SAE INTERNATIONAL

SURFACE VEHICLE STANDARD

J3175™ DEC2024

Issued 2019-11
Reaffirmed 2024-12

Superseding J3175 NOV2019

Road Vehicles - Friction Materials - Finished Brake Pad Normalized Elastic Constant of Friction Material

RATIONALE

Measurement of variations in elastic properties because of raw materials, internal cracks, or other factors can be useful for quality control. Elastic properties are also important for lining characterization. The purpose of this test procedure is to evaluate the normalized elastic constant of friction material on a finished brake pad.

SAE J3175 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This SAE standard specifies a method for testing and measuring a normalized elastic constant of brake pad assemblies using ultrasound. This document applies to disc brake pad assemblies and its coupons or segments used in road vehicles.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J380 Specific Gravity of Friction Material

SAE J2725 Road Vehicles - Friction Materials - Elastic Properties Measurements

3. DEFINITIONS

3.1 NORMALIZED ELASTIC CONSTANT OF FRICTION MATERIAL (NECFM)

A measure of the elastic constant (C_{44}) independent of friction material density.

C_{44} can be referred to from SAE J2725.

3.2 ULTRASONIC MODES

Shear wave/ultrasonic wave mode where the direction of wave propagation is perpendicular to the friction surface of a brake pad.

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For more information on this standard, visit https://www.sae.org/standards/content/J3175_202412/

3.3 COORDINATE SYSTEM DEFINITION

See Figure 1.

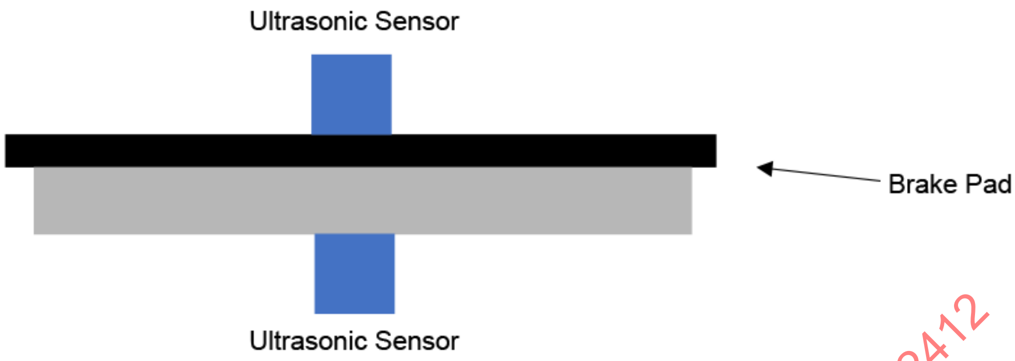

Figure 1 - Coordinate system

4. SYMBOLS

$D_{friction}$	Friction thickness (D_{total} - D_{plate}), in meters (m)
D_{plate}	Constant, nominal pressure plate design thickness, in meters (m)
D_{total}	Overall thickness of pad at given measurement point, in meters (m)
NECFM	Normalized Elastic Constant of Friction Material, in pascals (Pa)
$T^s_{measured}$	Transit time when measuring calibration steel block, in seconds (s)
T^s_{offset}	System delay ($T^s_{measured}$ - $T^s_{standard}$), in seconds (s)
T^s_{plate}	transit time through pressure plate (D_{plate} / V^s_{plate}), in seconds (s)
T^s_{total}	Transit time through brake pad, in seconds (s)
$T^s_{standard}$	Constant (known transit time through certified calibration block), in seconds (s)
$T^s_{friction}$	Measured transit time through friction material (T^s_{total} - T^s_{offset} - T^s_{plate}), in seconds (s)
$V^s_{friction}$	Velocity of shear wave in friction, in milliseconds (ms)
V^s_{plate}	Constant (3228), velocity through standard pressure plate, in milliseconds (ms)
$\rho_{normalized}$	1, in kilograms per cubic meter (kg/m³)

5. EQUIPMENT

The test equipment needs to be capable of meeting the specifications indicated on Table 1.

Table 1 - Minimum test system capabilities and specifications

Parameter	Minimum requirement or capability
Micrometer (or other means of measuring pad thickness)	±0.03 mm.
Ultrasonic pulse signal generator	Repeated pulses equal to or less than 0.2 µs in width and of sufficient amplitude to generate an averaged waveform with defined peaks and valleys at the receiver output.
Waveform digitizer and display	Acquisition sampling rate at least 50 MHz, ability to display waveforms in real-time, have automatic or manual peak detection, signal averaging (50 times minimum), and automatic time-of-flight measurement capability. Timing precision of ±10 nanoseconds.
Coupling load fixture	The coupling load test fixture must be capable of supplying and monitoring up to 1000 N (220 pounds) of compressive load to the samples and of maintaining the polarization of the ultrasonic sensors to better than ±5 degrees. The precision of the load fixture should be ±20 N (5 pounds). For shear wave transducers, the direction of polarization as is indicated on the sensors. The fixture must allow for rotation of each sensor (about the propagation direction) to ensure that the polarization of the sensors are co-linear.
Ultrasonic shear sensors (N=2)	The shear wave transducers must be linearly polarized with polarization clearly marked. They must operate with a center frequency in the range from 1 to 5 MHz and have a 10 dB bandwidth greater than 80%, and have an active piezoelectric element.
Optional: Software for waveform analysis and obtaining friction time-of-flight ($T^S_{friction}$)	
Propagation timing standard (calibration block)	With known shear wave transit time of ±5 nanoseconds.
Sensor concentricity relative to each other	Less than 0.5 mm.

5.1 Facilities

Test facility capable of maintaining test equipment.

5.2 Test stand verification

Verify the measurement capability of the test stand using with the following items:

a. Appropriate checklists to verify features, functionality, and specifications (full scales, accuracies, sampling rates, etc.).

b. Gage repeatability and reproducibility study with at least ten preselected brake pads and at least three operators, with three repeats each.

5.3 Test Stand Condition

All test equipment, fixtures, and samples shall be inspected prior to use. Nicks, burs, corrosion, or contamination on any contacting surfaces can cause variation in the test equipment that can exceed the intended measurement capability of the test procedure.

5.4 Calibration

a. Because of triggering delays in the instrumentation and propagation delays in the piezoelectric sensors, it is necessary to calibrate the system using a test sample where the propagation time is known or measured independently. A propagation timing standard with known shear waves must be accurate to ±0.2 µs. Stainless steel is recommended for calibration due to its uniform physiochemical properties. The calibration block whose transit time for shear waves has been measured independently should be used and should be 15 to 26 mm in thickness.

b. Performing a calibration involves making a transit time measurement using shear wave transducers on the calibration block. The measurement is then compared the known transit time of the calibration standard, $T^S_{standard}$, and the offset correction factor, T^s_{offset} (calibration factor), is calculated as shown in Equation 1. The measurement of the calibration block should occur using the first anti-node (valley) of the waveform. Calibration should be performed at the beginning of each measurement session. Drift in the system delay calculated by the calibration sample is allowable under the condition that the range of any ten consecutive calibration measurements shall be ≤0.15 µs. If the sample measures outside this range, duplicate the measurement N=5 times to ensure a repeatable system delay with a range of ≤0.10 µs. The total drift in system delay of the calibration sample shall not exceed 0.50 µs.

$$T^s_{offset} = T^s_{measured} - T^s_{standard} \quad \text{(Eq. 1)}$$

c. The offset correction factor is then subtracted from each subsequent transit time measurement to compensate for system delay. Once this offset value is confirmed, the system will be able to calculate the theoretical time-of-flight through the pressure plate of the brake pad, T^s_{plate}, which will be subtracted from the measured transit time $T^s_{measured}$ to yield the transit time through the friction material, $T^s_{friction}$, as shown in Equation 2.

$$T^s_{friction} = T^s_{total} - T^s_{offset} - T^s_{plate} \quad \text{(Eq. 2)}$$

$$T^s_{plate} = D_{plate}/V^s_{plate} \quad \text{(Eq. 3)}$$

Figure 2 shows the steel calibration block coupled between the two shear wave transducers. Because the steel is a linear ultrasonic material, the transit time is independent of the coupling load. For consistency, the transit time is measured using a coupling pressure of 5.27 MPa (700 N load over Ø13 mm sensor).

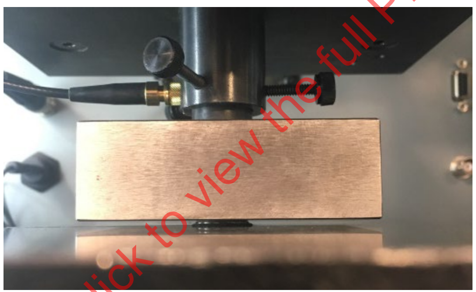

Figure 2 - Steel calibration block

6. SAMPLING AND PREPARATION

The brake pad is in finished condition with or without paint, with or without wear indicator or other hardware that does not interfere with sensor contact, without the presence of an insulating shim. Number of measurements per brake pad can vary depending on mold holes, chamfers, and slots with sensors at a minimum of 3 mm from any of these features. Average all of the measurements on a given pad for the final average modulus for a given brake pad. Typically, measurements per brake pad range from 2 to 4. Locating jigs should be used such that the measurement locations are the same location on a given brake pad.

6.1.1 System Calibration

Measure transit time on the standard calibration block. Then use Equation 1 to calculate the system delay, T^s_{offset}.

6.1.2 Depending upon the scope of the test plan, pads can be tested with or without anti-noise shims.

6.1.3 Measure total transit time through the finished brake pad at 700 N ± 20 N load, T^s_{total}, ensuring the first anti-node (valley) as shown on the receiver waveform is identified; see Figure 3. Manually adjust peak detection, if needed.

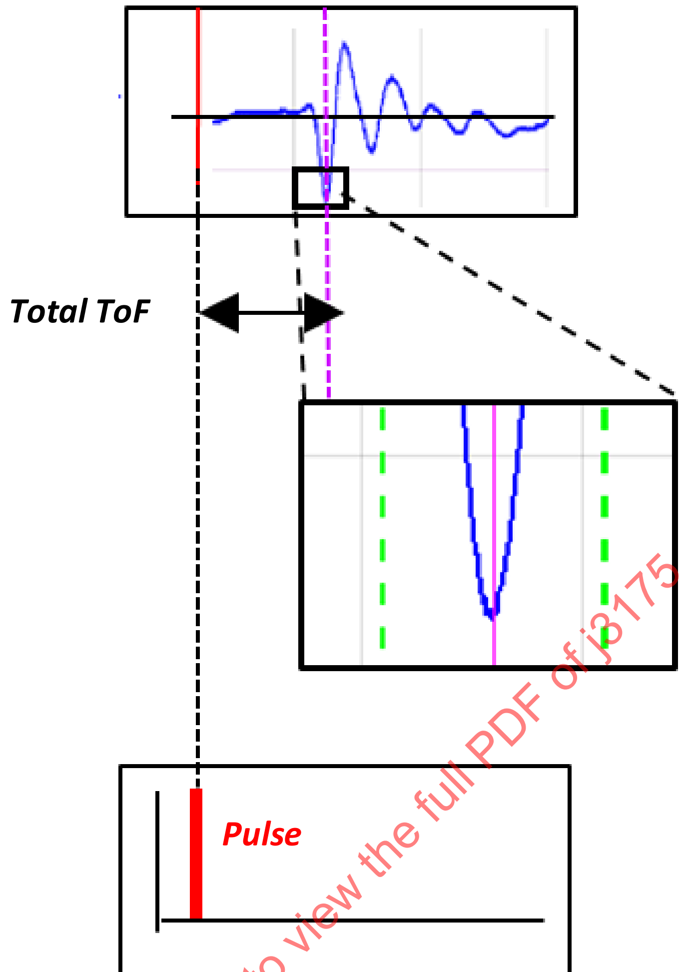

Figure 3 - Waveform time of flight illustration

6.1.4 Subtract the calibration offset, (T^{s}_{offset}), and transit time through the pressure plate, (T^{s}_{plate}), to calculate the transit time through the friction material, ($T^{s}_{friction}$), as shown in Equation 2.

6.1.5 Calculate the velocity of the wave through the friction material as shown in Equation 4.

$$V^{s}_{friction} = D_{friction} / T^{s}_{friction} \quad \text{(Eq. 4)}$$

6.1.6 Calculate the NECFM (Normalized Elastic Constant of Friction Material) as measured through shear wave sensors as shown in Equation 5.

$$NECFM = \rho_{normalized} \times V^{s^2}_{friction} \quad \text{(Eq. 5)}$$

7. CALCULATIONS AND TEST REPORT

a. Vehicle platform

b. Front or rear application

c. FMSI or WVA number, when applicable

d. Inboard or outboard identification

e. Manufacturer, identification of brake lining, material batch reference number

f. Number of samples measured and serialization of each

g. Design nominal pressure plate thickness (D_{plate}) of each sample

h. Density of each sample (constant for a given friction formulation)

i. Total thickness (D_{total}) of each measurement

j. Measured transit time through friction material ($T^{S}_{friction}$) of each measurement

k. Calculated NECFM for each measurement position

l. Average NECFM for each sample

m. Session calibration offset

n. Transducer frequency and serial number

o. Shear velocity in calibration block, calibrated system offset, steel velocity in pressure plate, ultrasonic pulse frequency rate, number of averages

Table 2 - Example data output

						Designations by Position							
						Position 1			Position 2			Summary	
Sample ID	#Positions	Target Load (N)	Steel Thickness (mm)	Shim Thickness (mm)	Density (kg/m3)	Total Thickness (mm)	ToF Friction Only (s)	NECFM (MPa)	Total Thickness (mm)	ToF Friction Only (s)	NECFM (MPa)	Avg Part Thickness (mm)	NECFM (MPa)
1	2	700	6.00	0.00	1	18.04	1.1000E-05	1198	18.07	1.0910E-05	1224	18.06	1211
2	2	700	6.00	0.00	1	18.09	1.1540E-05	1099	18.07	1.1430E-05	1115	18.08	1107
3	2	700	6.00	0.00	1	18.07	1.0870E-05	1233	18.08	1.0640E-05	1288	18.08	1261
4	2	700	6.00	0.00	1	17.92	1.0950E-05	1186	17.92	1.0980E-05	1179	17.92	1182
5	2	700	6.00	0.00	1	18.07	1.1020E-05	1199	18.05	1.1260E-05	1146	18.06	1172
6	2	700	6.00	0.00	1	18.07	1.1060E-05	1190	18.07	1.1190E-05	1164	18.07	1177
7	2	700	6.00	0.00	1	18.08	1.0850E-05	1240	18.08	1.1140E-05	1177	18.08	1208
8	2	700	6.00	0.00	1	18.08	1.1210E-05	1162	18.09	1.1440E-05	1116	18.09	1139
9	2	700	6.00	0.00	1	18.08	1.1300E-05	1143	18.06	1.0910E-05	1222	18.07	1183
10	2	700	6.00	0.00	1	18.09	1.1060E-05	1195	18.07	1.1370E-05	1127	18.08	1161
11	2	700	6.00	0.00	1	18.08	1.1130E-05	1178	18.08	1.0970E-05	1213	18.08	1196
12	2	700	6.00	0.00	1	18.09	1.1150E-05	1176	18.10	1.1140E-05	1180	18.10	1178
13	2	700	6.00	0.00	1	18.06	1.1290E-05	1141	18.06	1.1130E-05	1175	18.06	1158
14	2	700	6.00	0.00	1	18.07	1.1390E-05	1123	18.10	1.1380E-05	1130	18.09	1126
15	2	700	6.00	0.00	1	18.10	1.1440E-05	1119	18.11	1.1280E-05	1152	18.11	1135
16	2	700	6.00	0.00	1	18.04	1.0810E-05	1241	18.06	1.1700E-05	1063	18.05	1152
17	2	700	6.00	0.00	1	18.10	1.1410E-05	1124	18.09	1.1480E-05	1110	18.10	1117
18	2	700	6.00	0.00	1	18.09	1.1210E-05	1164	18.09	1.1250E-05	1156	18.09	1160
19	2	700	6.00	0.00	1	18.05	1.1340E-05	1130	18.07	1.1330E-05	1135	18.06	1132
20	2	700	6.00	0.00	1	18.10	1.1330E-05	1141	18.06	1.1720E-05	1059	18.08	1100
21	2	700	6.00	0.00	1	18.11	1.1480E-05	1114	18.10	1.1520E-05	1104	18.11	1109
22	2	700	6.00	0.00	1	18.05	1.1120E-05	1174	18.05	1.1360E-05	1124	18.05	1149
23	2	700	6.00	0.00	1	18.09	1.1310E-05	1142	18.07	1.1600E-05	1083	18.08	1113
24	2	700	6.00	0.00	1	17.94	1.1020E-05	1173	17.95	1.0990E-05	1182	17.95	1178
25	2	700	6.00	0.00	1	18.09	1.1350E-05	1134	18.01	1.1300E-05	1131	18.05	1132

8. NOTES

8.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

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