Static and Dynamic Testing of Engineering Materials and Components

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Testing of materials and products involves mechanical loading of a material specimen or product up to a pre-determined deformation level or up to the point where the sample fails. The material properties backed out from these tests are further used to characterize the materials and products. Testing is carried out under essentially two conditions viz; Static and Dynamic.

Physical testing of materials as per **ASTM D412, ASTM D638, ASTM D624** etc., can be categorized as slow speed tests or static tests. The difference between a static test and dynamic test is not only simply based on the speed of the test but also on other test variables and parameters employed like forcing functions, displacement amplitudes, and strain cycles. The difference is also in the nature of the information we back out from the tests. Static mechanical testing is carried out at lower frequencies, generally less than one Hertz. The associated loads and applied deformation amplitudes are also smaller and the strain rate is much lower as compared to typical engineering applications. Dynamic loading is generally carried out under forcing functions and with high deformation amplitudes. These forcing functions and amplitudes are applied under a very short time period. When related to polymers, composites and elastomers, the information from a conventional test is usually related to quality control aspects of the materials or products, while from dynamic tests we back out data regarding the functional performance of the materials and products. **ASTM D5992, D4092 and D5279** are some of the dynamic mechanical testing standards. High speed tensile, compression, impact, fracture tests using Split Hopkinson Pressure bars (SHPB), Servo-Hydraulic testing machines and cyclic fatigue tests fall under the category of dynamic testing.

Polymer materials are widely used in all kinds of engineering applications because of their superior performance in vibration isolation, impact resistance, rate dependency and time dependent properties. In some traditional applications they have consistently shown better performance combining with other materials like glass fibres etc., and are now replacing metals and ceramics in such applications. The investigations of polymer properties in vibration, shock, impact and other viscoelastic phenomena is now considered critical, and understanding of dynamic mechanical behaviour of polymers becomes necessary and compulsory.

Figure 1: Static and Dynamic Testing Systems at AdvanSES

The absolute values from frequency sweep, strain sweep, temperature sweep dynamic tests are meaningful, but have little utility as isolated data points. They do become valuable data points when compared to each other or some other known variables. A tan delta or damping coefficient value of 0.4 is poor for a natural rubber or EPDM based compound, but very good in FKM materials where the structure of the compound makes it venerable to lower than optimum dynamic properties. Most uncured rubbery compounds start on the viscous side, and as we cure the compound, we shift towards the elastic side.

The importance of dynamic testing comes from the fact that performance of elastomers and elastomeric products such as engine mounts, suspension bumpers, tire materials etc., cannot be fully predicted by using only traditional methods of static testing. Polymer and elastomer tests like hardness, tensile, compression-set, low temperature brittleness, tear resistance tests, ozone resistance etc., are all essentially quality control tests and do not help us understand the performance or the durability of the material under field service conditions. An elastomer is used in all major applications as a dynamic part being able to provide vibration isolation, sealing, shock resistance, and necessary damping because of its viscoelastic nature.

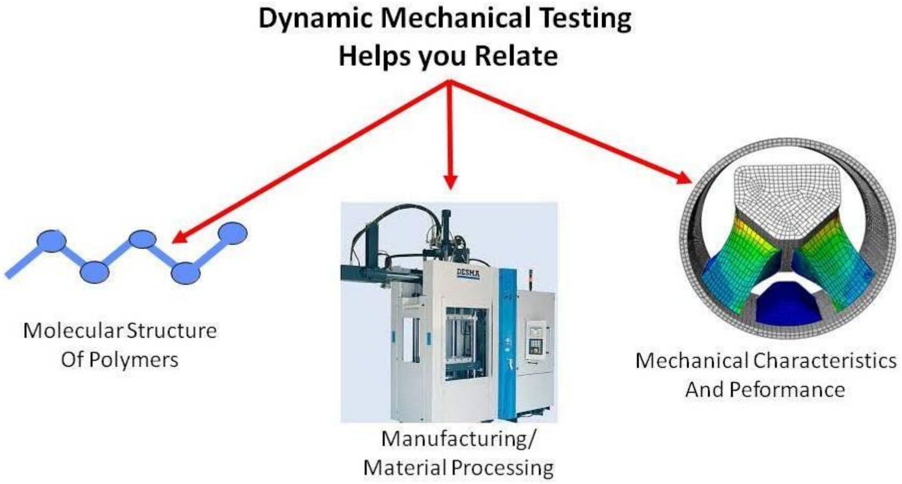

Figure 2: Viscoelastic and Dynamic Studies Correlate Molecular Structure to Manufacturing and Mechanical Properties of Engineering Components

As it stands today, the theory of dynamic properties can be applied judiciously to product development, performance characterization or failure analysis problems. The field of application has evolved over time with availability of highly sophisticated instruments. The problems need to be studied upfront for any time or frequency dependent loading conditions and boundary conditions acting on the components and the theory be suitably applied. Needless to say that dynamic properties have utmost importance when polymeric materials and components show heat generation, and fatigue related field failures. Dynamic characterization relates the molecular structure of the polymeric materials to the manufacturing processes and to the field performance of engineering products. Dynamic properties play an important part in comparing mechanical properties of different polymers for quality, performance prediction, failure analysis and new material qualification. Dynamic testing truly helps us to understand and predict these properties both at the material and component level.

Following are the testing modes that can be implemented and the results for materials and components that one may seek from dynamic testing;

Test Modes:

No.	Test Modes	Tests
1.	Oscillation	Frequency Sweep, Strain Sweep, Stress Sweep, Temperature Sweep, Fatigue Test
2.	Stress Control	Creep, Fatigue
3.	Strain Control	Stress Relaxation, Fatigue, Crack Growth
4.	Rate Control	Stress ramp and Strain ramp

Test Results Data:

1) Storage or Elastic Modulus (E') versus temperature, frequency, or % strain

2) Loss or Viscous Modulus (E") versus temperature, frequency, or % strain

3) Damping Coefficient (Tan Delta) versus temperature, frequency, or % strain

4) Stress vs Strain properties at different strain rates.

5) Strain vs Number of Cycles for a material or component under load control fatigue.

6) Load or Stress vs Number of Cycles for a material or component under strain control fatigue.

7) Fatigue crack growth vs Number of Cycles for a material under strain controlled fatigue.

No single testing technique or methodology provides a complete picture of the material quality or component performance. It is always a combination of testing methods and techniques that have to be applied to obtain a 360 degree view of the material quality and performance.

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