RECOMMENDED GUIDELINES FOR FATIGUE TESTING OF ELASTOMERIC MATERIALS AND COMPONENTS—SAE J1183

SAE Recommended Practice

Report of Nonmetallic Materials Committee approved January 1978.

1. Scope—The purpose of this document is to review factors that influence the behavior of elastomers under conditions of dynamic stress and to provide guidance concerning laboratory procedures for defining and specifying the fatigue characteristics of elastomeric materials and fabricated elastomeric components.

2. Introduction—These guidelines describe:

2.1 The manner in which elastomeric materials and components undergo changes due to stresses or strains in a fatigue environment that ultimately culminate in failure.

2.2 Factors to be considered in selecting from available test methods or in developing a test method to meet specific requirements.

2.3 A set of definitions and terminology to allow interchange of information on a common basis.

2.4 Important considerations in the evaluation and reporting of test information.

3. Elastomeric Behavior—An elastomer is a viscoelastic material. It acts as though it is composed of an elastic component and a viscous component. The elastic component controls stress versus strain behavior. Because of an elastomer's visco-elastic nature, the dynamic response and mechanical behavior are dependent upon stress or strain history, rate of loading, frequency and amplitude of strain, and specimen temperature.

The viscous component determines internal energy loss, or hysteresis. The lost energy is converted into heat and since elastomers are poor heat conductors this can result in a considerable temperature rise.

In addition to being viscoelastic, elastomers have a lower elastic modulus and lower strength than most metals and plastics. Although softer and weaker than structural metals and plastics, elastomers are like these materials from an energy per unit volume standpoint. For elastomers, metals, and plastics, a power form of a fatigue correlation exists:

$$N_f W^b = C$$

Where N_f = cycles to failure
W = energy input ($\sim\frac{1}{2}$ stress $\times$ strain)
b and C = constants for specific materials

The application of this fatigue law to elastomers is discussed in Appendix A. References 1, 4, 7, 8, and 9 listed in the Bibliography of this document provide comprehensive information on general elastomeric behavior.

4. Failure Criteria—Failure should be defined in such a manner that it can be accurately detected and the time of its occurrence accurately determined. Since different types of elastomeric components may fail in different ways, it is necessary that the definition of failure and the means used to detect it apply equally well to all materials scheduled for evaluation.

4.1 Commonly used failure criteria:

4.1.1 Complete rupture of the specimen, i.e., total separation in tensile specimens, bond failure, or metal-to-metal contact between opposing mounting surfaces in bushings or compression specimens.

4.1.2 Time until appearance of visible cracks of a specified size or growth of a crack, or rupture to a specified point. A cut may be used to initiate the crack before the start of the test.

4.1.3 A specified level of change in physical properties such as hardness, spring rate, spring rate under dynamic conditions, or damping.

4.1.4 A specified change in displacement due to creep, set, or abrasive wear.

4.1.5 Chemical changes as evidenced by porosity.

4.1.6 Failure to function as intended.

4.2 Since different failure criteria will rank various elastomers differently, it is important that the definition of failure has relevance to the type of failure that occurs in the intended application. If an elastomer material is replaced in service by another having a tendency to fail in a different manner, fatigue test criteria used in quality control may have to be changed to assure applicability.

5. Specimen History—Prior to fatigue testing it is important to know if the component has experienced any mechanical preflexing or temperature changes and to know the timing of these influences. This is necessary for consistency in comparing test results.

5.1 Mechanical Preflexing—It is well known that elastomers undergoing load deflection tests will progressively soften for the first 3–10 cycles until a steady state condition is reached. Depending on the elastomer, this change ranges from about 3–15%. It is also known that most of the stiffness on the first cycle can be regained if a period of about 8 h or more elapses between load deflection tests. Consequently, if some specific change in spring rate of the specimen is the failure definition, preflexing influences must be considered to establish the *initial* stiffness. For shock type applications the first cycle data might be the basis. For steady state vibration applications the third (or more) cycle data might be required. For preflexing to be effective the load or deflection must be at least that at which the stiffness is to be determined.

5.2 Temperature Changes—Because elastomers are viscoelastic materials, it is necessary to know the temperature of the specimen and its temperature history prior to testing. Temperature influences all the failure definitions previously mentioned. One common situation concerns periodic evaluation of some physical property during fatigue testing. The specimen will heat up during testing due to internal heat generation. Consequently, when the periodic test is run, the specimen must be allowed to cool down or the *initial* property must be run at this elevated temperature. This is especially important when running low ambient temperature tests.

Another influence is the temperature history. A specimen stored in a very cold or hot atmosphere prior to testing influences the first cycle data in mechanical preflexing as well as the time to wait before regaining the first cycle data after preflexing.

5.3 Aging—Oil assembled components such as silentblocs require sufficient time for the elastomer to absorb the assembly oil. One week is recommended. Oven aging for 3 h at 70°C is sometimes used as a substitute for natural aging.

6. Test Parameters

6.1 Mechanical.

6.1.1 Direction of deformation.

6.1.2 Types of deformation.

A. Static.

1. Applying a specified constant load.
2. Applying a fixed displacement.
3. Loading to a specified initial displacement and maintaining the load.
4. Displacing until a specified initial load is reached and fixing this displacement.

B. Dynamic.

1. Applying a specified dynamic load.
2. Applying a specified dynamic displacement.
3. Dynamically loading to a specified initial displacement and maintaining the load.
4. Dynamically displacing until a specified initial dynamic load is reached and fixing this displacement.

6.1.3 Magnitude of load or displacement (see Section 9.2).

6.1.4 Frequency of dynamic deformation.

6.1.5 Dynamic load or deflection waveform, i.e.: Sinusoidal, square wave, continuous or intermittent; positive, negative, or positive to negative reversal.

6.1.6 Compensation for specimen changes during test such as adjusting displacement to maintain a specified load as specimen stress relaxation or wear takes place.

6.1.7 In applying load(s) or deflection(s) the following shall be considered: Constant load application will favor hard specimens and penalize soft specimens. Fixed displacement will favor soft specimens, especially those having high set, and penalize hard specimens.

6.1.8 Methods 3 and 4 (Section 6.1.2 (A) and (B)) have advantages over 1 and 2 in that they tend to minimize differences due to hardness and are, therefore, useful for material comparisons, but they represent conditions rarely found in elastomeric component applications.

6.2 Application of Parameters

6.2.1 Methods of applying static and dynamic deformation must be studied carefully to ensure that only the intended parameter is applied to the specimen. Most methods have inherent characteristics resulting from mass, friction, geometry, compliance, misalignment, and nonlinearity which may affect the parameter being applied. Through design, many of these undesirable effects can be reduced to an acceptable level.

6.2.2 Proper instrumentation is a good aid to accuracy in that error can be seen in the parameter measurement and, if recognized as such, and the source of error identified, be corrected. In measuring displacement, direct specimen deflection measurement is recommended rather than that of a test machine component attached to the specimen. In measuring loads, a load measuring device located between the specimen and the loading mechanism is recommended.

6.2.3 Instrumentation alone is not assurance of equivalent data between machines of different design used to run the same test. Machine geometry can affect specimen restraint, and if significantly different, can dramatically influence test results even though the measured parameters are identical.

6.2.4 In many tests, the specimen will roll, shift, bulge or otherwise react when the major parameters are applied. These reactions are often of high force magnitude. Improper attempts to completely restrict motions of this type often cause bending and friction in machine components which may adversely affect test repeatability.

6.2.5 It is recommended that the influencing machine geometry that affords the best compromise of the following be chosen:

6.2.5.1 Restrains specimen similar to the intended application.

6.2.5.2 Has no inherent adverse effect on test repeatability.

6.2.5.3 Has minimum effect on data as a result of wear, changes in friction, minor misadjustment, or other slight loss of precision.

6.2.6 Test fixtures, poorly designed or improperly specified, may constitute a test variable. The following should be considered in the specifying of test fixtures:

6.2.6.1 Fixture stiffness.

6.2.6.2 Cleanliness and finish of surfaces in contact with specimen.

6.2.6.3 Heat sink effects.

6.2.7 To assure that a test can be duplicated at a future date, the following information should be recorded:

6.2.7.1 Test parameters used.

6.2.7.2 Load and/or deflection versus time photographs or charts.

6.2.7.3 Detailed and dimensioned sketches of the influencing machine components and their location.

6.2.7.4 Prints of fixtures used.

6.2.7.5 Test setup procedure.

6.2.7.6 Data obtained.

6.3 Part Temperature

6.3.1 Importance of Part Temperature—Elastomers are functional over a rather narrow temperature range compared to other materials such as metals. Further, each compound of a given elastomer has its own temperature range where it is functional. Within that functional range will lie a band of temperatures at which maximum fatigue life is obtained. It is not unusual for fatigue life to change by a factor of two or more over a 20°C change in temperature near the boundaries of that band. Therefore, select a temperature that is representative of service conditions, and control part temperature during the test.

6.3.2 Definition of Part Temperature—Since rubber is a poor heat conductor, thick parts will usually have large temperature gradients. Measurements should, therefore, be made by placing the temperature sensing element as close to the area of heat generation as possible. The location chosen and the type of temperature measurement should be carefully defined and consistently adhered to.

6.3.3 Part Temperature Control—Part temperature is a function of ambient temperature, hysteresis of the specimen, energy input, and external friction.

Ambient temperature control is necessary. First, it is recommended that the part and associated fixturing be allowed to reach equilibrium with the environment before starting the test. Guidelines for achieving this are given in the Appendix to SAE J1085[19] for elevated temperature testing. For elevated temperature testing, it is suggested that the part be enclosed in an air circulating heat chamber. At moderate temperatures, circulation of air over the specimen is commonly used to control part temperature. It should be recognized, however, that in some situations this may lower specimen surface temperature but have a relatively small effect on temperature within the specimen. Air cooling exaggerates the heat sink effect of fixturing in contact with the specimen so care must be taken to assure consistency in fixture contact area, shape, and mass. In cases where correlation between test facilities is necessary, air cooling may be undesirable as another source of variability.

The heating due to the combination of hysteresis and energy input should not cause the part to exceed the desired test temperature. High hysteresis elastomers will experience a relatively high temperature rise above ambient as compared to low hysteresis elastomers when tested under high frequency and/or amplitude. This sometimes makes it necessary to adjust test conditions when elastomers of different hysteresis levels are tested. In most cases, it is desirable to design the test in such a way that a significant portion of the testing takes place after the part temperature has stabilized.

Sometimes elastomer hysteresis is falsely blamed for high specimen temperature when the source of heat is actually friction due to slip between elastomer and metal components and/or test fixtures. When this is the case, and the elastomer has low hysteresis, reducing the test amplitude and/or load and increasing frequency will sometimes reduce temperature without adding significantly to test time.

6.4 Other Parameters

6.4.1 Ozone Concentration—Some elastomers are inherently ozone resistant so that ozone has little effect on their fatigue life. Other elastomers are not ozone resistant and must be chemically protected to prevent ozone cracking in stressed areas. Ozone cracking results in shortened flex life, particularly so for specimens with a high ratio of exposed surface to mass. Ozone crack rate increases with stress level and temperature.

It is desirable to avoid uncontrolled and excessive ozone concentrations as can be found in close proximity to electrical discharges or some motors. In critical situations, ozone concentration should be measured and reported in test conditions. ASTM D 1149, Standard Method of Test for Accelerated Ozone Cracking of Vulcanized Rubber[16] describes ozone concentration measurement.

The antiozonants used in many elastomer compositions must migrate to the surface of the specimen before they become fully effective. Testing of recently molded specimens should not be conducted before protective agents have migrated to the surface. Usually, 24 h is the minimum time for migration.

6.4.2 Oxidation—The reaction of oxygen (oxidation) with many elastomers can initiate crack formation as well as result in hardening or softening. At temperatures higher than room temperature, the effect of oxygen is accelerated. Elastomers may be protected by chemicals introduced during mixing or by coatings. However, protection is seldom complete. Test specimens should not be stored for long time periods at elevated temperatures unless this is a necessary and controlled part of the test requirement.

6.4.3 Deleterious Fluids and Gases—No elastomer is resistant to all fluids and gases. Oils, oil vapor, and solvents can seriously degrade non-resistant elastomers. Water, steam, coolants, acids, and alkalies in fluid or vapor form can reduce specimen fatigue life. The atmosphere surrounding the test specimen should be free of deleterious fluids and gases unless they are a necessary and controlled part of the test requirement.

7. Property Measurement—Since the properties of different elastomeric specimens in a fatigue environment change differently, it is desirable to measure as many of these changes as possible. The instrumentation required will depend on the nature and purpose of the test, i.e., a materials evaluation would call for more detailed data than a quality control test. In all cases, however, the instrumentation must be adequate to observe both:

7.1 Changes corresponding to those that adversely affect performance in the intended application and which, therefore, qualify as criteria for failure.

7.2 Changes which can affect the severity of the test, obscure the point of failure or affect the mode of failure, thereby giving misleading results. Stress relaxation, set, and excessive heat buildup due to accelerated test conditions are examples of such changes.

Table A shows changes that can be anticipated and examples of the types of instrumentation that can be used to detect them.

8. Test Apparatus—This document is intended to apply to all elastomer and elastomeric component fatigue testing apparatus. Typical commercially available testers are:

8.1 Chrysler "Diving Board".

8.2 De Mattia Flexing Machine (ASTM D 430 and D 813).[16]

8.3 E. I. duPont Flexing Machine (ASTM D 430).[16]

8.4 Firestone Flexometer (ASTM D 623).[16]

8.5 Goodrich Flexometer (ASTM D 623).[16]

8.6 Monsanto Flex to Failure Tester.[2][3]

8.7 Roelig Machine

8.8 Ross Flexing Machine (ASTM D 1052).[16]

8.9 St. Joe Flexometer.

8.10 Sonntag Low Frequency Fatigue Testing Machine.

Other applicable test machines may be proprietary or especially constructed to evaluate a specific component.

9. Degree of Test Acceleration

9.1 Elastomeric material and component fatigue tests are accelerated to various degrees depending on the type and/or purpose of the test. Most tests fall into one of the following categories:

9.1.1 Engineering Evaluation Tests—The purpose of evaluation testing is to rank and/or optimize material or component design performance under test conditions simulating the intended application as closely as practical.

9.1.2 Quality Test—The purpose of quality testing is to measure the fatigue life of a specimen against a standard that is based on tests run on known quality specimens. The test conditions used may or may not simulate the type or direction of deformation found in the intended application, and are usually highly accelerated.

9.1.3 Comparison Tests—This type of test is performed to compare fatigue performance of materials or components.

The initial comparison testing or screening may be performed under accelerated quality test conditions and final evaluation under conditions simulating the intended application.

9.2 Effects of Acceleration—Acceleration can introduce obvious or subtle factors that affect the test by changing the point of failure initiation, final location of failure, propagation, and the major cause of failure. This can be very misleading when materials for end use are chosen based on the results of such a test.

Table B describes examples of acceleration methods and possible effects they may have on the test and/or specimen.

TABLE A

Change in Specimen	Method of Observation	Notes
Abrasive wear.	Weight change.	May be dry or tacky depending on polymer type and formulation.
Amplitude of vibration under fixed force input.	LVDT[a], velocity transducer (integrated), accelerometer (integrated twice), leaf spring with strain gauge, optical methods, or micro switches.	If not fixed or controlled, amplitude usually increases during test due to the combined effect of temp. rise, chemical degradation, tearing, abrasion, etc. In some configurations amplitude can decrease due to overall movement relative to constraints.
Bond failure (to metal or fabric).	Visual.	Type and percentage of failure may be indicated using terminology of ASTM D429.
Cracks or tearing-initiation and rate of growth.	Visual and optical. May also be inferred from changes in deflection, damping or elastic rate.	Possibility of internal failure must be considered with thick specimens, in which case sectioning is required.
Deflection (mid-point) or drift.	LVDT[a], leaf spring with strain gauge or micrometer head (if member maintaining fixed load is different than member applying oscillating load) optical methods, micro-switches.	If constant force is maintained by a dead weight or servo system, deflection usually increases due to changes in the material, tearing, abrasion, etc. Temperature rise may result in decreased or increased deflection.
Distortion.	Visual.	Buckling, bending, etc. can lead to typical failure modes.
Dynamic properties-elastic rate and viscous damping.	Analysis of force and amplitude signals (magnitude and phase angle).	Increases or decreases in either property can occur due to chemical changes or changes in physical dimensions due to set.
Force—static and dynamic in displacement controlled test equipment.	Load cell—strain gauge or piezoelectric type.	Load cell must be placed so as to avoid the effects of the weight of surrounding machine elements and extraneous inertial forces.
Property Undergoing Change	**Instrumentation**	**Notes**
Permanent set.	Direct measurement after a specified period of recovery.	Method of measurement must be carefully defined. Usually not applicable to badly cracked or degraded specimens.
Porosity (internal).	Visual examination of sectioned specimen, comparison with standard specimens.	Indicative of chemical degradation due to internal heat build-up.
Temperature.	Thermocouple, thermistor in, on or adjacent to test specimen. Infrared pyrometer for surface temperature.	Sample temperature is normally non-uniform throughout the part due to the internal viscosity and poor heat transfer characteristics of elastomers.

[a] Linear variable differential transformer.

TABLE B

Method of Acceleration	Possible Effects on Test & Specimen
Increase static load or displacement.	Increase or decrease in cycles to failure.
	Failure by splitting and tearing (tensile failure) rather than by abrasive wear or fatigue cracking.
	Increased bulge area (compression).
	Decreased cross-sectional area (tension).
	Increased creep or slip.
	More data scatter (hardness sensitivity).
Increase dynamic load or displacement.	Decrease in cycles to failure.
	Increase in temp. due to hysteresis.
	Increase in temp. due to slip between specimen and fixturing.
	Decrease in modulus.
	Tensile failure rather than abrasive wear or fatigue cracking.
	Increase bulge area (compression).
	Decreased cross-sectional area (tension).
	More data scatter (hardness sensitivity).
Increase frequency of dynamic load or displacement.	Increased heat generation per unit time.
	Change from mechanical to chemical failure.
	Change in load or displacement waveform.
	Change in dynamic response of specimen.
	Increase or decrease in cycles to failure.
Increase ambient temperature.	Increased specimen temperature.
	Decrease in modulus.
	Change in cycles to failure.
	Change in dynamic response of specimen.
	Change in mode of failure.

10. Experiment Design—A designed experiment can obtain more information for less material and process cost than can be obtained by traditional methods. References 12, 13, and 14 listed in the Bibliography of this document cover experiment design in detail.

11. Reporting Data—Reporting test results in a clear, concise manner is every bit as important as assuring that the test conducted was valid and accurate. Also, hardware is often disassembled after a test is completed; the test report is needed to assure that the information of interest is not lost.

Following is a suggested outline of the minimum information that should be presented in a fatigue test report.

11.1 **Summary**—Present only the major important findings with some background information so that the report's contents can be rapidly digested and analyzed.

11.2 **Material Specification and Properties**—The minimum information presented should include the designation and/or specification, form of product, condition, chemical composition and note of any special treatment applied.

Also, to be included, a presentation of the mechanical properties of the material in the test component, designation of the test method used to procure those properties and identification of the location from which the samples were taken.

11.3 **Component Dimensions**—Present a drawing(s) or sketch(s) showing test section details, grip section, orientation with respect to force application and geometry of any induced notches.

11.4 **Specimen Preparation**—Report any observed deterioration of the specimen during storage since fabrication and changes in shape, dimensions or mechanical properties. Also desirable would be the environment in which the specimens were stored and any protection applied.

11.5 **Information on Test Procedures**—Included should be information on the test machine, its functional characteristics (electrohydraulic, pneumatic, etc.), frequency of load application, forcing function, method of calibration and load monitoring procedures. Further information would encompass the type of test (axial, torsional, etc.), failure criteria, number of cycles to run out and the statistical techniques used to design the test program and accommodate expected or unexpected deviations. Also desirable would be to spell out the procedure for mounting the specimen in the machine, grip details and precautions taken to ensure that unknown stresses induced by vibration, friction and eccentricity are negligible. Ambient conditions to include temperature and humidity average values and ranges together with controls applied should be reported. Special items of interest such as ozone level, deleterious substance presence, and so on, should also appear.

To complete the section, presentation of the reason for test termination for each specimen and a description of the failure and its location would be desirable.

11.6 **Original Data**—It is desirable in a test report to include copies of the original data sheets and test logs if these are not excessively voluminous. Proper planning before hand as to the data to be recorded and the method of recording to include log sheets and other forms will allow controlled compilation. All of the information expected to be utilized in the project write-up will be obtained from this single source so sufficient time must be spent in planning.

A primary item often overlooked is provision for and encouragement of the use of a remarks section in the log sheets. Orientation of the test technician to the log will often provide explanation for events, which otherwise would go unnoted, unnoticed, unexplained, or unknown. Be certain in this regard that the test personnel understand the use of the forms provided and the information that is of importance to the test.

As a minimum, the log sheets would be the primary original data. These should provide a chronological record of the test and its typical and atypical events. Intermittent readings of load, deflections, temperature and other important parameters as well as notes of interest should be input here. In conjunction with the sheets, it is desirable to have strip or X-Y charts providing direct, intermittent read-out of the essential parameters to back up and/or expand the information on the log sheets.

11.7 **Presentation of Results**—The most straightforward methods of presenting fatigue data are the tabulation and S-N_f curve. When used, the tabular form should include specimen identification, test sequence, stresses applied, cycles to end of test, cause of termination, results of post test examination and identification of station and machine used for each test.

On the S-N_f curve, the dependent variable fatigue life (N_f) in cycles is plotted on the abscissa, a logarithmic scale. The independent variable, maximum stress (S), is plotted on the ordinate and may be an arithmetic or logarithmic scale. If the data curve is fitted by regression analysis the stress-life relation equation and concomitant statistical measures of dispersion should be presented.

As discussed in Appendix A, the straight line obtained by plotting strain versus N_f (number of cycles) on log-log paper may be a more usable form of S-N_f data representation.

Photographs of failures, together with an explanation, provide a permanent record and valuable supplement to S-N_f curves.

12. Description of Terms—The following terms and definitions are applicable to this document:

12.1 **Aging**—The irreversible change of material properties after exposure to an environment for an interval of time.[16]

12.2 **Ambient Temperature**—The temperature of the environment surrounding the test specimen.[19]

12.3 **Compound**—An intimate admixture of a polymer with all the materials necessary for the finished article.[16]

12.4 **Compression**—Reduction of dimension from an external force.

12.5 **Creep**—The time-dependent part of a strain resulting from stress.[16]

12.6 **Elastomer**—Macromolecular material that returns rapidly to approximately the initial dimensions and shape after substantial deformation by a weak stress and release of the stress.[16]

12.7 **Equilibrium Temperature**—Stable temperature at which heat loss equals heat input.

12.8 **Failure**—When a material or component ceases to fulfill the design specified responses essential to the successful operation as a sub unit of a system. A rubber part may fail from tearing, cracking, rupture, hardening, softening, heat or chemical degradation, creep, set, or a combination thereof.

12.9 **Fatigue**—The process of progressive localized permanent structural changes occurring in a material or component subject to conditions which produce fluctuating stresses and strains at some point or points and which may culminate in loss of load bearing ability, cracks or complete fracture after a sufficient number of fluctuations.[11]

12.10 **Fatigue Life**—The number of cycles of stress or strain of a specified character that a given specimen sustains before failure of a specified nature occurs.[11]

12.11 **Frequency**—The number of complete cycles, whole periods, of forced vibrations per unit of time caused and maintained by a periodic excitation, usually sinusoidal.[19]

12.12 **Hysteresis**—The percent energy lost per deformation cycle.[18]

12.13 **Maximum Stress—S_{max}**—The stress having the highest algebraic value in the stress cycle, tensile stress being considered positive, and compressive stress negative. In this definition the nominal stress is used most commonly.[11]

12.14 **Mean Stress (or Steady Component of Stress)—S_m**—The algebraic average of the maximum and minimum stresses in one cycle, that is,

$$S_m = \frac{S_{max} + S_{min}}{2} \tag{11}$$

12.15 **Minimum Stress—S_{min}**—The stress having the lowest algebraic value in the cycle, tensile stress being considered positive and compressive stress negative.[11]

12.16 **Modulus of Elasticity**—Ratio of stress to the strain produced by that stress. $E = \frac{\text{Stress}}{\text{Strain}}$ property of material.[18]

12.17 **Nominal Stress—S**—The stress at a point calculated on the net cross-section by simple elastic theory, without taking into account the effect on the stress produced by geometric discontinuities such as holes, grooves, fillets, etc.[11]

12.18 **Permanent Set**—The residual deformation of a specimen or component after removal of the external load.

12.19 **Polymer**—A macromolecular material formed by the chemical combination of monomers having either the same or different chemical composition.[16]

12.20 **Preload**—An external static load producing a strain in a test specimen. Preload is imposed prior to forced vibration testing. Preload is usually expressed in pounds of load instead of inches of deflection.[19]

12.21 **Resilience**—The ratio of energy output to energy input in a rapid (or instantaneous) full recovery of a deformed specimen.[16]

12.22 **Resonant Frequency**—The frequency at which maximum amplitude occurs for a given input force in a forced vibration system.

12.23 **S-N_f Diagram**—A plot of stress against the number of cycles to failure. The stress can be S_{max}, S_{min}, or S_a. The diagram indicates the S-N_f relationship and a specified probability of survival. For N_f a log scale is almost always used. For S a log scale is used most often but a linear scale is sometimes used.[11]

12.24 **Shear**—Force which causes two contiguous parts of the same body to slide relative to each other in a direction parallel to their plane of contact.[17]

12.25 **Specimen Temperature**—The temperature obtained by placing or locating a temperature sensing device in or on the specimen. In most cases, temperature gradients that develop within flexing rubber specimens make it necessary to define the precise points and techniques used to measure temperature.