \frac{B}{1 + A} \right) \]

\[ B = \left( \frac{b/t + t/b}{4(t/b) - 2.52(t/b)^2 + 0.21(t/b)^6} \right) \]

\[ A = \left( \frac{0.5062 - 0.8776(b/t) + 0.3504(b/t)^2 - 0.0078(b/t)^3}{12.03(b/t) + 9.892(b/t)^2} \right) \]

- \( f_t \) is the natural frequency in the torsion mode
- \( m \) is mass
- \( b \) is width
- \( L \) is length
- \( t \) is thickness
Cylindrical Rod

**Young’s Modulus**

\[ E = 1.6067 \left( \frac{L^3}{d^4} \right) m f_f^2 T' \]
\[ T' = 1 + 4.939 \left( \frac{d}{L} \right)^2 \]

- \( E \) is Young's modulus
- \( m \) is mass
- \( f_f \) is the natural frequency in flexure dimension
- \( d \) is diameter
- \( L \) is length
- The above formula can be used should \( L/t \geq 20 \)

**Shear Modulus**

\[ G = 16 \left( \frac{L}{\pi d^2} \right) m f_t^2 \]

- \( f_t \) is the natural frequency in the torsion mode
- \( m \) is mass
- \( d \) is diameter
- \( L \) is length

**Poisson ratio**

\[ \nu = \left( \frac{E}{2G} \right) - 1 \]
RFDA MF basic

*Temperature*: RT
*Atmosphere*: Air

**HT650**
*Temperature*: RT up to 650°C
*Atmosphere*: Air, Inert flow

**HTVP1600**
*Temperature*: RT up to 1600°C
*Atmosphere*: Air, Inert, Reducing

**LTVP800**
*Temperature*: -100°C up to 800°C
*Atmosphere*: Vacuum

RFDA MF professional

*Temperature*: RT
*Atmosphere*: Air

**HT1750**
*Temperature*: RT up to 1750°C
*Atmosphere*: Air

**HTVP1750-C**
*Temperature*: RT up to 1750°C
*Atmosphere*: Vacuum, Inert

**Sample supports**
RT sample support devices for different geometrical shapes.
Measurements can be performed continuously from room temperature (RT) up maximum 1750°C,

- **Room temperature**
- Samples should be machined to predefined shapes as good as possible
- measure samples of different dimensions
- **High temperature**
- Measurements are performed every couple of seconds onto the sample while the temperature is rising
Application Fields

- **Steel**
  Detecting defects through internal friction measurements

- **Refractories**
  High temperature properties modeling

- **Coatings**
  Measurement of coating's elastic properties at different temperatures
Application Fields

- Ceramics
  Non-destructive testing in different stages

- Cast iron
  Non-destructive testing

- Porous materials
  Non-destructive measurements of elastic properties
Advantages in the use of impulse excitation technique,

- Quick
- Easy
- Repeatable
- Non-destructive
- Highly accurate analysis
- Much lower costs than traditional analog instruments
- Understanding the physical properties of certain materials
Disadvantages of IET,

- Serious noise
- Signal truncation
- ILLsuited for frequency response testing of highly nonlinear structures and certain other types of structures
Thanks for listening…