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SURFACE FRICTION
CHARACTERISTICS OF
SILICONE RUBBER PADS

BDX-613-447

July, 1971

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Interim Report

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ABSTRACT

Frictional force between silicone rubber pads and flat ground steel increases with normal force, is not affected by the rate at which the opposing force is applied (for rates below 20.0 inches per minute), has a lower dynamic than static value, and does not vary significantly with vendor material lots.

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SUMMARY

A test method was developed to determine variations in surface friction characteristics of silicone rubber pads. Test pads were compressed between parallel steel plates that had been flat ground to a surface finish of approximately 32 microinches. A shear force directed parallel to the surface under compression was applied to the steel plates at a known rate. The magnitude of the shear force as a function of plate movement at constant rate leads to the following conclusions about the frictional resistance force, F , related to plate movement at the test pad surface.

F increases with compressive force.

F increases to a peak (static) value before decreasing to a lower (dynamic) value that remains fairly constant with continued plate movement.

F is not affected by the rate of movement of the plates for low rates.

F does not vary significantly with vendor material lots.

To determine the coefficient of friction of silicone rubber cushions, LRL had previously investigated variables such as pad thickness, compressive force, relative humidity during testing, adjacent surface finish, and adjacent surface material. Results showed that the surface finish and composition of the adjacent material significantly affected the coefficient, but the relative humidity and test pad thickness had no measurable effect.

Product acceptance testing to surface friction requirements will continue on cellular silicone D-test parts. Future test work, pending equipment availability, will include tests at constant shear force. Tests similar to those performed on cellular silicone may be done on RTV materials (polysiloxane flexible foams) which are used in similar types of applications.

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DISCUSSION

SCOPE AND PURPOSE

LRL Weapons Division proposed the development of test methods to determine the lot-to-lot variation in surface friction characteristics of silicone rubber pads.

Development and preliminary testing has been completed with funding from Process Development Order 6984549.

PRIOR WORK

Work has been done at LRL to determine the coefficient of friction of silicone rubber cushions (LRL report number WDIV 71-006). Variables investigated were pad thickness, compressive force, relative humidity during testing, adjacent surface finish, and adjacent surface material. In the investigation, a sled of 1-square-inch surface area, covered with the silicone rubber test sample, was caused to slip across a test surface by the application of a load through the center of gravity of the sled and parallel to the test surface. Results indicated that the surface finish and composition of the adjacent material significantly affected the coefficient. The relative humidity and test pad thickness had no measurable effect.

ACTIVITY

Cellular silicone test pads were installed in a test fixture to provide for the application of a shear force at a calibrated rate to the compressed surface of the pad. Figure 1 is a sketch of the test fixture showing sample positioning for a test. Various sample thicknesses can be tested at desired gaps by altering the dimensions of the fixture.

The test fixture was designed for adaptation to a Tinius-Olsen test machine (BKC 18869) used in production inspection area 442/34E (Figure 2). After preliminary tests, a standard test procedure (Appendix A) was established. Shear force application rate may be varied between 0.025 and 20.0 inches per minute. The machine records shear force magnitude as a function of test assembly elongation in inches. The first 1/2 pound of force is applied as fixture weight and is not automatically recorded.

Figure 3 is a sketch of a test assembly cross-section. Section A moves relative to Section B at a preset rate. The sum of the frictional resistance forces acting in one direction is equal to the applied force acting in the opposite direction.

Figure 1. Friction Test Fixture

Figure 2. Test Assembly Installation in
Tinius-Olsen Machine

Figure 3. Test Assembly Cross-Sectional View

$$F_I = F_1 + F_4 = F_2 + F_3$$

At some point during loading, movement of the test sample relative to the fixture plate occurs. Movement may occur at any of the following combinations of interfaces:

- (1) F_1, F_4
- (2) F_1, F_3
- (3) F_2, F_3
- (4) F_2, F_4
- (5) F_1, F_2, F_3
- (6) F_1, F_2, F_4
- (7) F_1, F_3, F_4
- (8) F_2, F_3, F_4
- (9) F_1, F_2, F_3, F_4

The frictional resistance force reaches a peak (static) value just before movement of the test sample relative to the flat plate; thereafter, it diminishes slightly, to about 95-percent of the peak value, and assumes a fairly constant (dynamic) value for the remainder of the test (Appendix B). Depending upon the interfaces at which movement occurs, the frictional forces resisting the applied force may be all dynamic or a combination of static and dynamic. If movement occurs at interface combinations (1), (2), (3), or (4), the rate of movement of the pad surface across the plate surface is equal to the rate at which the force is applied. Movement at interface combinations (5), (6), (7), (8), or (9) would occur at an indeterminate rate not to exceed the rate at which the force is applied.

Results of tests conducted on cushioning materials simulating assembly conditions (Appendix C) indicate that the frictional resistance force:

1. Increases with the degree of compression to which the pads are subjected;
2. Reaches a peak (static) value before decreasing to a lower dynamic value that remains fairly constant with continued plate movement;
3. Is not affected by the rate of movement of the plates for low rates (up to 20 inches per minute);
4. Does not vary with vendor material lots; and
5. Is dependent upon pad surface treatment.

ACCOMPLISHMENTS

A method to determine the surface friction properties of silicone rubber pads was developed, and test work was done on pads at simulated assembly conditions. Determination of cellular silicone lot-to-lot variation in surface friction characteristics was the primary objective of the testing. Eight material lots were comparatively tested. No significant surface friction property variation between lots was detected.

Interesting findings beyond the objective of the work included the effects of force application rate, test gap, and pad surface treatment on frictional properties. Limited tests on polysiloxane (RTV) flexible foams were performed. All test results are in Appendix C.

FUTURE WORK

Product acceptance testing to surface friction requirements is being conducted on cellular silicone D-test parts. Frictional testing is expected to continue to be a product acceptance criterion.

Available test capability does not permit the application of a constant load in the desired range. Future test work, pending equipment availability, will include tests at constant shear force.

Appendix A

FRICTION TEST PROCEDURE

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Appendix A

FRICITION TEST PROCEDURE

Re: KCD 660 No. _____

1. Using the 1-3/4-inch by 3/4-inch plexiglass trim template and blade, trim out Friction Coupons as specified on the referenced 660. Where possible, trim the Coupons from part locations that are uniform in thickness and/or surface appearance.
2. Measure the Coupons for thickness as they are cut. Record the Coupon thickness on a pressure sensitive label and mark the label in the same manner as the identification of the piece from which the Coupon was taken. Affix the label to a 2- by 3-inch poly bag and maintain the Coupons in the appropriate poly bag without excessive stacking or restriction until Step 3.
3. If more than one pair of Coupons have been taken from a piece, pair the Coupons so that the sums of the thicknesses of the individual Coupon pairs are as equal as possible.
4. Assemble the Coupon pair from Step 3 in the Friction Test Assembly, one Coupon on each side of the Tongue. Use the Spacer as specified on the referenced 660.
5. Place the Assembly in the T-0 with the Spacer in the Upper Adapter and the Slide in the Lower Adapter. Use the spring-held Lower Adapter.
6. Zero the pen with no load. (Note: 0.5 pound should be added to the readings to compensate for the weight of the Tongue.)
7. Use the following T-0 settings.
  - a. Scale: 120 pounds.
  - b. Range: 1/2.
  - c. Deflection: 0.020 = 1 inch.
  - d. Speed: 0.050 inch per minute.
8. Label each load curve with all necessary test condition and Coupon identification for the sample it represents. Save the Coupons for Engineering disposition.

Appendix B

REPRESENTATIVE TEST CURVES

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Figure B-1. Applied Force as a Function of Assembly Elongation: Y-3333 Cellular Silicone
0.045-Inch-Thick Pads

Figure B-2. Applied Force as a Function of Assembly Elongation: Y-3333 Cellular Silicone
0.060-Inch-Thick Pads

Figure B-3. Applied Force as a Function of Assembly Elongation: Y-3260 Cellular Silicone
0.082-Inch-Thick Pads

Appendix C

TEST CONDITIONS AND RESULTS

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Figure C-1. Frictional Force as a Function of Force Application Rate: Y-3333 Cellular Silicone 0.060-Inch Nominal Thickness Test Pads

Figure C-2. Frictional Force as a Function of Compressed Thickness: Y-3333 Cellular Silicone 0.060-Inch Nominal Thickness Test Pads

Table C-1. Test Conditions and Results

Material	Batch Number	Test Pad Thickness (Inches)	Compressed Thickness (Inches)	Test Pad Surface Treatment	Test Speed (in./min)	Number of Tests	Test Assembly Elongation, Average (Inches)	Frictional Force, Average (psi)	
								Static (Peak)	Dynamic
Y-3333	G-14-1	0.065	0.044	None	0.050	3	-----	2.7	----
Y-3333	G-14-1	0.065	0.036	None	0.050	3	-----	4.7	----
Y-3333	G-14-1	0.065	0.044	Talc	0.050	4	0.009	0.6	0.5
Y-3333	G-14-1	0.065	0.036	Talc	0.050	6	0.012	1.5	1.3
Y-3333	F-5-1	0.062	0.044	None	0.050	6	0.0290	2.8	2.7
Y-3333	F-5-1	0.062	0.036	None	0.050	3	0.0340	4.0	3.9
Y-3333	F-15-1	0.062	0.044	None	0.050	3	0.0313	2.7	2.7
Y-3333	F-15-1	0.062	0.036	None	0.050	3	0.0390	4.0	3.9
Y-3333	F-19-1	0.062	0.044	None	0.050	3	0.0327	2.6	2.6
Y-3333	F-19-1	0.062	0.036	None	0.050	3	0.0430	4.0	3.9
Y-3333	G-1-1	0.062	0.044	None	0.050	3	0.0320	2.7	2.6
Y-3333	G-1-1	0.062	0.036	None	0.050	3	0.0390	3.7	3.6
Y-3333	G-14-1	0.062	0.044	None	0.050	3	0.0327	2.7	2.6
Y-3333	G-14-1	0.062	0.036	None	0.050	3	0.0380	3.8	3.7
Y-3333	H-3-1	0.062	0.044	None	0.050	3	0.0327	2.2	2.2
Y-3333	H-3-1	0.062	0.036	None	0.050	3	0.0380	3.5	3.4
Y-3333	H-7-1	0.062	0.044	None	0.050	3	0.0300	2.6	2.5
Y-3333	H-7-1	0.062	0.036	None	0.050	3	0.0460	3.8	3.8
Y-3333	I-15-1	0.062	0.044	None	0.050	3	0.0307	2.3	2.3

Table C-1 Continued. Test Conditions and Results

Material	Batch Number	Test Pad Thickness (Inches)	Compressed Thickness (Inches)	Test Pad Surface Treatment	Test Speed (in. /min)	Number of Tests	Test Assembly Elongation, Average (Inches)	Frictional Force, Average (psi)	
								Static (Peak)	Dynamic
Y-3333	I-15-1	0.062	0.036	None	0.050	3	0.0380	3.5	3.4
Y-3333	G-14-1	0.062	0.044	None	0.025	3	0.0280	2.7	2.6
Y-3333	I-15-1	0.062	0.044	None	0.100	3	0.0270	2.3	2.2
Y-3333	G-14-1	0.062	0.036	None	0.025	3	0.0350	3.8	3.8
Y-3333	I-15-1	0.063	0.036	None	0.100	3	0.0380	3.6	3.7
Y-3333	F-5-1	0.063	0.036	None	0.050	3	0.0330	3.8	3.7
Y-3333	L-11-1	0.061	0.044	None	0.050	4	0.0293	3.4	3.4
Y-3333	L-11-1	0.061	0.037	None	0.050	3	0.0330	4.3	4.2
Y-3333	L-11-1	0.061	0.036	None	0.050	4	0.0310	4.9	4.8
Y-3333	L-11-1	0.061	0.033	None	0.050	3	0.032	5.6	5.4
Y-3333	L-11-1	0.061	0.044	None	0.100	1	0.032	3.7	3.6
Y-3333	L-11-1	0.061	0.036	None	0.100	1	0.040	5.4	5.3
Y-3333	L-11-1	0.061	0.044	None	0.200	1	0.030	3.3	3.2
Y-3333	L-11-1	0.061	0.036	None	0.200	1	0.030	5.1	5.1
Y-3333	L-11-1	0.061	0.044	None	0.300	1	0.028	3.1	3.0
Y-3333	L-11-1	0.061	0.036	None	0.300	1	0.032	5.3	5.1
Y-3333	L-11-1	0.061	0.044	None	0.500	1	0.028	3.4	3.3
Y-3333	L-11-1	0.061	0.036	None	0.500	1	0.028	5.3	5.0
Y-3333	L-11-1	0.061	0.044	None	1.00	1	0.026	3.6	3.4

Table C-1 Continued. Test Conditions and Results

Material	Batch Number	Test Pad Thickness (Inches)	Compressed Thickness (Inches)	Test Pad Surface Treatment	Test Speed (in./min)	Number of Tests	Test Assembly Elongation, Average (Inches)	Frictional Force, Average (psi)	
								Static (Peak)	Dynamic
Y-3333	L-11-1	0.061	0.036	None	1.00	1	0.036	5.3	5.1
Y-3333	L-11-1	0.061	0.044	None	2.00	1	0.032	3.5	3.4
Y-3333	L-11-1	0.061	0.036	None	2.00	1	0.040	5.5	5.3
Y-3333	L-11-1	0.061	0.044	None	10.00	1	0.026	4.0	3.8
Y-3333	L-11-1	0.061	0.036	None	10.0	1	0.038	5.9	5.7
Y-3333	L-11-1	0.061	0.044	None	20.0	1	0.032	4.0	4.1
Y-3333	L-11-1	0.061	0.036	None	20.0	1	0.040	5.5	5.4
Y-3333	L-3-1	0.060	0.044	None	0.050	3	0.030	2.9	2.9
Y-3333	L-3-1	0.060	0.037	None	0.050	3	0.033	3.9	3.8
Y-3333	L-3-1	0.060	0.035	None	0.050	3	0.033	4.5	4.4
Y-3333	L-3-1	0.060	0.033	None	0.050	3	0.034	5.2	5.1
Y-3333	L-3-1	0.045	0.033	None	0.050	3	0.023	2.3	2.2
Y-3333	L-3-1	0.045	0.022	None	0.050	3	0.025	6.0	5.8
Y-3333	N-18-1	0.045	0.033	None	0.050	3	0.020	2.6	2.4
Y-3333	N-18-1	0.045	0.022	None	0.050	3	0.029	6.3	6.0
Y-3333	N-18-1	0.048	0.024	None	0.050	3	0.033	6.6	6.5
Y-3333	N-18-1	0.048	0.027	None	0.050	3	0.025	2.5	2.3

Table C-1 Continued. Test Conditions and Results

Material	Batch Number	Test Pad Thickness (Inches)	Compressed Thickness (Inches)	Test Pad Surface Treatment	Test Speed (in. /min)	Number of Tests	Test Assembly Elongation, Average (Inches)	Frictional Force, Average (psi)	
								Static (Peak)	Dynamic
Y-3333	L-3-1	0.048	0.024	None	0.050	3	0.022	5.5	5.0
Y-3333	L-3-1	0.048	0.037	None	0.050	3	0.021	2.3	2.1
Y-3260	L-15-1	0.082	0.071	None	0.050	2	0.019	4.0	4.0
Y-3260	L-15-1	0.082	0.051	None	0.050	2	0.032	9.6	9.3
Y-3260	L-15-1	0.083	0.071	None	0.050	2	0.019	4.2	4.2
Y-3260	L-15-1	0.083	0.051	None	0.050	2	0.029	8.7	8.6
Y-3260	L-15-1	0.089	0.051	Soap and	0.050	6	0.048	14.8	13.5
Y-3260	L-15-1	0.089	0.071	D.I. Scrub	0.050	6	0.035	8.1	7.6
RTV	L-15-1	0.095	0.051	None	0.050	2	0.093	13.7	13.0
RTV	L-15-1	0.095	0.071	None	0.050	2	0.053	7.9	8.1

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