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ELASTOMERIC BUSHING "TRAC" APPLICATION CODE

Foreword—This Reaffirmed Document has been changed only to reflect the new SAE Technical Standards Board Format.

Elastomeric bushing life from different machines has resulted in significant data variations.

The designs of the test machines include differing approaches to creating similar geometric environments. When examined closely, these differing approaches actually affect the environment of the test specimen.

The "TRAC" code was developed to separate the axes of this environment, so that each may be examined and discussed individually.

The acronym "TRAC" is derived from the labels of the most commonly discussed bushing axes: **T**orsional **R**adial **A**xial **C**onical.

1. Scope—The bushing "TRAC" code is intended to be a tool that will aid in the definition of the geometric environment for the test, or use, of an elastomeric bushing.

2. Reference—There are no referenced publications specified herein.

3. Test Axes—Since radial load and torsional rotation are the most commonly controlled input quantities to a bushing, they are usually the principal determinants of axis orientation. (See Figure 1).

a. Radial—The translational axis on which the radial load is applied (by definition).
b. Axial—The translational axis coinciding with the bushing inner and outer sleeve axes.
c. Normal—The translational axis perpendicular to both the radial and axial axes.
d. Torsional—The rotational axis coinciding with the axial axis.
e. Conical (1st group)—The rotational axis coinciding with the normal axis.
f. Conical (2nd group)—The rotational axis coinciding with the radial axis.

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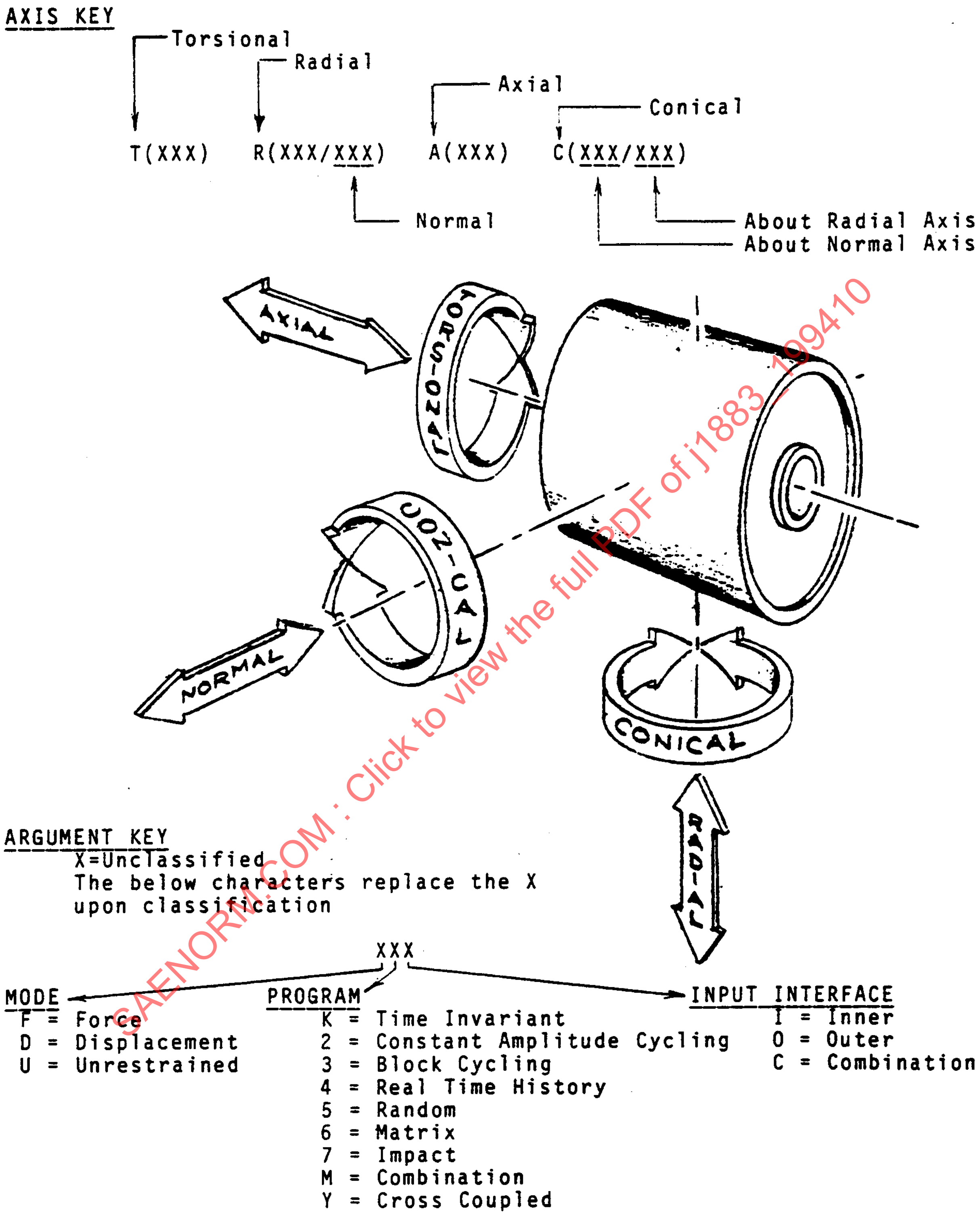

ARGUMENT KEY

X=Unclassified

The below characters replace the X upon classification

MODE
F = Force
D = Displacement
U = Unrestrained

PROGRAM
K = Time Invariant
2 = Constant Amplitude Cycling
3 = Block Cycling
4 = Real Time History
5 = Random
6 = Matrix
7 = Impact
M = Combination
Y = Cross Coupled

INPUT INTERFACE
I = Inner
O = Outer
C = Combination

FIGURE 1—AXIS KEY

4. Mode

4.1 F = Force—A force being exerted along an axis.

Typical examples:

a. A force exerted by an air cylinder.
b. The force exerted by a spring supported in a stationary manner at the other end, and with a preload relatively high compared to its rate.
c. The force exerted by a hanging weight.
d. The force exerted by a servo-hydraulic actuator operating in load control.

4.2 Displacement—A controlled deflection of the specimen, whether fixed in a stationary position or time variant.

Typical Examples:

a. The displacement caused by a rotating eccentric or cam.
b. The displacement caused by a servo-hydraulic actuator being operated in displacement control.
c. The displacement (or lack of) caused by securely holding a portion of the specimen in a fixed location.

NOTE—An immobilized (fixed) axis has not been readily perceived as being in displacement mode.

4.3 Unrestrained—The specimen may move freely without restriction.

5. Program

a. K = Time Invariant—The condition that exists when the restrained (or unrestrained) portion of the specimen is subjected to a force or displacement that remains constant in time.

   Typical examples:

   1. The exerted force is caused by a hanging weight or a cylinder maintained at constant pressure.
   2. The displacement is maintained in a fixed location, that is, by stationary fixturing.
   3. The specimen is unrestrained—the force remains zero at all times.

b. 2 = Constant Amplitude Cycling—When the specimen is subjected to a time varying force or displacement where amplitude of each peak and valley (usually a sine function) is the same as the previous one.

c. 3 = Block Cycling—The same as constant amplitude cycling except that the amplitude and/or frequency is changed after a specified quantity of cycles. There may be any number of blocks in a test program.

d. 4 = Real Time History—The load or displacement history is identical to that of one which has occurred during some actual event history. This history would include the amplitudes, order, and frequencies of the original events.

e. 5 = Random—A load or displacement history, where the amplitudes, order, and frequencies occur nonperiodically.

f. 6 = Matrix—A load or displacement history in which the event information is tabulated in the matrix format. In this form, the order and frequency of the events are lost.

g. 7 = Impact—The sudden application and removal of a load or displacement.

h. M = Combination—Any combination of the previous.

i. Y = Cross Coupled—The condition that exists when the load or displacement of one axis (usually by intent) affects the load or displacement of another axis.

6. Input Interface—The interface is that into which the stated input is induced.

I = Inner
O = Outer
C = Combination—Frequently, both interfaces are constructed where neither may be selected as the one being activated.

7. Discussion

7.1 Normal Forces Created by Torsional Rate of the Bushing—Torsional stressing of the elastomer bushing results in a *force couple*. In a system (test machine), one sleeve is prevented from following the rotational oscillations of the other by means of a moment arm attached to one of the sleeves. The most evident force of the force couple is at the reaction point (Fa—opposite end from the sleeve) of this moment arm. Usually not considered is a normal force acting through the rotation axis (Fb). This force is directly proportional to the bushing torsional (spring) rate multiplied by the angle of rotation and inversely proportional to the moment arm (Da—length) of the rotation restraint force. (See Figure 2).

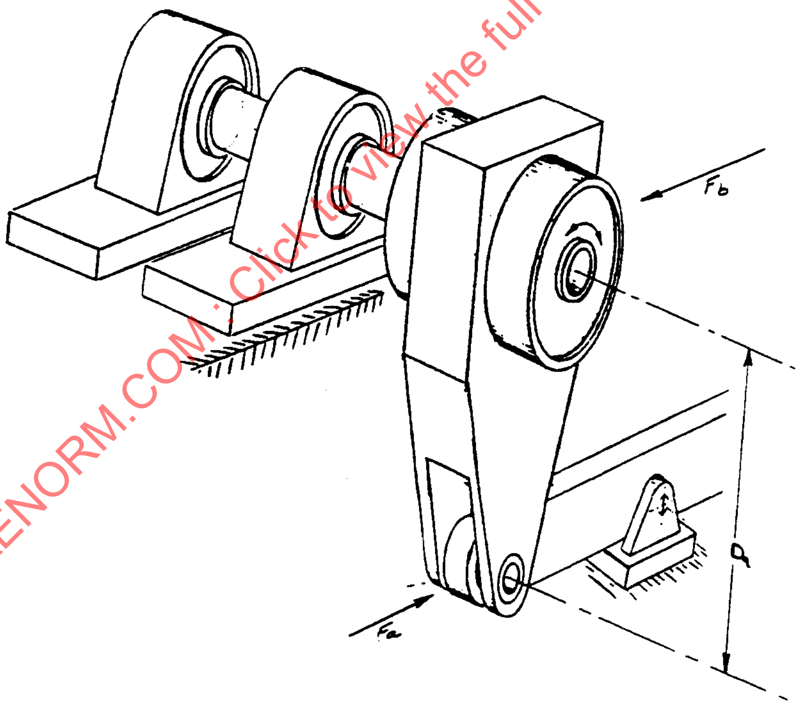

FIGURE 2—FORCE COUPLE

8. Design Intent—Many factors may affect the actual performance of the designed environment of a suspension bushing. Some may or may not be considered during the classification of this environment.

8.1 Factors Not Included in This Classification

8.1.1 Bearing Condition—Bearings that have been worn or sloppy may change the bushing environment to something other than original intent.

8.1.2 Seal Characteristics—Linear actuators (that is, pneumatic cylinders) have differing "break away" characteristics between the piston and bore when subjected to torsional forces.

8.2 Factors Affecting Classification

8.2.1 Cross Coupling—Effects that are present, but often overlooked, during design conception.

8.2.2 Previously Not Considered—Effects that are present, but no effort to relate to them was expended.

9. Existing Machine Concepts

9.1 Clevite Test Machine—See Figure 3.

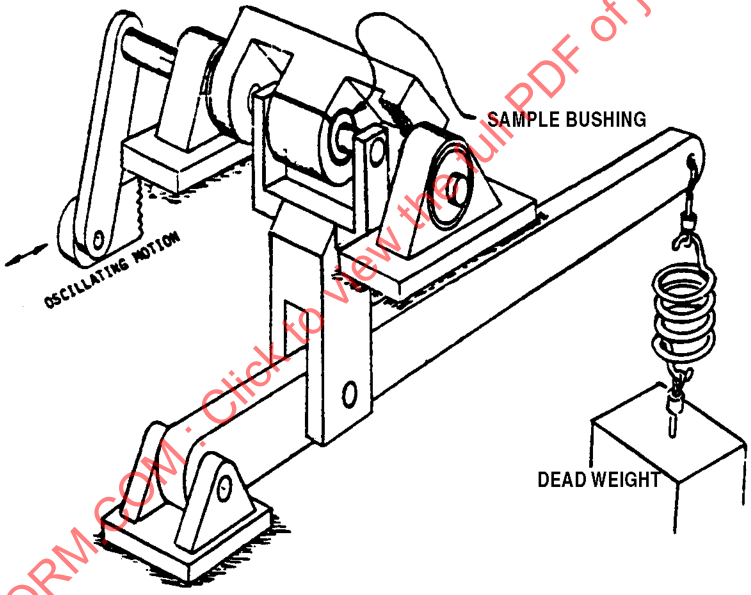

FIGURE 3—CLEVITE TEST MACHINE

9.1.T Torsional [T(D20)]

(D__)
The displacement of the oscillation is fixed by the unchanging lengths and geometry of the crank throws of the driving eccentric and driven crank.

(_2_)
The oscillating motion is generated by a rod connecting the crank arm of a constant angular velocity, electric motor driven shaft, to another crank arm driving a second shaft supported with pillow blocks. This is a constant amplitude, constant frequency motion.

(__O)
This second shaft is attached to a clevis which securely clamps to the outer sleeve of the test sample bushing, forcing this outer sleeve to rotate about the axis of the bushing.

9.1R Radial [R(FKI/FYI)]

(F__/___)
The force generated by a dead weight is transmitted (and multiplied) along the principal radial axis through a lever and link system.

(_K_/___)
The dead weight generates a constant (time invariant) force. A spring between the end of the lever and the weight minimizes any inertial forces that may be generated by lever motion.

(__I/___)
The principal radial load (defined by this code) is induced into the inner sleeve of the sample bushing.

(___/F___)
A force generated by the bushing torsional rate is induced into the normal (to the principal) to the radial axis by the "other" force of the couple moment (as described in 7.1).

(___/_Y_)
Since this force is generated by the torsional rate of the bushing, as described in 7.1, and not by any directly induced by mechanical design of the system, it is induced by cross coupling.

(___/__I)
This normal force is induced into the inner sleeve of the sample bushing.

9.1A Axial [A(DKC)]

(D__)
Since a line joint (bolt through a hole) is assumed at the interface of the lever and link, the inner sleeve of the sample bushing is prevented from moving along its axis, and is considered as completely restrained.

(_K_)
The restrained condition is continuous (time invariant).

(__C)
This restraint results from a combination of fixturing that includes both sleeves.

9.1C Conical [C(DKC/DKC)]

(D__/___)
The principal radial axis (along the input radial force) is along the link. The lower end of the link is restrained from any horizontal motion; by the lever fulcrum in the fore-aft direction and the line joint (bolt through a hole) in the lateral direction. This geometry prevents any motion about the normal axis.

(_K_/___)
This restraint is continuous (time invariant).

(__C/___)
This restraint results from a combination of fixturing that includes both sleeves.

(___/D__)
Rotation about the radial axis is prevented by the line joint (bolt through hole) at the intersection of the lever and the link, resulting in no angular displacement.

(___/_K_)
This restraint is continuous (time invariant).

(___/__C)
This restraint results from a combination of fixturing that includes both sleeves.

9.2 Low Test Machine—See Figure 4.

9.2T Torsional [T(D2I)]

(D___)
The displacement of the oscillation is fixed by the unchanging lengths and geometry of the crank throws of the driving eccentric and driven crank.

(_2_)
The oscillating motion is generated by a rod connecting the crank arm of a constant angular velocity, electric motor driven shaft, to another crank arm driving a second shaft supported with pillow blocks. This is a constant amplitude, constant frequency motion.

(__I)
This second shaft is attached to the inner sleeve and forces it to rotate about its fixed axis.

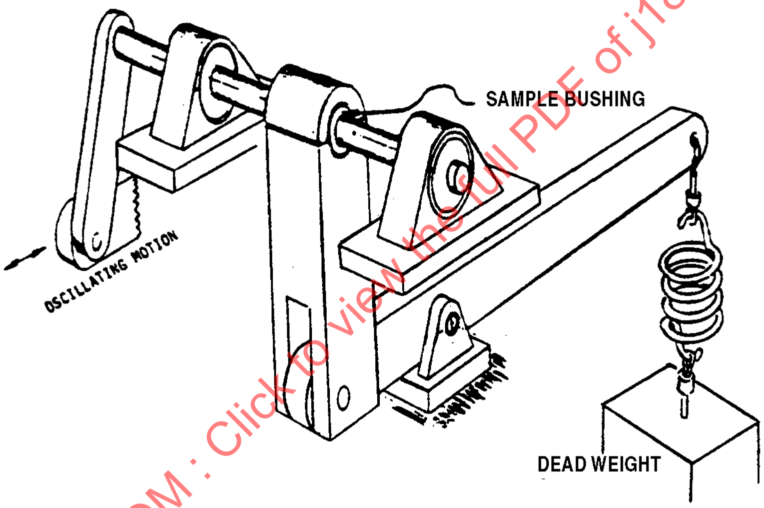

FIGURE 4—LOW TEST MACHINE

9.2R Radial [R(FKO/FYO)]

(F__/___)
The force generated by a dead weight is transmitted (and multiplied) along the principal radial axis through a lever and link system.

(_K_/___)
The dead weight generates a constant (time invariant) force. A spring between the end of the lever and the weight minimizes any inertial forces that may be generated by lever motion.

(__O/___)
The principal radial load (defined by this code) is induced into the outer sleeve of the sample bushing.

(___/F__)
A force generated by the bushing torsional rate is induced into the normal to the radial axis by the "other" force of the couple moment (as described in 7.1).

(___/_Y_)
Since this force is generated by the torsional rate of the bushing, as described in 7.1, and not directly induced by mechanical design of the system (that is, link length), it is cross coupled.

(___/__O)
This normal force is induced in the outer sleeve of the sample bushing.

9.2A Axial [A(DKO)]

(D__)
Since a line joint (bolt through a hole) is assumed to be at the interface of the lever and link, the inner sleeve of the sample bushing is prevented from moving along its axis and is considered as being completely restrained.

(_K_)
The restrained condition is continuously (time invariant) existent.

(__O)
This restraint is created at the outer sleeve of the sample bushing.

9.2C Conical [C(DKC/DKC)]

(D__/___)
The principal radial axis (along the input radial force) is along the link. The lower end of the link is restrained from any horizontal motion by the lever fulcrum in the fore-aft direction, and the line joint (bolt through hole) in the lateral direction. This geometry prevents any motion about the normal axis.

(_K_/___)
This restraint is continuous (time invariant).

(__C/___)
This restraint results from a combination of fixturing that includes both sleeves.

(___/D__)
Rotation about the radial axis is prevented by the line joint (bolt through hole) at the intersection of the lever and the link, resulting in no angular displacement.

(___/_K_)
This restraint is continuous (time invariant).

(___/__C)
This restraint results from a combination of fixturing that includes both sleeves.

9.3 Wahl Joint Test Machine—See Figure 5.

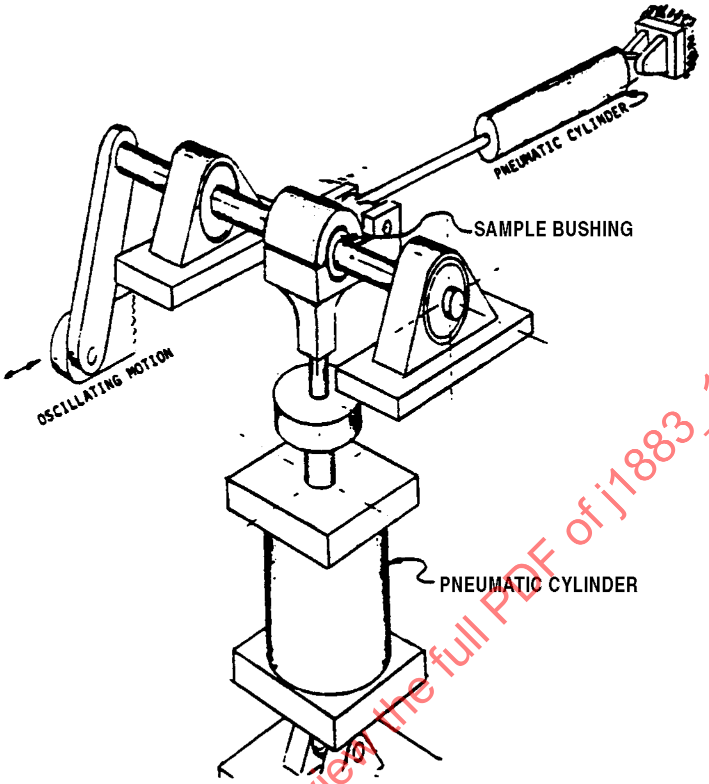

FIGURE 5—WAHL JOINT TEST MACHINE

9.3T Torsional [T(D2I)]

(D__)
The displacement of the oscillation is fixed by the unchanging lengths and geometry of the crank throws of the driving eccentric and driven crank.

(_2_)
The oscillating motion is generated by a rod connecting the crank arm of a constant angular velocity, electric motor driven shaft, to another crank arm driving a second shaft supported with pillow blocks. This is a constant amplitude, constant frequency motion.

(__I)
This second shaft is attached to the inner sleeve and forces it to rotate about its fixed axis.

9.3R Radial [R(FKO/FMO)]

(F__/___)
A force is imparted to the principal radial axis by a pneumatic cylinder. It is proportional to the air pressure behind the piston. Piston seal friction is either neglected or compensated for by adjusting the air pressure according to the load cell indication of actual imparted force.

(_K_/___)
The constant (time invariant) air pressure maintains a constant force.

An optional mode of machine operation permits this load to be cycled (code entry would then be “_2_/__").