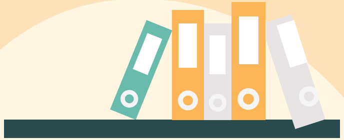
EBP 311: POLYMER ANALYTICAL METHOD AND FAILURE ANALYSIS

GROUP 2

DMA WORKING PRINCIPLES & THEORETICAL METHOD/CONCEPT



WHAT IS DMA!

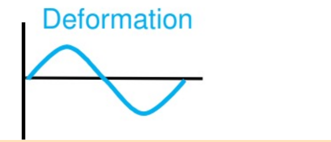
Theoretical Concept of DMA

- DMA measures the mechanical properties (stiffness, as a function of modulus) of a viscoelastic material (polymer) as a function of time, temperature or frequency while the material is subjected to a periodically oscillating force.
- The measurements can be made in several modes: tension, shear, compression, torsion and flexure.
- Modulus values change with temperature and transitions in materials can be seen as changes in the E’ or tan delta curves.
- The results properties obtained modulus (E and G) / Compliance (J), damping factor (tan δ) and transition temperatures (e.g. T g).
- Dynamic mechanical analysis involves imposing a small cyclic strain on a sample and measuring the resulting stress response, or vice versa, by imposing a cyclic stress on a sample and measuring the resultant strain response.
- In DMA this is done sinusoidally. How much it deforms is related to its stiffness.

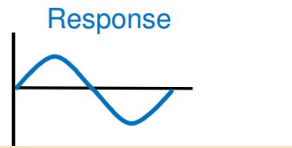
Theoretical Concept of DMA

Typically a sinusoidal oscillatory force is applied to the material and the resulting deformation or strain is measured in response to the applied stress in the linear viscoelastic region of the material.

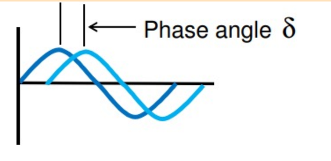
i. An oscillatory (sinusoidal) deformation (stress or strain) is applied to a sample



ii. The material response (strain or stress) is measured.

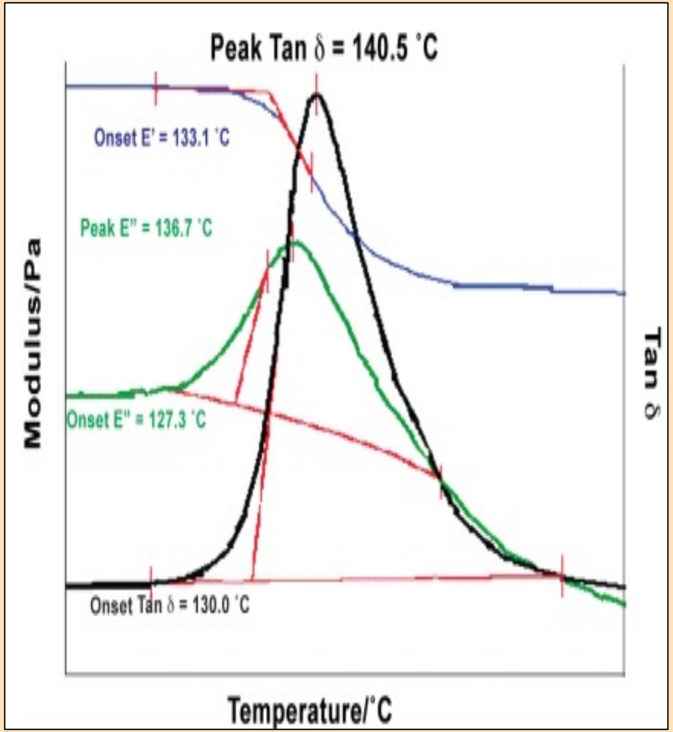


iii. The phase angle δ, or phase shift, between the deformation and response is measured.



Theoretical Concept of DMA

1. Top of tan delta peak: Can obtain glass transition temperature of polymer sample.
2. Storage modulus, E': Measure an elastic behavior of polymer sample.
3. Loss modulus, E": Measure viscosity behavior.
4. Ratio of loss to the storage, tan delta also known as damping.
   - Damping is the dissipation of energy in a material under cyclic load.
   - Measure of how well a material can get rid of energy and is reported as the tangent of the phase angle. It tells us how good a material will be at absorbing energy. It varies with the state of the material, its temperature, and with the frequency.



LET'S GO DEEPER

Basic working principle

Basic working principle

- The instrumentation of a DMA consists of a displacement sensor such as a linear variable differential transformer.
- Linear response of the material has to be evaluated before advancing to the dynamic force (strain) based experiments. Further, the amplitude of the dynamic perturbation should be so small that it should not go beyond the linear Hookean region of the material.
- Hooke's law states that strain in a material is proportional to the applied stress within the elastic limit of the material. This has been schematized in Figure 2.

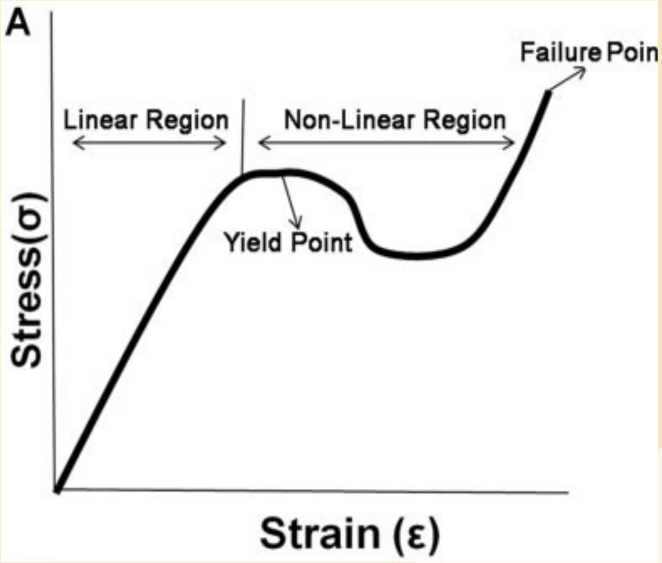


Figure 2 A typical stress–strain curve of a polymer obtained via controlled force mode

- An oscillatory (sinusoidal) input (stress or strain) is applied to a sample.
- The material response or resulting sinusoidal (strain or stress) is measured.
- The phase angle δ, or phase shift between the input and response is measured.
- The phase difference is 0° for a perfectly elastic material, 90° for a pure viscous material, and intermediate for a viscoelastic material.

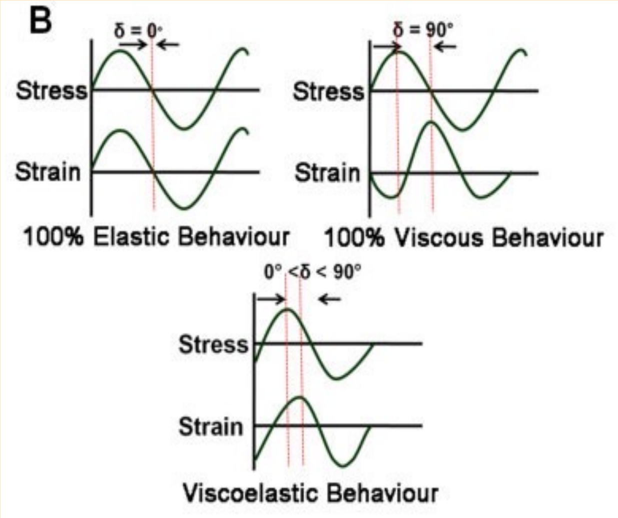


Figure 3 The dynamic stress–strain curves of different materials namely, elastic, viscous, and viscoelastic.

The mode of the analysis determines which type of modulus is evaluated.

01.

The sample is clamped in the measurement head of the DMA instrument.

02.

The force motor is used to generate the sinusoidal wave.

03.

During measurement, sinusoidal force is applied/ transmitted to the sample via the probe.

04.

Deformation caused by the sinusoidal force is detected and the relation between the deformation and the applied force is measured.

05.

The viscoelastic properties of the polymer sample are measured from the applied stress and strain plotted as a function of temperature or time.

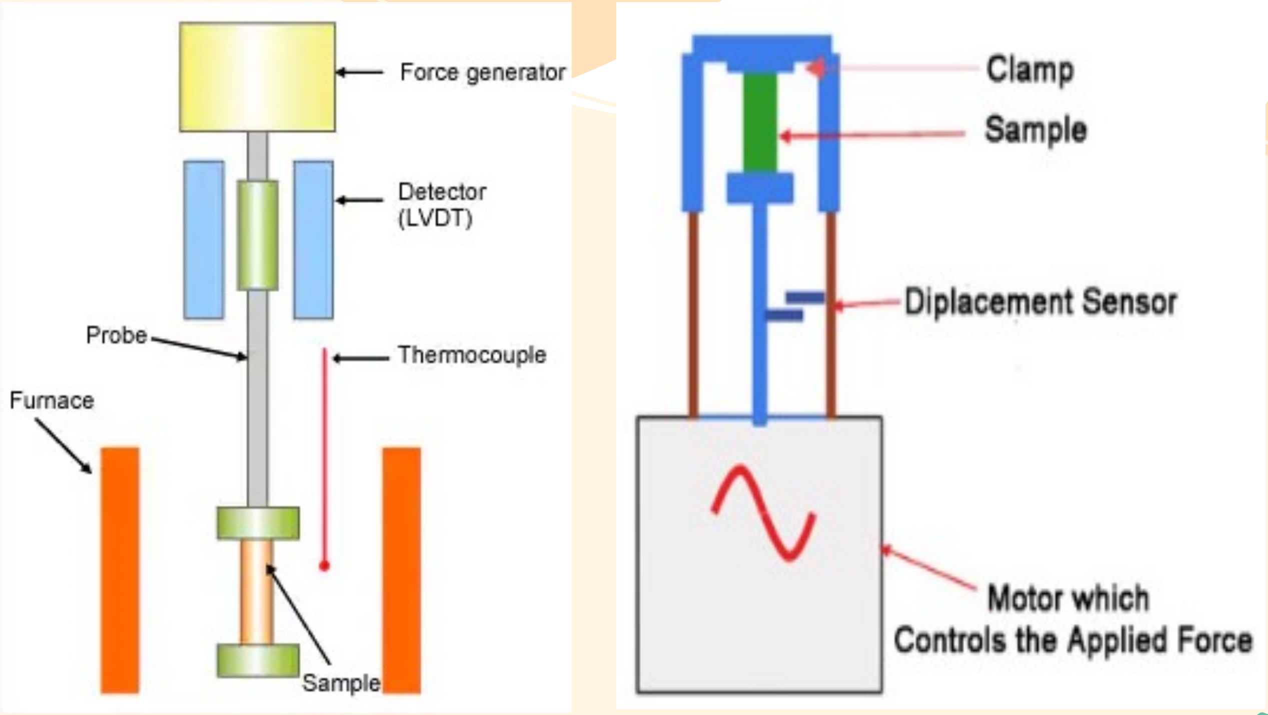


Figure 4 Block diagram of typical DMA

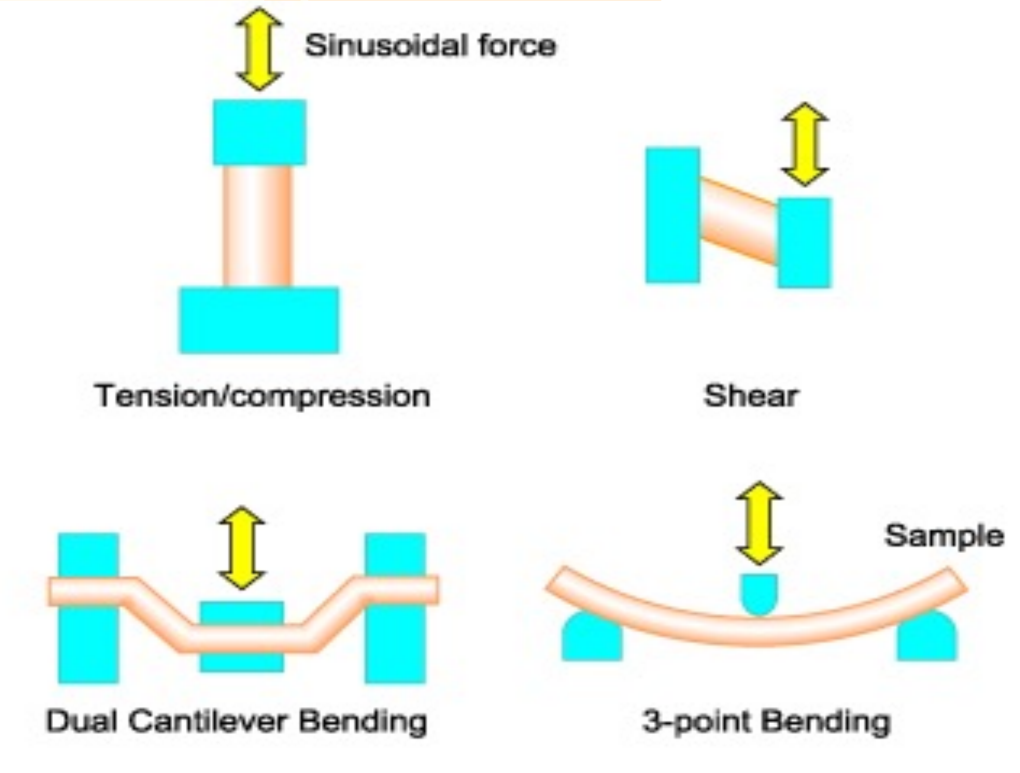
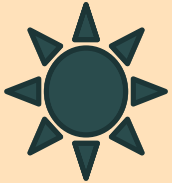


Figure 5 The different of deformation modes

KEEP GOING!

The DMA can be either stress or strain controlled: strain-controlled analyzers move the probe a certain distance and measure the stress applied; strain-controlled analyzers provide a constant deformation of the sample



Axial deformation **Torsional analyzer**

Axial deformation

i. Applies a linear force to the sample and is typically used for solid and semisolid materials to test flex, tensile strength, and compression.
ii. Axial instrument should not be used for fluid samples with viscosities below 500 Pa-s.
iii. Commonly used fixtures is extension/tensile geometry used for thin films or fibers. The sample is held both vertically and lengthwise by top and bottom clamps, and stress is applied upwards

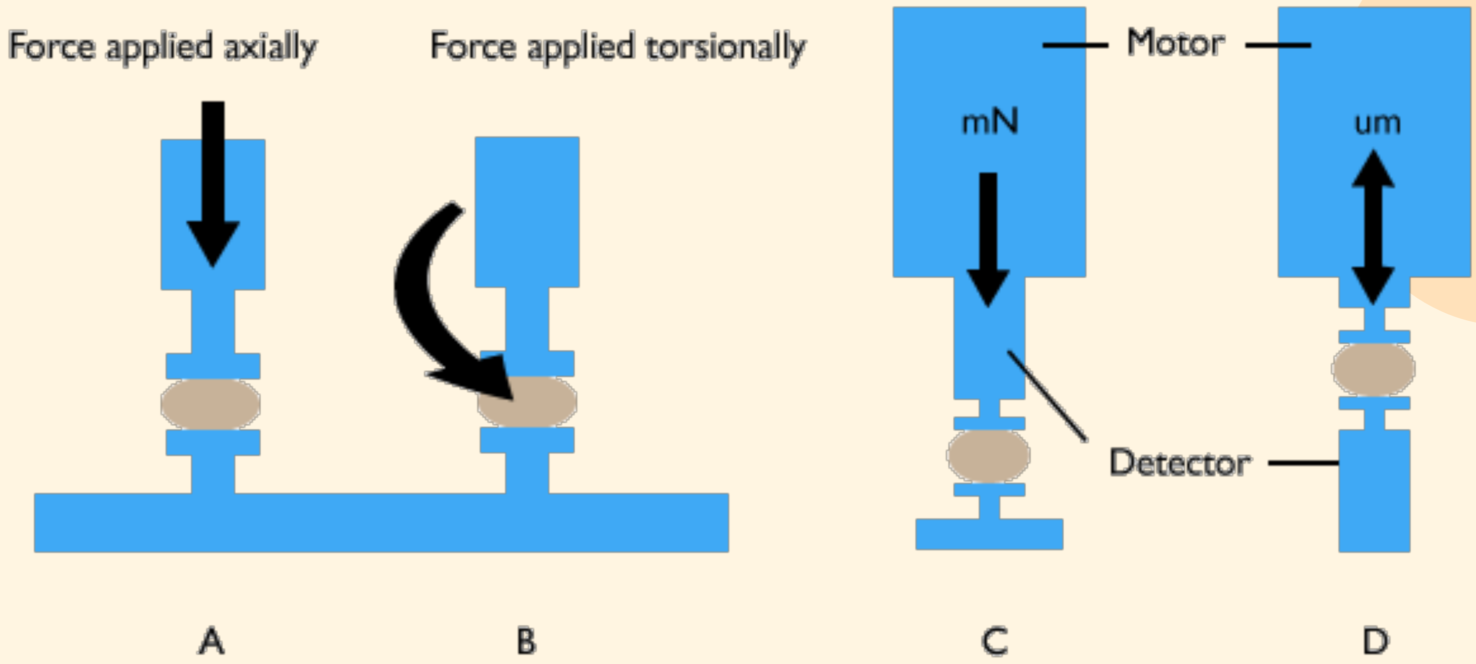
Torsional analyzer

i. Applies force in a twisting motion, this type of analysis is used for liquids and polymer melts but can also be applied to solids.

ii. Torsional analyzers cannot handle materials with high modulus.

iii. Simplest geometry is use of parallel plates. The plates are separated by a distance determined by the viscosity of the sample.

Figure 6 adapted from M. Sepe, Dynamic Mechanical Analysis for Plastics Engineering, Plastics Design Library: Norwich, NY (1998).



“NOBODY CARES, KEEP STUDYING”

—YOUR FUTURE-SELF

Our Group Members

MUN KIT MASSARA WEN CAI ANIS CHOW PEEI FITRAH

thanks!

Do you have any questions?