Spoke Wheels and Hub Fatigue Test Procedures

1. *Scope*—This SAE Recommended Practice provides uniform laboratory procedures for fatigue testing of spoke wheels and hubs intended for normal highway use on trucks, buses, truck trailers, and multipurpose passenger vehicles. The hubs included have bolt circle diameters from 165.1 to 335.0 mm (6.50 to 13.19 in). It is up to each hub and/or spoke wheel developer to determine what test method, accelerated load factor and cycle life requirements are applicable to obtain satisfactory service life in a given application. When deviations from the procedures recommended herein are made, it is the responsibility of the hub and/or spoke wheel developer to modify other parameters to obtain satisfactory service life.

2. *References*

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated, the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J393—Nomenclature—Wheels, Hubs, and Rims for Commercial Vehicles
SAE J694—Disc Wheel/Hub or Drum Interface Dimensions—Commercial Vehicles
SAE J851—Dimensions—Wheels for Demountable Rims, Demountable Rims, and Spacer Bands—Commercial Vehicles
SAE J1835—Fastener Hardware for Spoke Wheels

3. *Test Procedures*

3.1 Spoke Wheels and Hubs for Test—Use only fully processed spoke wheels or hubs which are representative of production parts intended for vehicle installation. New spoke wheels or hubs and related parts shall be used for each test. If the spoke wheel or hub application is always used with a brake drum or rotor, the spoke wheel or hub may be tested with a brake drum or rotor attached. If the spoke wheel or hub application is ever to be used without a brake drum or rotor, the spoke wheel or hub must be tested without a brake drum or rotor attached.

3.2 Hub Dynamic Fatigue Test—The dynamic fatigue test may be conducted by one of the following methods:

3.2.1 CORNERING FATIGUE, 90 DEGREE LOADING METHOD

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3.2.1.1 *Equipment*—The test machine shall be one with a means to impart a constant rotating bending moment and radial load to the hub (see Figure 1). Test fixture adaptor dimensions are described in Table 1.

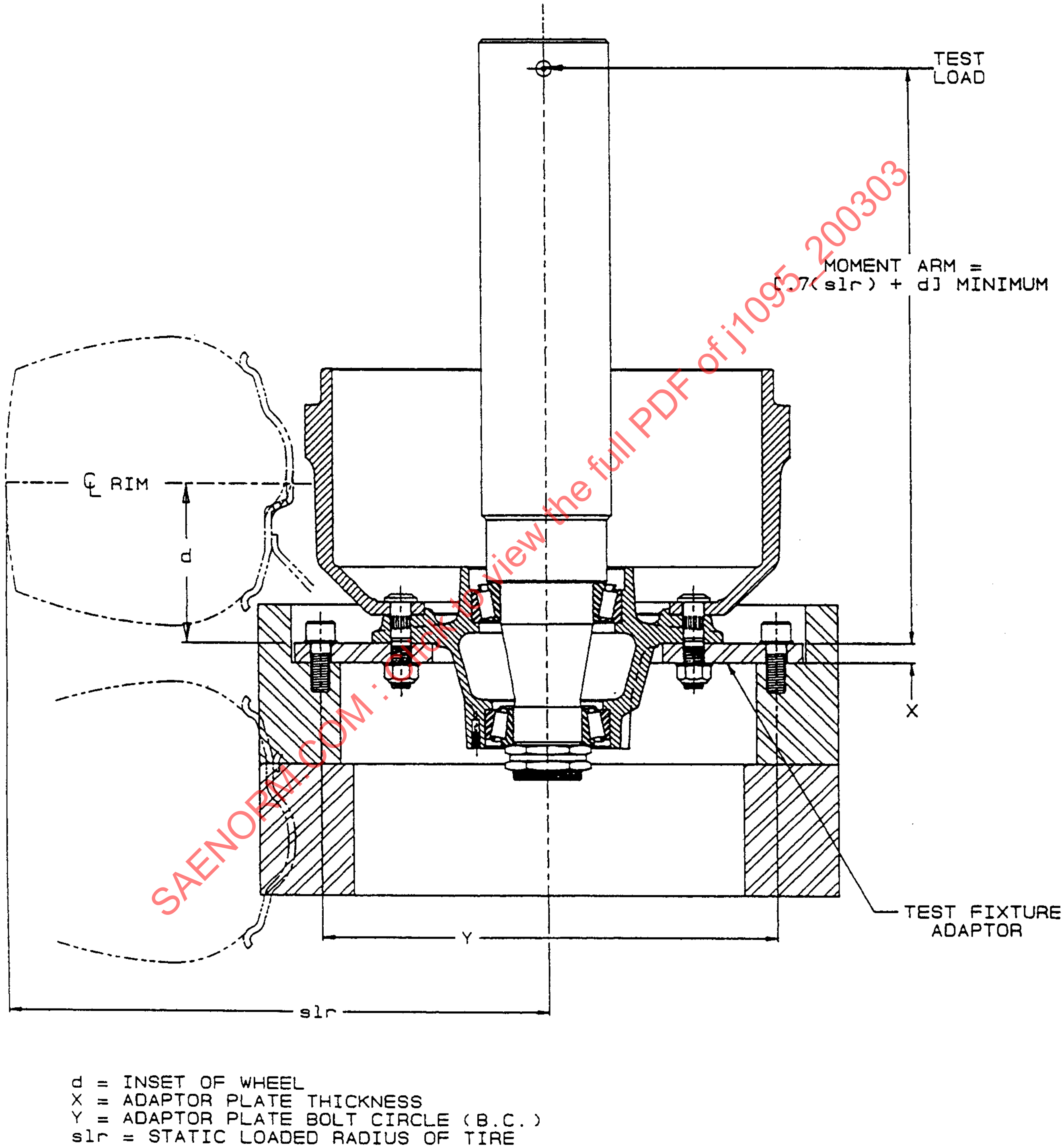

FIGURE 1—90 DEGREE CORNERING FATIGUE TEST (TYPICAL SET-UP)

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TABLE 1—TEST FIXTURE ADAPTOR DIMENSIONS

Hub Bolt Circle Diameter mm	Hub Bolt Circle Diameter in	X Plate Thickness mm	X Plate Thickness in	Y Plate Outside Bolt Circle Diameter mm	Y Plate Outside Bolt Circle Diameter in
165.1	6.500	22.22	0.875	317.50	12.50
170.0	—	22.22	0.875	317.50	12.50
205.0	8.000	20.00	0.787	317.50	12.50
222.25	8.750	19.05	0.750	317.50	12.50
275.00	—	22.22	0.875	444.50	17.50
285.75	11.250	22.22	0.875	444.50	17.50
335.00	13.188	17.16	0.675	444.50	17.50

NOTE—These steel plate thickness selections give 131 to 145 MPa (19 000 to 21 000 psi) radial bending stress at the inner bolt circle of the adaptor plate when loaded with the typical test loading for each specified bolt circle.

3.2.1.2 *Procedure*—Mount the hub assembly to a test fixture adaptor using wheel nuts representative of those required by the application, and torqued to the limits specified in Table 2 for the appropriate application. Bearings and test speed may be adjusted so as to maximize bearing life; however, bearing adjustments may not necessarily be those recommended for commercial practice. Excessively loose bearings may change the failure mode of the hub structure. The mating surfaces of the test adaptor and hub shall be free of paint, dirt, or foreign matter. The final clamped position of the hub without load must not exceed an eccentricity of 0.25 mm (0.010 in) total indicator reading normal to the shaft axis at the point of loading. The system shall maintain the specified load within ± 3%. The application of the test load shall be parallel to the plane of the wheel mounting surface of the hub assembly at a specified distance (moment arm) as shown in Figure 1.

3.2.1.3 Test Load and Bending Moment Determination—The test load is determined by Equation 1:

$$\text{Test Load} = \frac{M}{\text{Moment Arm}} \text{ (See Figure 1)} \qquad \text{(Eq. 1)}$$

M is determined by the formula:

$$M = [\mu(slr) + d](S)L \qquad \text{(Eq. 2)}$$

where:

M = Bending moment, N·m (lbf-in)
μ = Coefficient of friction developed between tire and road (0.7)
slr = Static loaded radius of the largest tire to be used with the hub as specified by the vehicle manufacturer, millimeters x 10^{-3} (in). Refer to Table 3 for static loaded radius.
d = Inset or outset (positive for inset, negative for outset) of the wheel, millimeters x 10^{-3} (in), as measured from the centerline of the rim to the wheel mounting surface of the hub assembly. For hubs used only with dual wheels, d is zero. For hubs used with single wheels and d values other than zero, use the largest absolute value.
S = Accelerated test load factor
L = Load rating of the hub as specified by the hub manufacturer, N (lbf)

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TABLE 2—MOUNTING NUT TORQUES FOR LABORATORY WHEEL/RIM TESTS

Application[1]	Thread Size	Torque (dry)[2] +10% -0% N·m	Torque (dry)[2] +10% -0% N·m	Torque (dry)[2] +10% -0% N·m	Torque (dry)[2] +10% -0% lbf-ft	Torque (dry)[2] +10% -0% lbf-ft	Torque (dry)[2] +10% -0% lbf-ft
Disc Wheels	M12 × 1.5		110			80	
Passenger type light truck mounting	7/16–20		110			80	
	1/2 –20		110			80	
	9/16–18		150			110	
	5/8 –18		170			125	
In-out coined mounting cone seat nut	9/16–18		240			175	
	5/8 –18		240			175	
In-out coined mounting flange nut	5/8 –18		370			275	
		1-pc. nut		2-pc. nut	1-pc. nut		2-pc. nut
Hub piloted mounting	9/16–18	160		170	120		125
	5/8 –18	—		180	—		130
	11/16–16	410		340	300		250
	3/4 –16	610		410	450		300
	7/8 –14	—		470	—		350
	M14 × 1.5	—		170	—		125
	M18 × 1.5	—		260	—		190
	M20 × 1.5	—		380	—		280
	M22 × 1.5	—		610	—		450
Hub piloted mounting with clamp plate	9/16–18		150			110	
	M14 × 1.5		150			110	
	5/8 –18		180			130	
Ball seat mounting	3/4 –16		610			450	
	1– 1/8 –16		610			450	
Heavy-duty ball seat mounting	15/16–12		1020			750	
	1– 5/16–12		1020			750	
Demountable Rims							
Studs and nuts	5/8 –11		200			150	
	3/4 –10		260			190	

1. For applications and sizes not shown, use torque recommendations prescribed by the wheel/rim or vehicle manufacturer.
2. Nut torque values shall be checked and reset periodically during the course of a test in order to compensate for “wearing in” of mating surfaces.

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TABLE 3—AVERAGE STATIC LOADED RADII FOR CORNERING TEST CALCULATIONS

Light Truck Tires Size	Light Truck Tires slr mm	Light Truck Tires slr in	Heavy Truck Tires Size	Heavy Truck Tires slr mm	Heavy Truck Tires slr in
6.50–16 LT	356	14.0	7.50–15 TR	381	15.0
6.70–15 LT	348	13.7	7.50–17	404	15.9
7.00–15 LT	356	14.0	7.50–18	419	16.5
7.50–16 LT	381	15.0	7.50–20	452	17.8
			8.25–15 TR	401	15.8
			8.25–17	427	16.8
Tubeless–5 degree			8.25–20	472	18.6
			9.00–15 TR	419	16.5
LT175/75-14	292	11.5	9.00–20	488	19.2
			10.00–15 TR	434	17.1
LT185/75-14	282	11.1	10.00–20	508	20.0
LT195/75-14	300	11.8	10.00–22	531	20.9
			11.00–15 TR	450	17.7
LT195/75-15	312	12.3	11.00–20	516	20.3
			11.00–22	541	21.3
LT215/75-14	312	12.3	11.00–24	572	22.5
LT205/75-15	305	12.0	12.00–20	531	20.9
			12.00–24	582	22.9
			13.00–20	541	21.3
LT215/75-15	325	12.8	14.00–20	584	23.0
LT235/75-15	338	13.3	14.00–24	635	25.0
LT225/75-16	345	13.6	16.00–20	612	24.1
LT245/75-16	358	14.1			
LT265/75-16	371	14.6	Tubeless-15 degree		
LT285/75-16	384	15.1			
LT215/85-16	361	14.2	8R17.5 HC	371	14.6
LT235/85-16	373	14.7	8–19.5	409	16.1
LT255/85-16	389	15.3	8–22.5	447	17.6
9–15 LT	351	13.8	9R17.5 HC	391	15.4
10–15	361	14.2	9–22.5	465	18.3
11–15 LT	384	15.1	10R17.5 HC	401	15.8
12–15 LT	394	15.5	10–22.5	488	19.2
			11R17.5 HC	419	16.5
Tubeless-15 degree			11–22.5	503	19.8
			11–24.5	528	20.8
7–17.5 LT	361	14.2	12–22.5	516	20.2
8.00–16.5 LT	340	13.4	12–24.5	536	21.1
8–17.5 LT	373	14.7	12.5–22.5	518	20.4
8.75–16.5 LT	356	14.0	12.75–22.5	521	20.5
9.50–16.5 LT	366	14.4	245/75–22.5	437	17.2
10–16.5 LT	361	14.2	265/75–22.5	457	18.0
10–17.5 LT	368	14.5	295/75–22.5	480	18.9
12–16.5 LT	386	15.2	285/75–24.5	495	19.5

For tire sizes not shown, use the slr listed in the individual tire manufacturer's Tire Data Book.

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3.2.1.4 Accelerated Test Load Factor—(See Table 4.)

TABLE 4—TYPICAL "S" FACTORS FOR HUBS

SAE J1095 Paragraph	Load Angle	Reference Arm	"S" Factor
3.2.1	90 degrees with respect to the load shaft axis	See Figure 1	1.0
			1.2
			1.4
3.2.2	40 degrees with respect to the adaptor plate plane	See Figure 2	1.6
	10 degrees with respect to the adaptor plate plane	See Figure 2	2.0
			2.5
3.2.3	Camber Angle 0 degrees		1.4
	Steer Angle 0 degrees		1.6
			1.9
			2.0
			2.8

3.2.2 CORNERING FATIGUE, ANGULAR LOADING METHOD

3.2.2.1 Equipment—The test machine shall be one with a means to impart constant rotating bending moment and axial and radial load to the hub (see Figure 2). Test fixture adaptor dimensions are shown in Table 1.

3.2.2.2 Procedure—Mount the hub assembly to a test fixture adaptor using wheel nuts representative of those required by the application, and torqued to the limits specified in Table 2 for the appropriate application. Bearings and test speed may be adjusted so as to maximize bearing life; however, bearing adjustments may not necessarily be those recommended for commercial practice. Excessively loose bearings may change the failure mode of the hub structure. The mating surfaces of the test adaptor and hub shall be free of paint, dirt, or foreign matter. The final clamped position of the hub without load must not exceed an eccentricity of 0.25 mm (0.010 in) total indicator reading normal to the shaft axis at the point of loading. The system shall maintain the specified load within ±3%. The application of the test load shall be at an angle from a plane through the load centerline of the rim as shown in Figure 2.

3.2.2.3 Test Load and Reference Arm Determination—The test load and reference arm are determined as follows:

$$D = \frac{(L) \times (S)}{\cos\phi} \qquad \text{(Eq. 3)}$$

where:

D = Diagonal test load resultant; N (lbf)
L = Load rating of the hub as specified by the hub manufacturer; N (lbf)
S = Accelerated test load factor
ϕ = Test load angle

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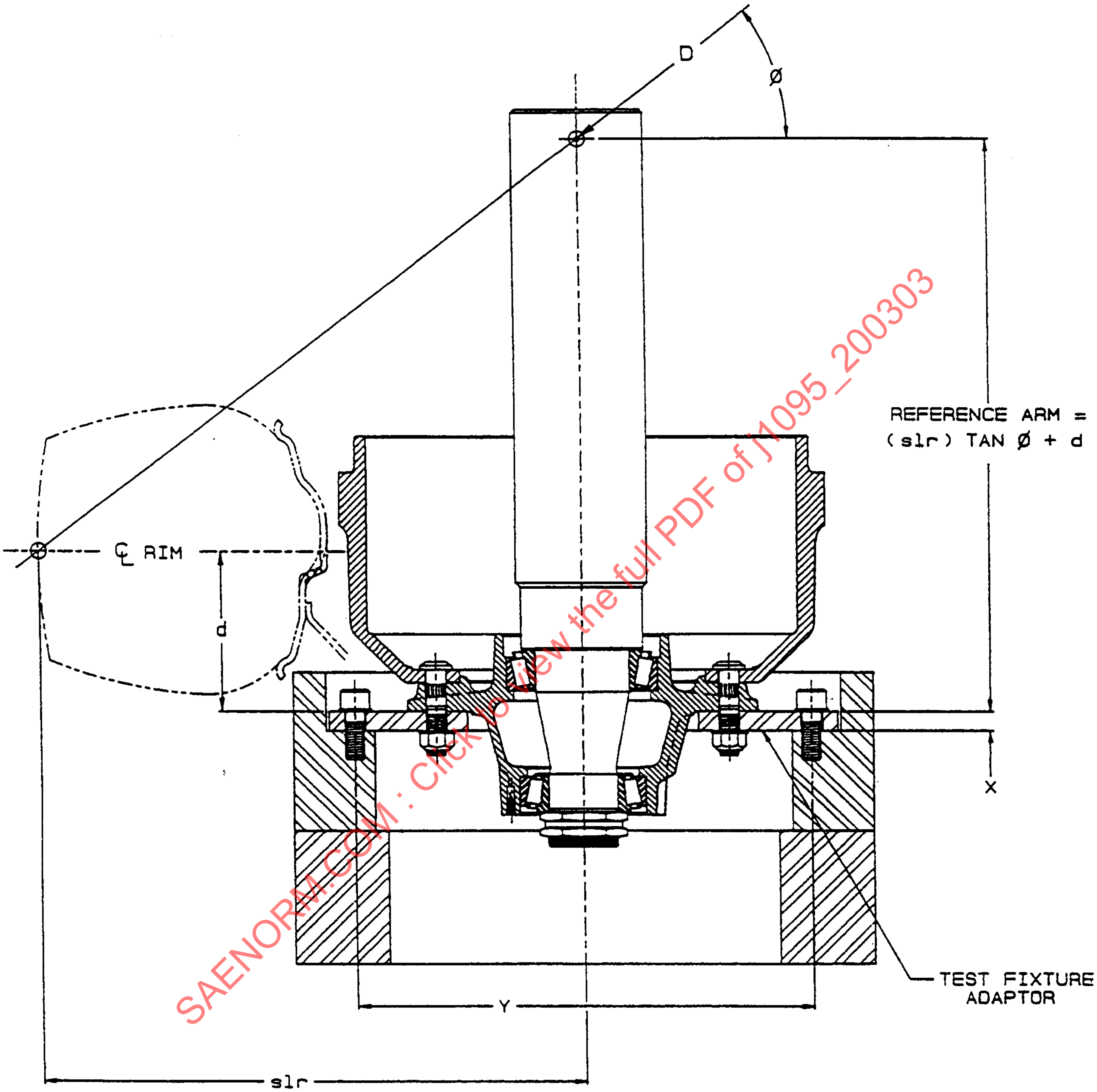

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D = DIAGONAL LOAD
d = INSET OF WHEEL
X = ADAPTOR PLATE THICKNESS
Y = ADAPTOR PLATE BOLT CIRCLE (B.C.)
slr = STATIC LOADED RADIUS OF TIRE

FIGURE 2—ANGULAR CORNERING FATIGUE TEST (TYPICAL SET-UP)

$$\text{Reference Arm} = (slr)\ \tan¢ + d \qquad \text{(Eq. 4)}$$

where:

slr = Static loaded radius of the largest tire to be used with the hub as specified by the vehicle manufacturers, millimeters (in). Refer to Table 3 for static loaded radius.
d = Inset or outset (positive for inset, negative for outset) of the wheel, millimeters (in), as measured from the centerline of the rim to the wheel mounting surface of the hub assembly. If the wheel may be used as inset or outset, use inset (see SAE J393). For hubs used only with dual wheels, d is zero. For hubs used with both dual and single wheels with d values other than zero, use the largest absolute value.

3.2.2.4 *Accelerated Test Load Factor*—(See Table 4.)

3.2.3 DYNAMIC RADIAL FATIGUE TEST

3.2.3.1 *Equipment*—The test machine shall be one with a driven, rotatable drum which presents a smooth surface wider than the loaded test tire section width. The suggested diameter of the drum is 1707.6 mm (67.23 in) which results in 186 revolutions per kilometer (300 revolutions per mile). The test wheel and tire fixture must provide loading normal to the surface of the drum, and in line radially with the center of the test wheel and the drum.

3.2.3.2 *Procedure*—Tires selected for this test shall be representative of a size and construction approved by the Tire and Rim Association and the wheel/rim manufacturer for the wheel/rim under test. The spoke wheel or hub assembly shall be mounted to the test fixture spindle substantially as in service. Camber and/or steer angles may be incorporated in the test; however, these angles must be noted in the test results. Bearings may be adjusted to maximize bearing life. The wheel nuts shall be torqued to the limits specified in Table 2 for the size and type of nut used. The test load and the inflation pressure are based on the wheel/rim ratings. Test inflation pressure should be selected in accordance with Table 5. The selected test inflation pressure and load shall both be maintained within ±3%.

TABLE 5—TEST INFLATION PRESSURES

Maximum Inflation Pressure Rating kPa	Maximum Inflation Pressure Rating psi	Minimum Test Pressure
0 through 310	0 through 45	450 kPa (65 psi)
Over 310	Over 45	1.2 x Maximum Inflation Pressure Rating

3.2.3.3 *Radial Load Determination*—The radial load is determined as follows:

$$R = L \cdot S \qquad \text{(Eq. 5)}$$

where:

R = Radial load, N (lbf)
L = Load rating of the hub as specified by the hub manufacturer, N (lbf)
S = Accelerated test factor

3.2.3.4 *Accelerated Test Load Factor*—(See Table 4.)

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3.3 Spoke Wheels, Cornering Fatigue Test

3.3.1 EQUIPMENT—The test machine shall be such that either the spoke wheel rotates under the influence of a stationary bending moment, or the stationary spoke wheel is subjected to a rotating bending moment (see Figure 3).

3.3.2 PROCEDURE—The spoke wheel shall be clamped securely to the test device using studs and nuts representative of those specified for the wheel assembly. The rim clamp nuts shall be tightened to the torque limits specified in Table 2 for the thread size listed for spoke wheels. Bearings and test speed may be adjusted so as to maximize bearing life; however, bearing adjustments may not necessarily be those recommended for commercial practice. Excessively loose bearings may change the failure mode of the wheel structure. The mating surface of the test adaptor and spoke wheel shall be free of excessive buildup of paint, dirt, or foreign material. A rigid load arm shaft shall be attached to the hub of the spoke wheel. The final clamped position of the wheel without load shall not exceed 0.25 mm (0.010 in) total indicator reading normal to the shaft axis at the point of loading. The load system must maintain the specified test load within ±3%.

3.3.3 TEST LOAD AND BENDING MOMENT DETERMINATION—The test load is determined by:

$$\text{Test Load} = \frac{M}{\text{Moment Arm}} \text{(See Figure 3)} \qquad \text{(Eq. 6)}$$

M is determined by the formula:

$$M = \mu(slr)(S)(L) \qquad \text{(Eq. 7)}$$

where:

M = Bending moment, N·m (lbf in)
μ = Coefficient of friction developed between tire and road (0.7)
slr = Static loaded radius of the largest tire to be used on the spoke wheel as specified by the vehicle or wheel manufacturer, millimeters x 10^{-3} (in). Refer to Table 3 for static loaded radius.
S = Accelerated test factor. Refer to Table 6.
L = Load rating of the spoke wheel as specified by the wheel manufacturer, N (lbf)

3.3.4 TEST FACTOR AND CYCLE REQUIREMENTS—Refer to Table 6.

3.4 Test Termination Definitions

3.4.1 Inability to sustain load.

3.4.2 A visually detected fatigue crack penetrating through a section.

3.4.3 Loose bearing cup.

3.4.4 Broken studs before 20 000 cycles.

3.5 Test Disqualification—If any failure of the test fixture or associated parts (i.e., shaft, bearings, adaptor plate, etc.) occurs during test, the test may be disqualified if the failure is deemed to have affected the life characteristics of the spoke wheel or hub under test.

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