NCHRP 12-68

FY 2004

Rotational Limits for Elastomeric Bearings

Final Report

APPENDIX A

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APPENDIX A TEST DATA

This appendix contains the data summary from each test. The tests can be broken into three groups, for each of which the data presented is slightly different. Each specimen has a test number (e.g. CYC5), which describes the loading, followed by a specimen number (e.g. A2), which defines the manufacturer (A, B, C or D) and the batch number (1 or 2). Details are given in the bearing test matrix, Chapter 2, Table 2-2.

A.1 Tests PMI 1a through PMI 1d.

The PMI series was intended to provide data points for the creation of Axial force-Moment Interaction curves. The PMI 1 series were all tested under the 2400 kip Baldwin Universal Test Machine, and were subjected to high average axial stresses (up to 12 ksi). In some cases a tapered plate was used to impose rotation as well. The rotation could not be cycled independently of the axial load.

Each result is presented on a single page, which shows a numerical summary of the data, and an axial force-displacement plot. The numerical summary contains the bearing properties (gross dimensions, etc.), the test regime (axial stress, rotation, etc.) and the results. The results are subdivided into the debonding history and the shim fracture history, if any. The debonding history records the total length of shim over which debonding occurred on the long edges. The maximum is 2 shims * 2 edges * 22 inches each = 88 inches. Debonding could only be detected o the center two shims, because holding plates from the rig obscured the outer two. The holding plates were needed to prevent the bearing from slipping out of place.

A.2 Tests PMI 4 through PMI 5.

These specimens were subjected to a single slow cycle of rotation (referred to as monotonic rotation) plus a constant axial load. To achieve this they were tested in the rotation rig, which has an absolute maximum axial capacity of 800 kips. The stresses are therefore smaller than those reached in the PMI 1 series.

The numerical data summary is similar to that presented for the PMI 1 series. Because debonding occurred on the compression side of the bearing, and a complete cycle of rotation was imposed, debonding during the positive and negative parts of the rotation cycle are recorded separately (i.e. they occurred on different sides of the bearing). Debonding progressed during the loading quarter cycles but not during the unloading quarter cycles. The next two pages for each PMI 4 and 5 test show the history of the bulge heights as a function of rotation angle. The bulge height for each of the three layers is given separately.

A.3 Cyclic Tests (CYC, SHR, MAT, SHF, ASR, PLT series)

For each of the cyclic tests of the CYC and other series, two pages of summary data are presented. The first sheet contains the numerical summary and three plots. The second page shows the bulge height history.

The numerical data summary contains the specimen data and the loading regime, as for the two previous series. However, the debonding is expressed as a percentage of the full length, because in some cases the bearings were not the standard size of 22" x 9". The debonding is also related to the cycle count. Because both debonding and readings occurred at irregular times, the results from each test were interpolated to provide cycle counts at fixed debonding "milestones" of initial, 25%, 50%, 75% and 100% debonded. The rotational stiffness of the bearings was also measured at different times throughout the test, and the initial and final values are presented. Because the true response was slightly hysteretic, an equivalent elastic stiffness was obtained by fitting a straight line to two cycles of data, using a least squares technique. The theoretical rotational stiffness value from the Linear Model is also provided. It used a G modulus that was based on the hardness supplied by the manufacturer. The shear strains due to the constant axial load and cyclic rotations were calculated from the Linear Model and are given as well. Finally the energy dissipated per cycle (EDC) and the Equivalent Viscous Damping (EVD) were obtained from the properties of the hysteresis loops.

Similar data are given in graphical form. The first plot, (a), shows the debonding history (expressed as an absolute length vs. cycle count). Separate curves show the progression on the top and bottom of the bearing. Plot (b) shows the moment-rotation relationship for the initial and final cycles. Plot (c) shows the variation with cycling of the rotational stiffness, the EDC and the EVD, each normalized with respect to the initial value. In many cases, sudden jumps in the plot (c) curves can be seen. These represent pauses in the testing for taking photos or bulge height readings, and in some cases overnight, during which the elastomer recovered some of the stiffness and other properties that had been temporarily lost during cycling. This issue is discussed in more detail in Appendix D.

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A.4 PMI Series

PMI1a-A2

Debonding	
0 psi	0 in
4200	2
5400	4
6000	6
6600	8
7200	13
7800	50
9000	80

Shim Fracture	
10100 psi	1st shim
10900	2nd

Test Properties	
Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

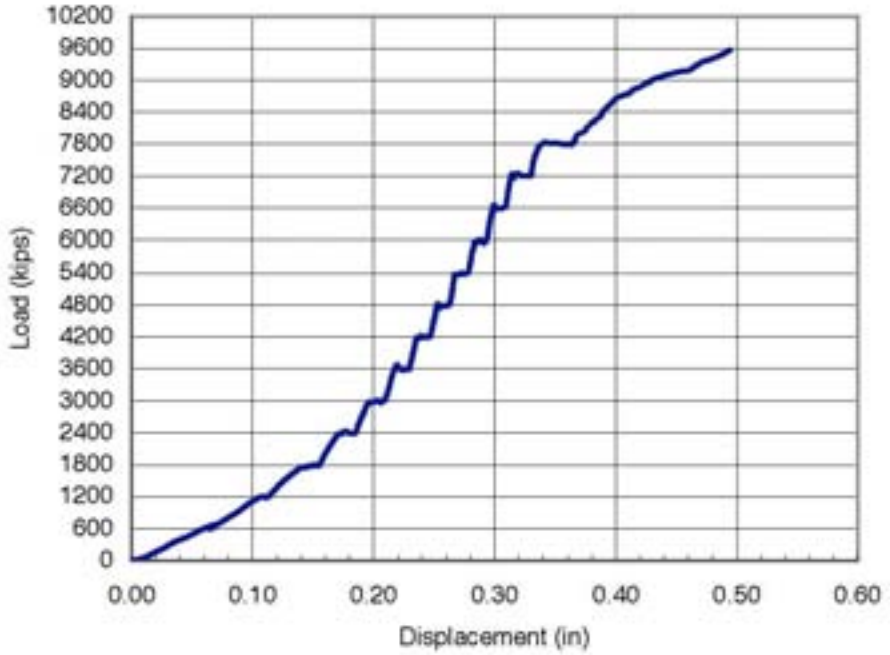


Figure A.1: Test PMI1a-A2 Summary

PMI1a-B1

Debonding

0 psi	0 in
7200	0

Shim Fracture

11900 psi	1st shim
6100	2nd
9100	3rd

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

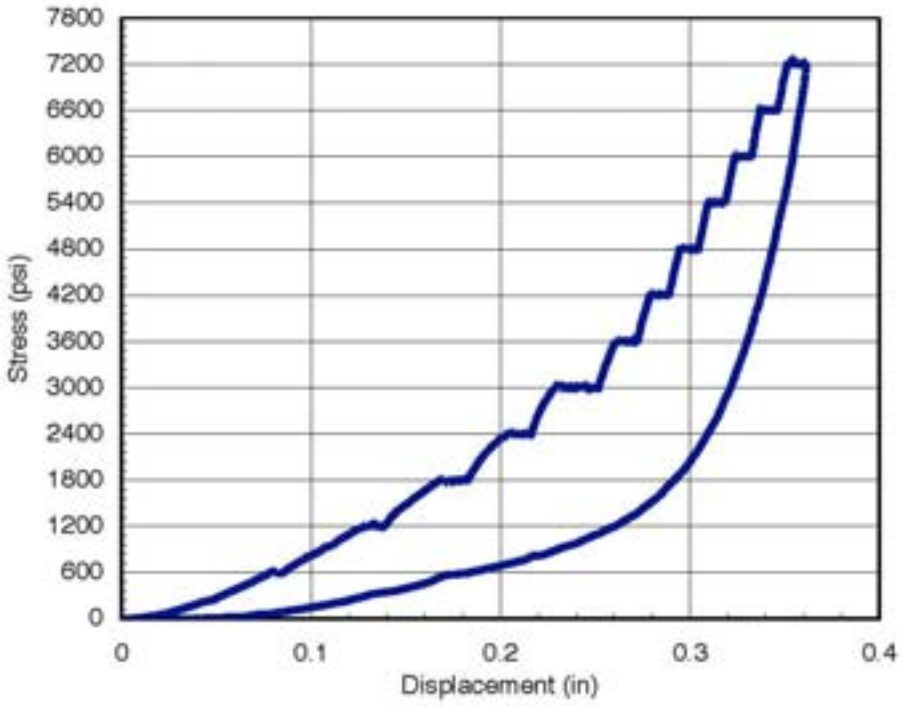


Figure A.2: Test PMI1a-B1 Summary

PMI1a-C1

Debonding

0 psi	0
7800	8

Shim Fracture

none

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

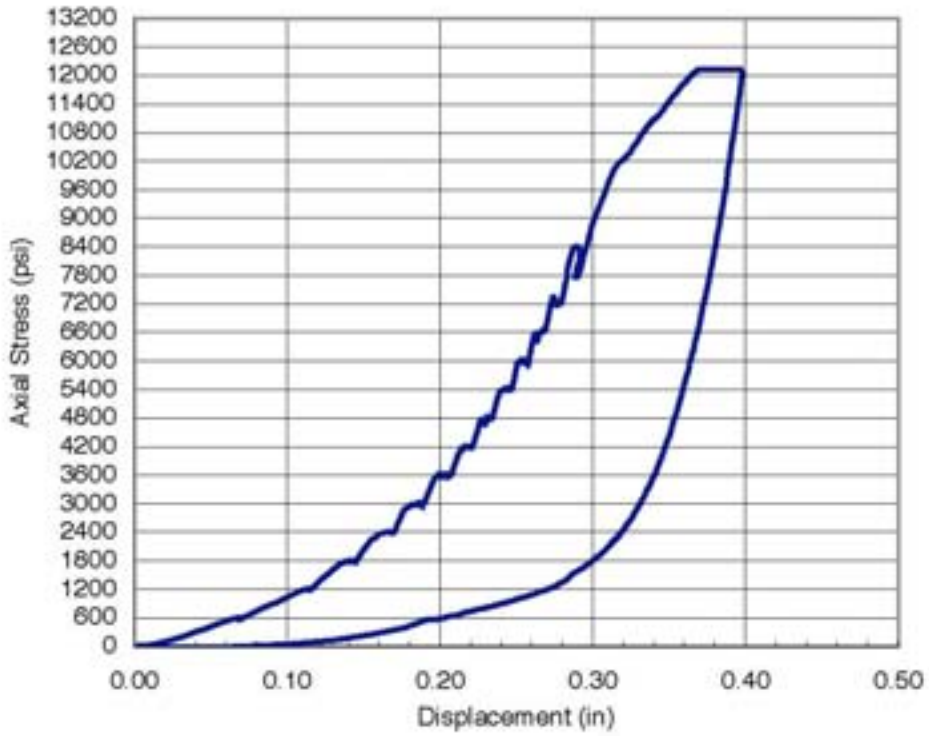


Figure A.3: Test PMI1a-C1 Summary

PMI1a-D1

Debonding
none

Shim Fracture
none

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

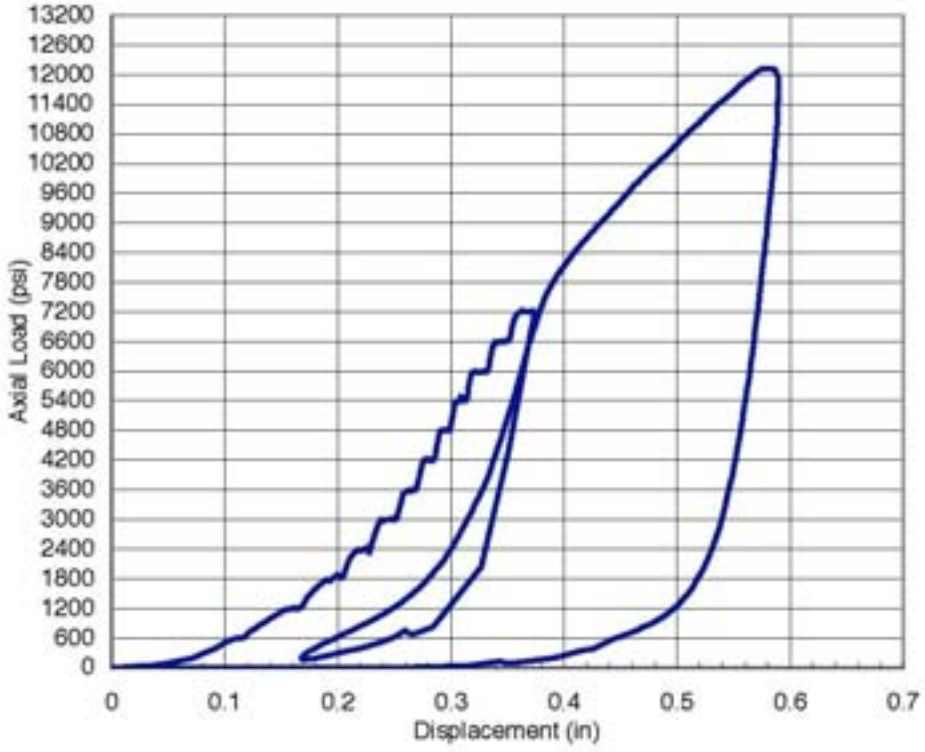


Figure A.4: Test PMI1a-D1 Summary

PMI1b-A2

Debonding	
Cycle 1	0 in
4	2
5	10
6	16
7	18
9	22
10	23
11	28
12	29
14	35
15	46
16	49
17	56
19	62
20	67

Test Properties	
Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Shim Fracture
none

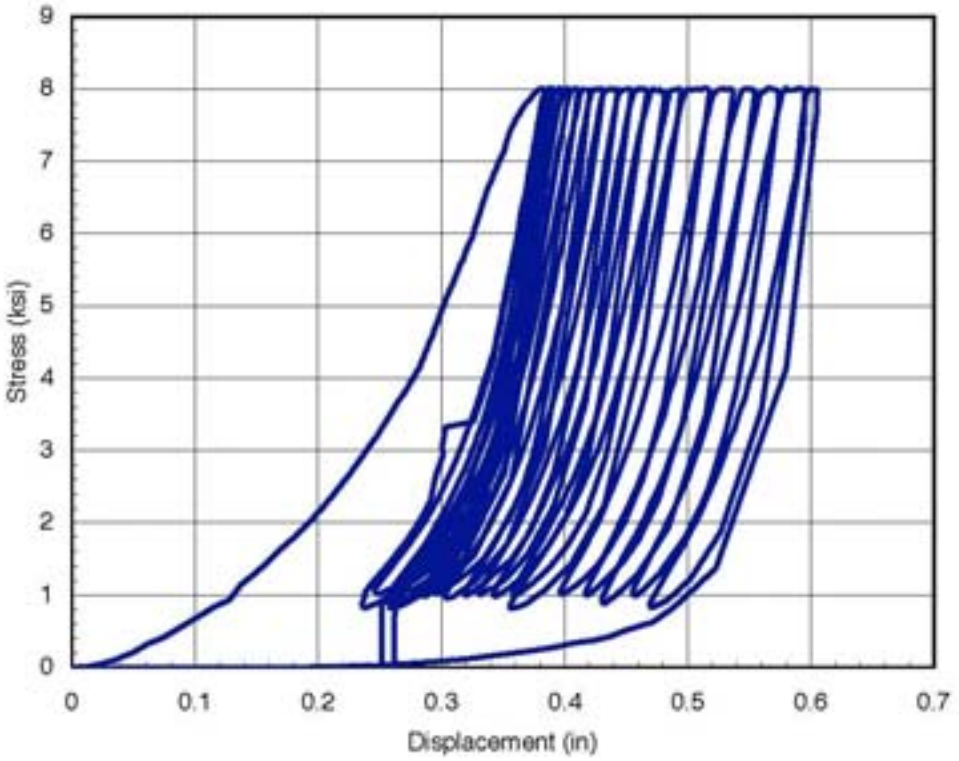


Figure A.5: Test PMI1b-A2 Summary

PMI1b-B1

Debonding

1 cycle	0 in
3	12
4	27
5	40
30	40

Shim Fracture

none

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

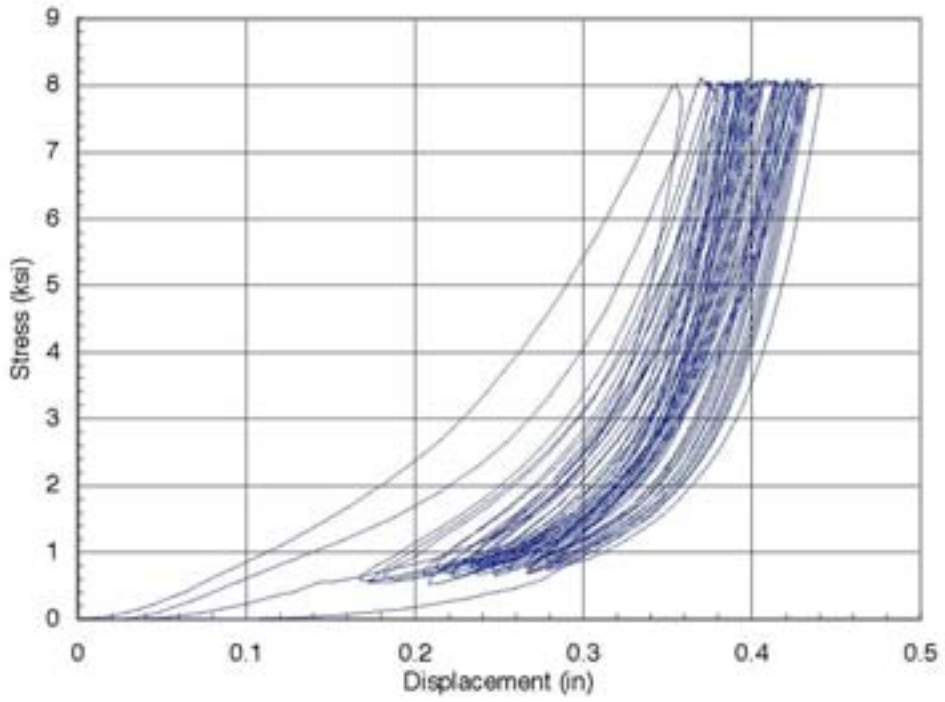


Figure A.6: Test PMI1b-B1 Summary

PMI1b-C1

Debonding	
1 cycle	0 in
2	0.5
4	1
6	1.5
7	2.5
8	6.5
9	8.5
11	14.5

Shim Fracture
none

Test Properties	
Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

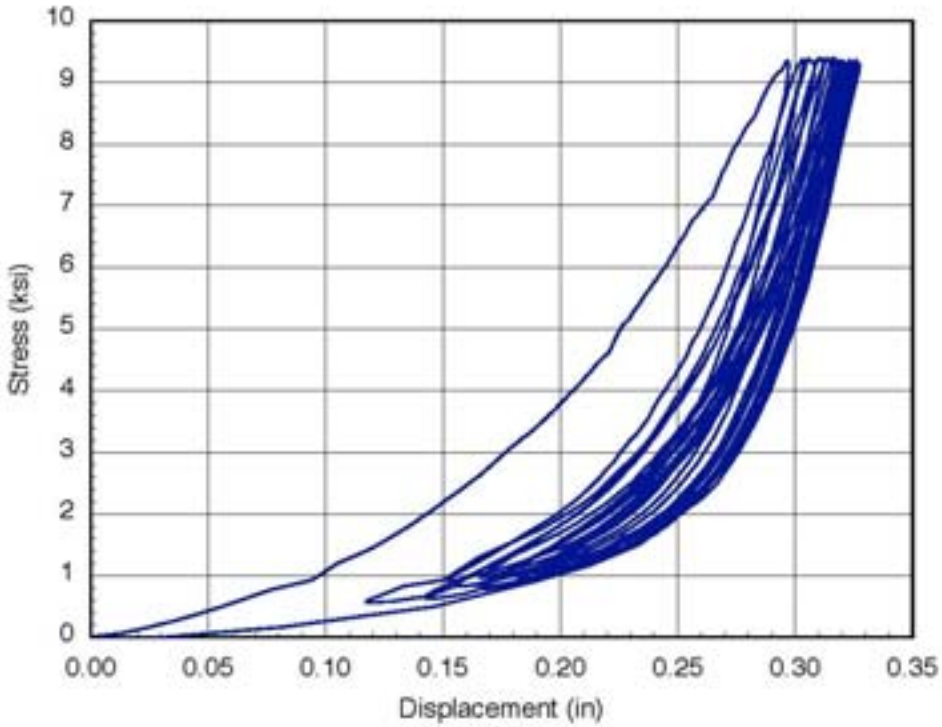


Figure A.7: Test PMI1b-C1 Summary

PMI1b-D1

Debonding

1 cycle	0 in
5	6
8	9
10	13
11	16
13	21

Shim Fracture

none

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

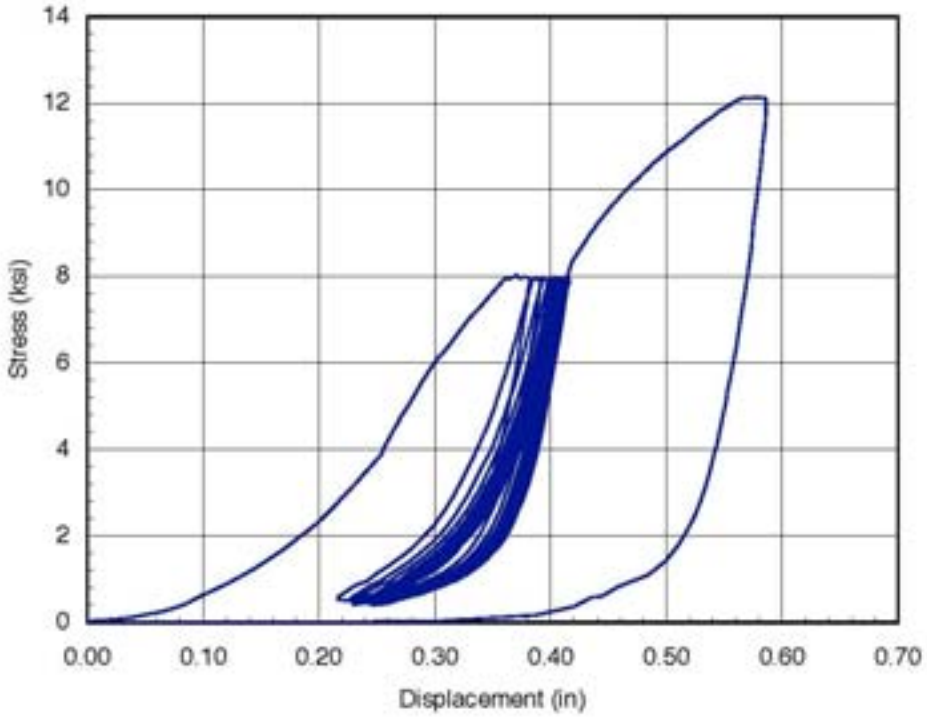


Figure A.8: Test PMI1b-D1 Summary

PMI1c-A2

Debonding	
0 psi	0 in
8100	6
11100	40

Shim Fracture
none

Test Properties	
Axial Stress	Varies
Static Rotation	0.04 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Load-displacement curve unavailable

Figure A.9: Test PMI1c-A2 Summary

PMI1c-B1

Debonding

0 psi	0 in
8100	6
11100	40

Shim Fracture

none

Test Properties

Axial Stress	Varies
Static Rotation	0.04 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

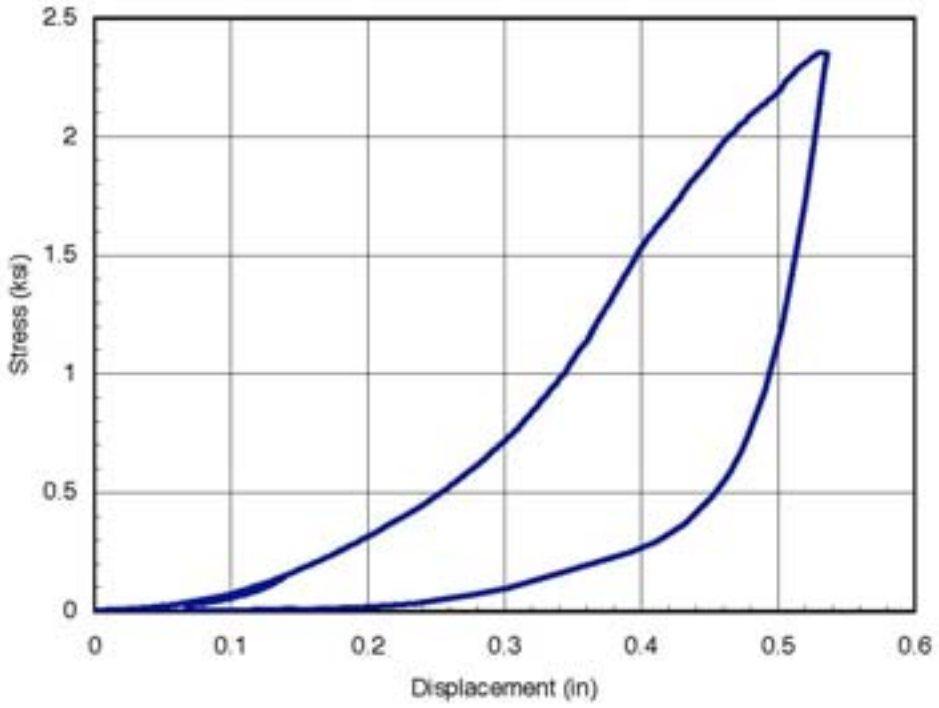


Figure A.10: Test PMI1c-B1 Summary

PMI1d-A2

Debonding	
1 cycle	0 in
2	8
3	15
4	22
6	22

Shim Fracture
none

Test Properties	
Axial Stress	Varies
Static Rotation	0.04 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

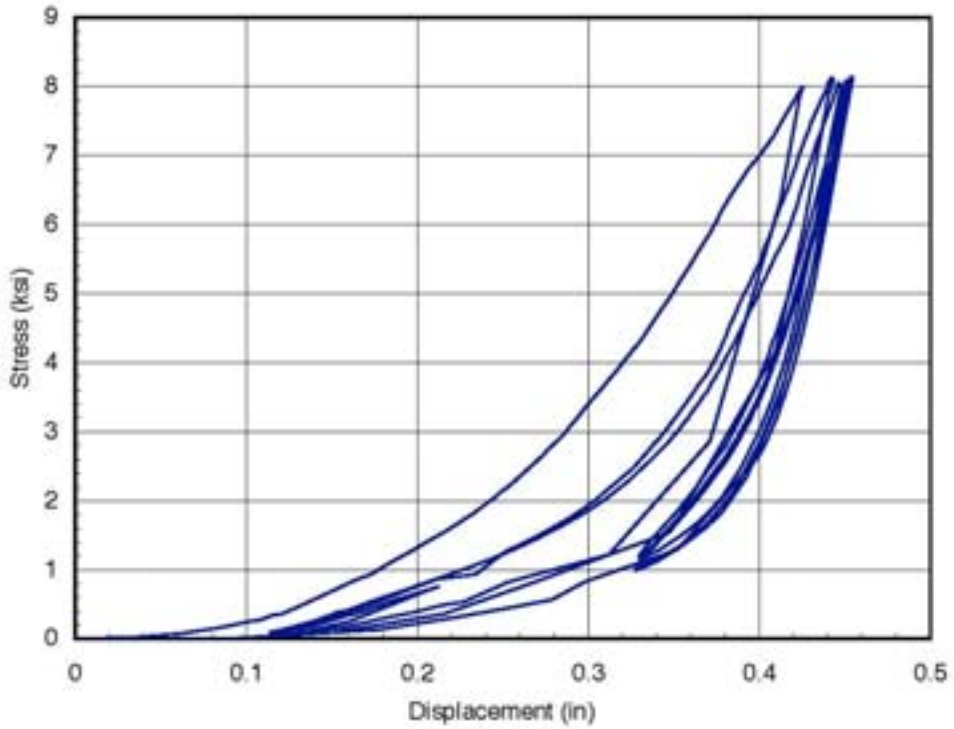


Figure A.11: Test PMI1d-A2 Summary

PMI1d-B1

Debonding	
1 cycle	16 in
2	21
3	24
6	25

Test Properties	
Axial Stress	Varies
Static Rotation	0.04 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Shim Fracture
none

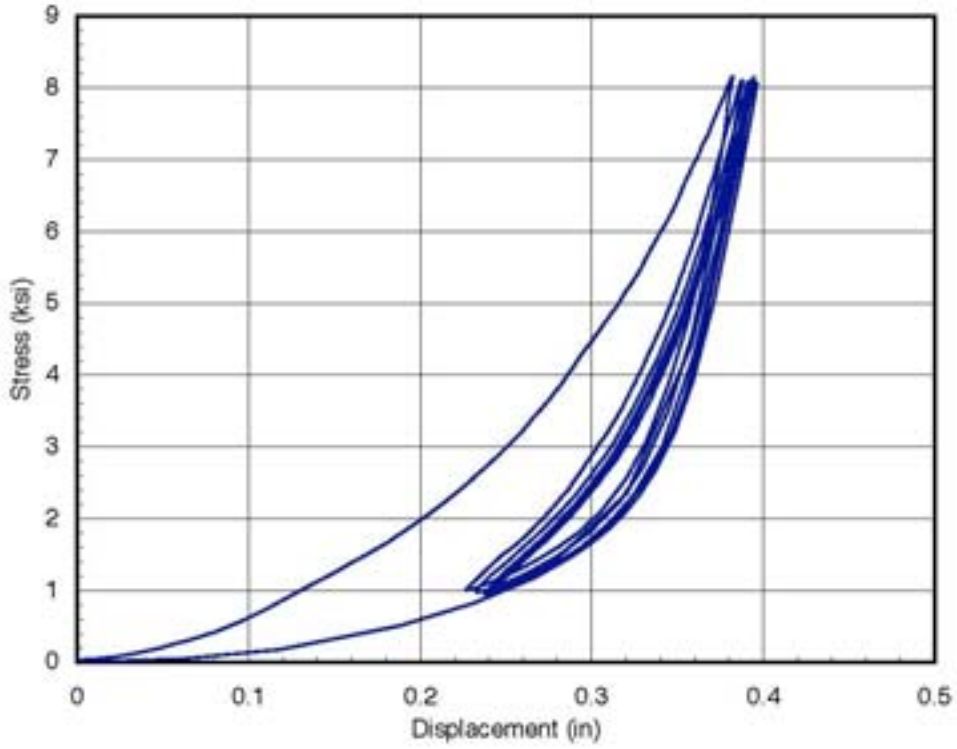


Figure A.12: Test PMI1d-B1 Summary

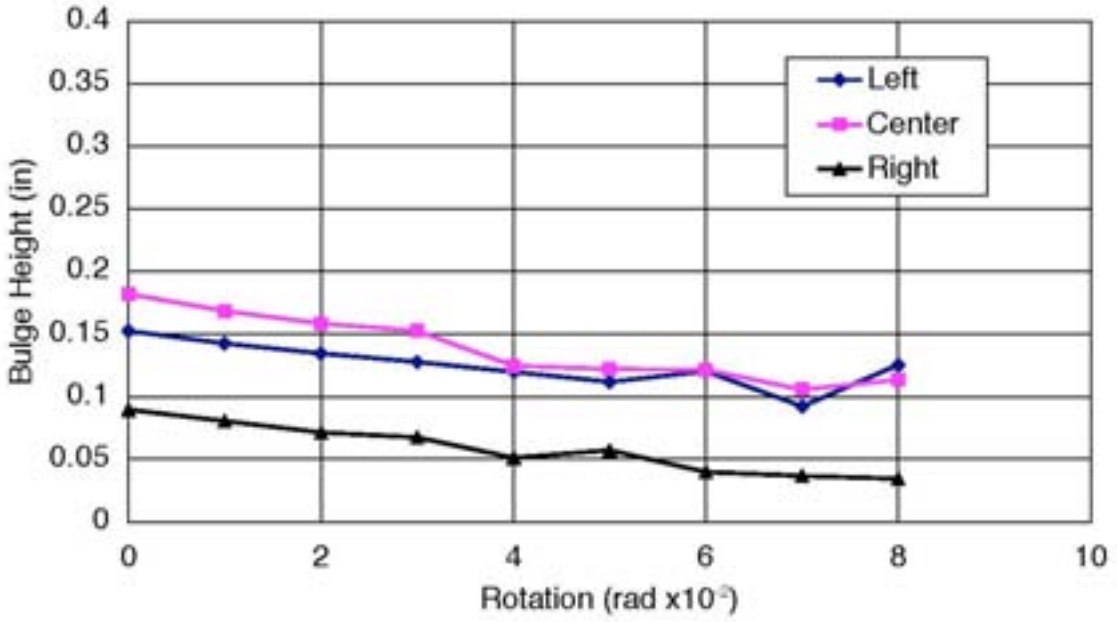
PMI4-A2

Debonding	
0 rad	0 in
0.06	0.5
0.07	1
-0 rad	1 in
-0.02	1.5
-0.03	6.5
-0.05	15.5
-0.08	35.5

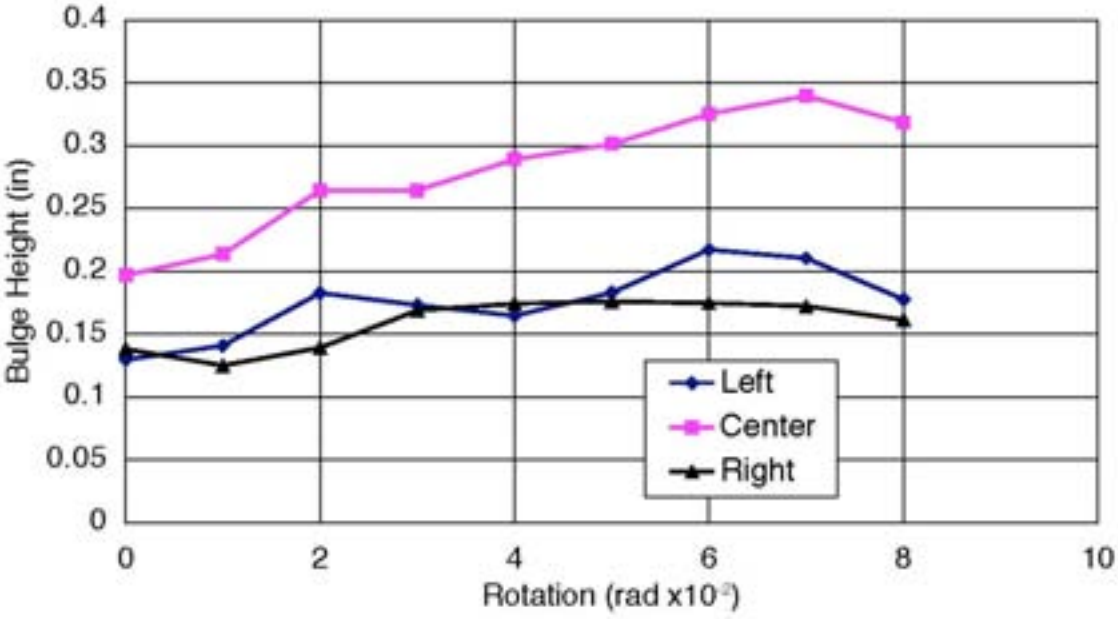
Test Properties	
Axial Stress	3GS = 1800 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Figure A.13: Test PMI4-A2 Summary

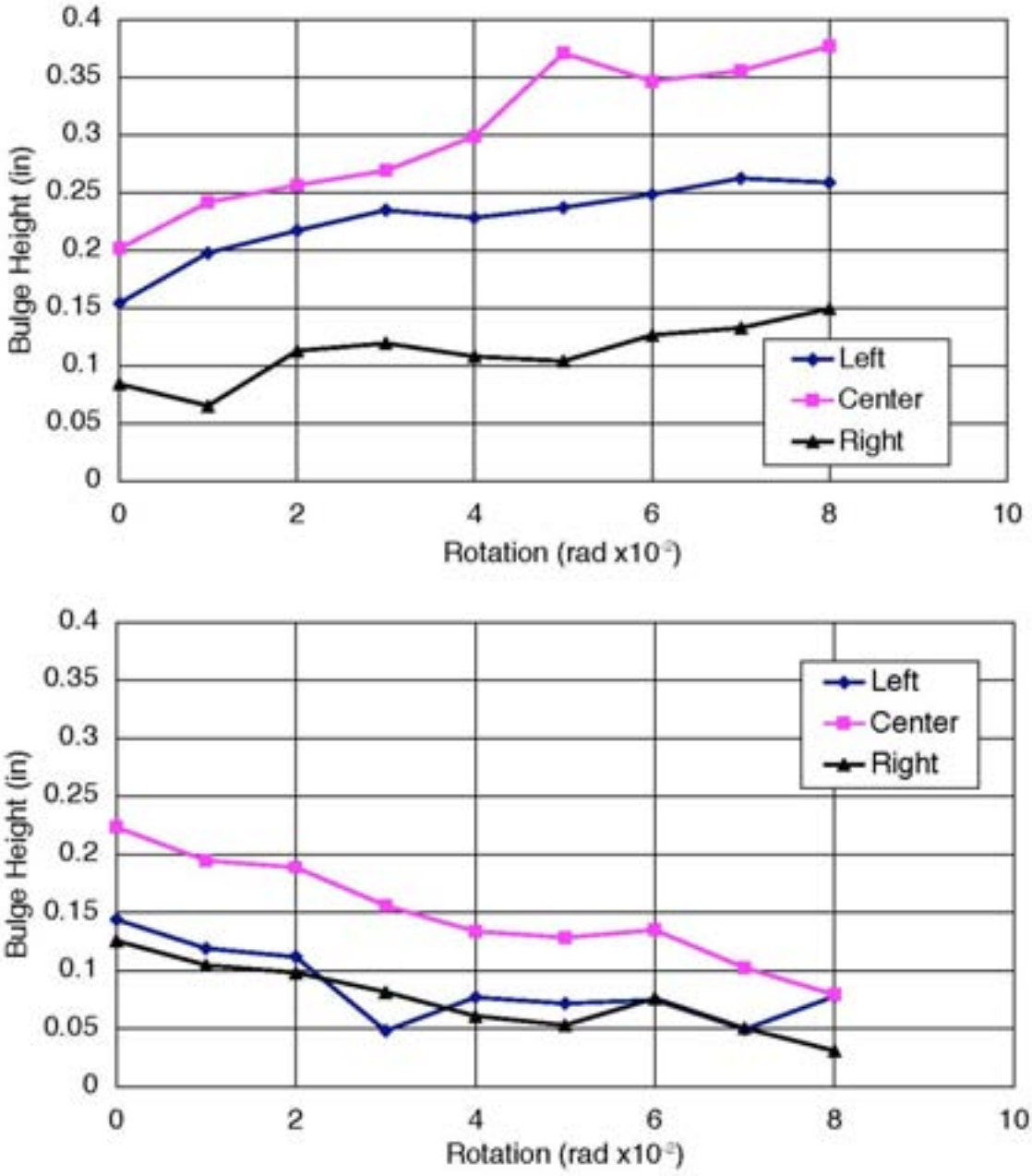


(a) Top



(b) Bottom

Figure A.14: PMI4-A2 Positive Rotation Bulge Heights (a) Top of Bearing and (b) Bottom



(b) Bottom

Figure A.15: PMI4-A2 Negative Rotation Bulge Heights (a) Top of Bearing and (b) Bottom

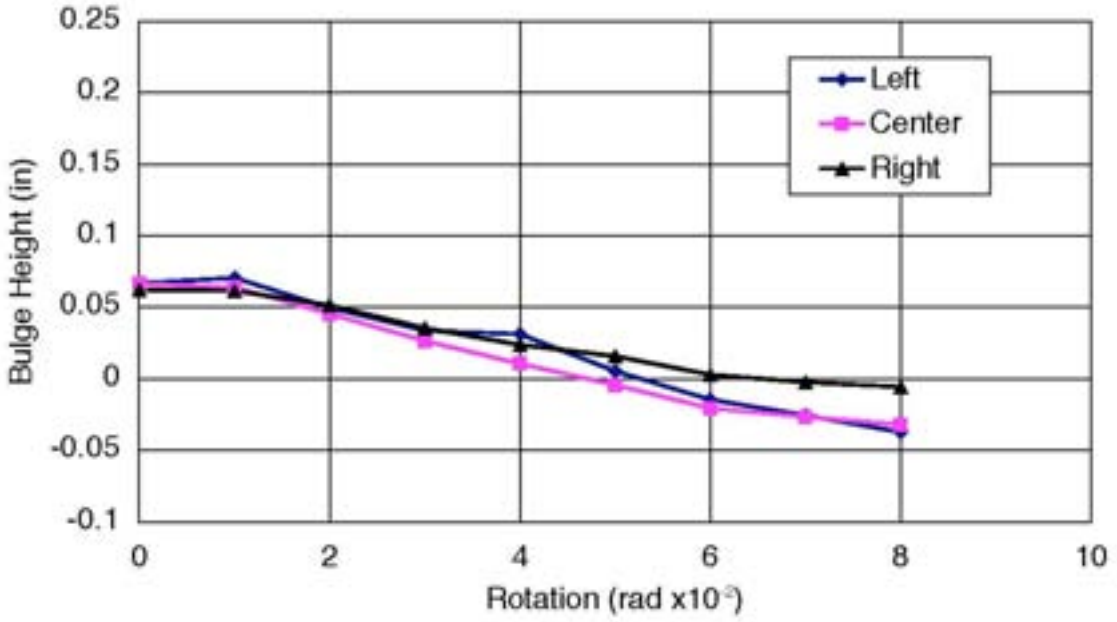
PMI4-B1

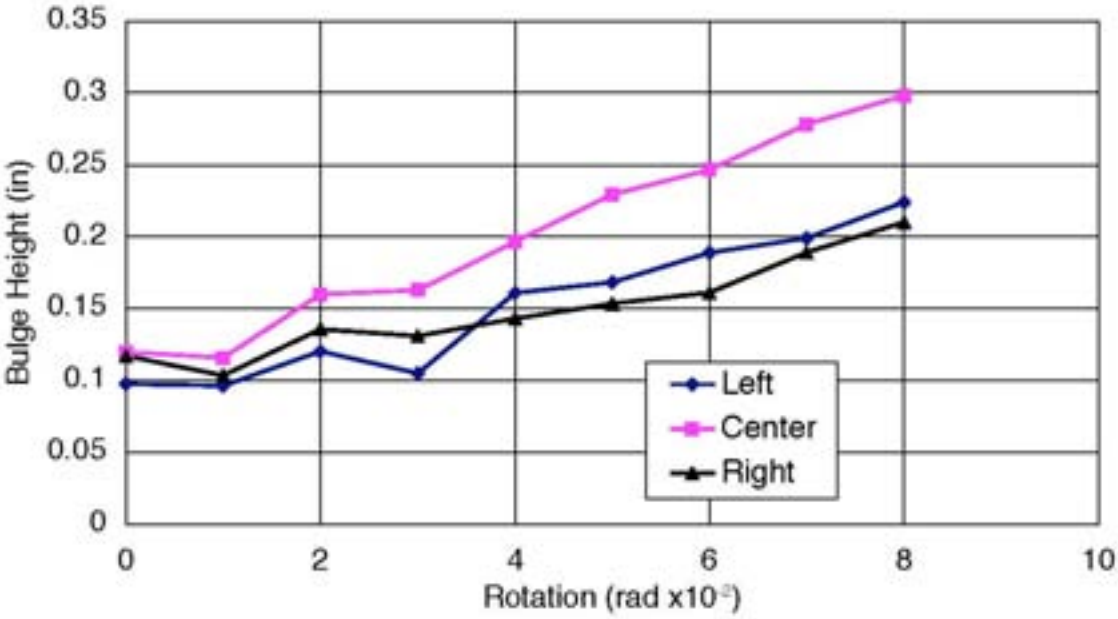
Debonding	
0 rad	0 in
0.08	0
-0 rad	0 in
-0.08	0.5

Test Properties	
Axial Stress	3GS = 1800 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

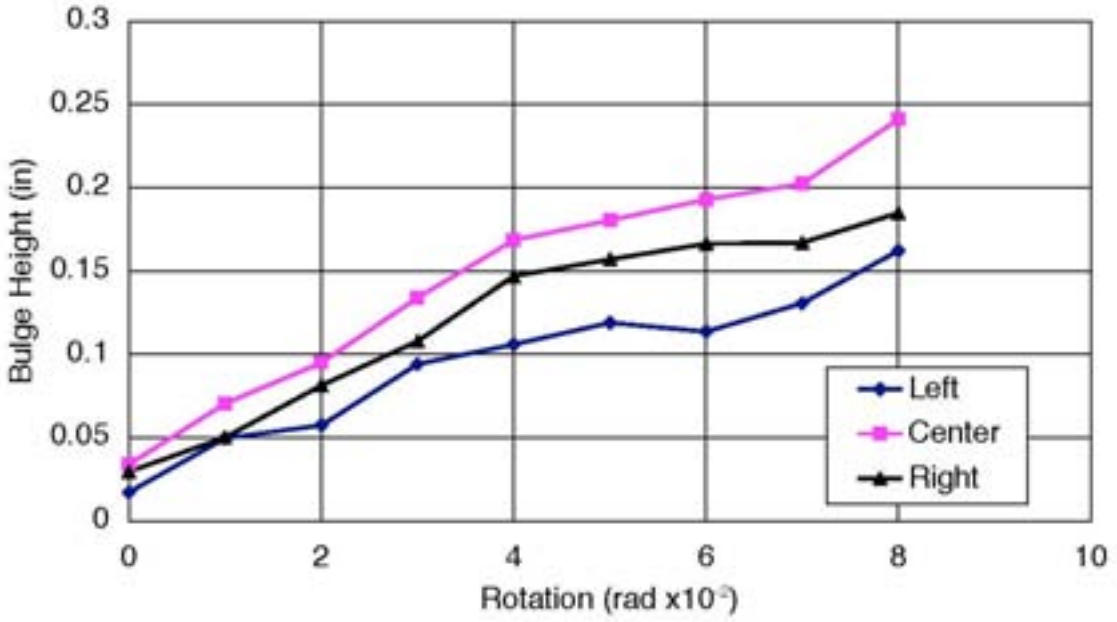
Figure A.16: Test PMI4-B1 Summary

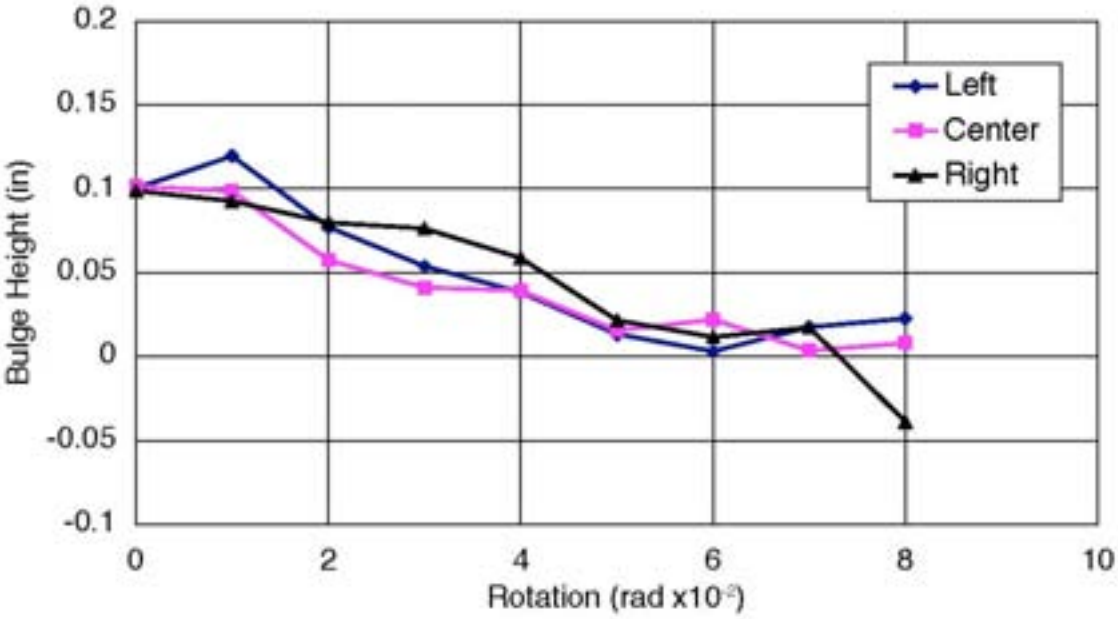




(b) Bottom

Figure A.17: PMI4-B1 Positive Rotation Bulge Heights (a) Top of Bearing and (b) Bottom





(b) Bottom

Figure A.18: PMI4-B1 Negative Rotation Bulge Heights (a) Top of Bearing and (b) Bottom

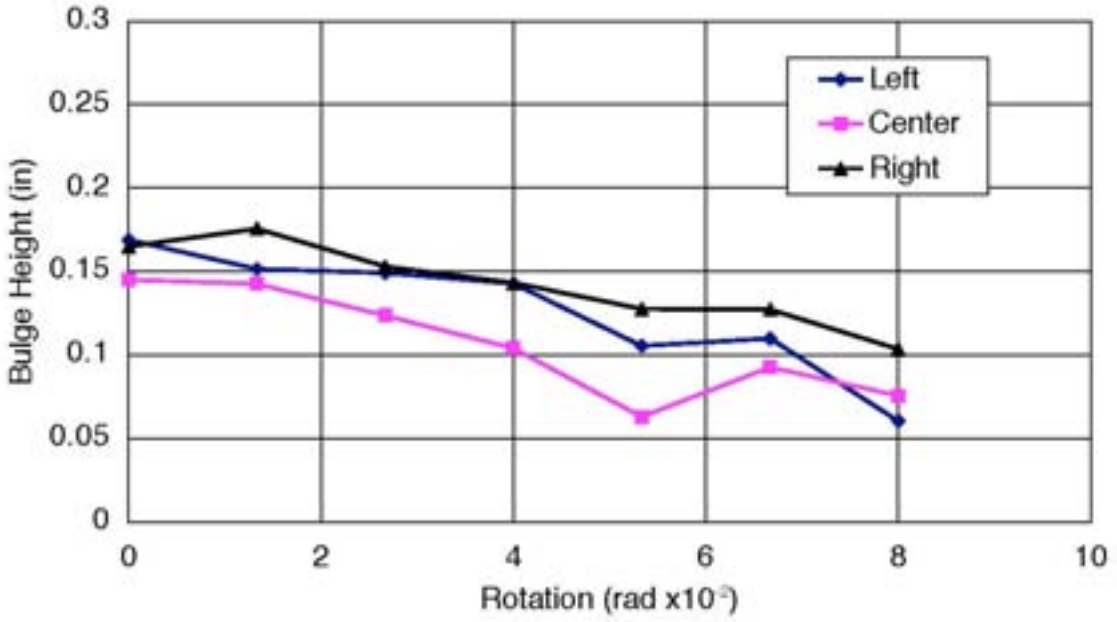
PMI5-A1

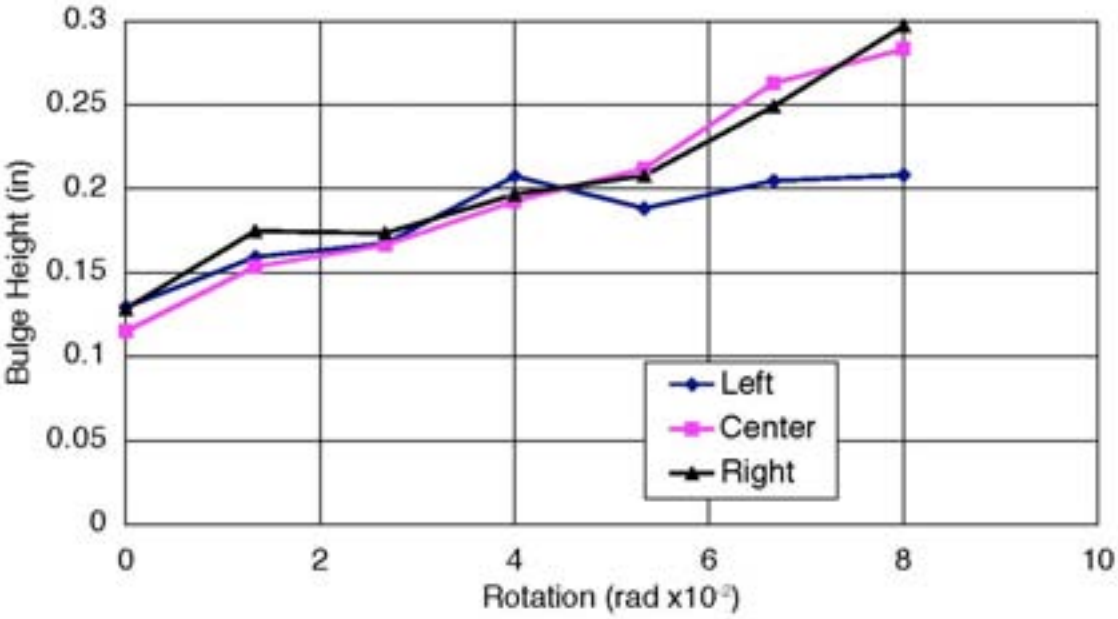
Debonding	
0 rad	0 in
0.01	2
0.03	3
0.04	4.5
0.05	12
0.07	13.5
-0 rad	44 in
-0.02	49
-0.03	51
-0.05	54

Test Properties	
Axial Stress	4GS = 2400 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

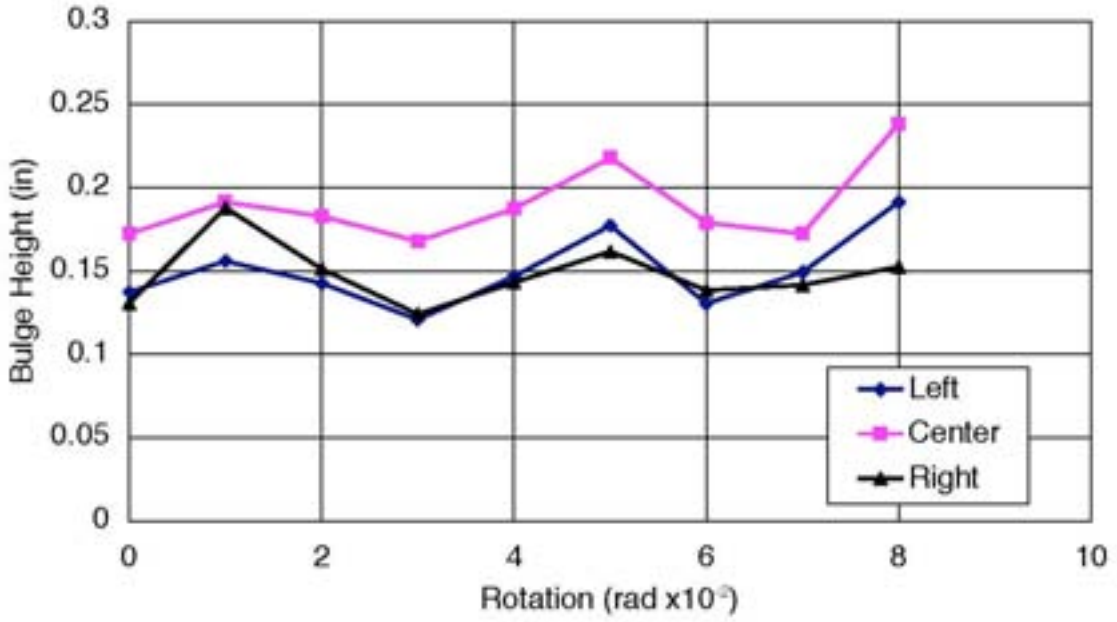
Figure A.19: Test PMI5-A1 Summary

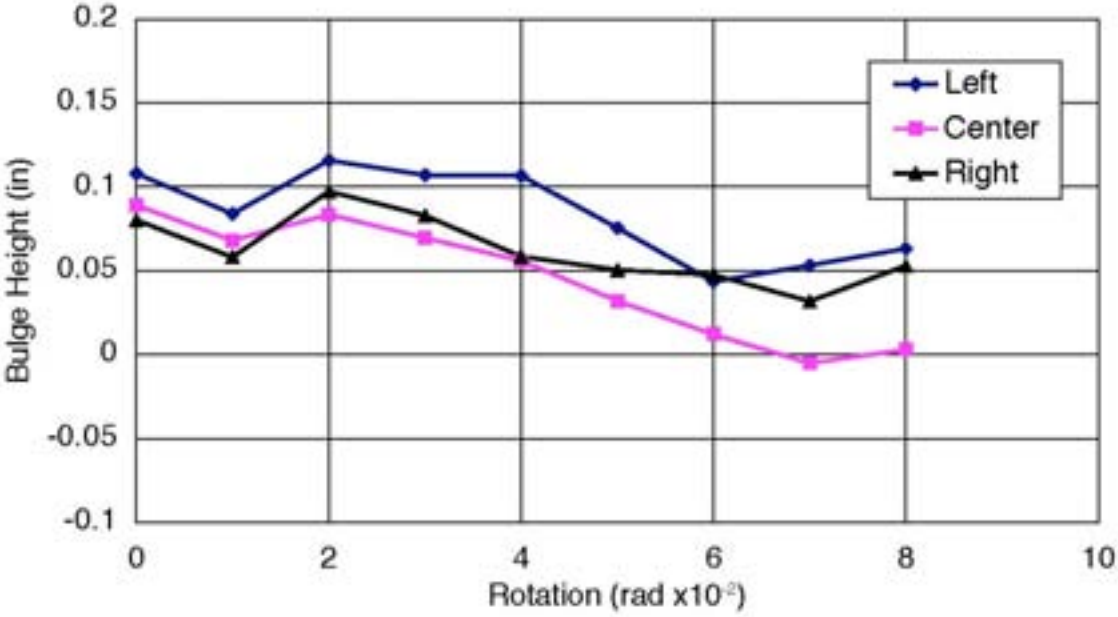




(b) Bottom

Figure A.20: PMI5-A1 Positive Rotation Bulge Heights (a) Top of Bearing and (b) Bottom





(b) Bottom

Figure A.21: PMI5-A1 Negative Rotation Bulge Heights (a) Top of Bearing and (b) Bottom

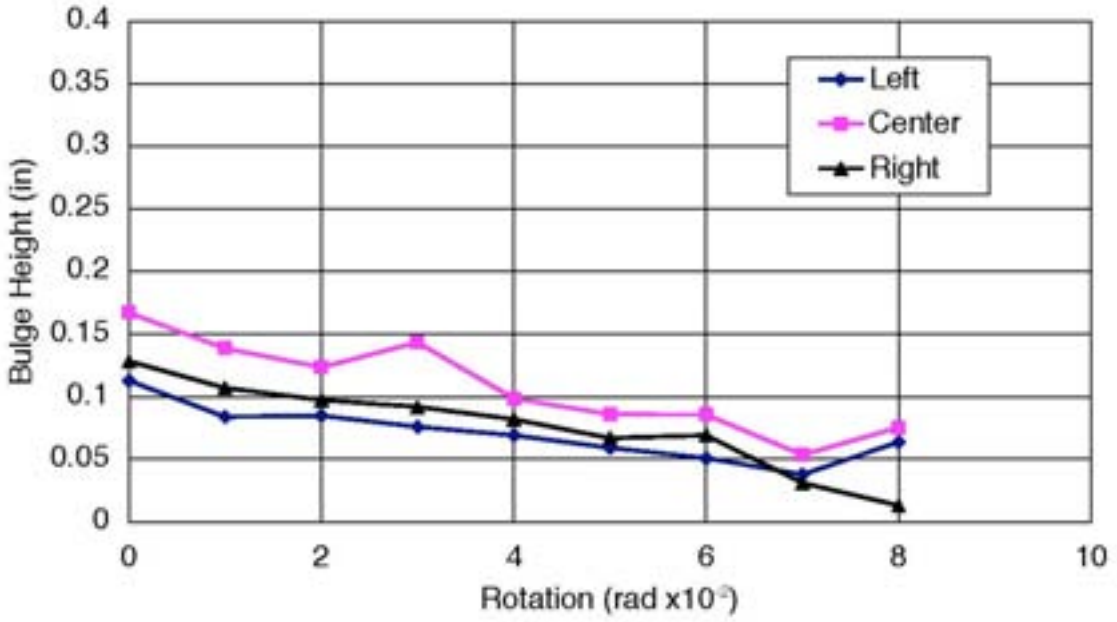
PMI5-A2

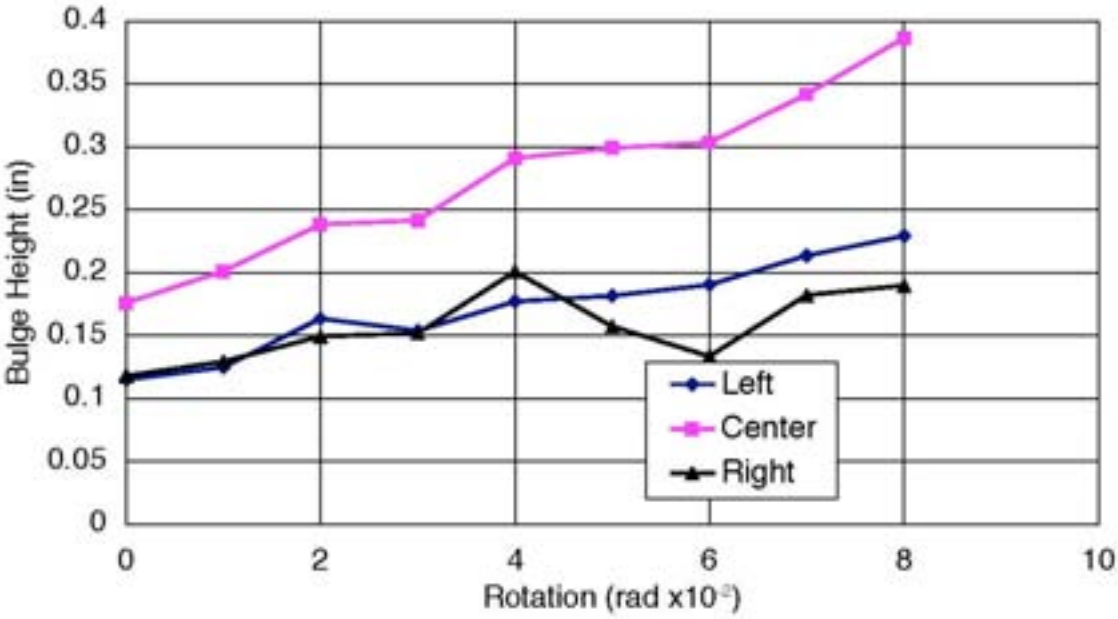
Debonding	
0 rad	0 in
0.06	1
0.07	2
0.08	5
-0 rad	16 in
-0.03	17
-0.04	19
-0.06	29
-0.07	35
-0.08	58

Test Properties	
Axial Stress	4GS = 2400 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

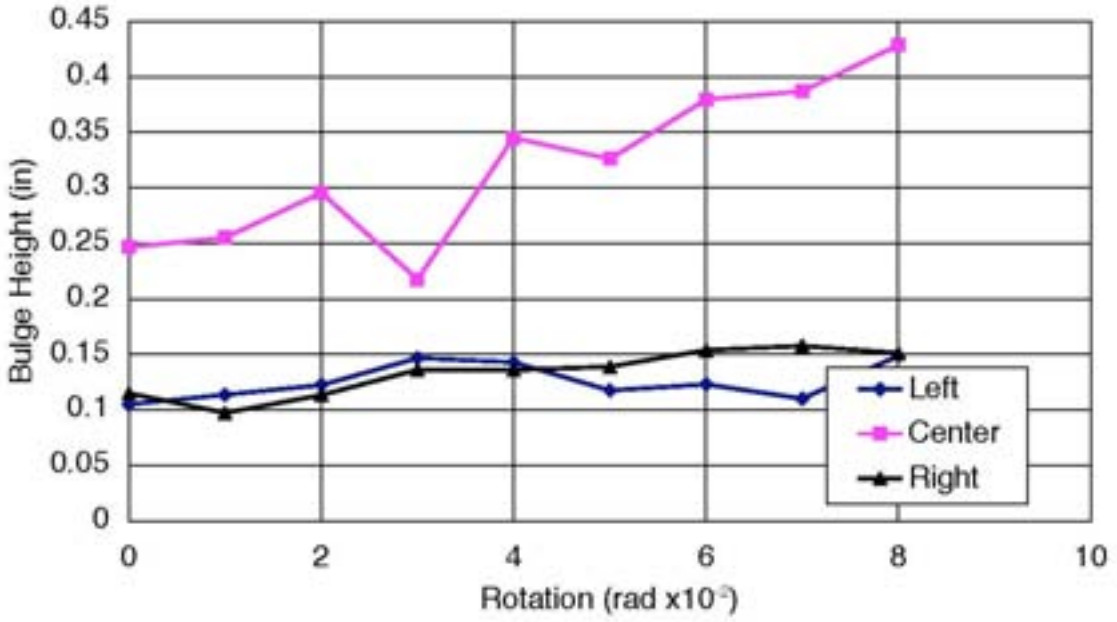
Figure A.22: Test PMI5-A2 Summary

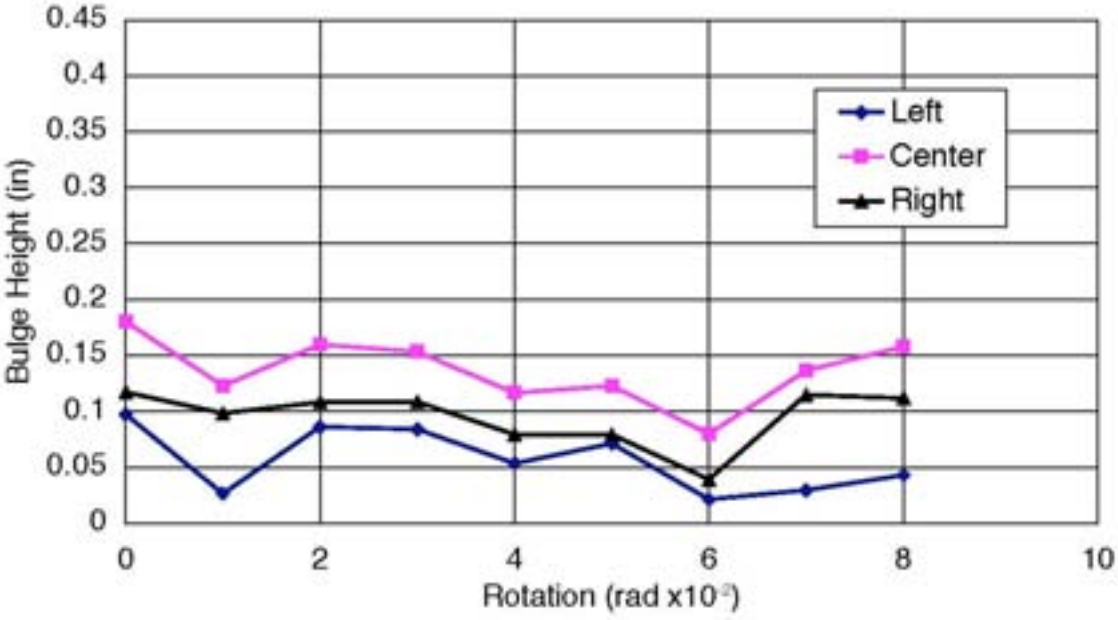




(b) Bottom

Figure A.23: PMI5-A2 Positive Rotation Bulge Heights (a) Top of Bearing and (b) Bottom





(b) Bottom

Figure A.24: PMI5-A2 Negative Rotation Bulge Heights (a) Top of Bearing and (b) Bottom

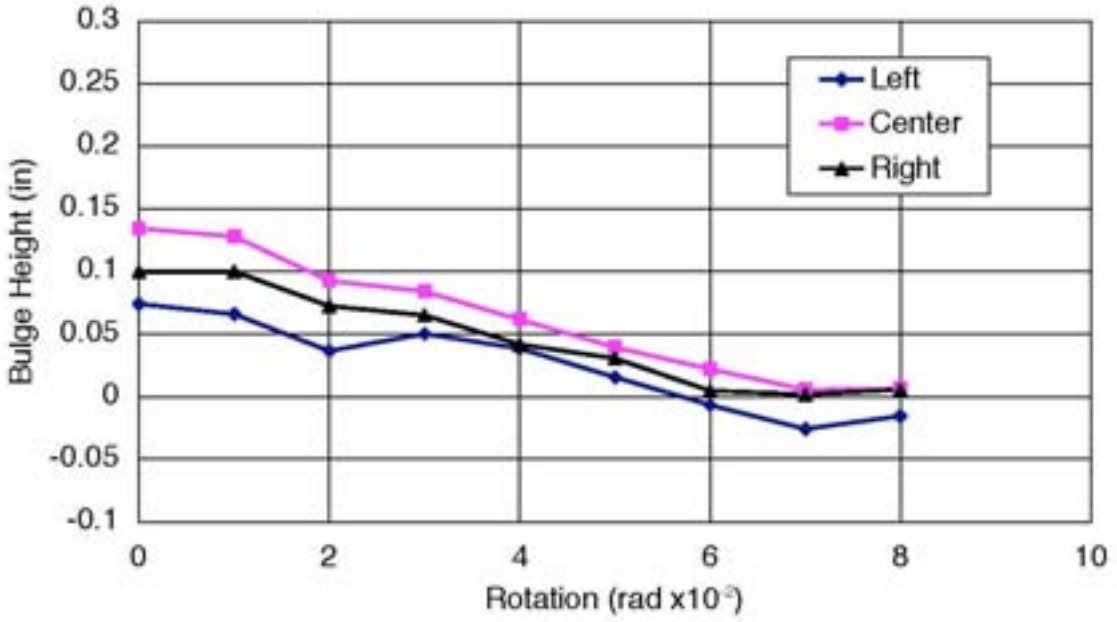
PMI5-B1

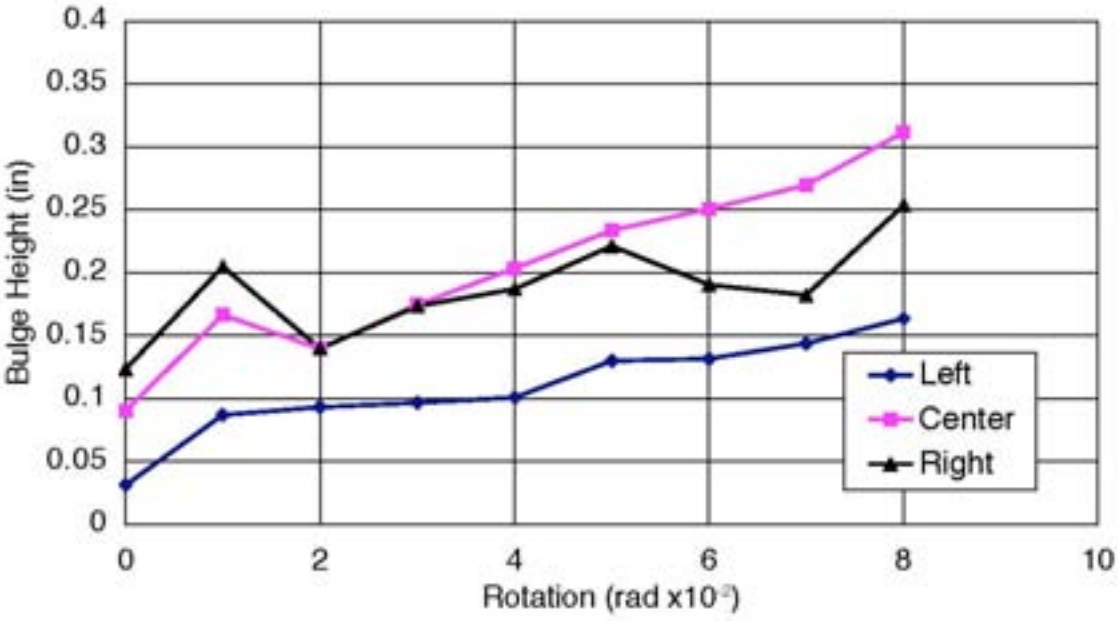
Debonding	
0 rad	0 in
0.08	0
-0 rad	0 in
-0.08	5

Test Properties	
Axial Stress	4GS = 2400 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

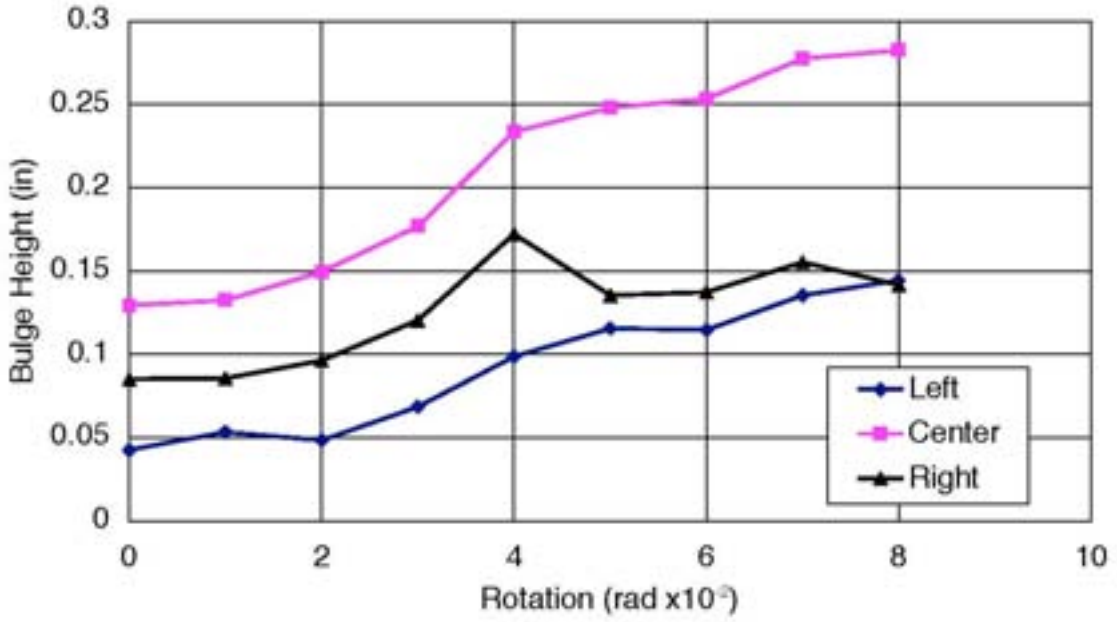
Figure A.25: Test PMI5-B1 Summary

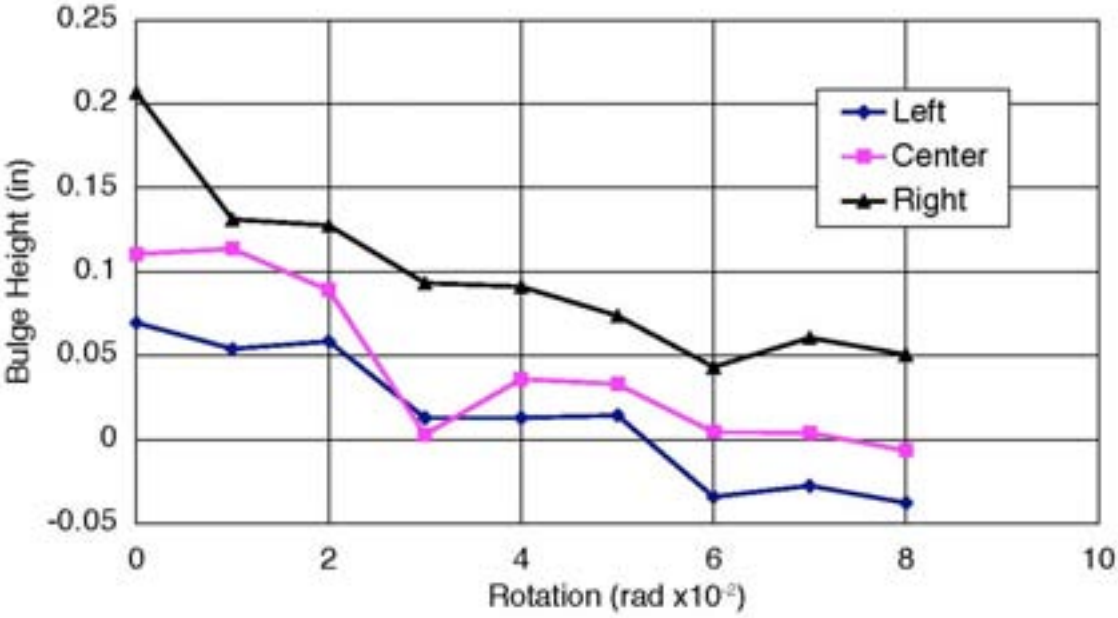




(b) Bottom

Figure A.26: PMI5-B1 Positive Rotation Bulge Heights (a) Top of Bearing and (b) Bottom





(b) Bottom

Figure A.27: PMI5-B1 Negative Rotation Bulge Heights (a) Top of Bearing and (b) Bottom

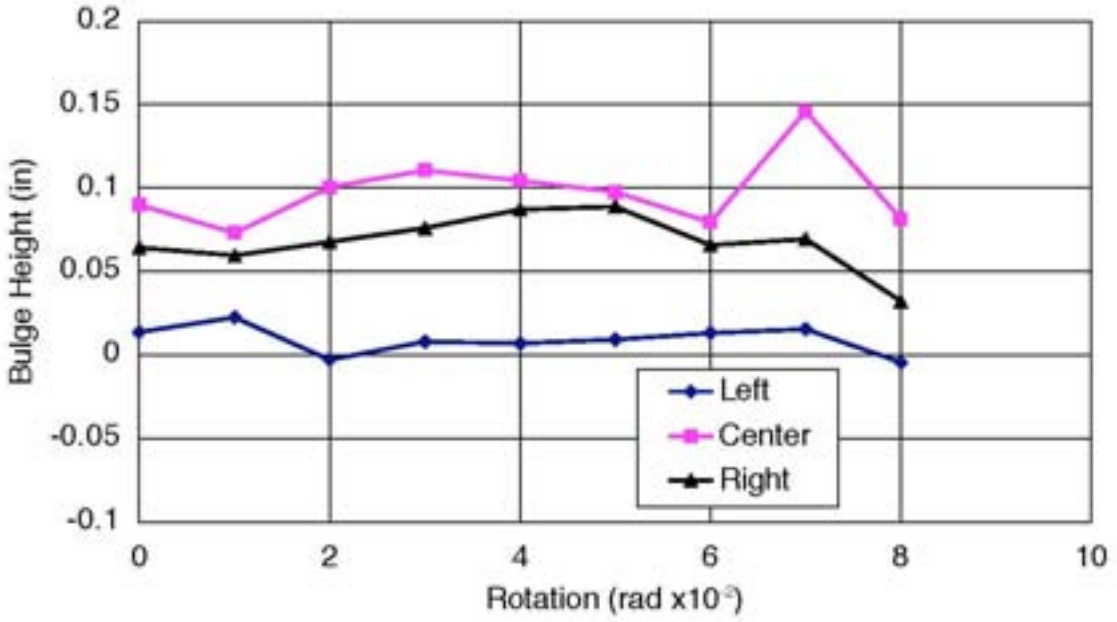
PMI5-C1

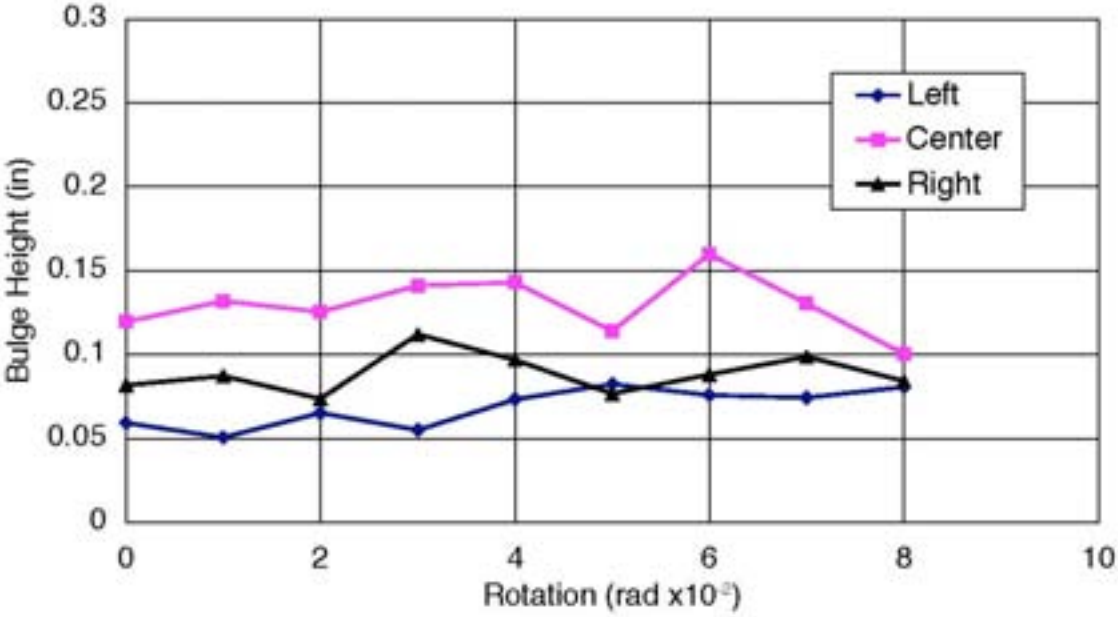
Debonding	
0 rad	0 in
0.08	11
-0 rad	11 in
-0.01	18
-0.05	34

Test Properties	
Axial Stress	4GS = 2400 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

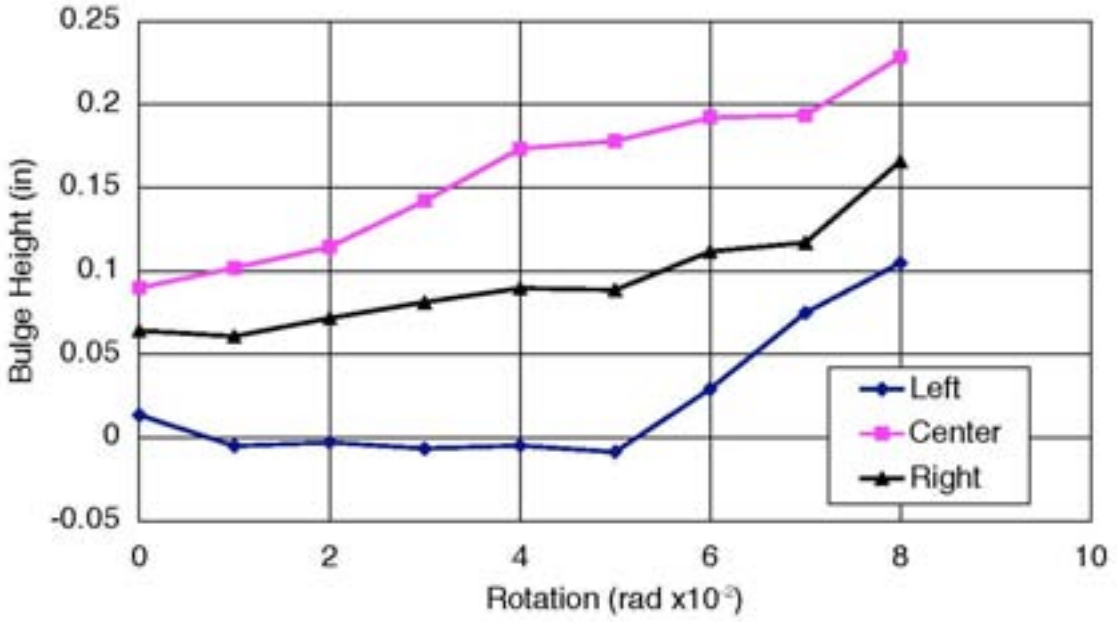
Figure A.28: Test PMI5-C1 Summary

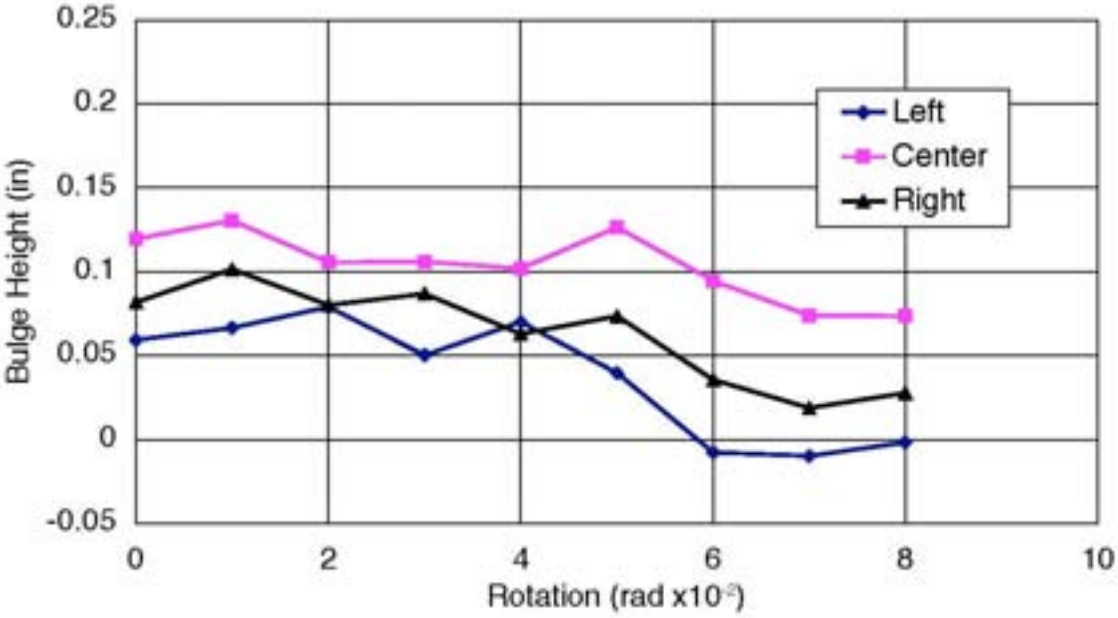




(b) Bottom

Figure A.29: PMI5-C1 Positive Rotation Bulge Heights (a) Top of Bearing and (b) Bottom





(b) Bottom

Figure A.30: PMI5-C1 Negative Rotation Bulge Heights (a) Top of Bearing and (b) Bottom

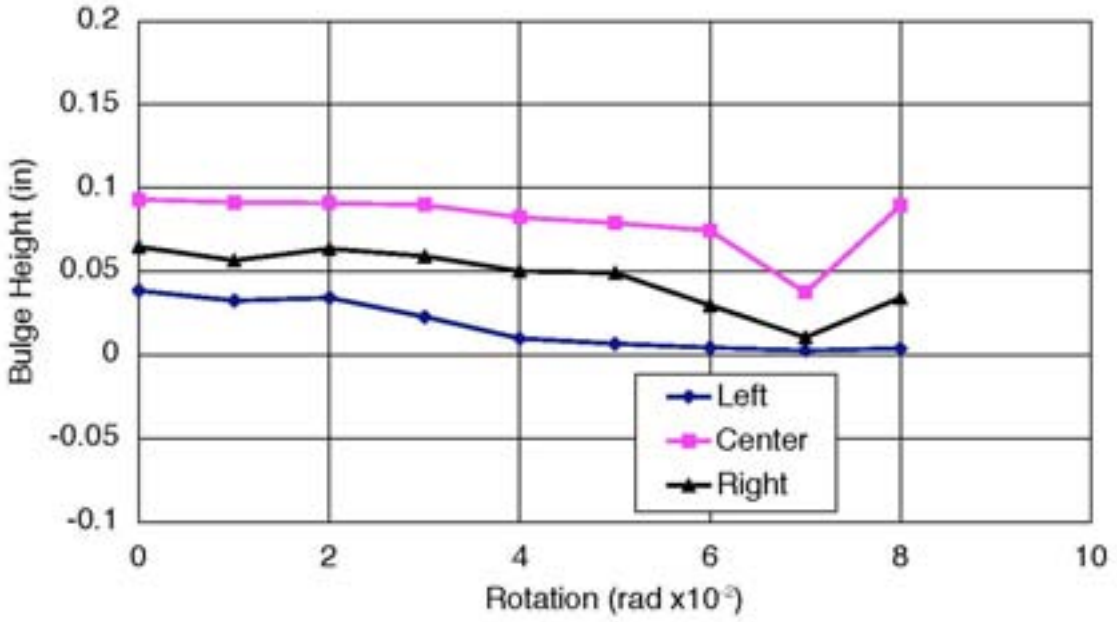
PMI5-D1

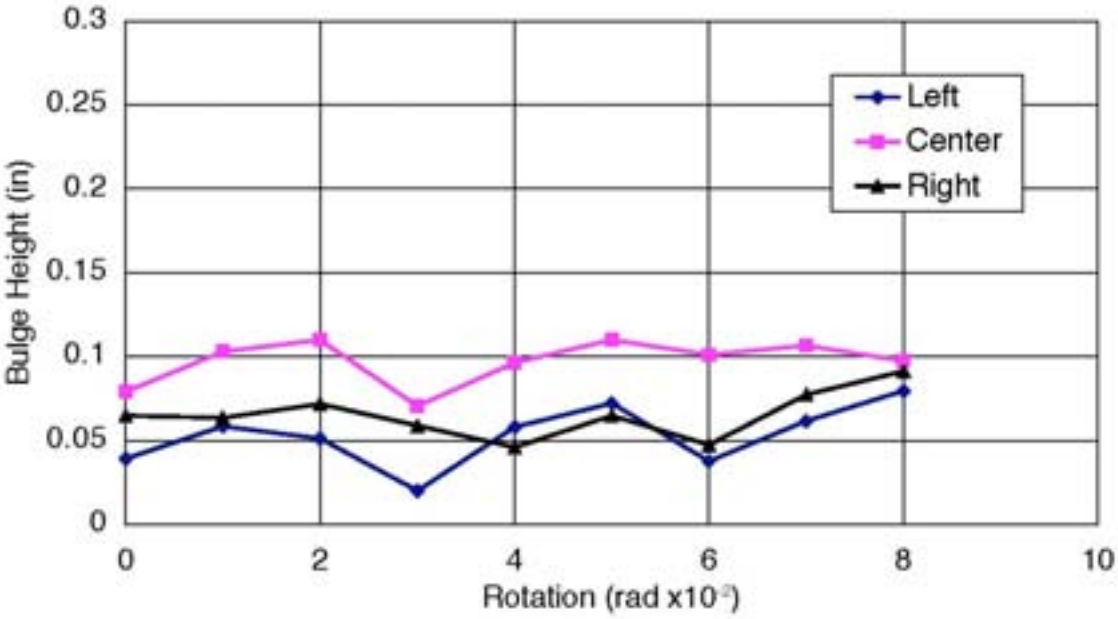
Debonding	
0 rad	0 in
0.08	0
-0 rad	0 in
-0.01	35
-0.08	44

Test Properties	
Axial Stress	4GS = 2400 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

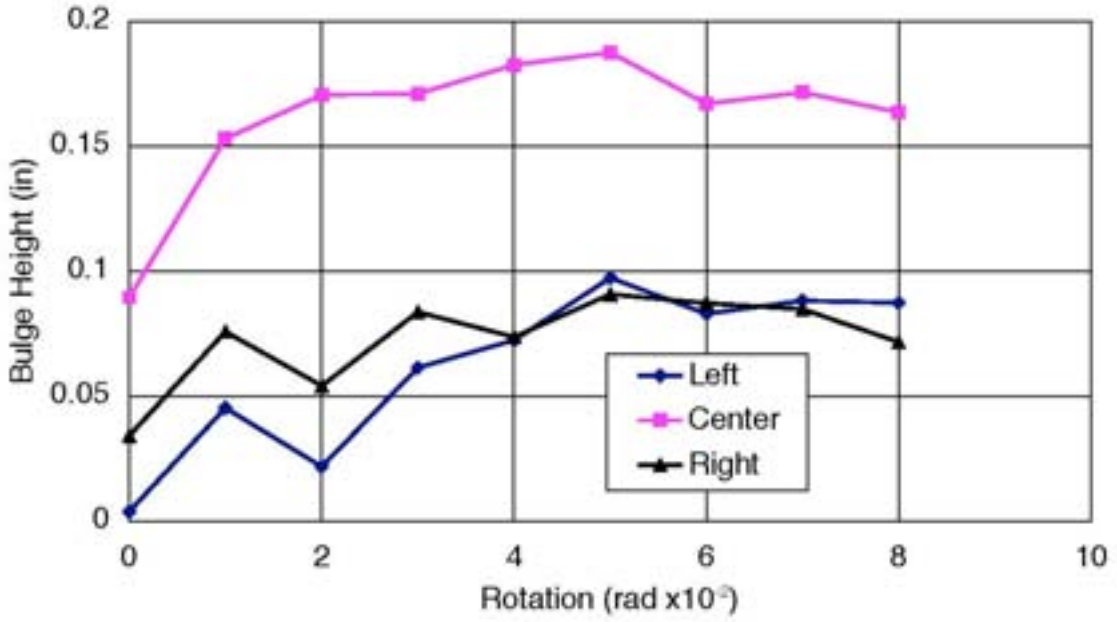
Figure A.31: Test PMI5-D1 Summary

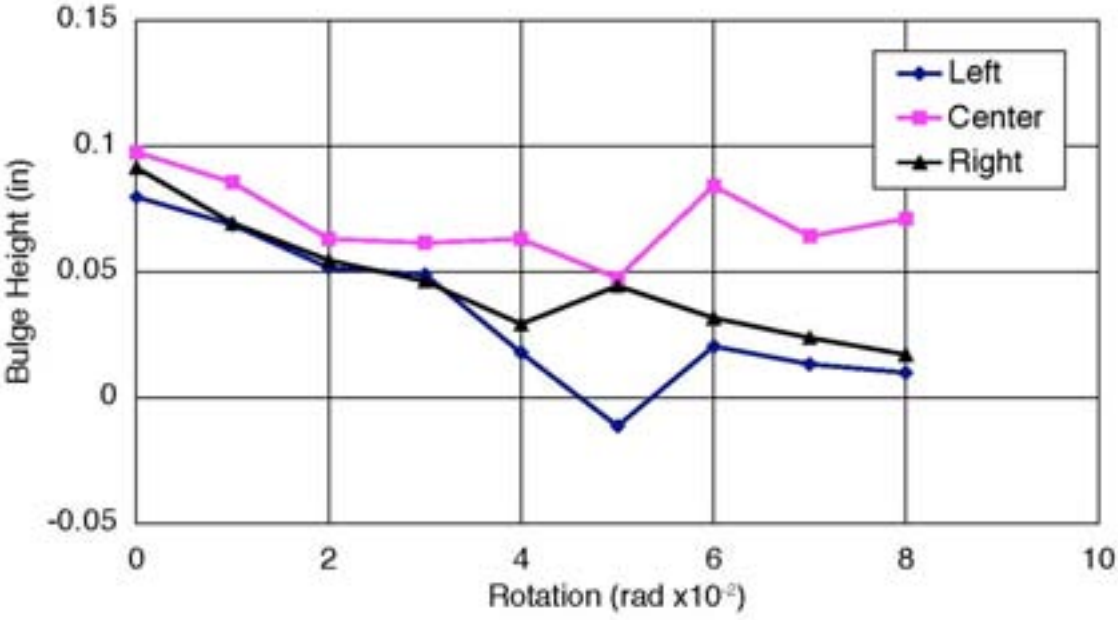




(b) Bottom

Figure A.32: PMI5-D1 Positive Rotation Bulge Heights (a) Top of Bearing and (b) Bottom





(b) Bottom

Figure A.33: PMI5-D1 Negative Rotation Bulge Heights (a) Top of Bearing and (b) Bottom

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A.5 CYC Series

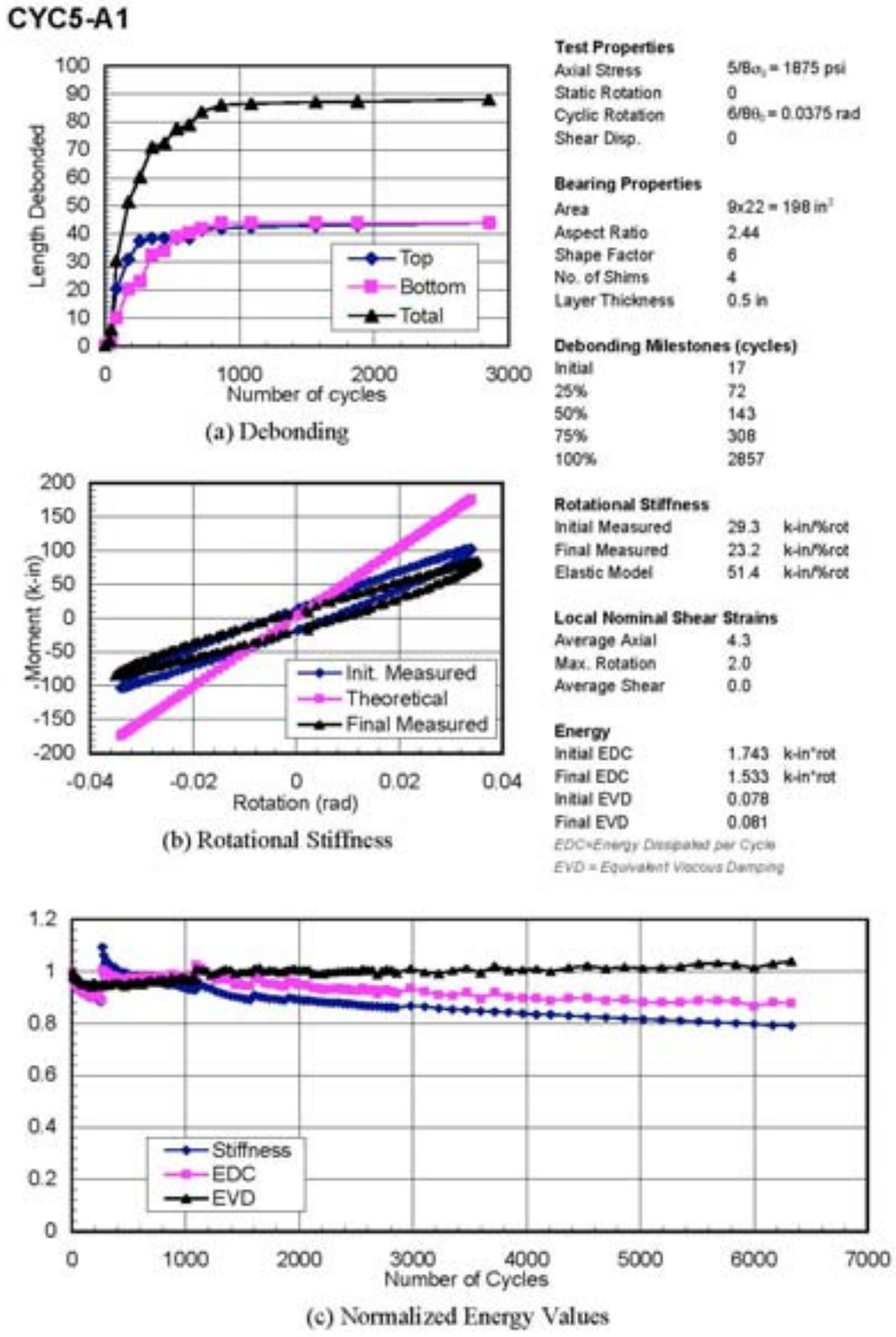
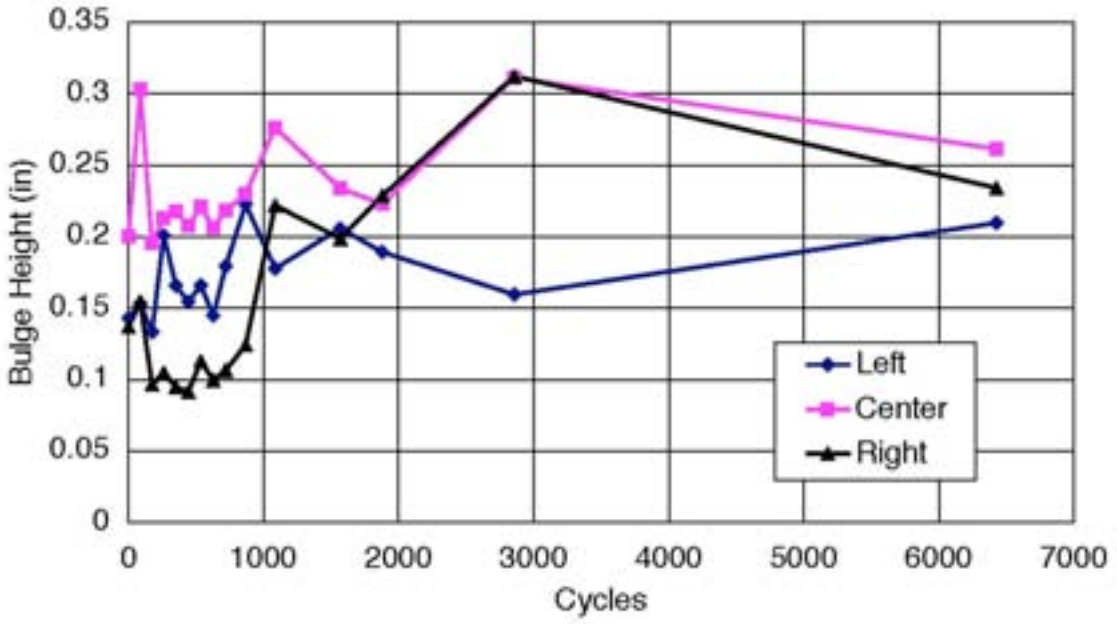
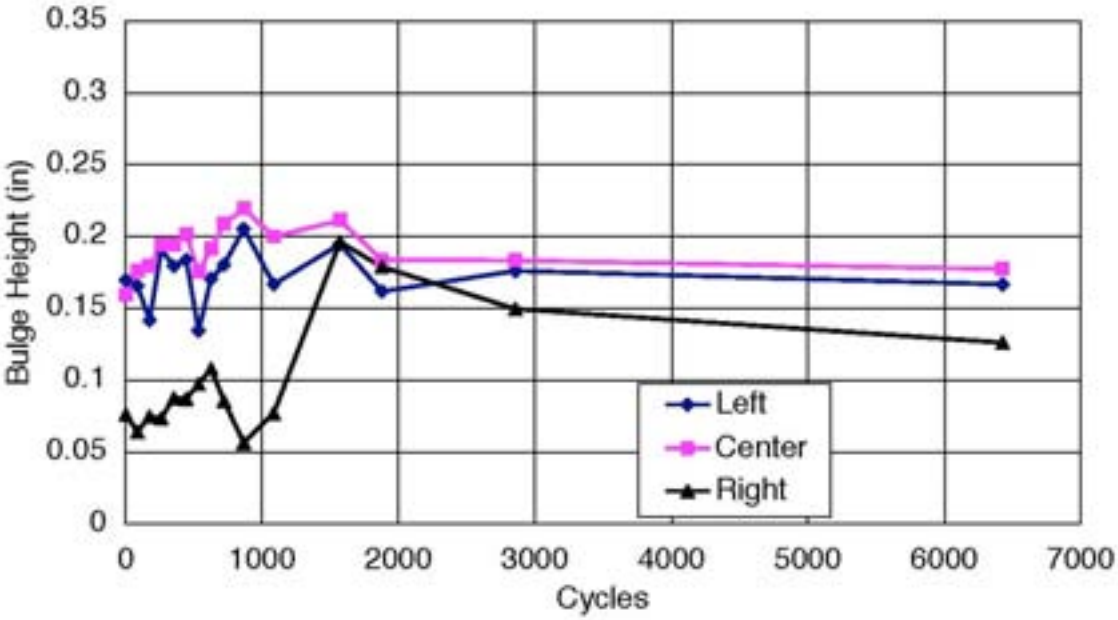


Figure A.34: Test CYC5-A1 Summary



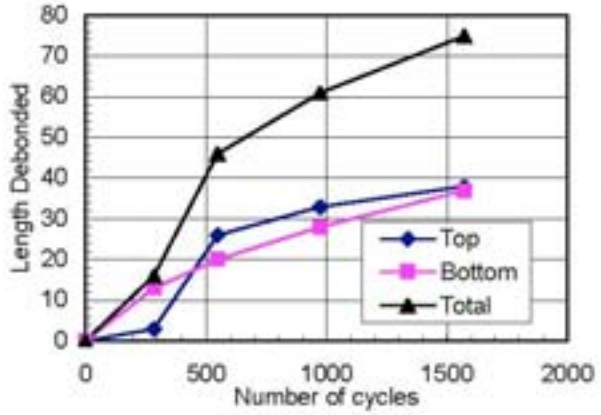
(a) Top



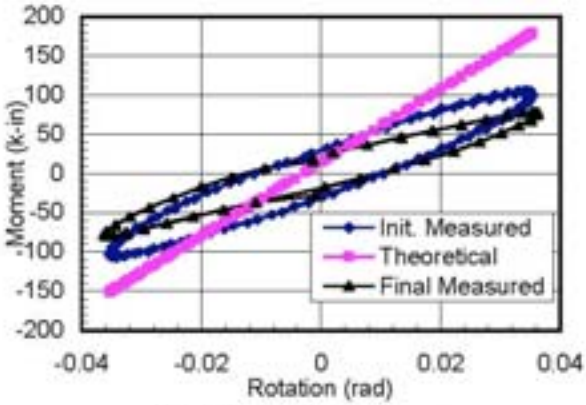
(b) Bottom

Figure A.35: CYC5-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC5-A2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	18
25%	337
50%	531
75%	1189
100%	N/A

Rotational Stiffness

Initial Measured	28.2	k-in/%rot
Final Measured	20.5	k-in/%rot
Elastic Model	46.7	k-in/%rot

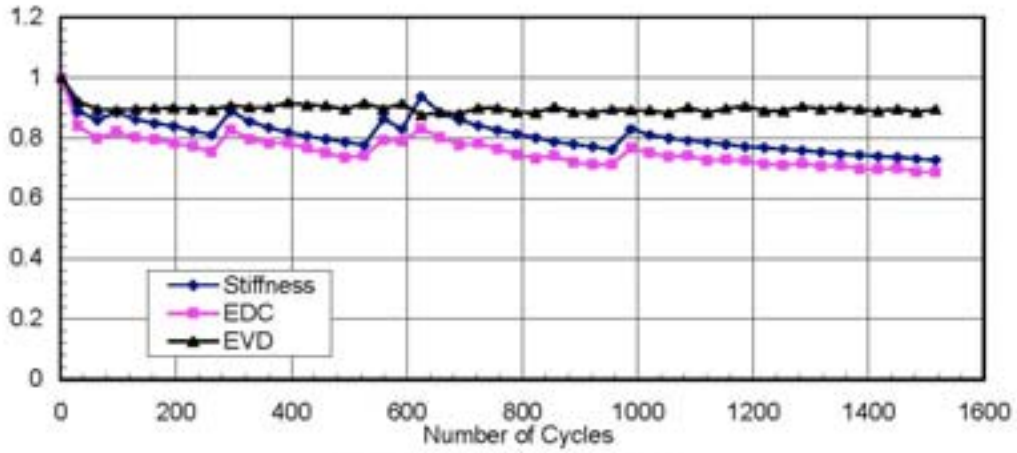
Local Nominal Shear Strains

Average Axial	4.6
Max. Rotation	2.1
Average Shear	0.0

Energy

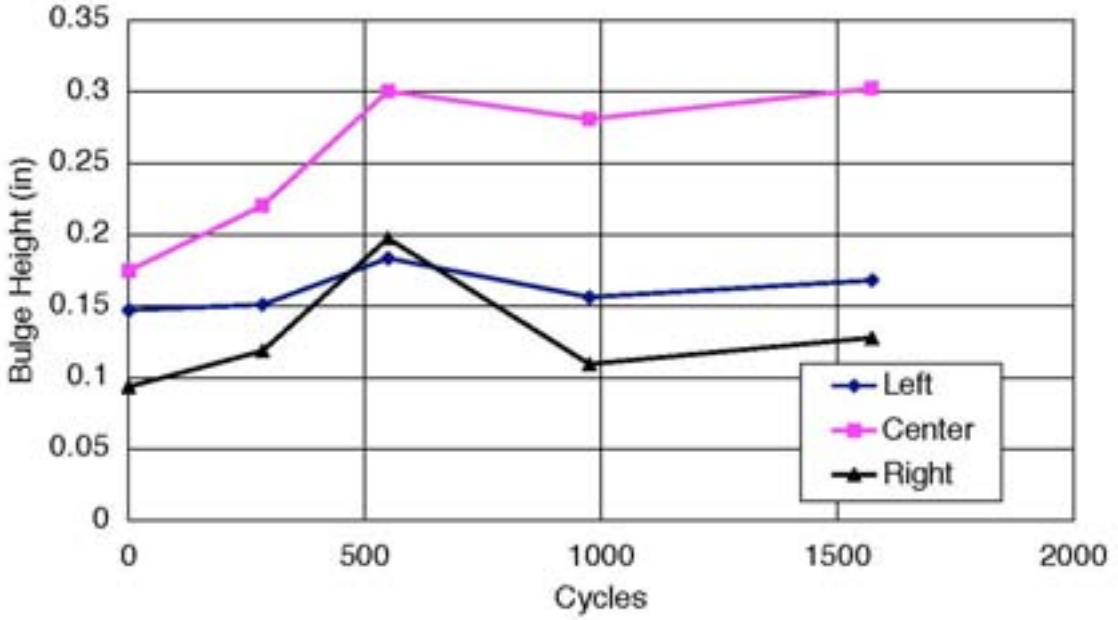
Initial EDC	3.385	k-in*rot
Final EDC	2.332	k-in*rot
Initial EVD	0.143	
Final EVD	0.128	

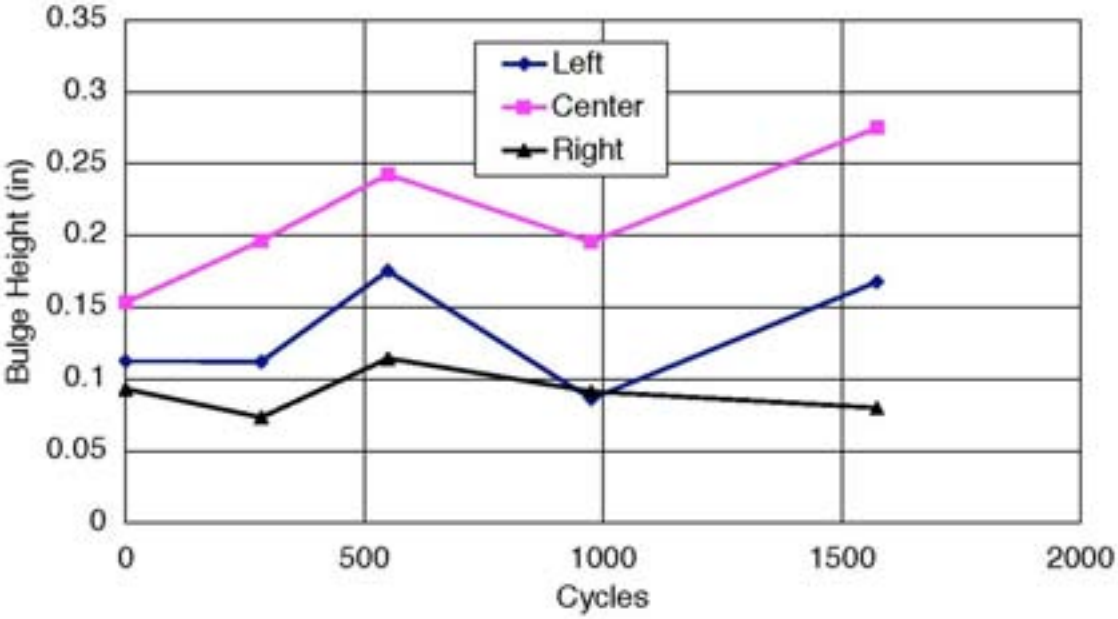
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.36: Test CYC5-A2 Summary

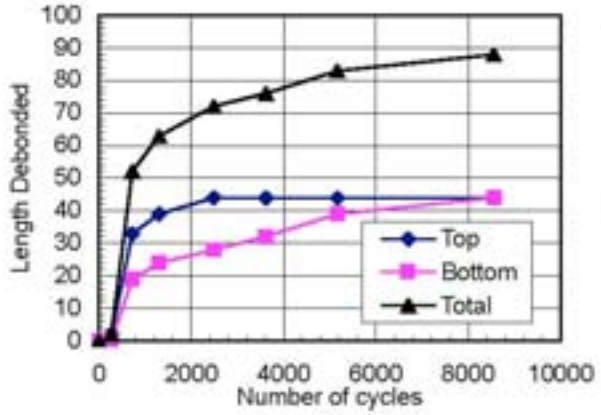




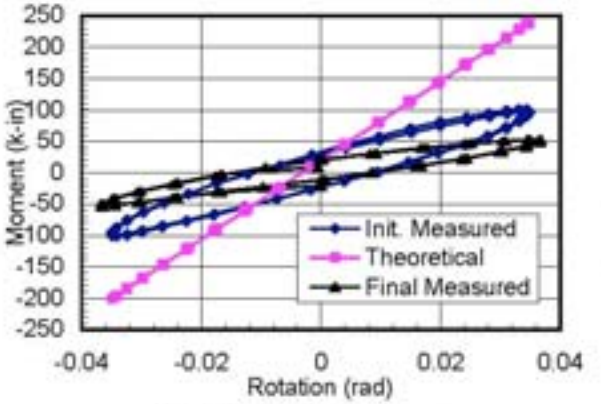
(b) Bottom

Figure A.37: CYC5-A2 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC5-B1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	79
25%	217
50%	398
75%	1261
100%	N/A

Rotational Stiffness

Initial Measured	27.0	k-in/%rot
Final Measured	13.5	k-in/%rot
Elastic Model	63.0	k-in/%rot

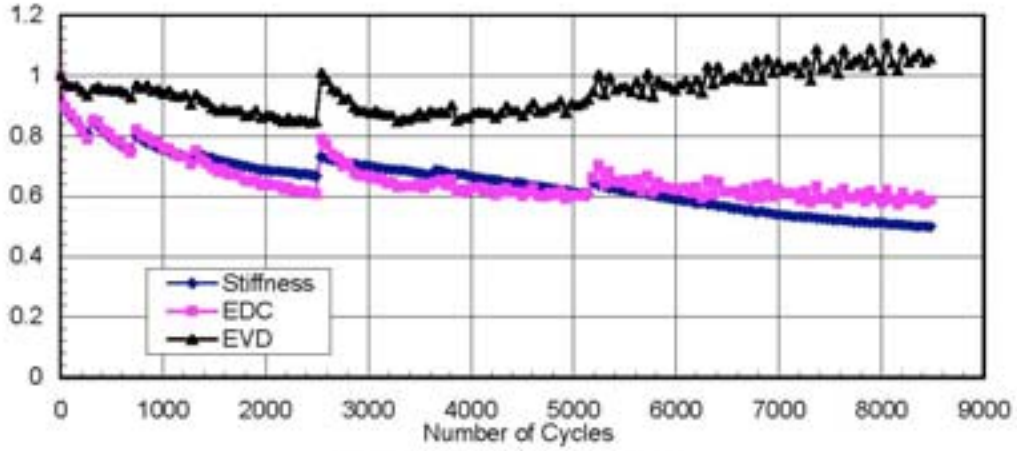
Local Nominal Shear Strains

Average Axial	3.4
Max. Rotation	2.2
Average Shear	0.0

Energy

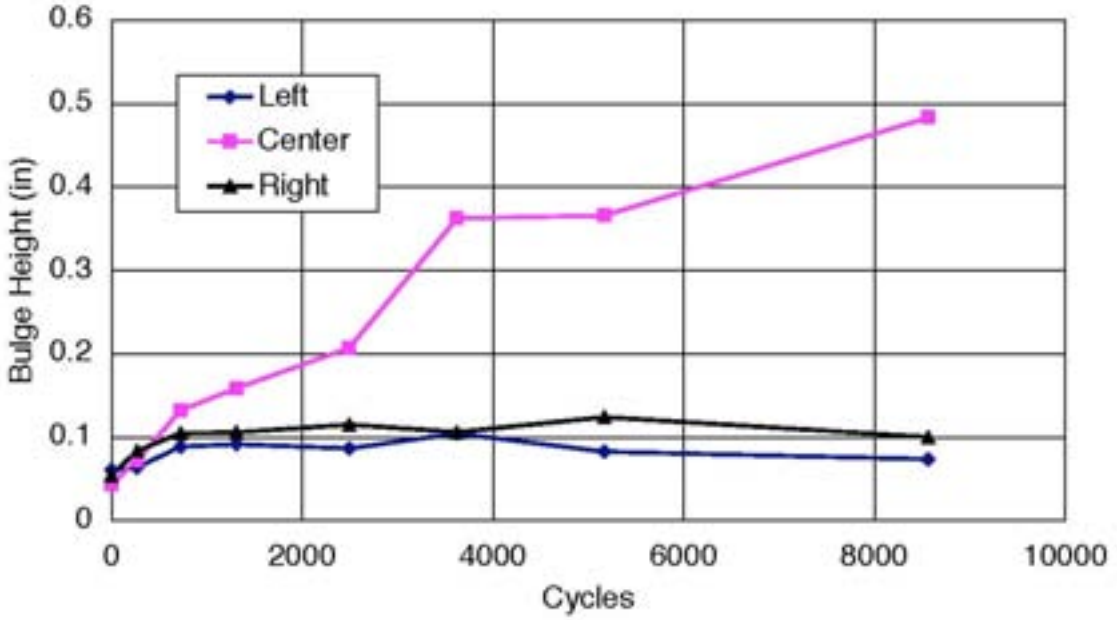
Initial EDC	2.988	k-in*rot
Final EDC	1.754	k-in*rot
Initial EVD	0.135	
Final EVD	0.143	

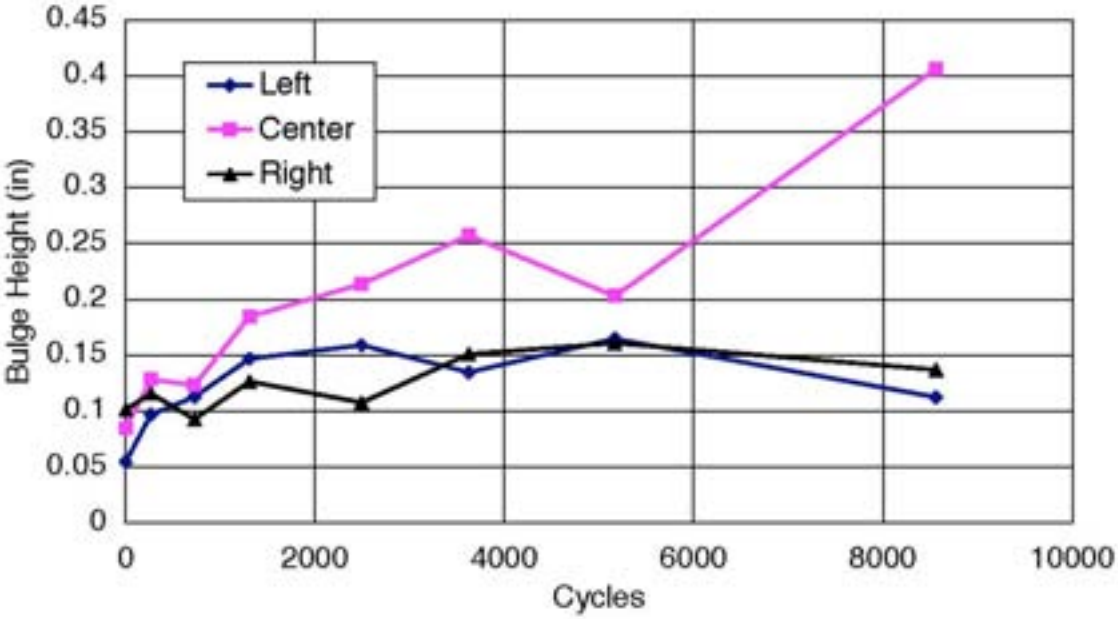
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.38: Test CYC5-B1 Summary

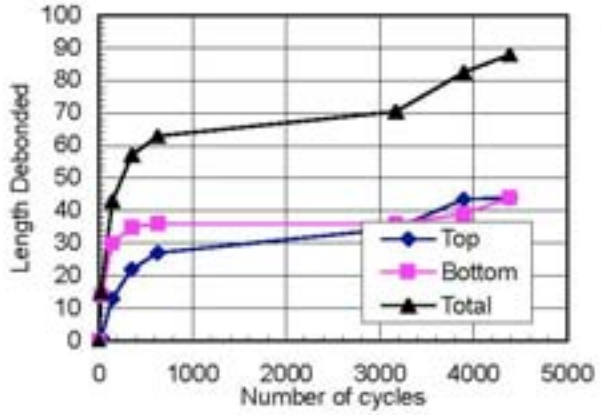




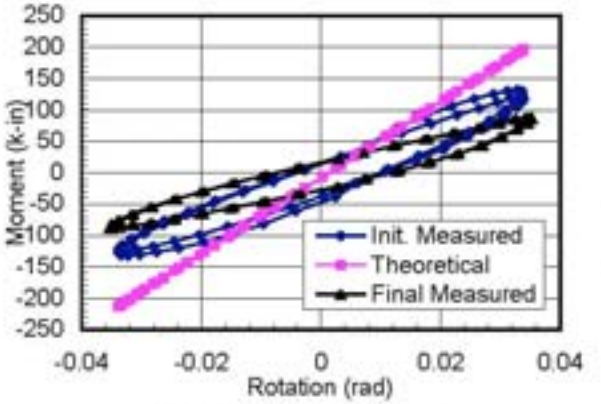
(b) Bottom

Figure A.39: CYC5-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC5-C1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	2
25%	56
50%	156
75%	1645
100%	4388

Rotational Stiffness

Initial Measured	36.5	k-in/%rot
Final Measured	23.6	k-in/%rot
Elastic Model	60.5	k-in/%rot

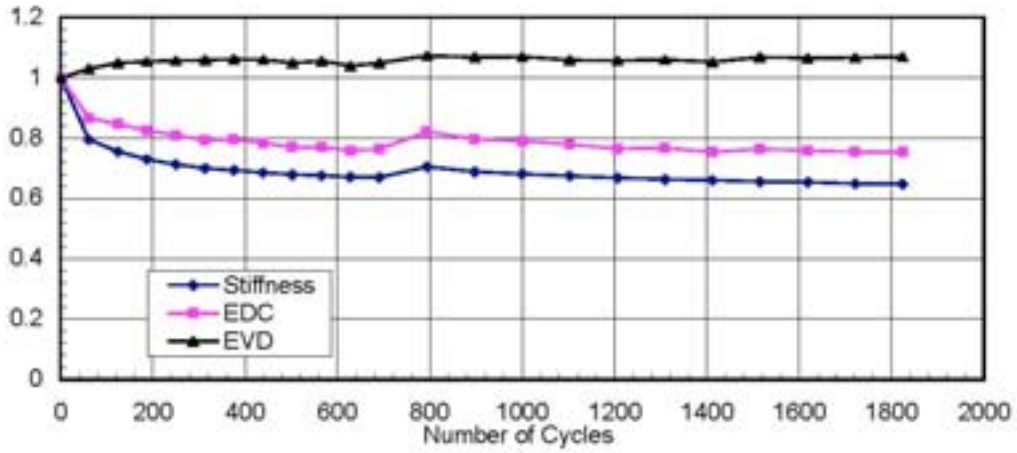
Local Nominal Shear Strains

Average Axial	3.7
Max. Rotation	1.8
Average Shear	0.0

Energy

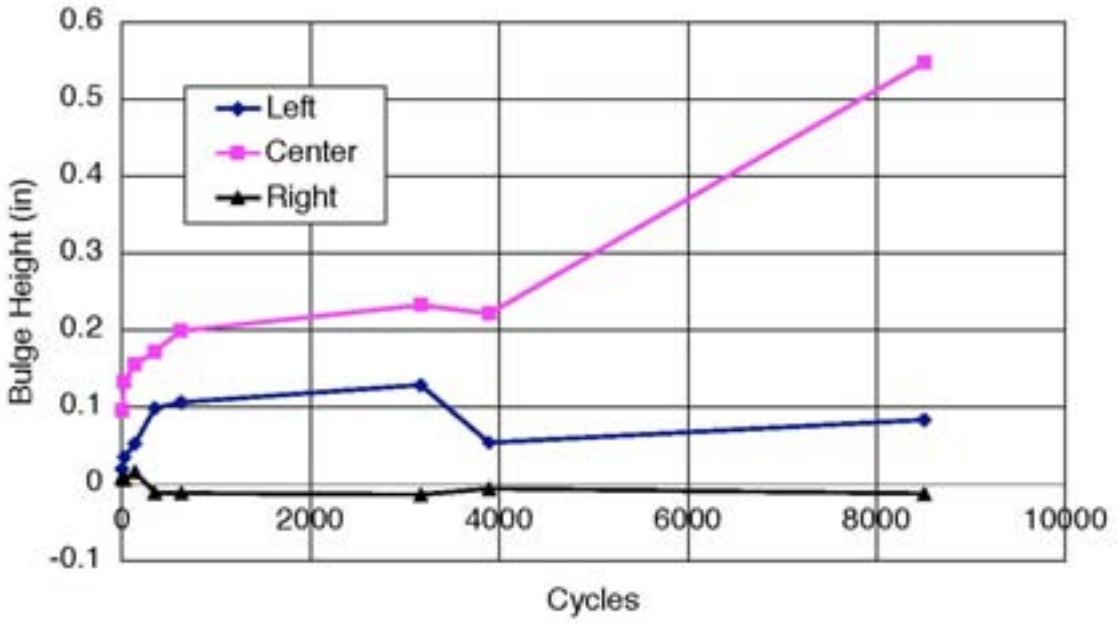
Initial EDC	3.175	k-in*rot
Final EDC	2.393	k-in*rot
Initial EVD	0.113	
Final EVD	0.121	

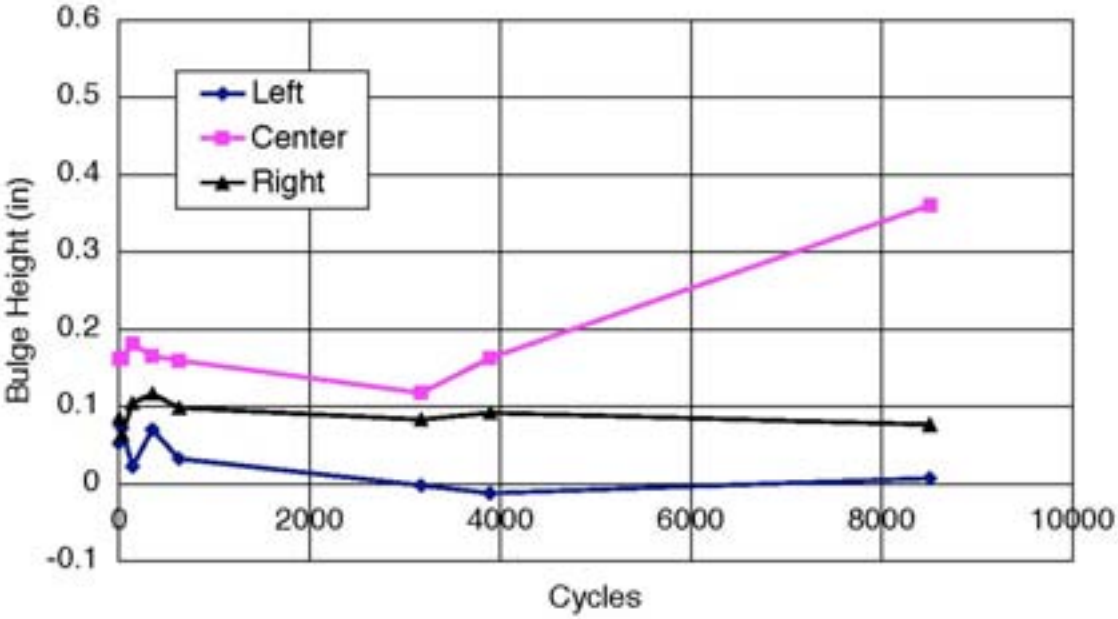
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.40: Test CYC5-C1 Summary

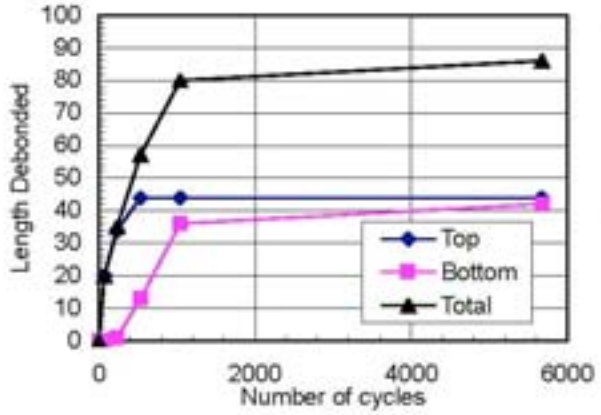




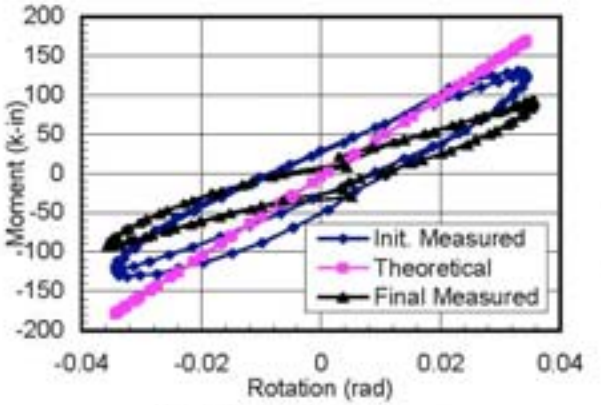
(b) Bottom

Figure A.41: CYC5-C1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC5-D1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	4
25%	95
50%	354
75%	733
100%	7214

Rotational Stiffness

Initial Measured	35.2	k-in/%rot
Final Measured	23.9	k-in/%rot
Elastic Model	50.6	k-in/%rot

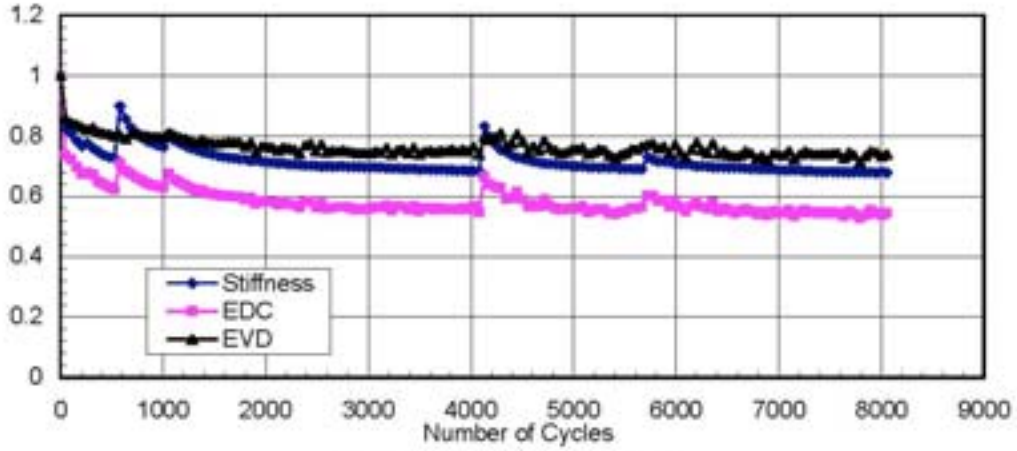
Local Nominal Shear Strains

Average Axial	4.5
Max. Rotation	1.9
Average Shear	0.0

Energy

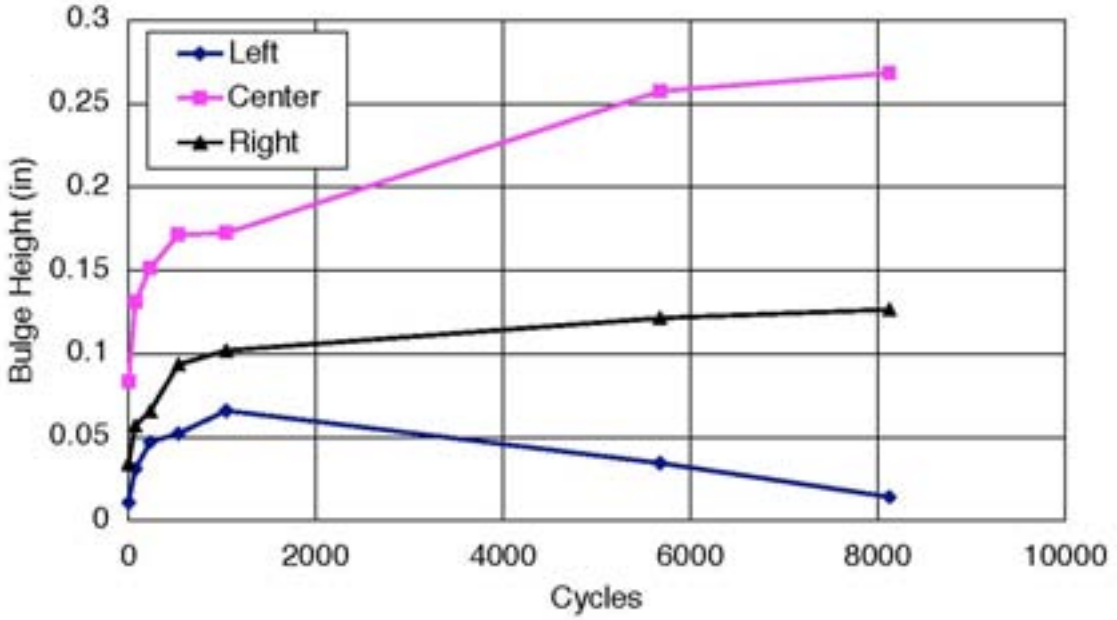
Initial EDC	3.788	k-in*rot
Final EDC	2.054	k-in*rot
Initial EVD	0.133	
Final EVD	0.099	

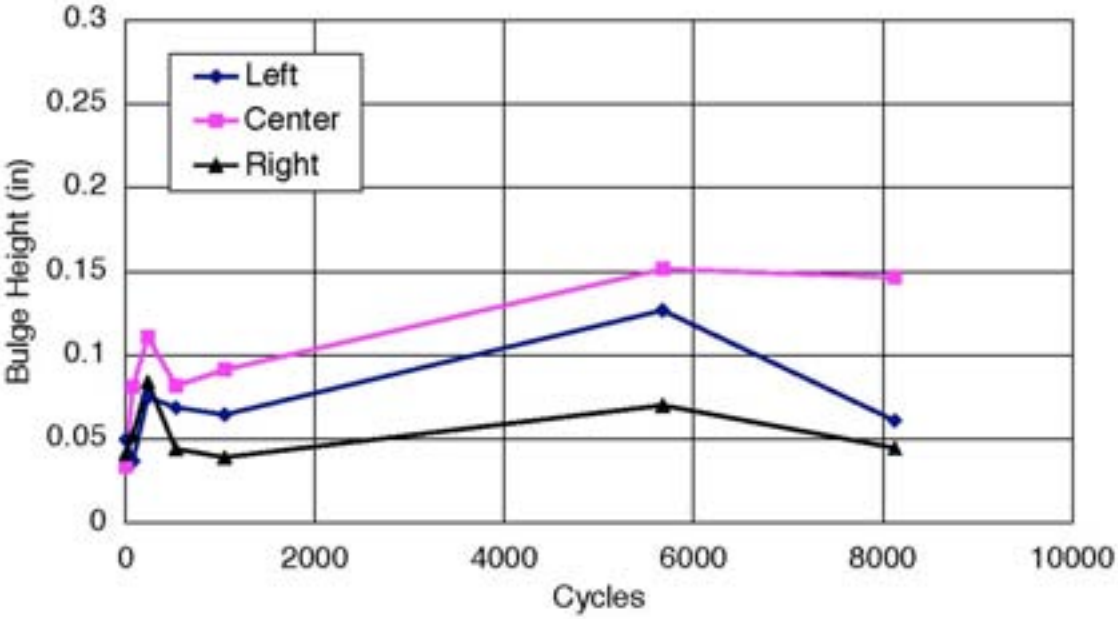
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.42: Test CYC5-D1 Summary

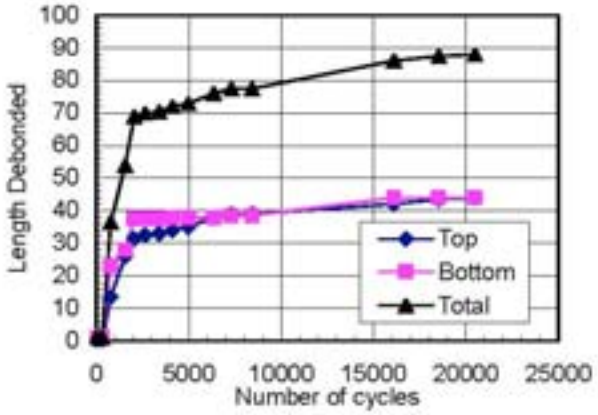




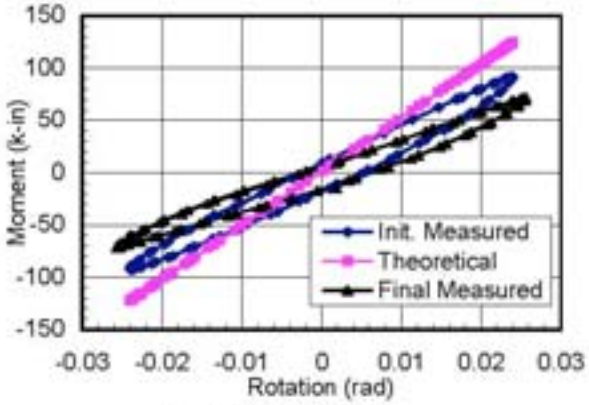
(b) Bottom

Figure A.43: CYC5-D1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC7-A1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_s$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_s$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	591
50%	1112
75%	1939
100%	20495

Rotational Stiffness

Initial Measured	37.3	k-in/%rot
Final Measured	26.6	k-in/%rot
Elastic Model	51.4	k-in/%rot

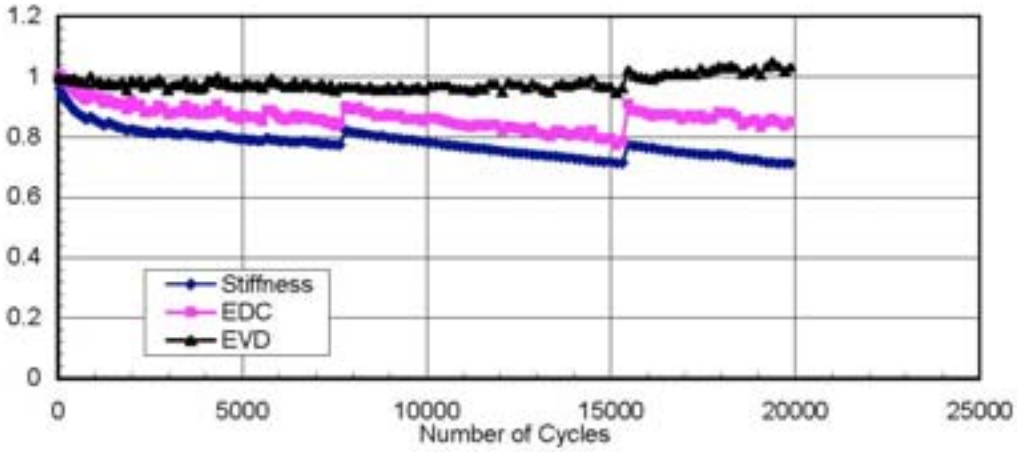
Local Nominal Shear Strains

Average Axial	4.1
Max. Rotation	1.3
Average Shear	0.0

Energy

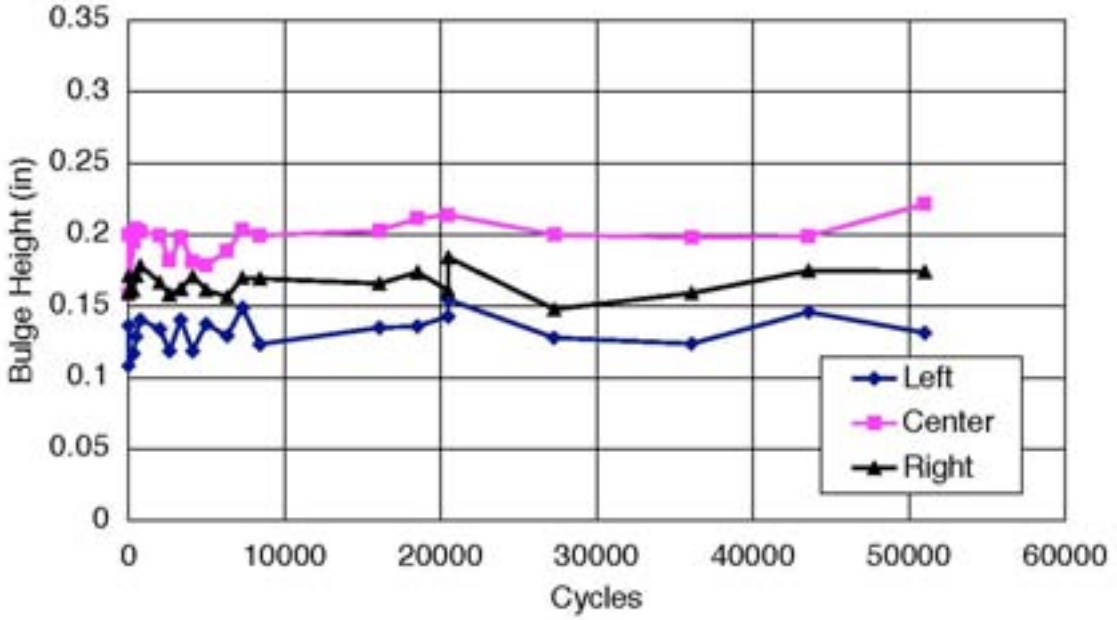
Initial EDC	1.027	k-in*rot
Final EDC	0.875	k-in*rot
Initial EVD	0.074	
Final EVD	0.076	

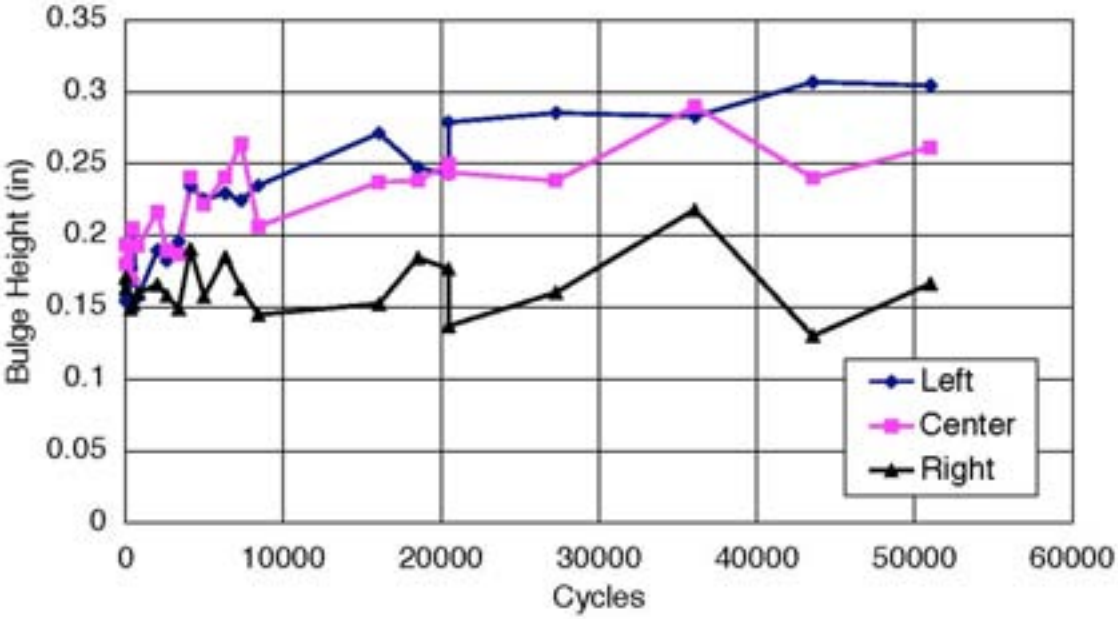
EDC = Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.44: Test CYC7-A1 Summary

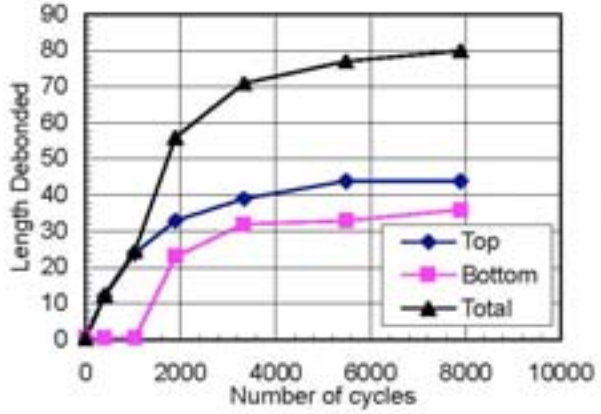




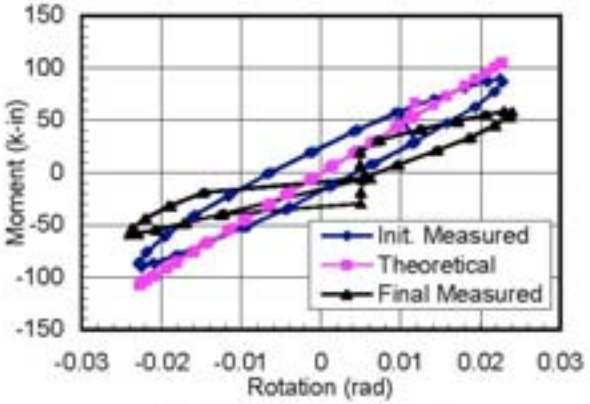
(b) Bottom

Figure A.45: CYC7-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC7-A2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_0$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	17
25%	907
50%	1572
75%	2856
100%	N/A

Rotational Stiffness

Initial Measured	37.4	k-in/%rot
Final Measured	22.9	k-in/%rot
Elastic Model	46.7	k-in/%rot

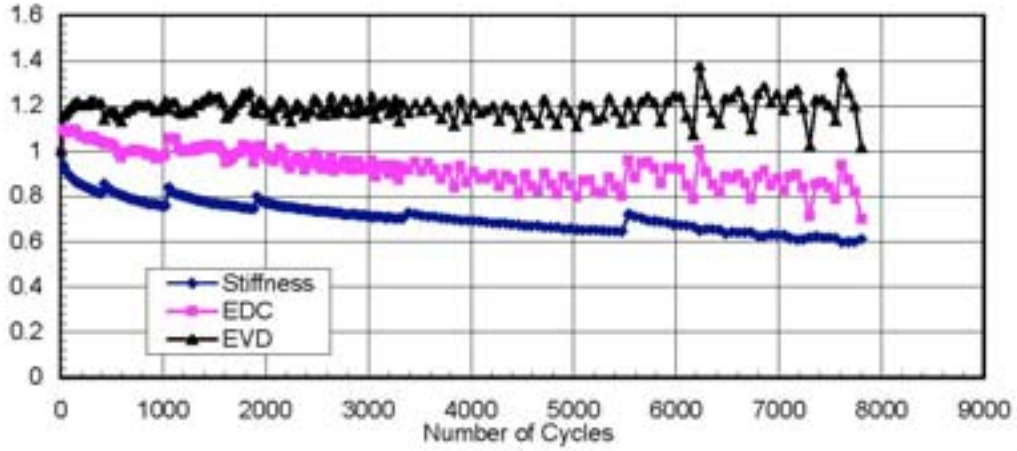
Local Nominal Shear Strains

Average Axial	4.4
Max. Rotation	1.4
Average Shear	0.0

Energy

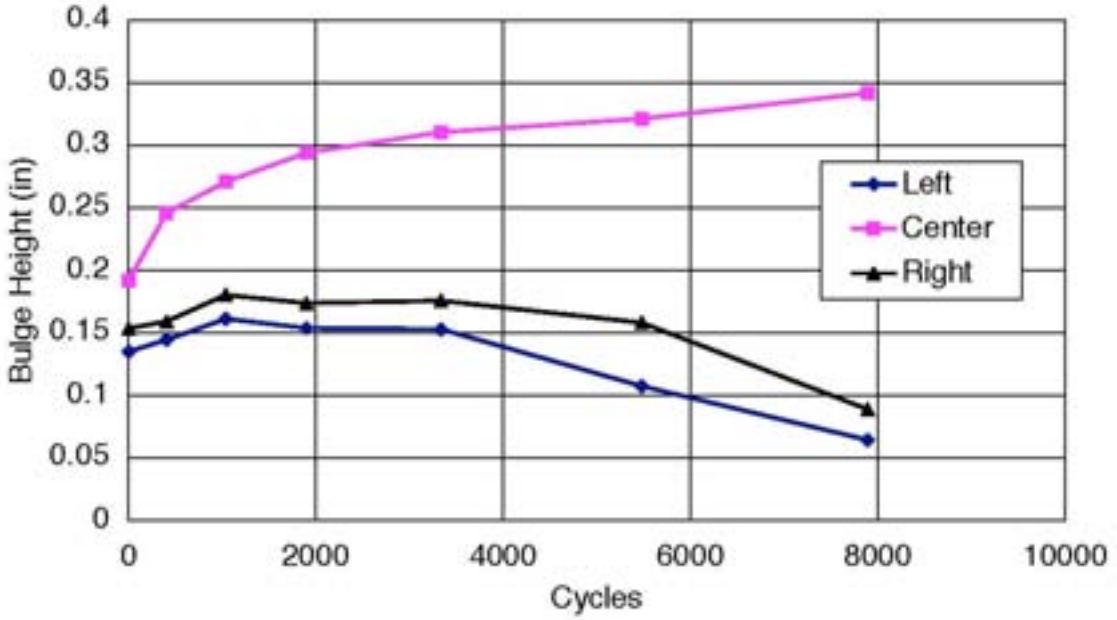
Initial EDC	1.331	k-in*rot
Final EDC	0.929	k-in*rot
Initial EVD	0.103	
Final EVD	0.105	

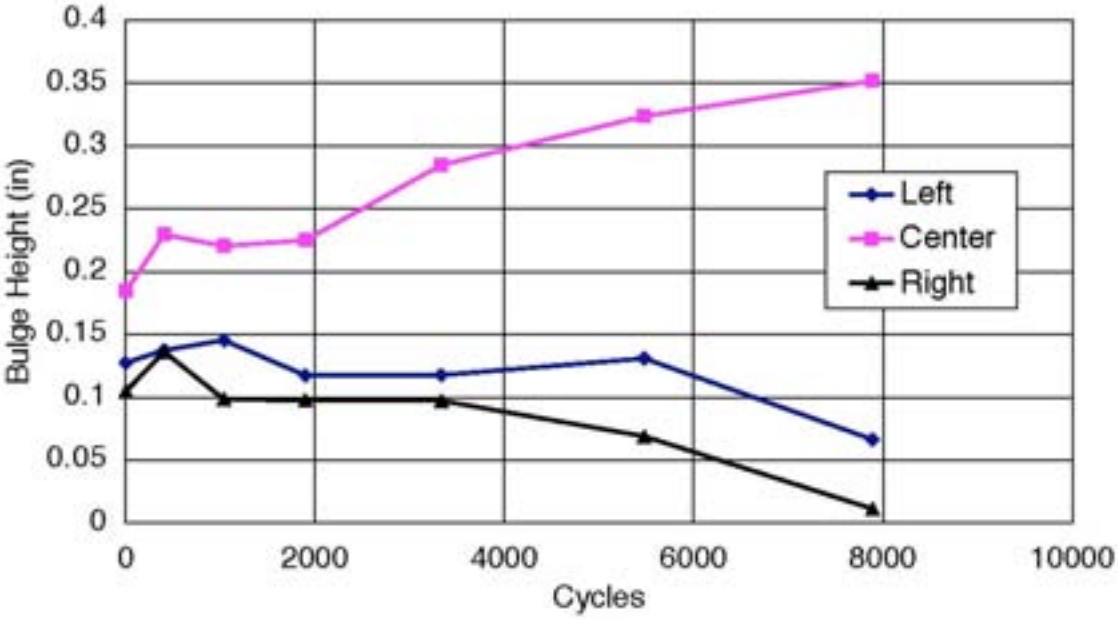
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.46: Test CYC7-A2 Summary

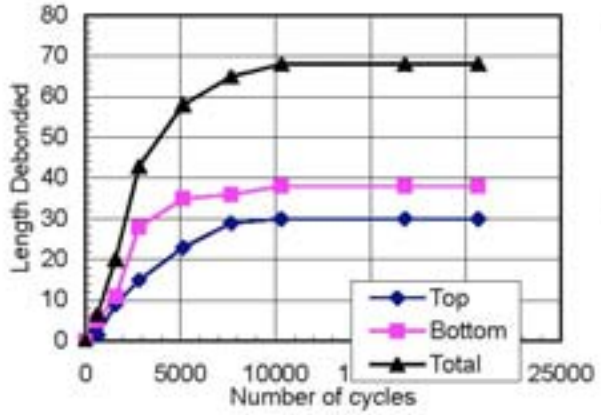




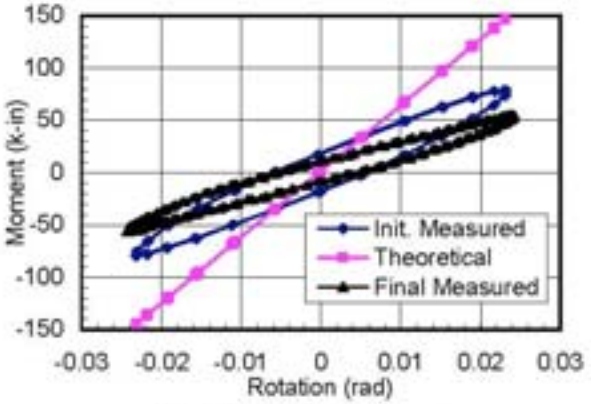
(b) Bottom

Figure A.47: CYC7-A2 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC7-B1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_0$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	95
25%	1692
50%	2989
75%	8541
100%	N/A

Rotational Stiffness

Initial Measured	32.7	k-in/%rot
Final Measured	21.7	k-in/%rot
Elastic Model	63.0	k-in/%rot

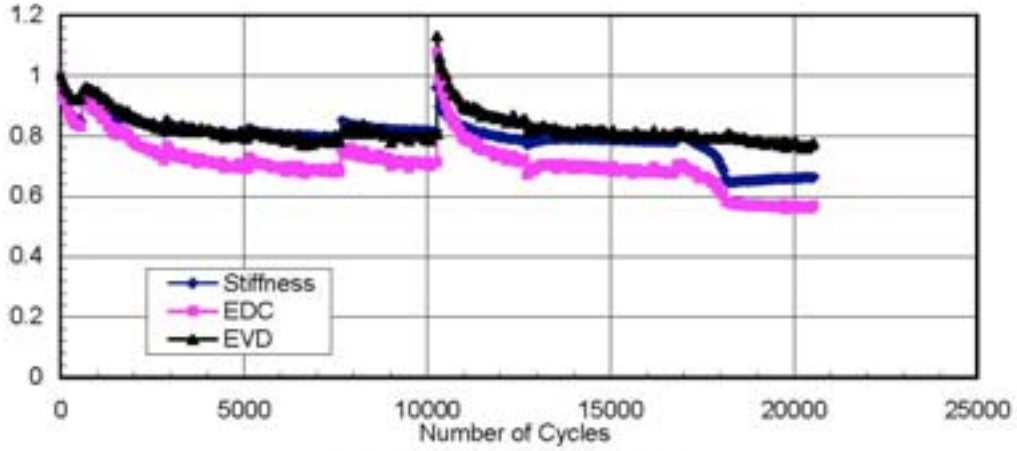
Local Nominal Shear Strains

Average Axial	3.4
Max. Rotation	1.5
Average Shear	0.0

Energy

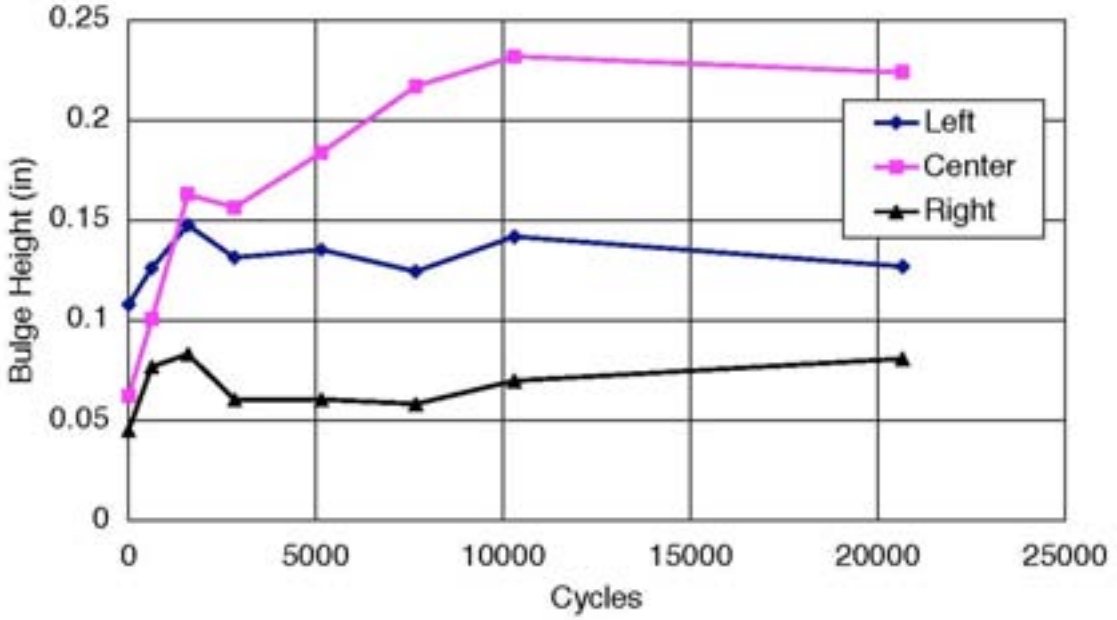
Initial EDC	1.328	k-in*rot
Final EDC	0.757	k-in*rot
Initial EVD	0.115	
Final EVD	0.089	

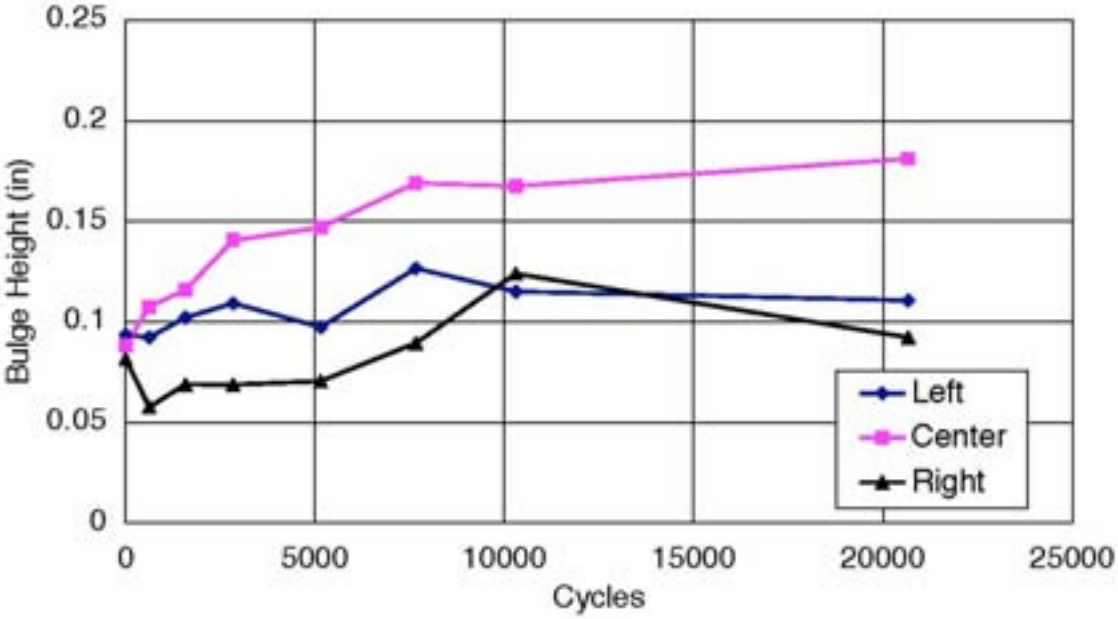
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.48: Test CYC7-B1 Summary

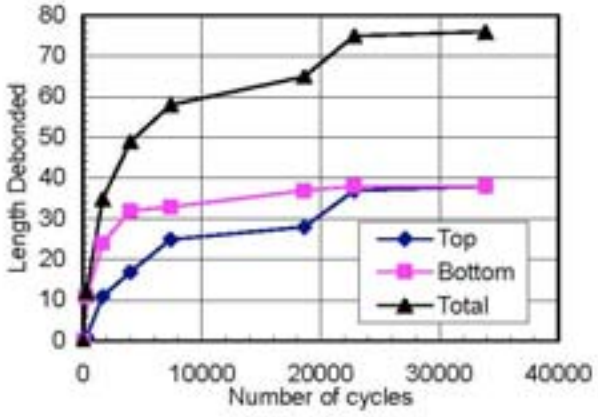




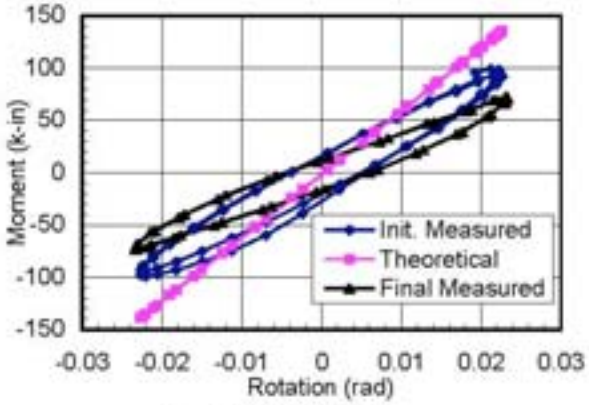
(b) Bottom

Figure A.49: CYC7-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC7-C1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_{cr}$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$4/9\theta_r$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	23
25%	883
50%	3152
75%	19037
100%	N/A

Rotational Stiffness

Initial Measured	41.9	k-in/%rot
Final Measured	29.2	k-in/%rot
Elastic Model	60.5	k-in/%rot

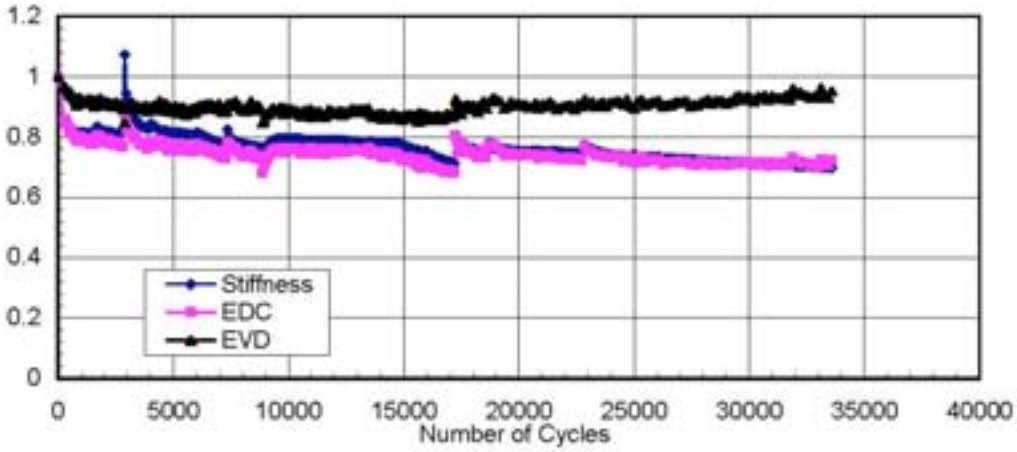
Local Nominal Shear Strains

Average Axial	3.6
Max. Rotation	1.3
Average Shear	0.0

Energy

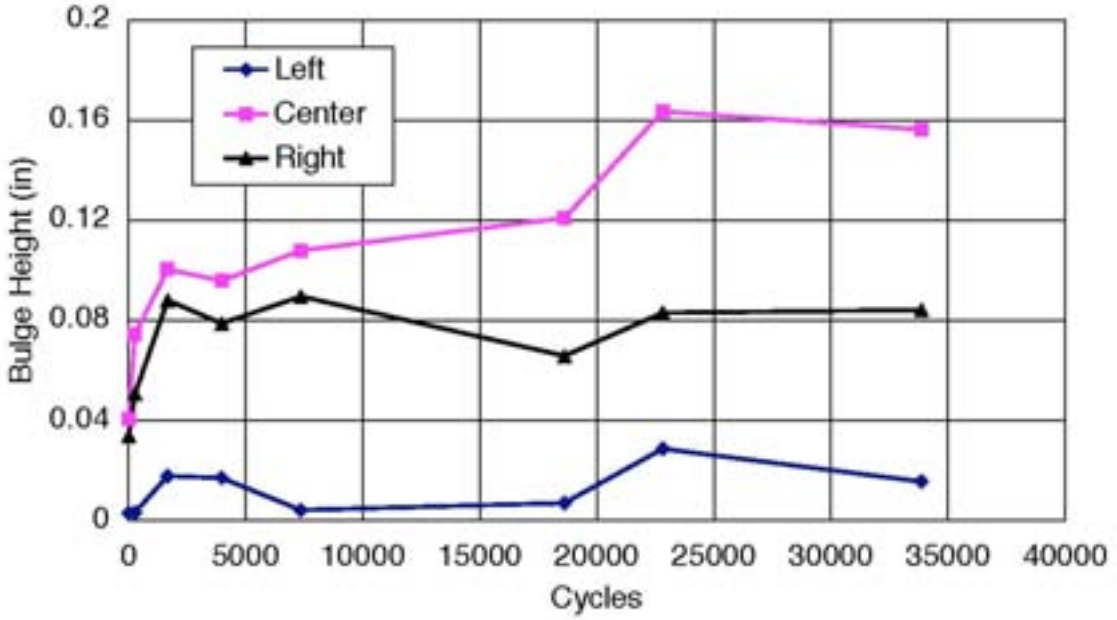
Initial EDC	1.418	k-in*rot
Final EDC	1.024	k-in*rot
Initial EVD	0.101	
Final EVD	0.096	

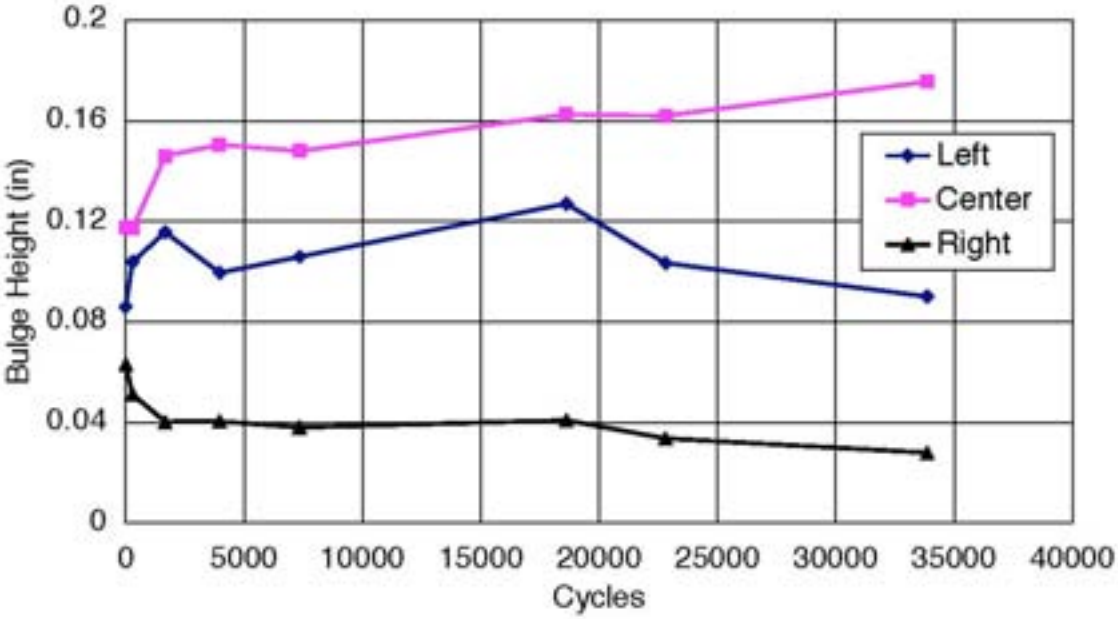
EDC = Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.50: Test CYC7-C1 Summary

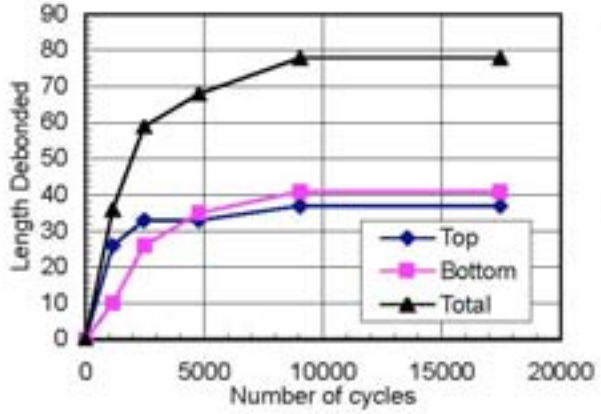




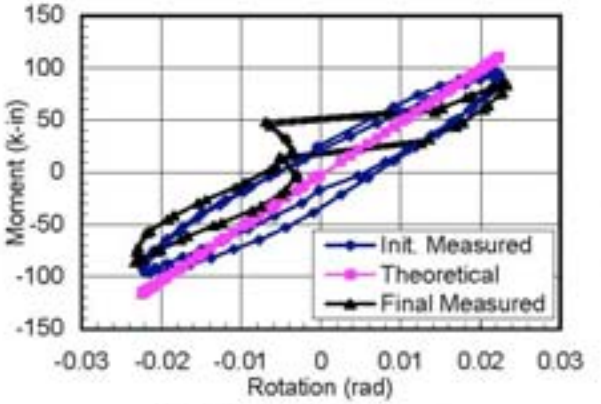
(b) Bottom

Figure A.51: CYC7-C1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC7-D1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_0$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	32
25%	705
50%	1613
75%	4262
100%	N/A

Rotational Stiffness

Initial Measured	40.5	k-in/%rot
Final Measured	31.6	k-in/%rot
Elastic Model	50.6	k-in/%rot

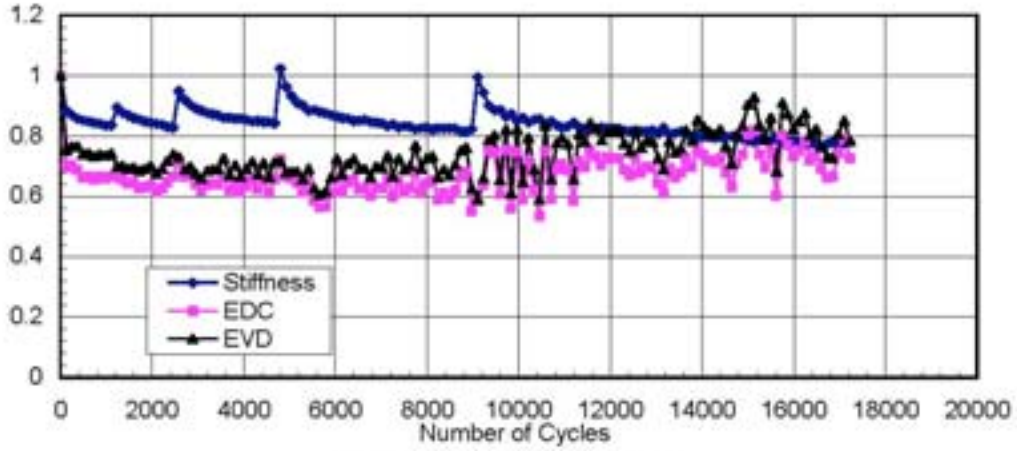
Local Nominal Shear Strains

Average Axial	4.4
Max. Rotation	1.2
Average Shear	0.0

Energy

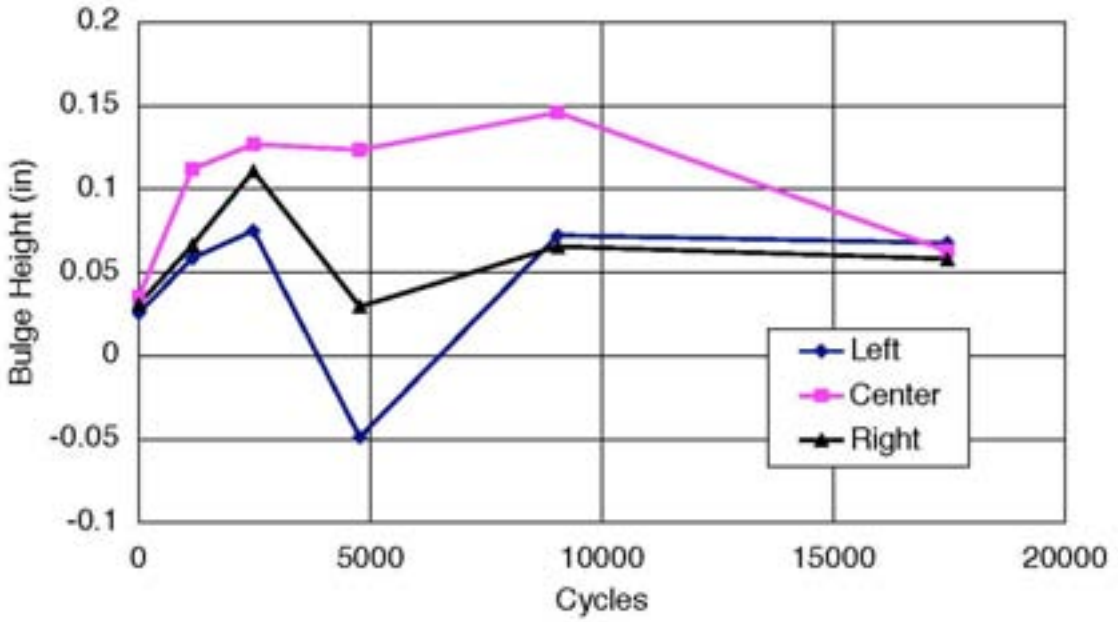
Initial EDC	1.769	k-in*rot
Final EDC	1.286	k-in*rot
Initial EVD	0.131	
Final EVD	0.103	

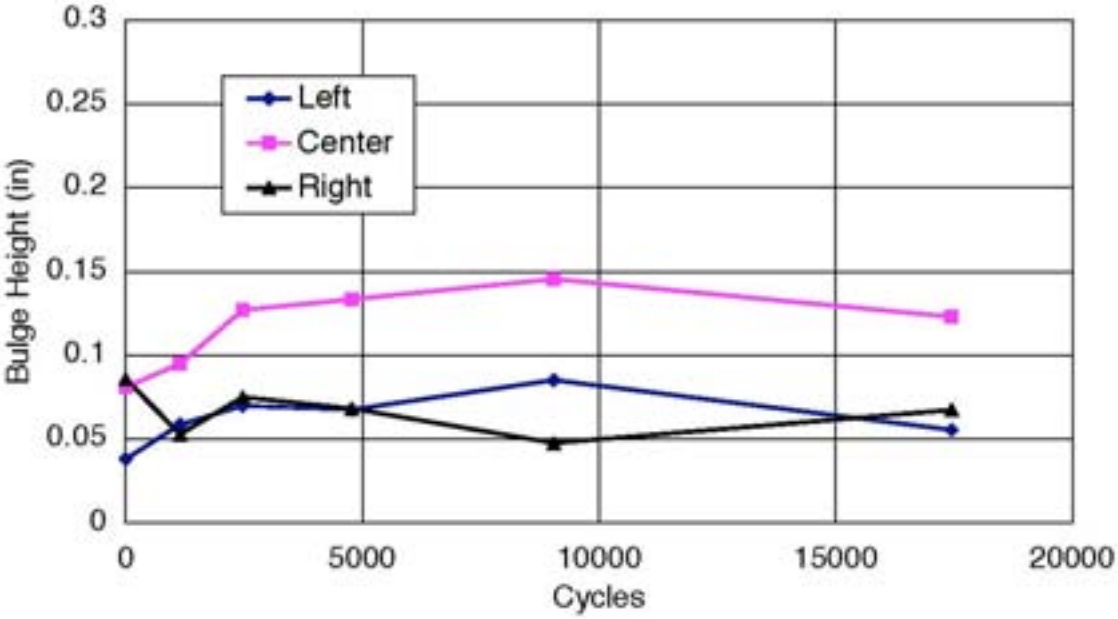
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.52: Test CYC7-D1 Summary

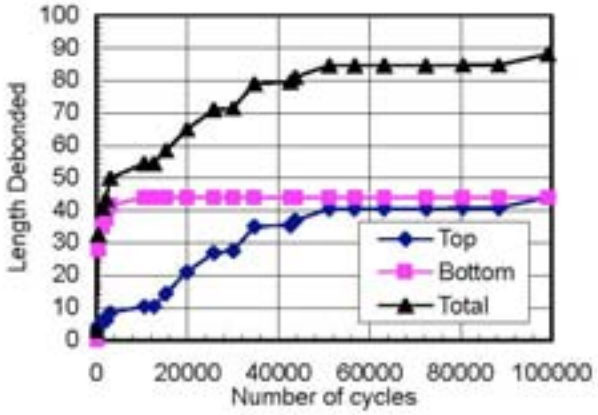




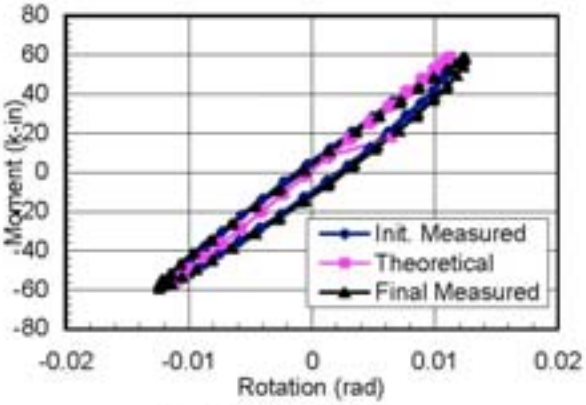
(b) Bottom

Figure A.53: CYC7-D1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC8-A1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_D$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$2/8\theta_D$ = 0.0125 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	1
25%	305
50%	2152
75%	20916
100%	99160

Rotational Stiffness

Initial Measured	47.6	k-in/%rot
Final Measured	45.7	k-in/%rot
Elastic Model	51.4	k-in/%rot

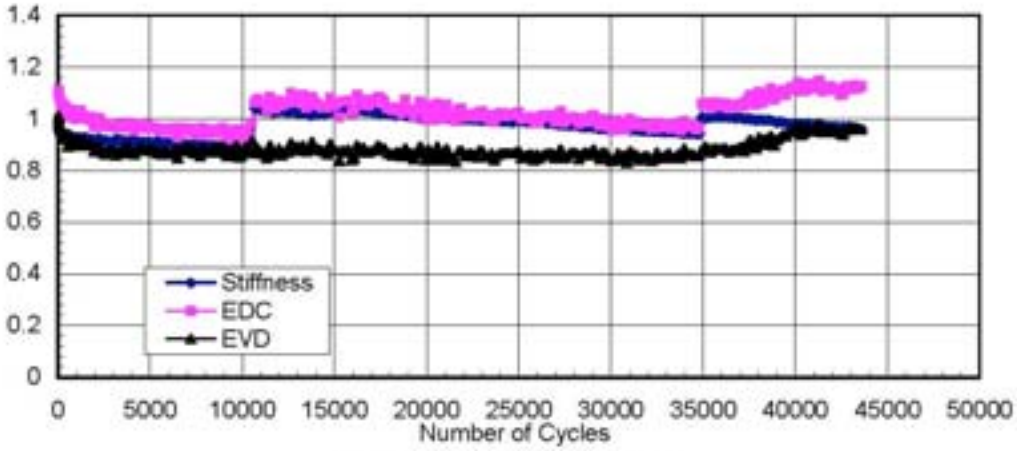
Local Nominal Shear Strains

Average Axial	4.1
Max. Rotation	0.8
Average Shear	0.0

Energy

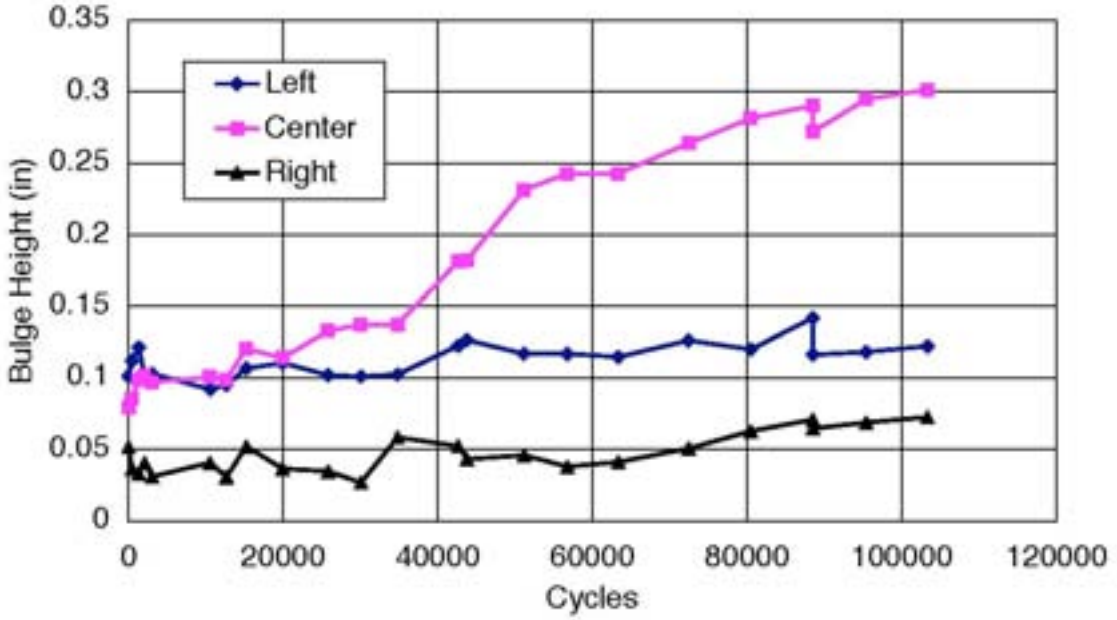
Initial EDC	0.277	k-in*rot
Final EDC	0.311	k-in*rot
Initial EVD	0.070	
Final EVD	0.067	

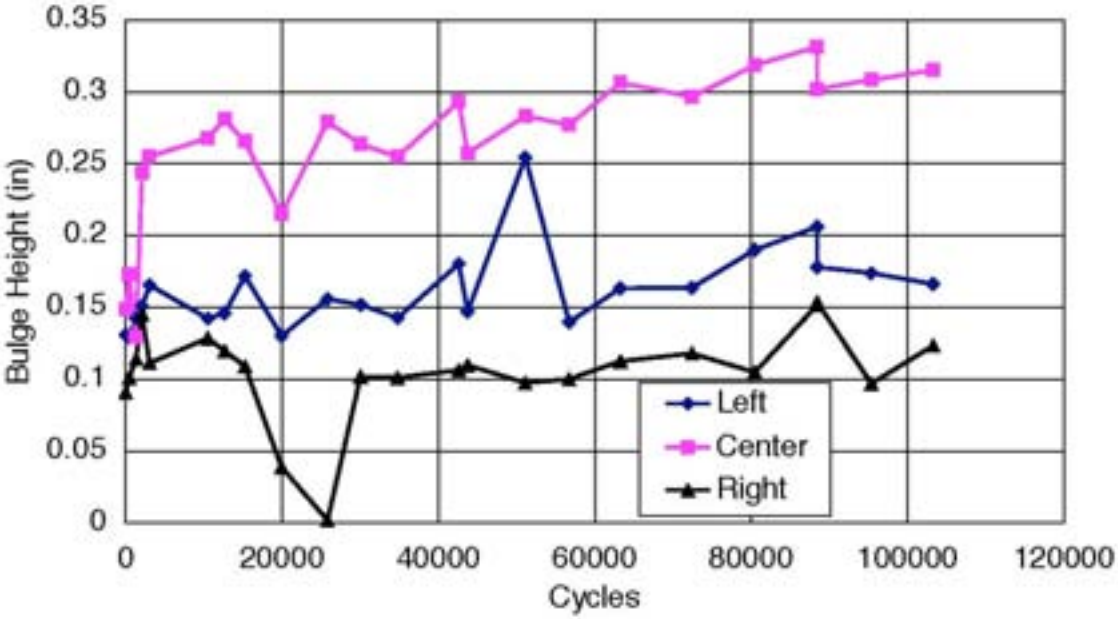
EDC = Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.54: Test CYC8-A1 Summary

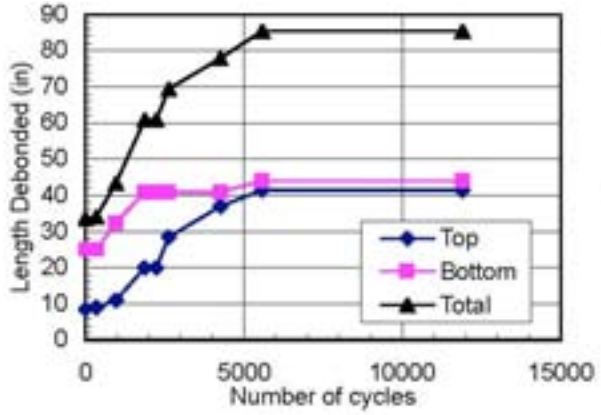




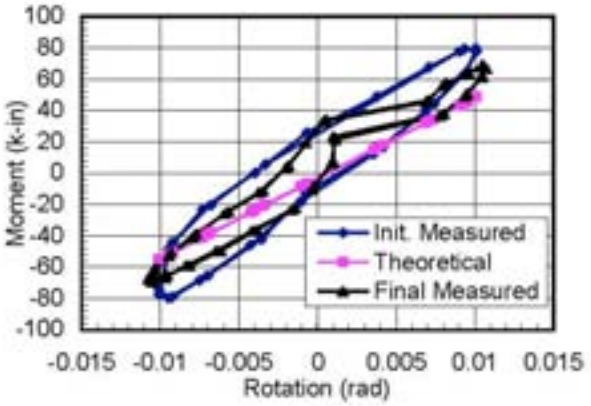
(b) Bottom

Figure A.55: CYCS-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC9-A1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$2/8\theta_0$ = 0.0125 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	0
50%	994
75%	2469
100%	N/A

Rotational Stiffness

Initial Measured	71.7	k-in/%rot
Final Measured	62.0	k-in/%rot
Elastic Model	51.4	k-in/%rot

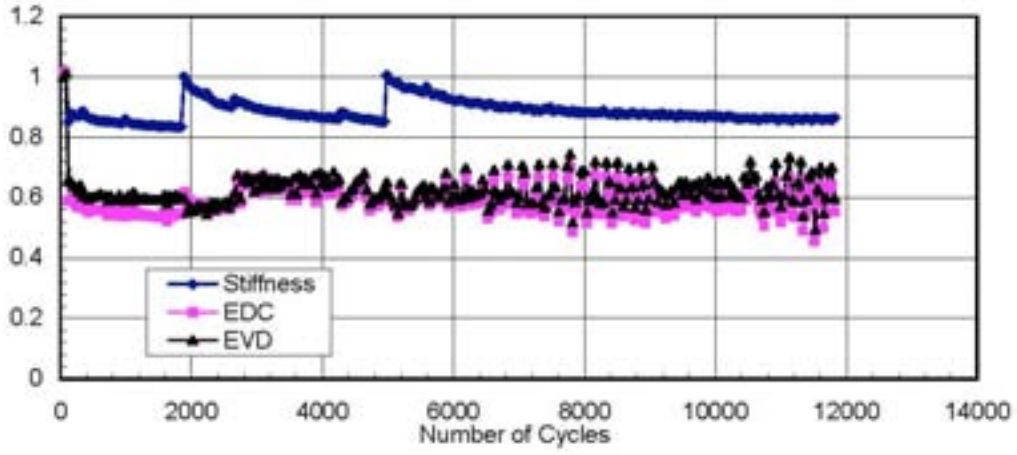
Local Nominal Shear Strains

Average Axial	5.6
Max. Rotation	0.6
Average Shear	0.0

Energy

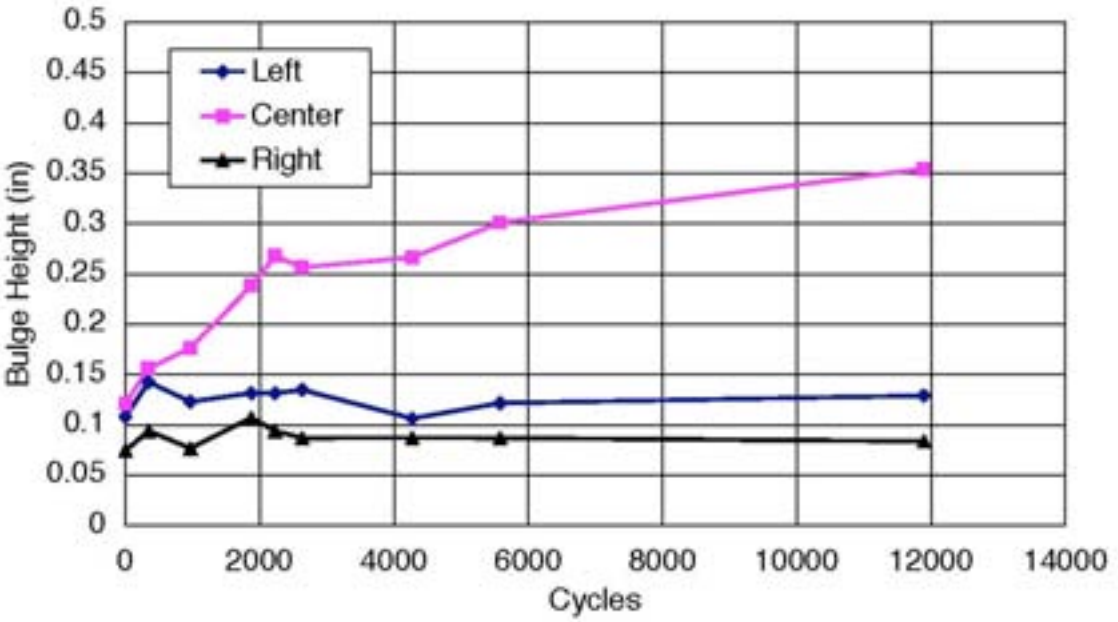
Initial EDC	0.685	k-in*rot
Final EDC	0.378	k-in*rot
Initial EVD	0.136	
Final EVD	0.081	

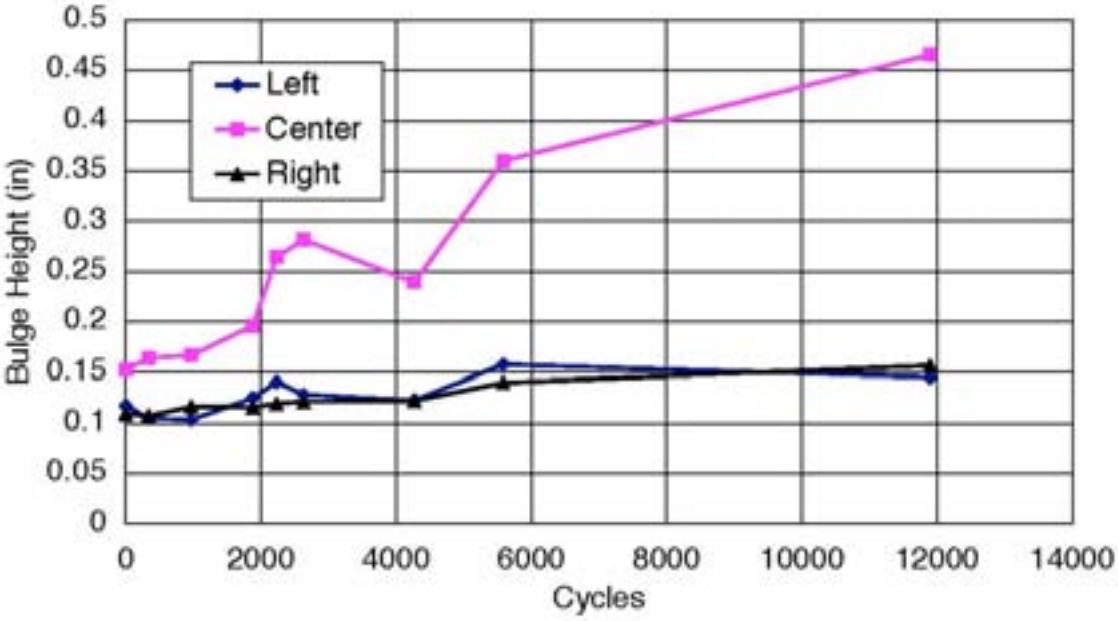
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.56: Test CYC9-A1 Summary

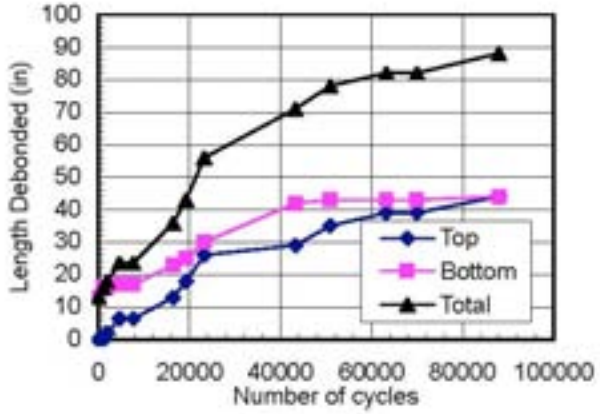




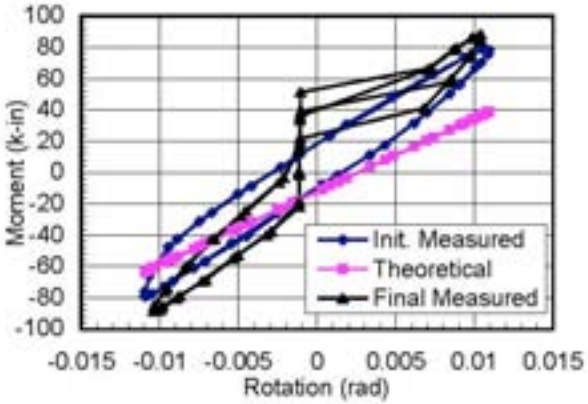
(b) Bottom

Figure A.57: CYC9-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC9-A2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_{cr}$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$2/8\theta_c$ = 0.0125 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	3927
50%	19599
75%	36629
100%	88026

Rotational Stiffness

Initial Measured	67.4	k-in/%rot
Final Measured	81.4	k-in/%rot
Elastic Model	46.7	k-in/%rot

Local Nominal Shear Strains

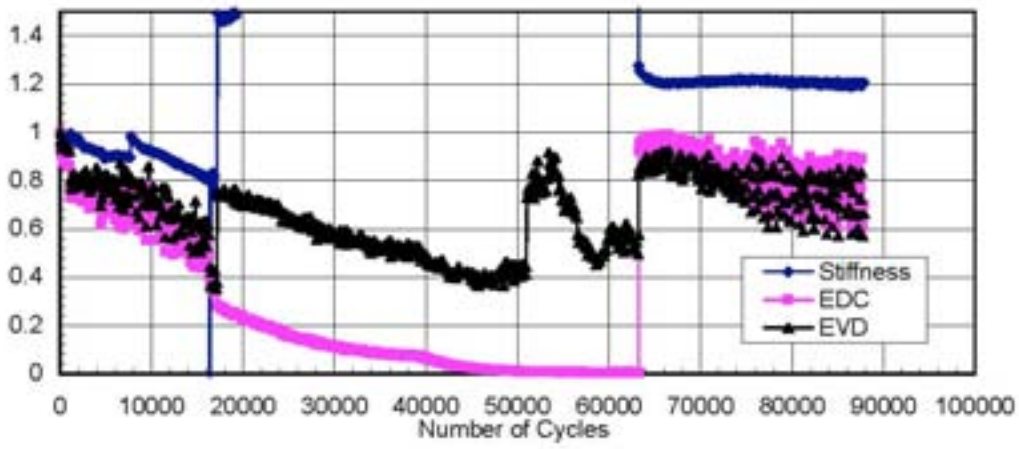
Average Axial	5.9
Max. Rotation	0.5
Average Shear	0.0

Energy

Initial EDC	0.531	k-in*rot
Final EDC	0.372	k-in*rot
Initial EVD	0.098	
Final EVD	0.064	

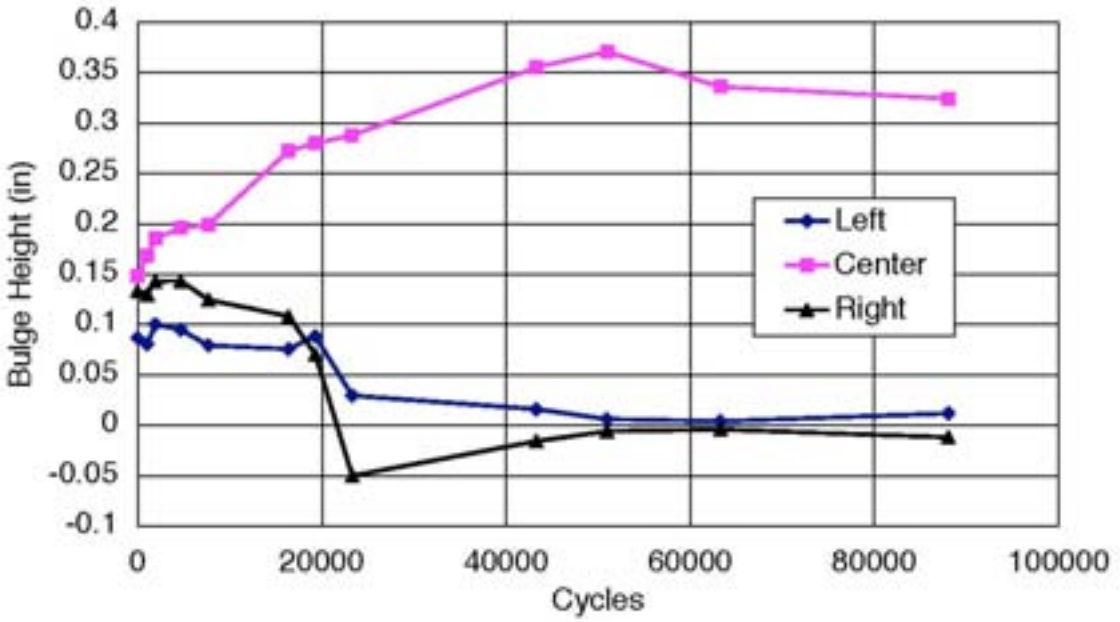
EDC=Energy Dissipated per Cycle

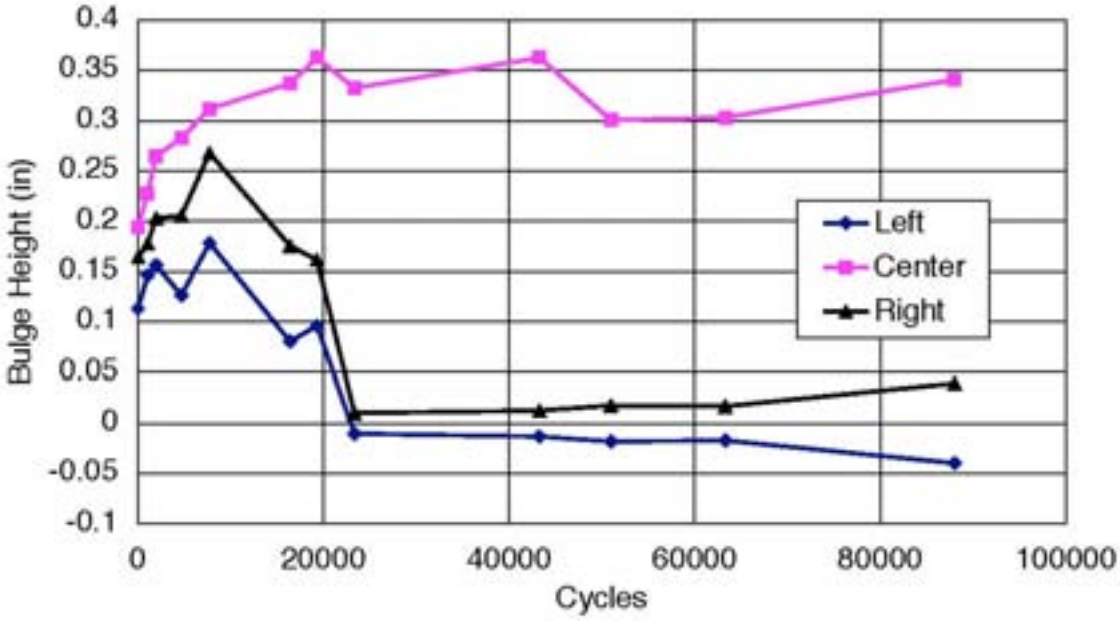
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.58: Test CYC9-A2 Summary

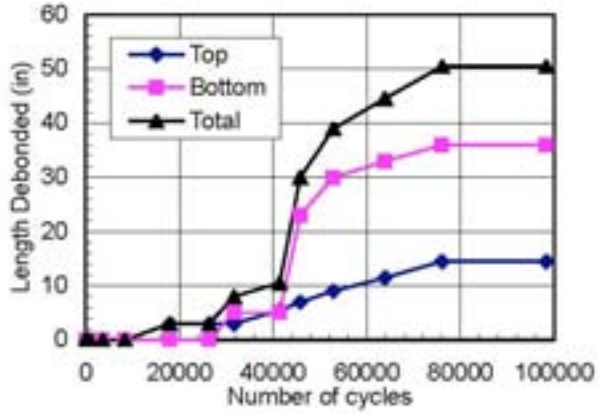




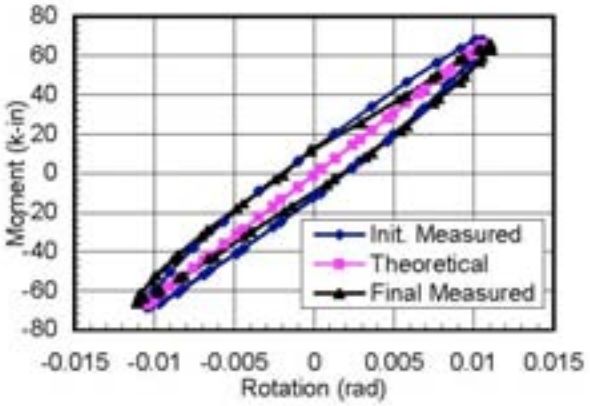
(b) Bottom

Figure A.59: CYC9-A2 Bulge Heights (a) Top of Bearing and (b) Bottome

CYC9-B1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_c$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$2/8\theta_c$ = 0.0125 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	11566
25%	43956
50%	62936
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	58.4	k-in/%rot
Final Measured	57.2	k-in/%rot
Elastic Model	63.0	k-in/%rot

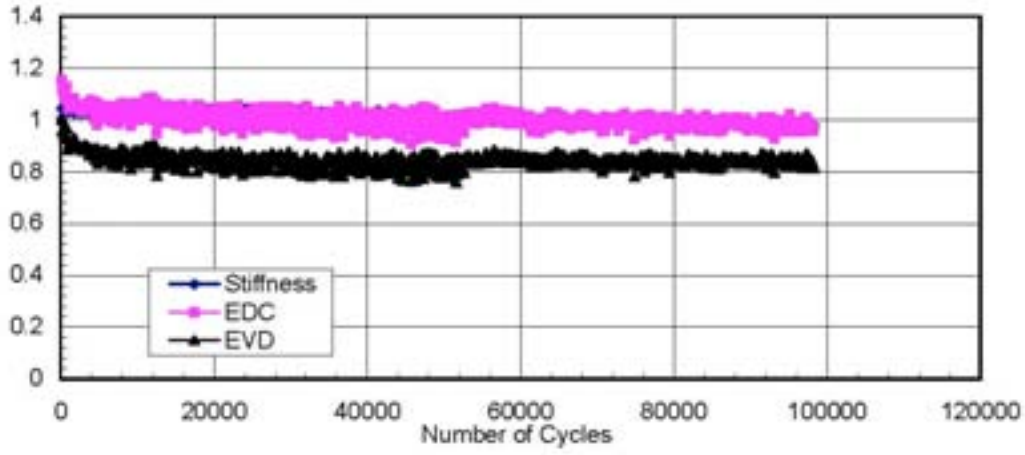
Local Nominal Shear Strains

Average Axial	4.7
Max. Rotation	0.6
Average Shear	0.0

Energy

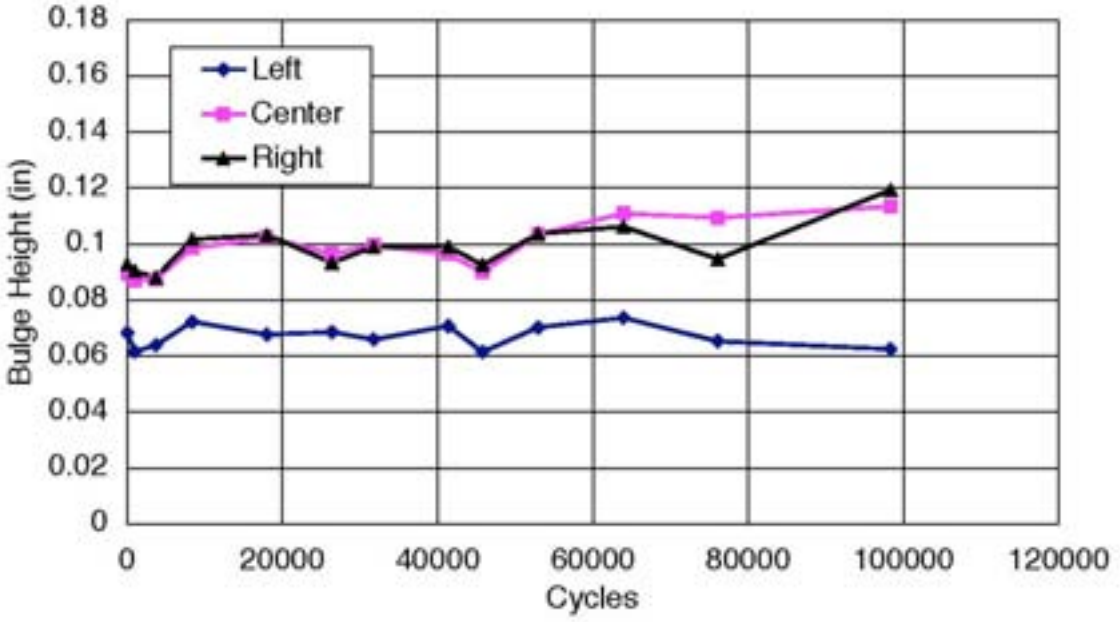
Initial EDC	0.1677	k-in*rot
Final EDC	0.1628	k-in*rot
Initial EVD	0.043	
Final EVD	0.0357	

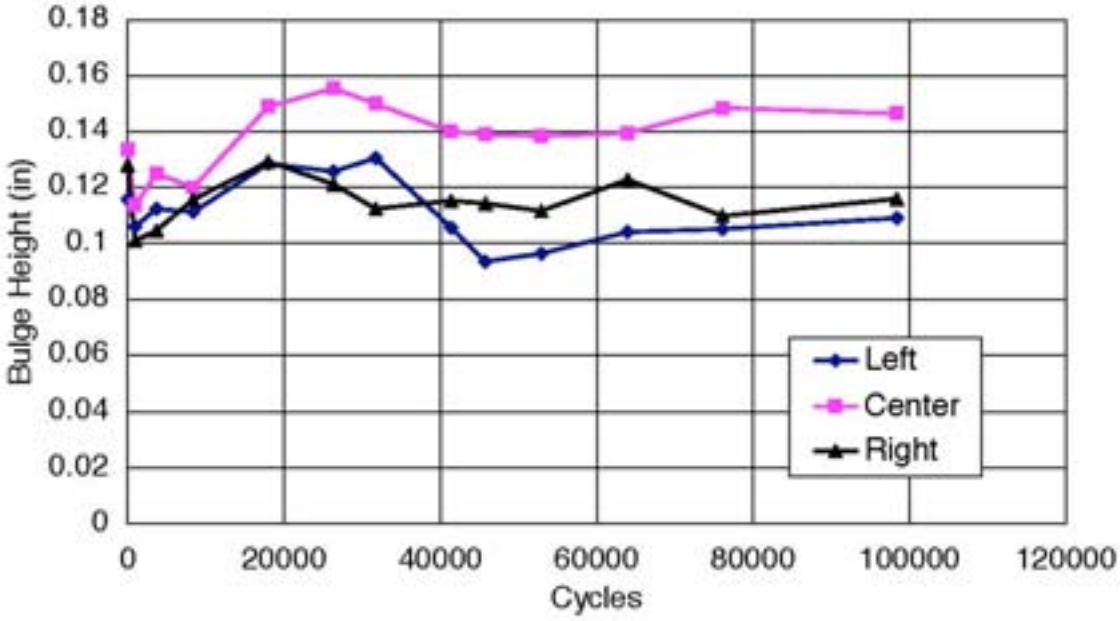
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.60: Test CYC9-B1 Summary

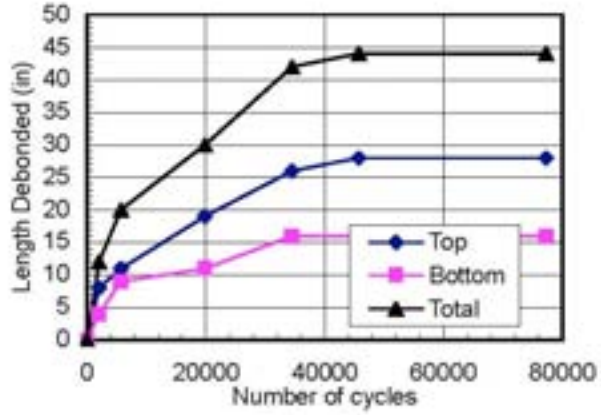




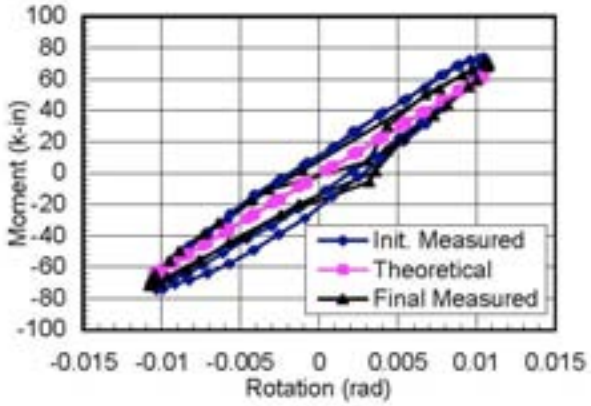
(b) Bottom

Figure A.61: CYC9-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC9-C1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	7/Bx$_1$ = 2625 psi
Static Rotation	0
Cyclic Rotation	2/Bθ_1 = 0.0125 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	169
25%	8557
50%	45749
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	68.0	k-in/%rot
Final Measured	63.2	k-in/%rot
Elastic Model	60.5	k-in/%rot

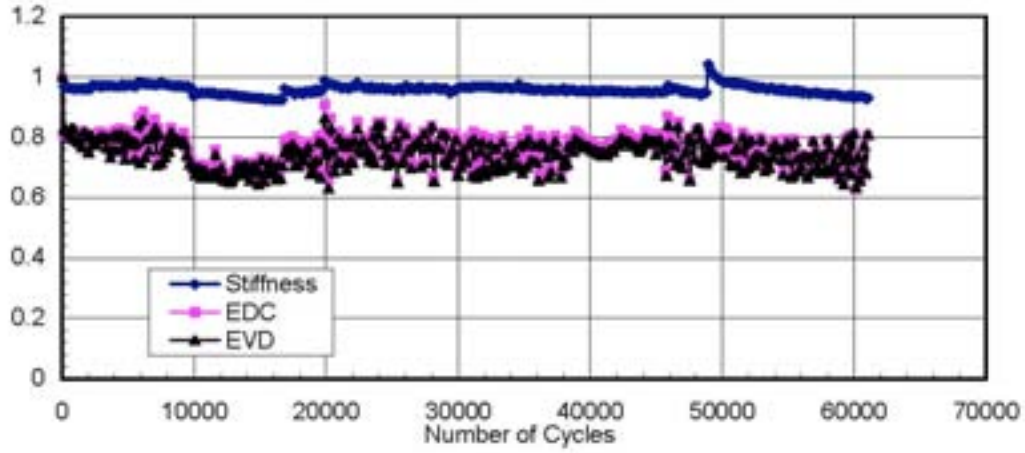
Local Nominal Shear Strains

Average Axial	5.0
Max. Rotation	0.6
Average Shear	0.0

Energy

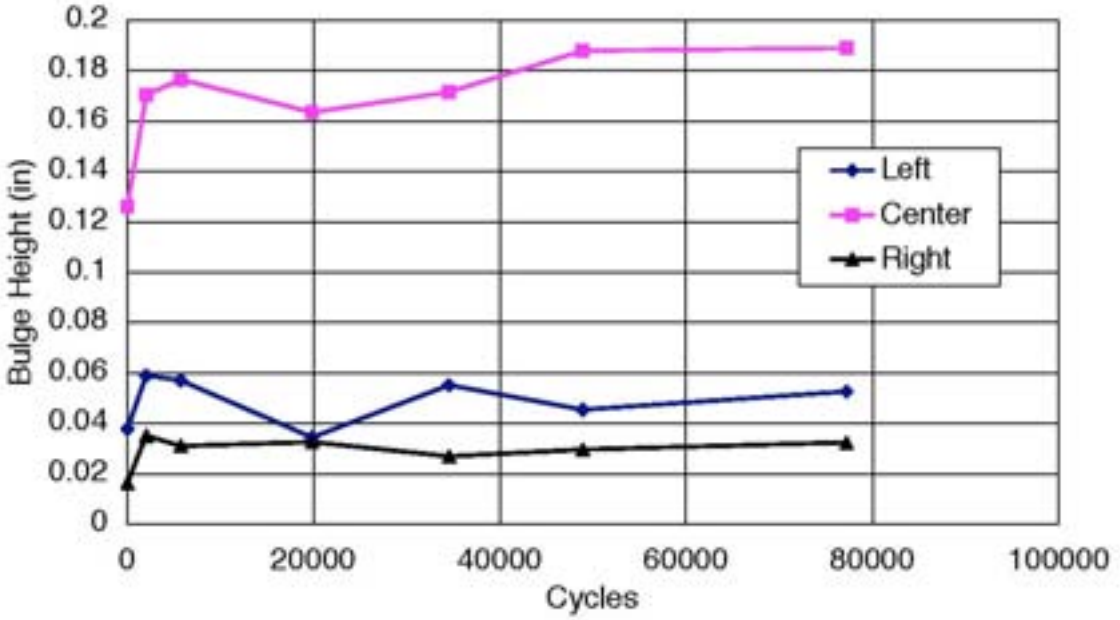
Initial EDC	0.49	k-in*rot
Final EDC	0.395	k-in*rot
Initial EVD	0.1	
Final EVD	0.081	

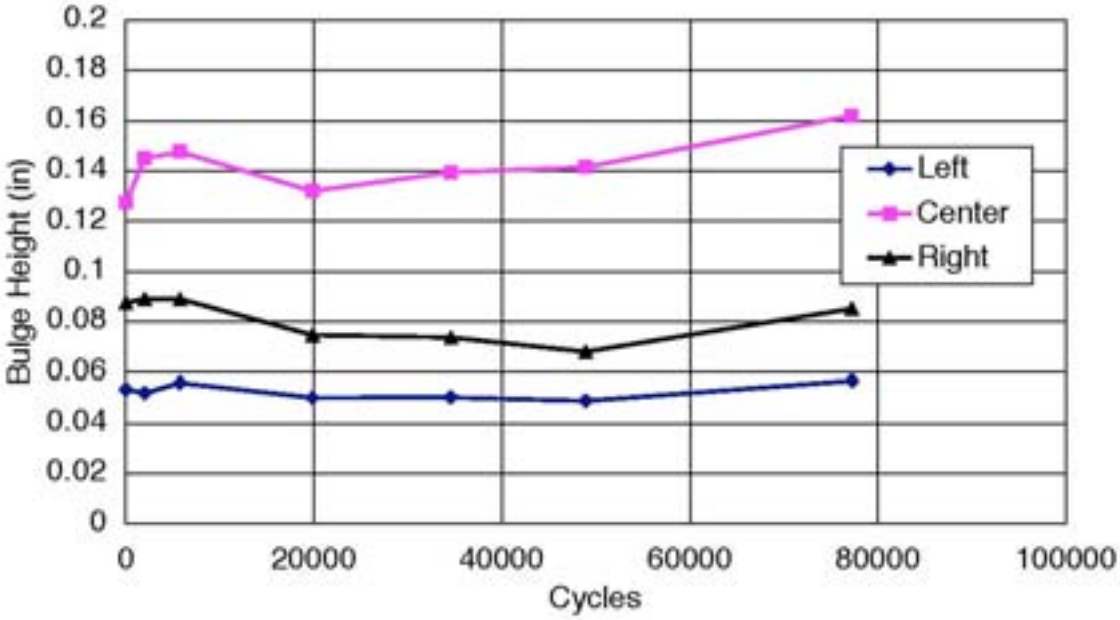
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.62: Test CYC9-C1 Summary

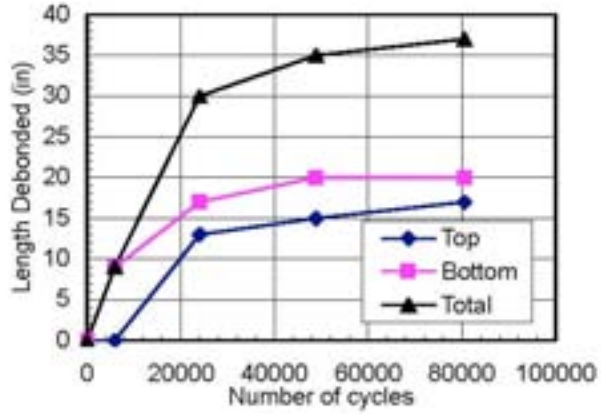




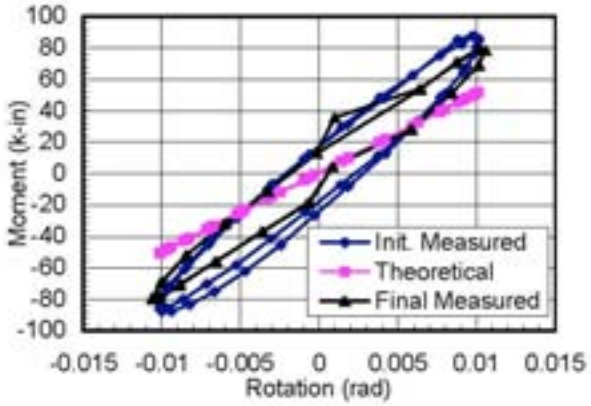
(b) Bottom

Figure A.63: CYC9-C1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC9-D1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/Bx_1$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$2/Bθ_c$ = 0.0125 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	658
25%	17117
50%	N/A
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	82.7	k-in/%rot
Final Measured	72.7	k-in/%rot
Elastic Model	50.6	k-in/%rot

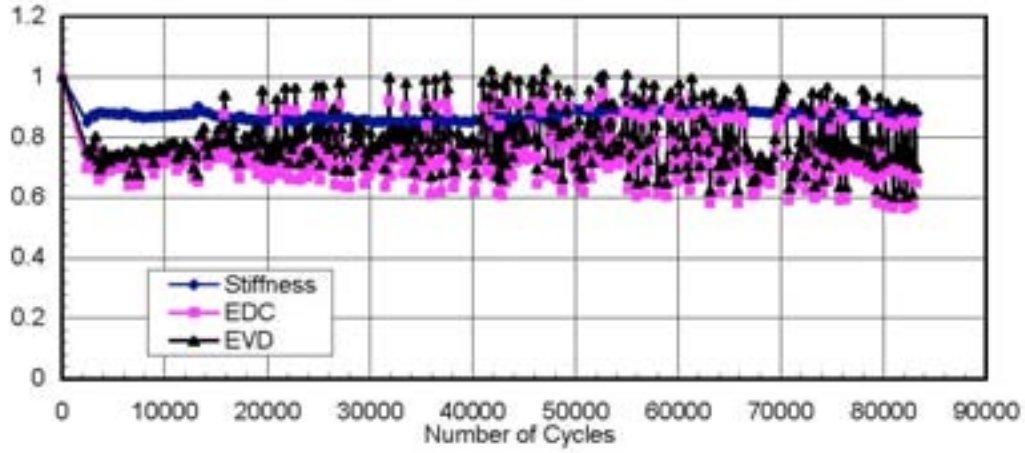
Local Nominal Shear Strains

Average Axial	6.0
Max. Rotation	0.5
Average Shear	0.0

Energy

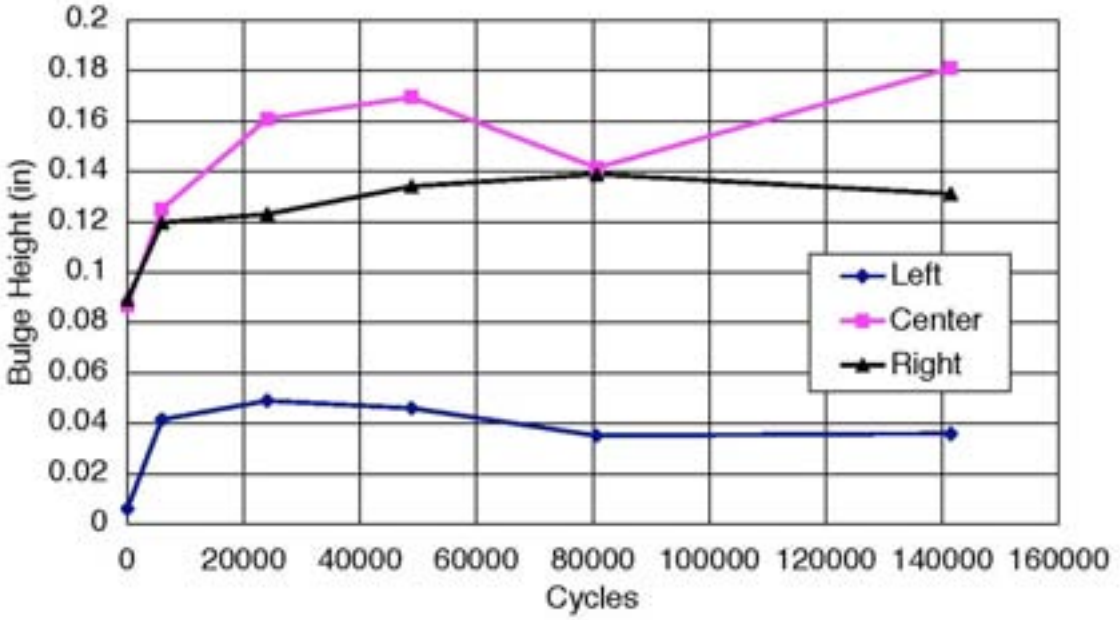
Initial EDC	0.630	k-in*rot
Final EDC	0.410	k-in*rot
Initial EVD	0.113	
Final EVD	0.079	

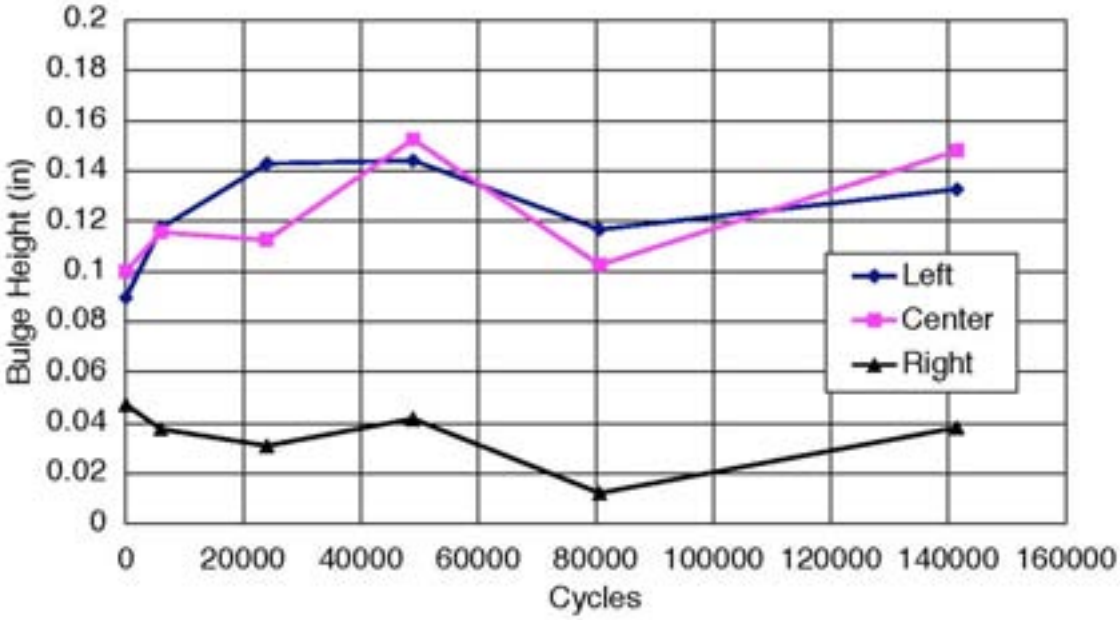
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.64: Test CYC9-D1 Summary

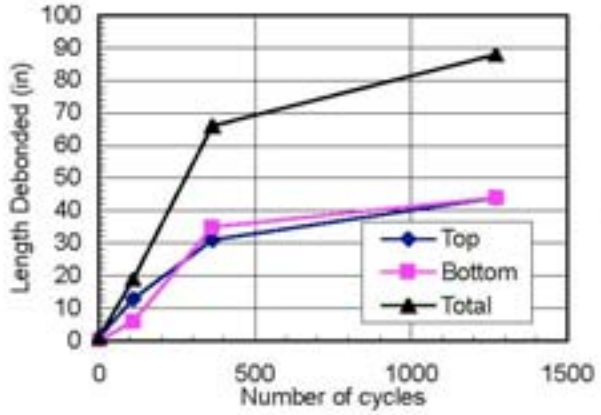




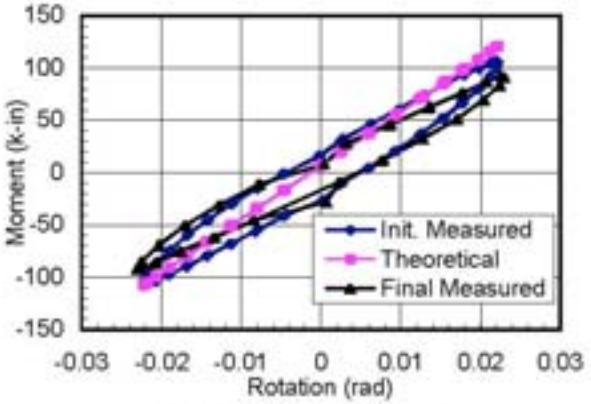
(b) Bottom

Figure A.65: CYC9-D1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC11-A1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_0$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	127
50%	245
75%	363
100%	1271

Rotational Stiffness

Initial Measured	45.8	k-in/%rot
Final Measured	38.3	k-in/%rot
Elastic Model	51.4	k-in/%rot

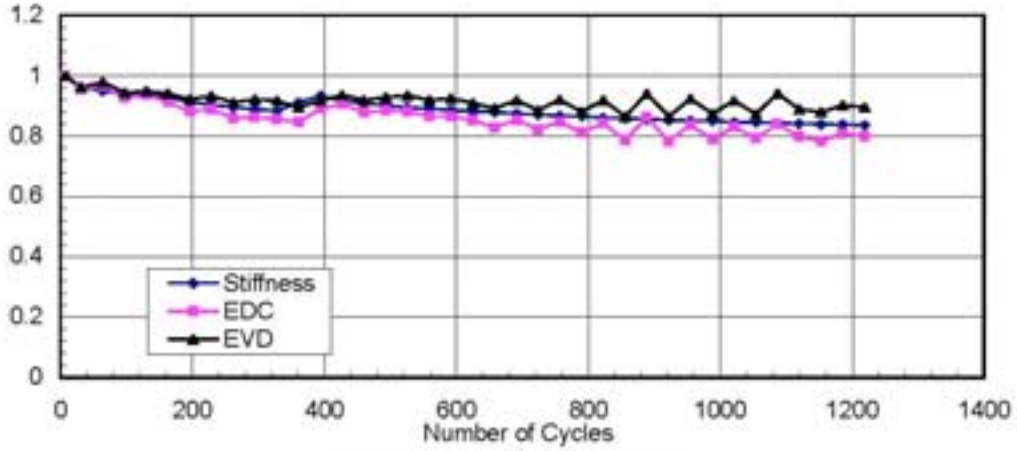
Local Nominal Shear Strains

Average Axial	5.7
Max. Rotation	1.3
Average Shear	0.0

Energy

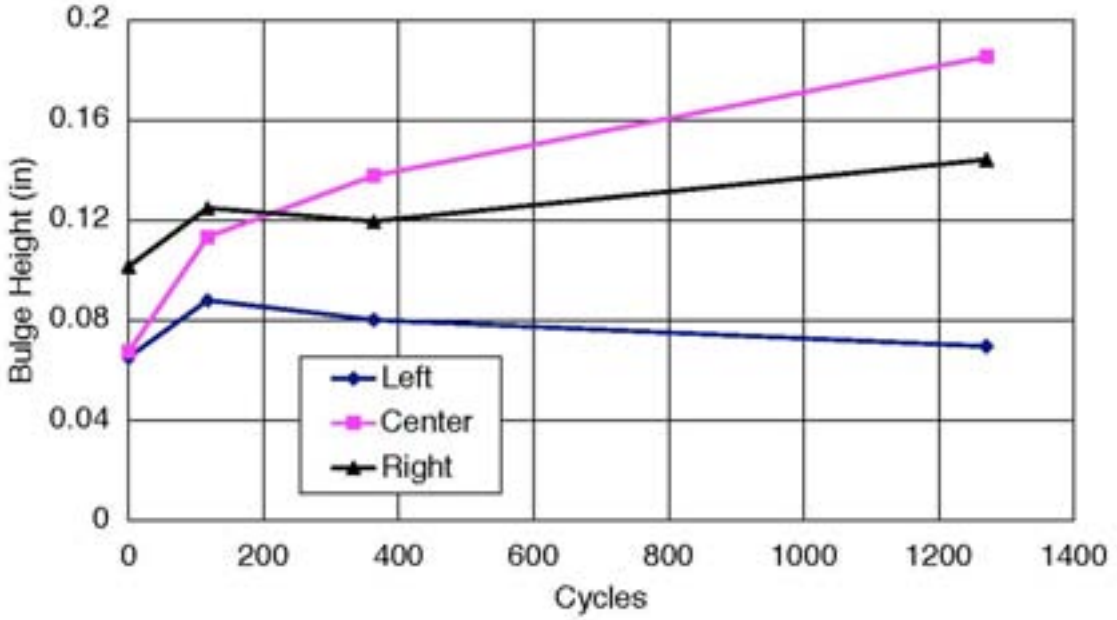
Initial EDC	1.495	k-in*rot
Final EDC	1.197	k-in*rot
Initial EVD	0.1	
Final EVD	0.089	

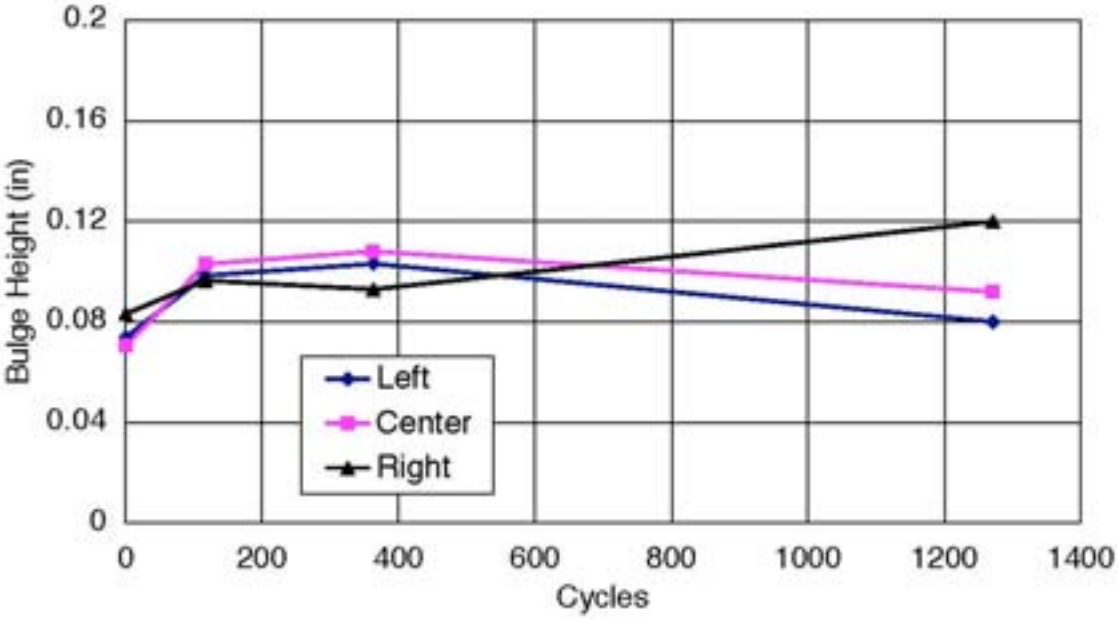
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.66: Test CYC11-A1 Summary

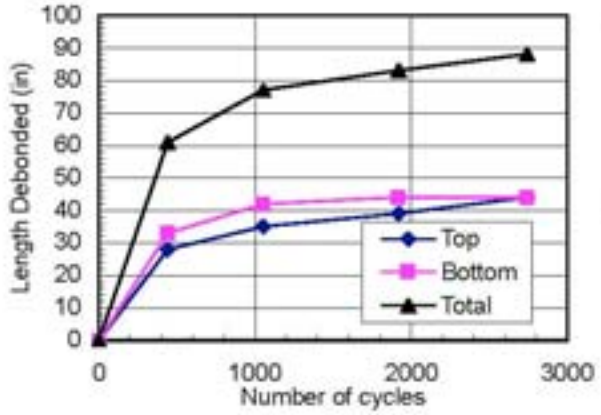




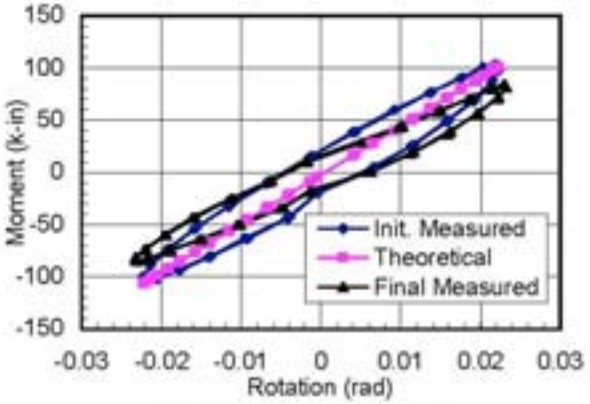
(b) Bottom

Figure A.67: CYC11-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC11-A2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_s$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_c$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	7
25%	160
50%	320
75%	633
100%	2743

Rotational Stiffness

Initial Measured	44.5	k-in/%rot
Final Measured	34.5	k-in/%rot
Elastic Model	46.7	k-in/%rot

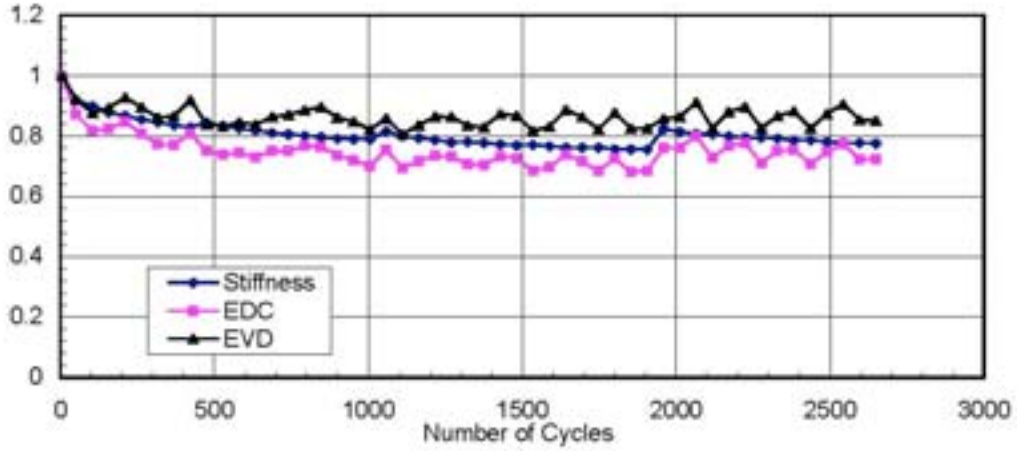
Local Nominal Shear Strains

Average Axial	6.1
Max. Rotation	1.2
Average Shear	0.0

Energy

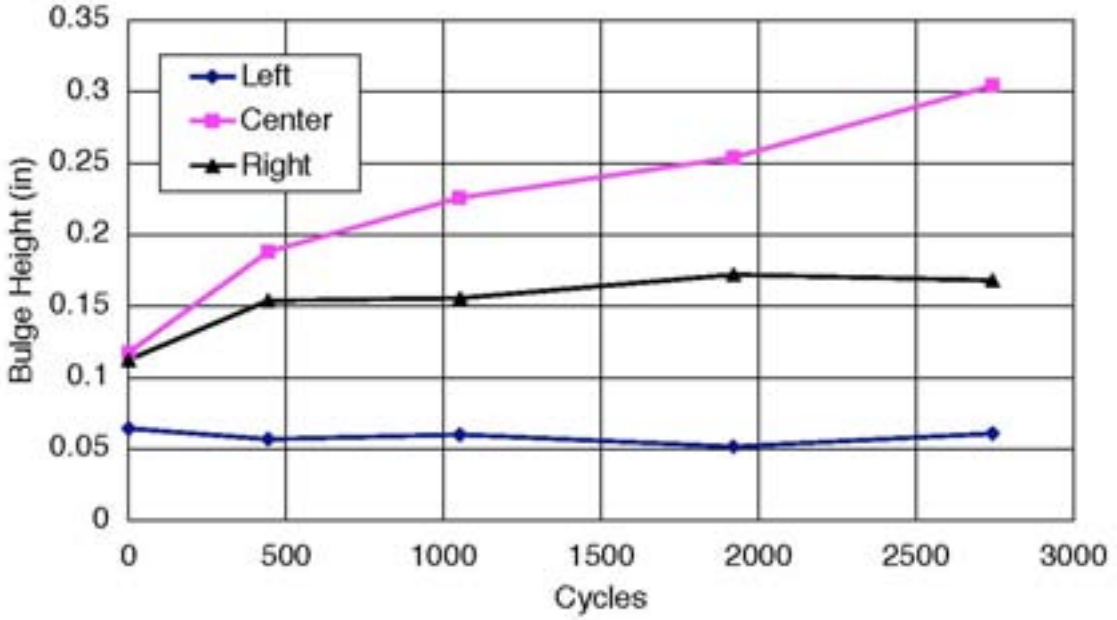
Initial EDC	1.606	k-in*rot
Final EDC	1.162	k-in*rot
Initial EVD	0.11	
Final EVD	0.094	

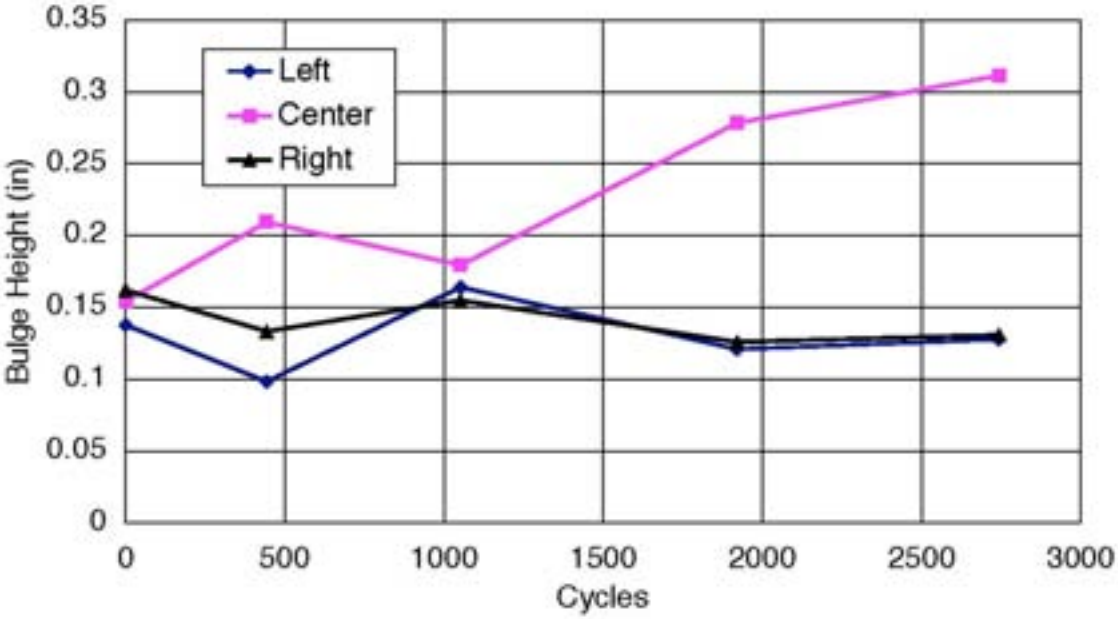
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.68: Test CYC11-A2 Summary

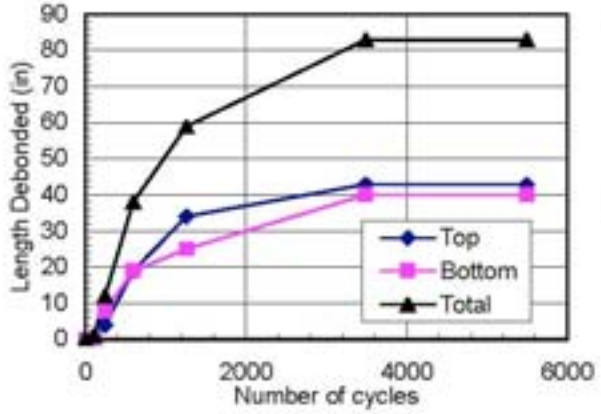




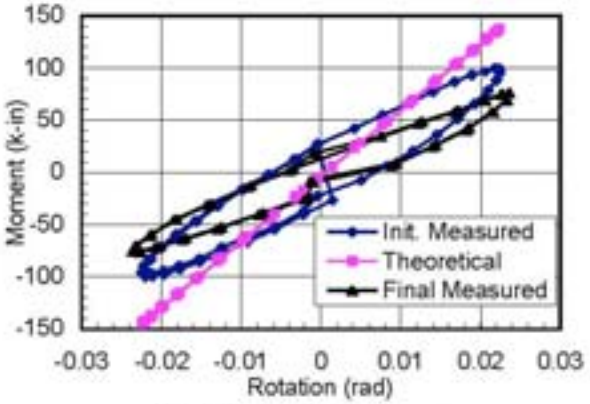
(b) Bottom

Figure A.69: CYC11-A2 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC11-B1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_0$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	105
25%	378
50%	784
75%	1909
100%	N/A

Rotational Stiffness

Initial Measured	42.0	k-in/%rot
Final Measured	30.6	k-in/%rot
Elastic Model	63.0	k-in/%rot

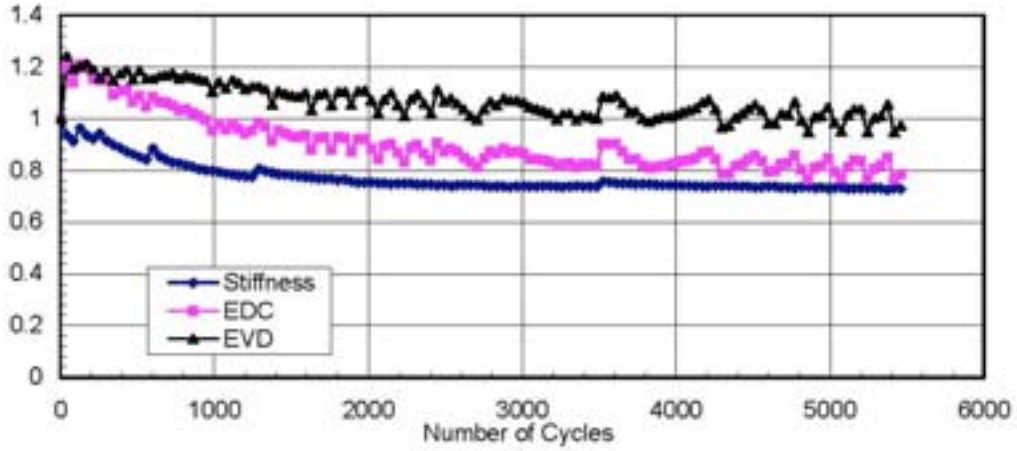
Local Nominal Shear Strains

Average Axial	4.6
Max. Rotation	1.2
Average Shear	0.0

Energy

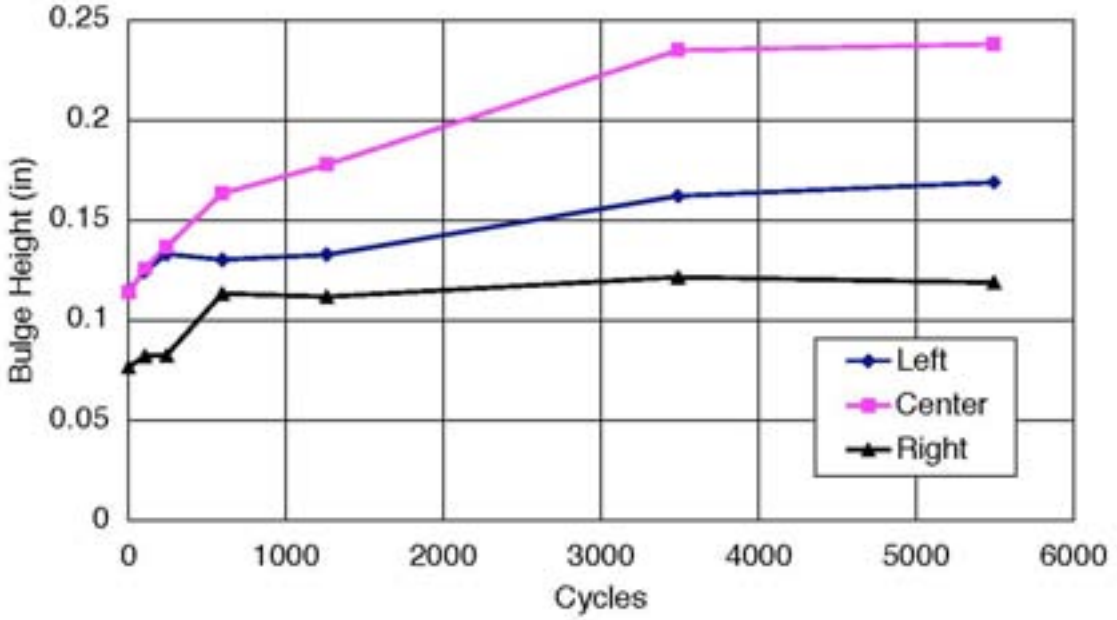
Initial EDC	1.466	k-in*rot
Final EDC	1.152	k-in*rot
Initial EVD	0.104	
Final EVD	0.101	

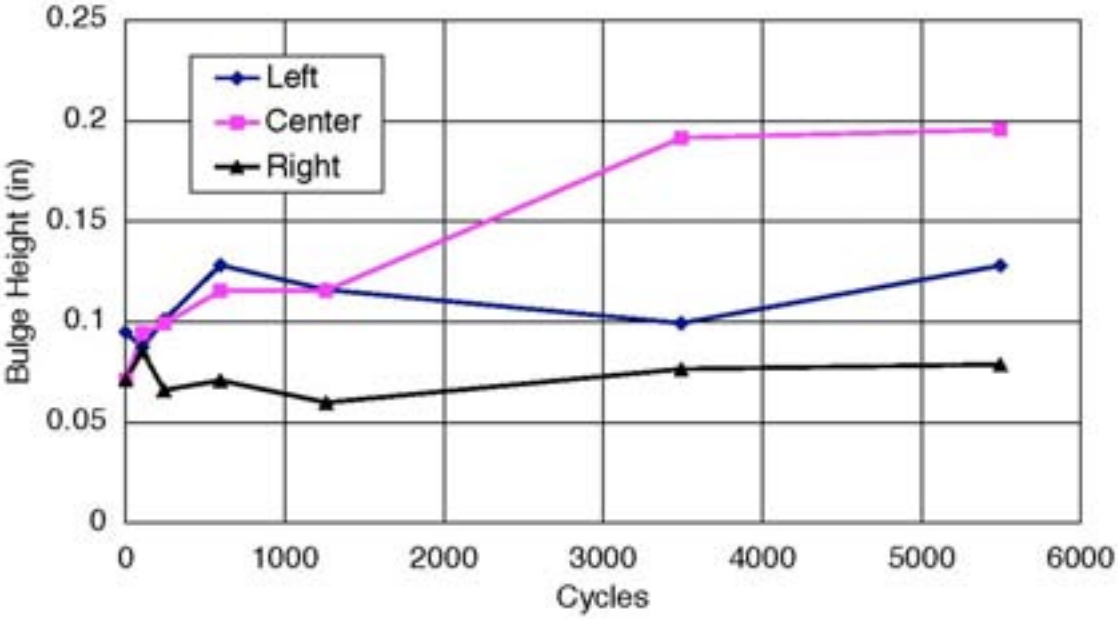
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.70: Test CYC11-B1 Summary

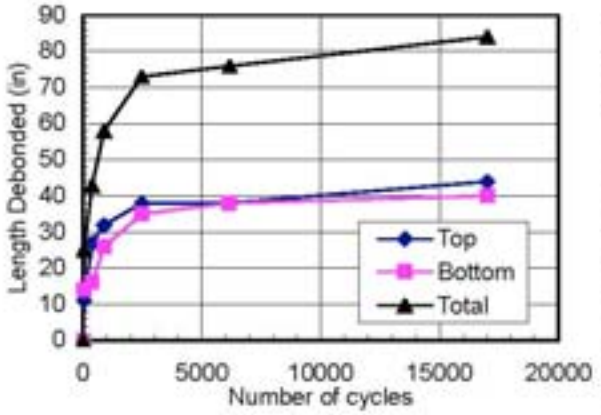




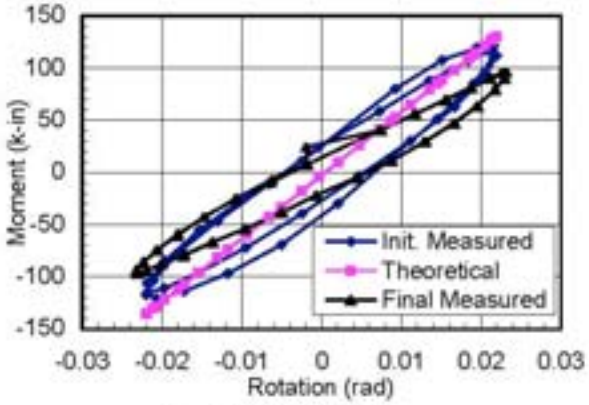
(b) Bottom

Figure A.71: CYC11-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC11-C1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_s$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_s$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	2
25%	44
50%	408
75%	1736
100%	22449

Rotational Stiffness

Initial Measured	52.2	k-in/%rot
Final Measured	39.2	k-in/%rot
Elastic Model	60.5	k-in/%rot

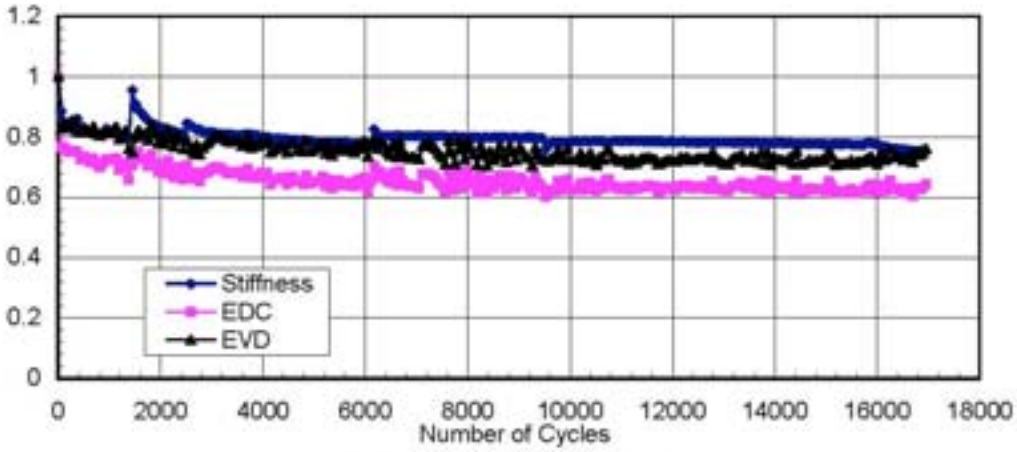
Local Nominal Shear Strains

Average Axial	5.1
Max. Rotation	1.2
Average Shear	0.0

Energy

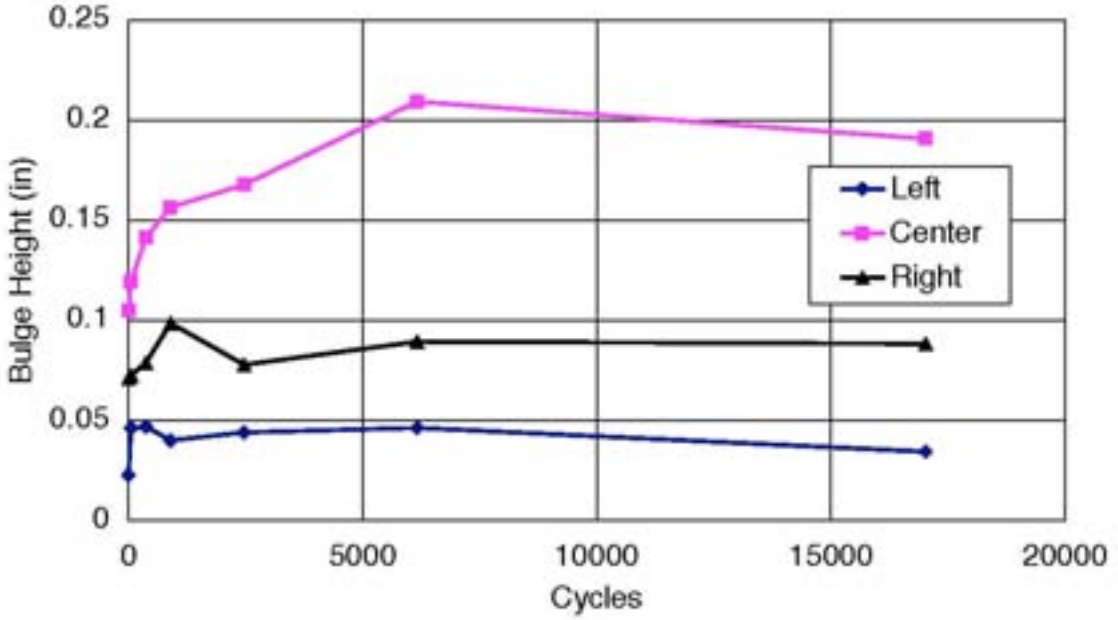
Initial EDC	2.084	k-in*rot
Final EDC	1.339	k-in*rot
Initial EVD	0.125	
Final EVD	0.095	

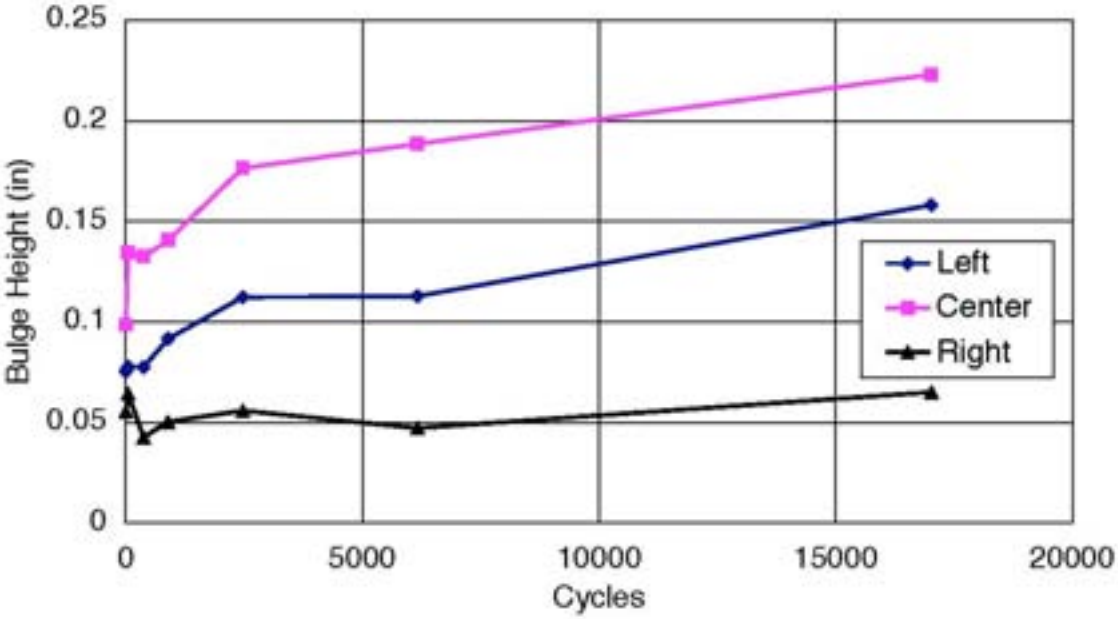
EDC = Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.72: Test CYC11-C1 Summary

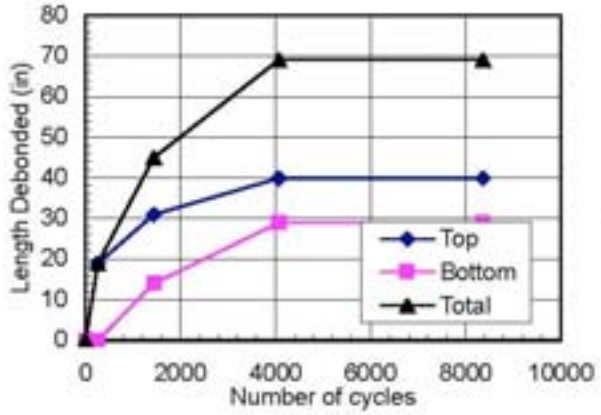




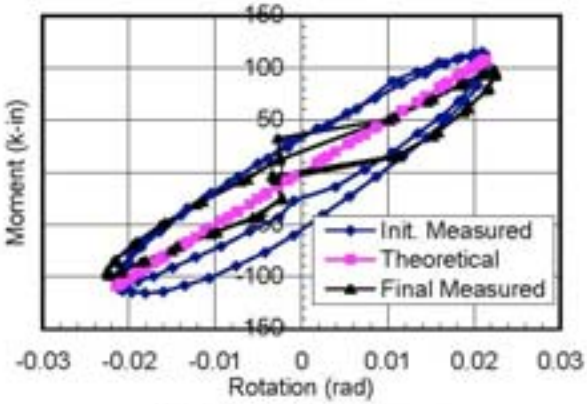
(b) Bottom

Figure A.73: CYC11-C1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC11-D1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	7/8σ_s = 2625 psi
Static Rotation	0
Cyclic Rotation	4/8θ_s = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	14
25%	395
50%	1396
75%	3741
100%	N/A

Rotational Stiffness

Initial Measured	49.1	k-in/%rot
Final Measured	40.3	k-in/%rot
Elastic Model	50.6	k-in/%rot

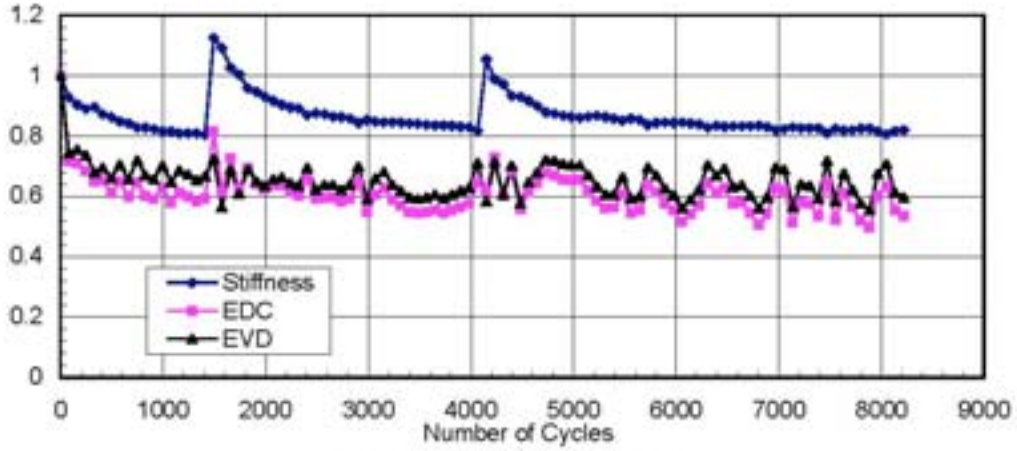
Local Nominal Shear Strains

Average Axial	6.2
Max. Rotation	1.2
Average Shear	0.0

Energy

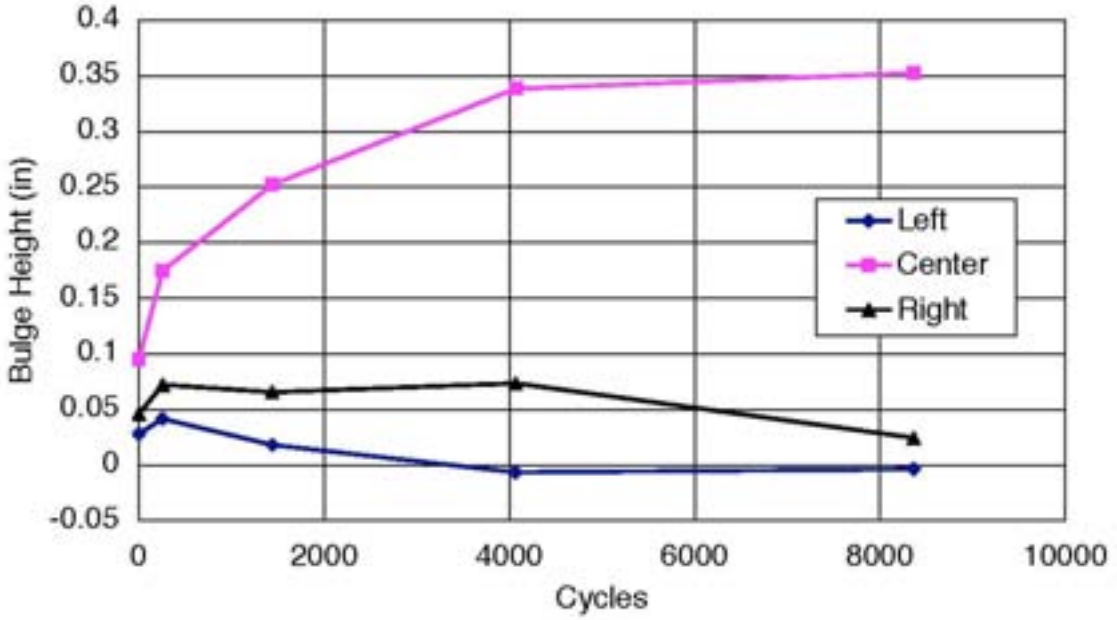
Initial EDC	2.595	k-in*rot
Final EDC	1.389	k-in*rot
Initial EVD	0.167	
Final EVD	0.1	

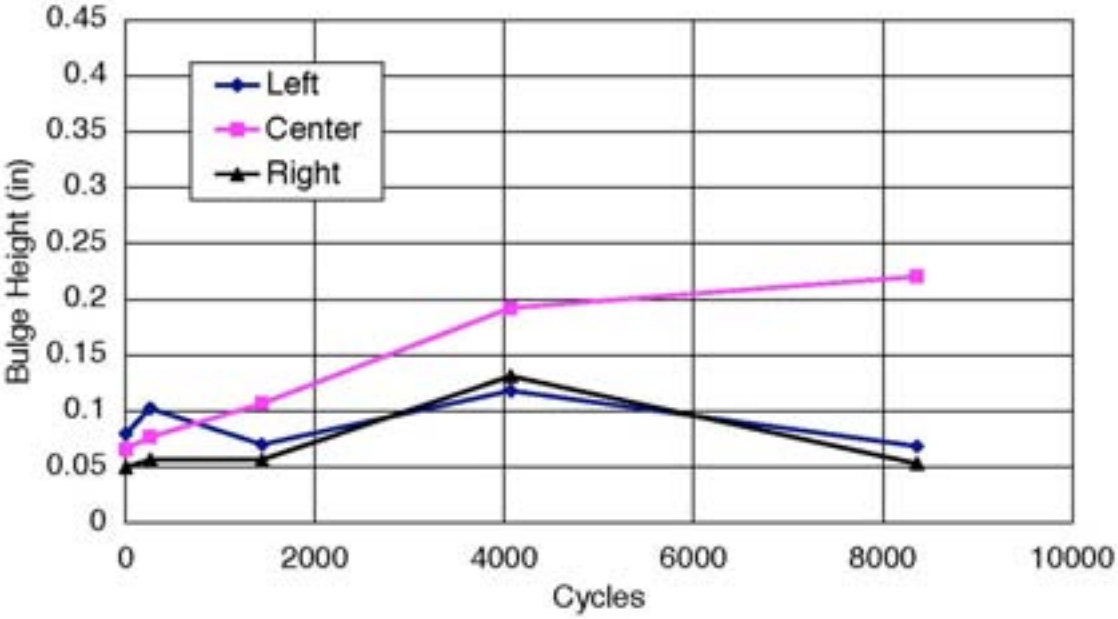
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.74: Test CYC11-D1 Summary

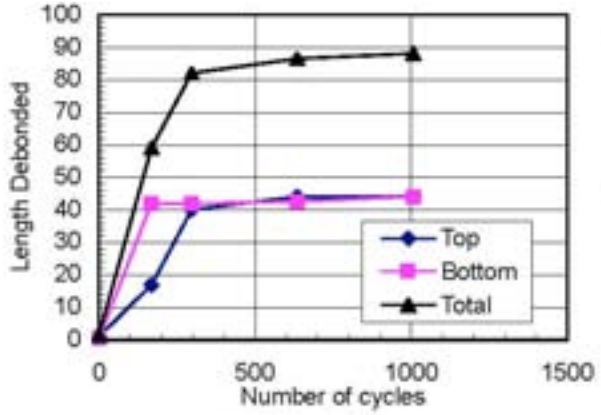




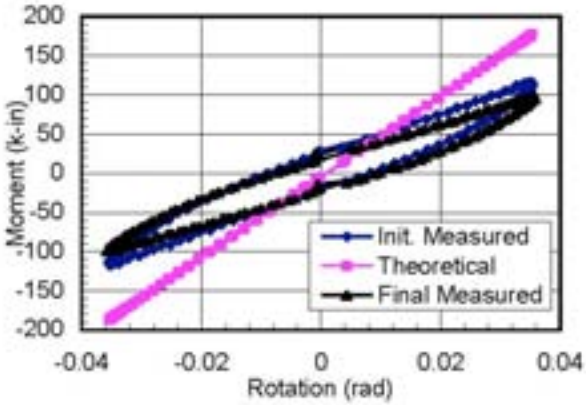
(b) Bottom

Figure A.75: CYC11-D1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC12-A1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	60
50%	124
75%	208
100%	1007

Rotational Stiffness

Initial Measured	30.6	k-in/%rot
Final Measured	25.9	k-in/%rot
Elastic Model	51.4	k-in/%rot

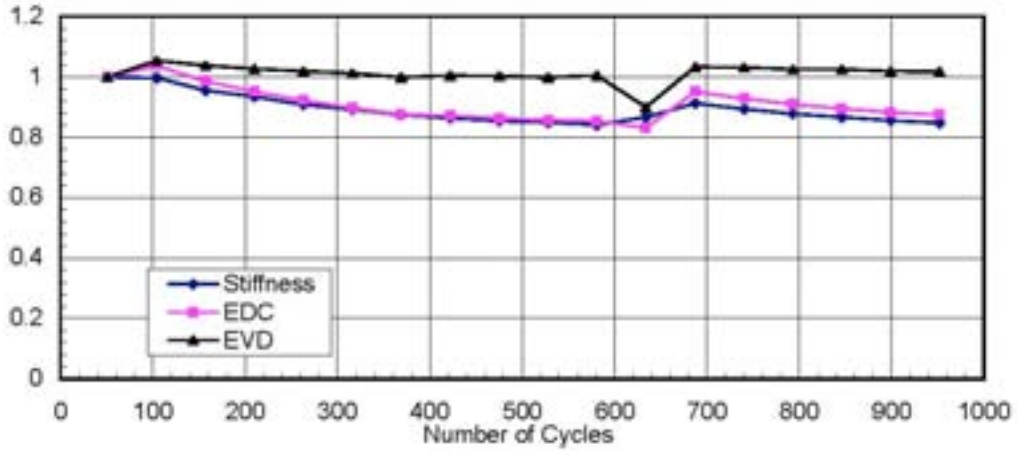
Local Nominal Shear Strains

Average Axial	5.2
Max. Rotation	1.8
Average Shear	0.0

Energy

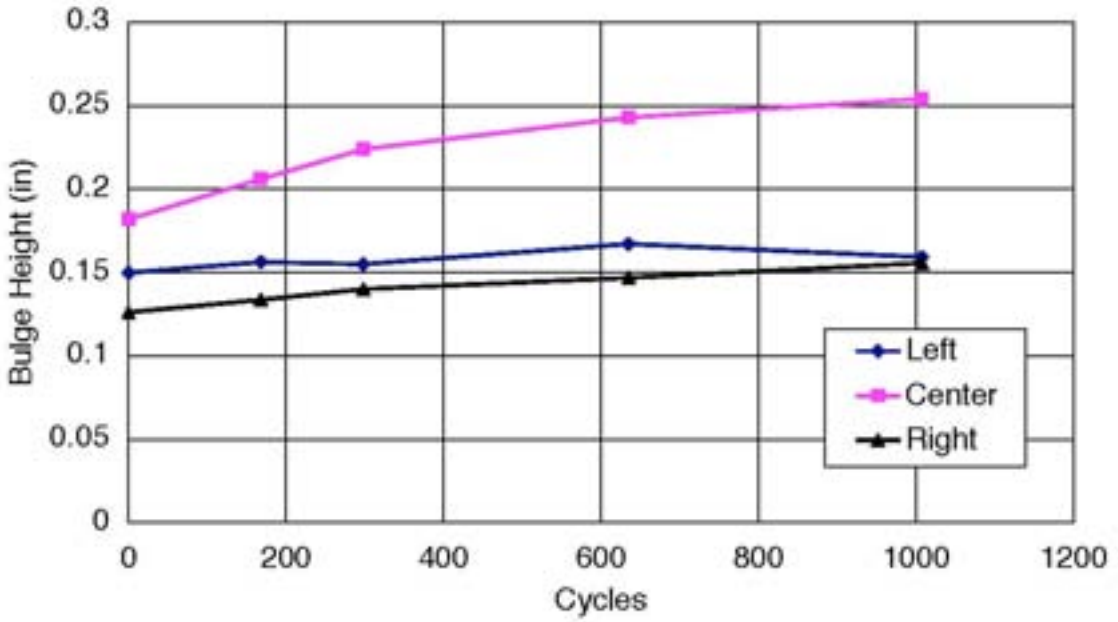
Initial EDC	2.556	k-in*rot
Final EDC	2.236	k-in*rot
Initial EVD	0.098	
Final EVD	0.100	

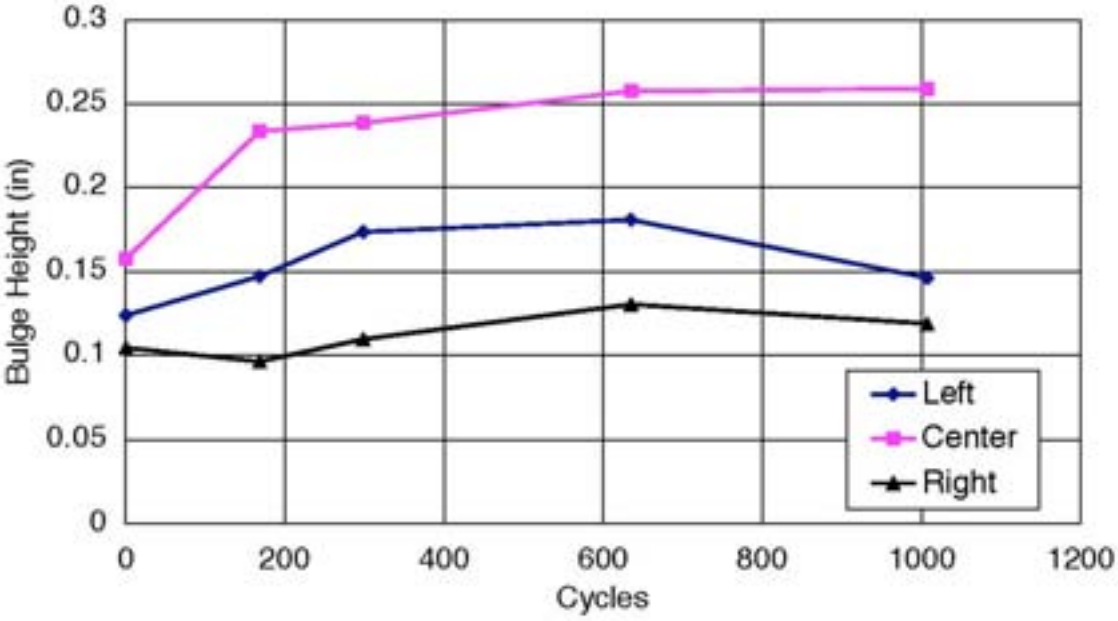
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.76: Test CYC12-A1 Summary

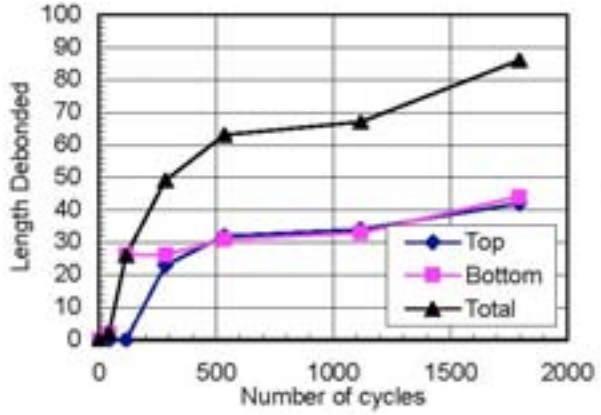




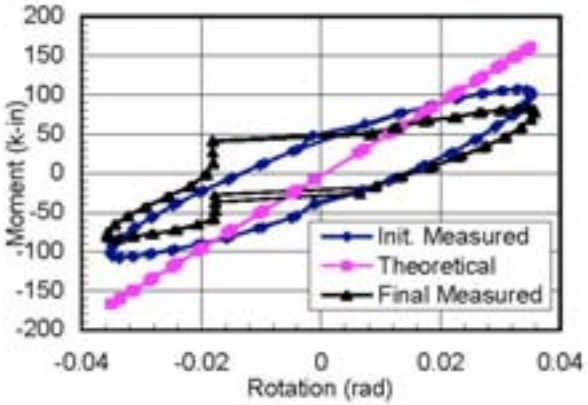
(b) Bottom

Figure A.77: CYC12-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC12-A2



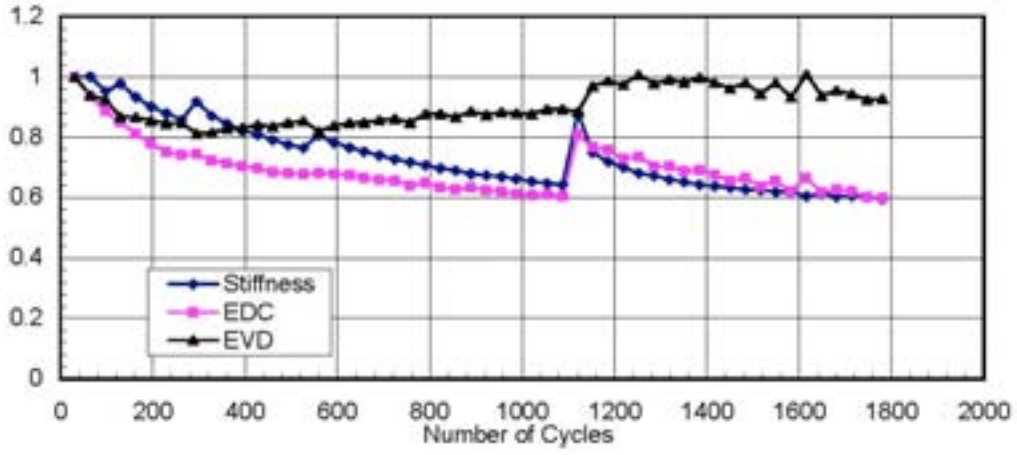
(a) Debonding



(b) Rotational Stiffness

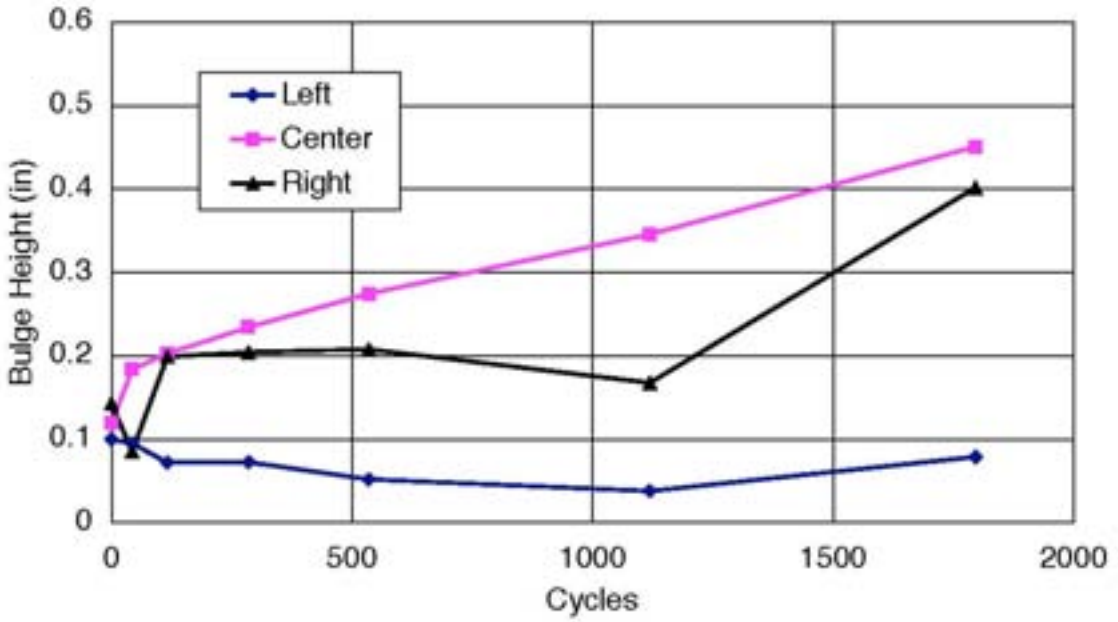
Test Properties		
Axial Stress	$7/8\sigma_0$ = 2625 psi	
Static Rotation	0	
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad	
Shear Disp.	0	
Bearing Properties		
Area	9x22 = 198 in^2	
Aspect Ratio	2.44	
Shape Factor	6	
No. of Shims	4	
Layer Thickness	0.5 in	
Debonding Milestones (cycles)		
Initial	22	
25%	104	
50%	248	
75%	973	
100%	1867	
Rotational Stiffness		
Initial Measured	28.3	k-in/%rot
Final Measured	16.9	k-in/%rot
Elastic Model	46.7	k-in/%rot
Local Nominal Shear Strains		
Average Axial	5.5	
Max. Rotation	2.2	
Average Shear	0.0	
Energy		
Initial EDC	4.584	k-in*rot
Final EDC	2.749	k-in*rot
Initial EVD	0.192	
Final EVD	0.178	

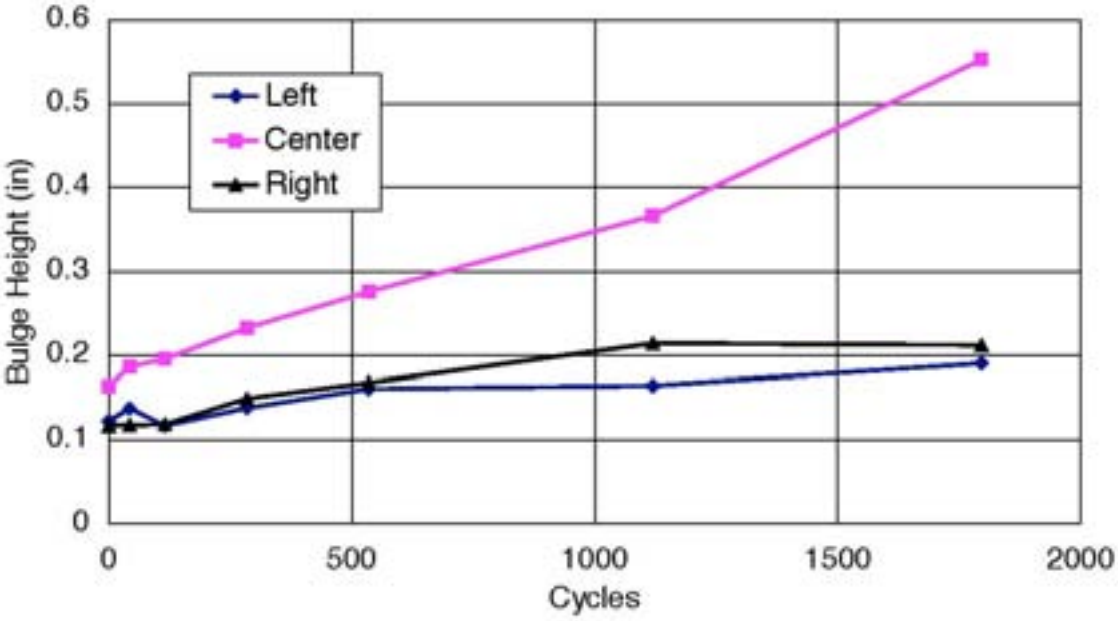
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.78: Test CYC12-A2 Summary

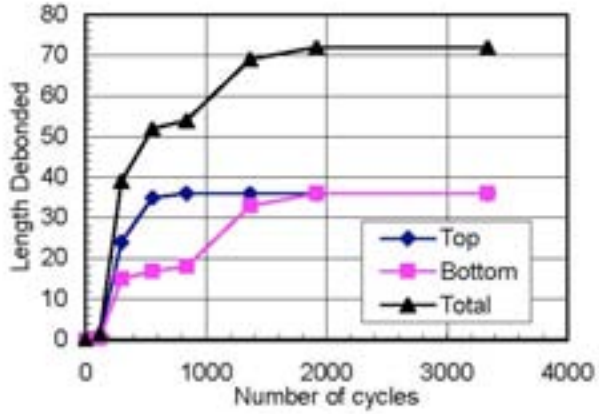




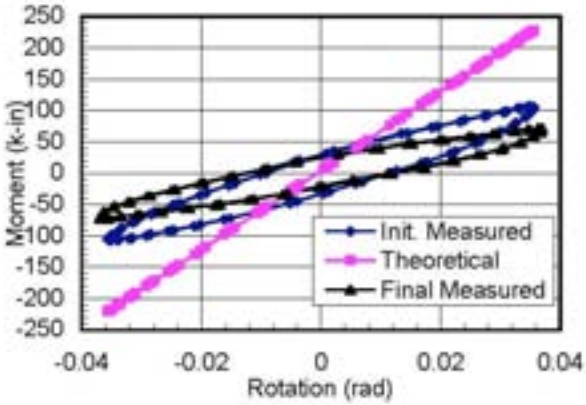
(b) Bottom

Figure A.79: CYC12-A2 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC12-B1



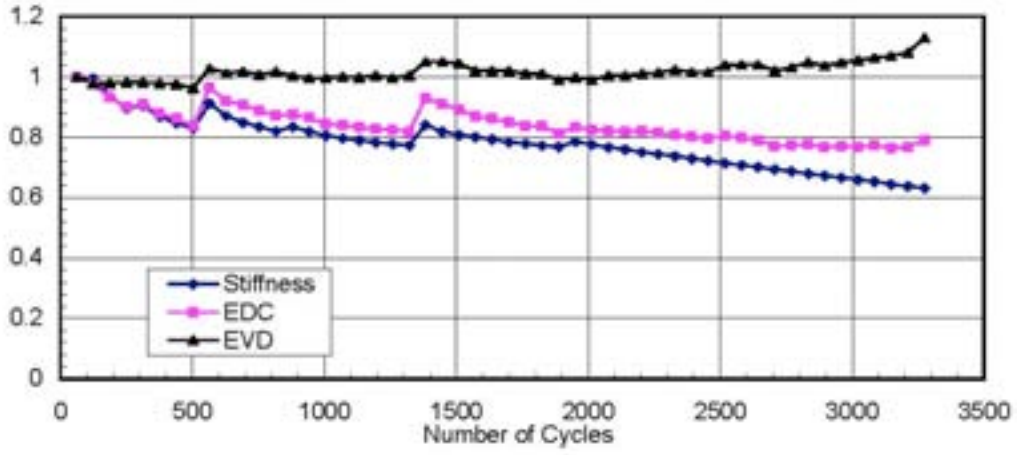
(a) Debonding



(b) Rotational Stiffness

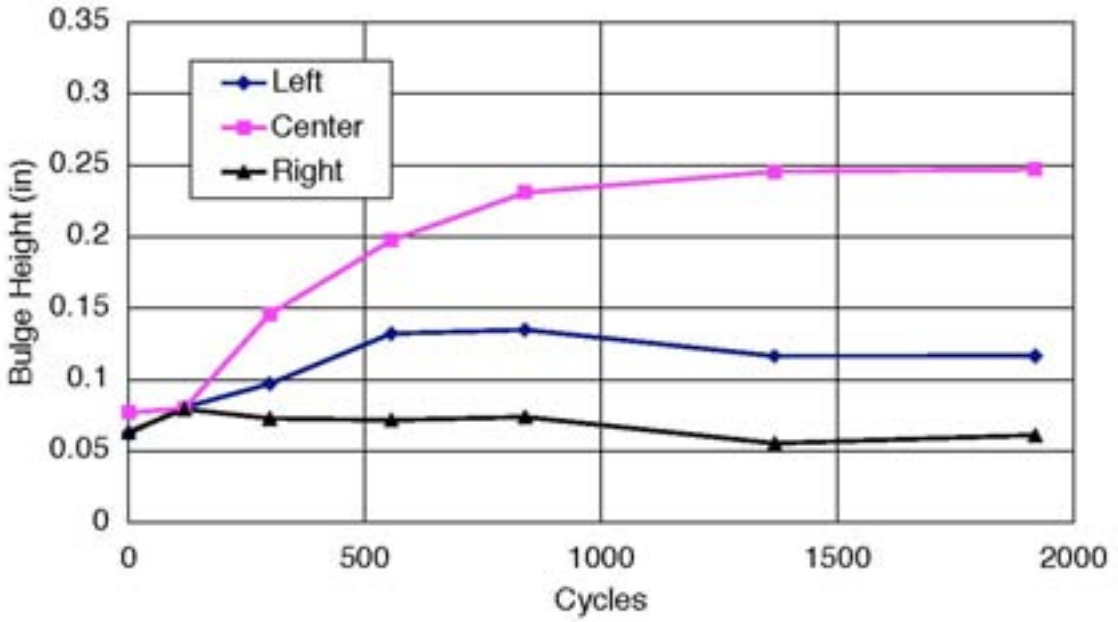
Test Properties		
Axial Stress	$7/8\sigma_0$ = 2625 psi	
Static Rotation	0	
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad	
Shear Disp.	0	
Bearing Properties		
Area	9x22 = 198 in^2	
Aspect Ratio	2.44	
Shape Factor	6	
No. of Shims	4	
Layer Thickness	0.5 in	
Debonding Milestones (cycles)		
Initial	79	
25%	217	
50%	398	
75%	1261	
100%	N/A	
Rotational Stiffness		
Initial Measured	28.4	k-in/%rot
Final Measured	17.9	k-in/%rot
Elastic Model	63.0	k-in/%rot
Local Nominal Shear Strains		
Average Axial	4.6	
Max. Rotation	2.1	
Average Shear	0.0	
Energy		
Initial EDC	3.328	k-in*rot
Final EDC	2.633	k-in*rot
Initial EVD	0.139	
Final EVD	0.157	

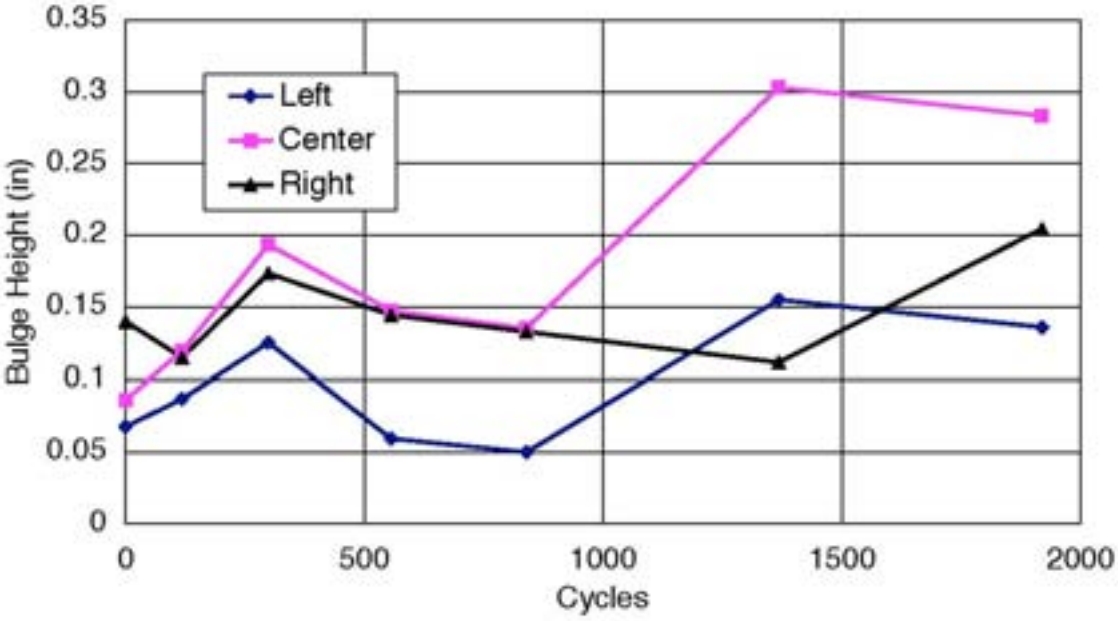
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.80: Test CYC12-B1 Summary

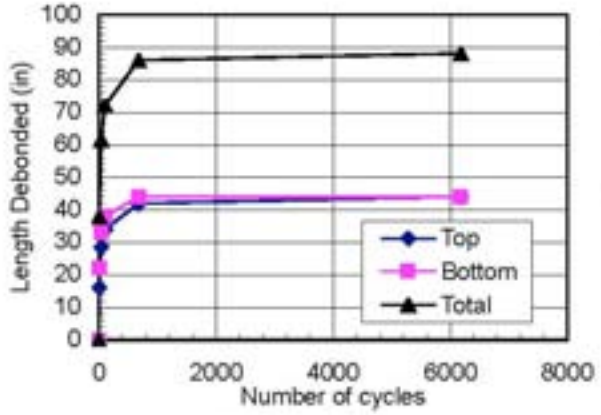




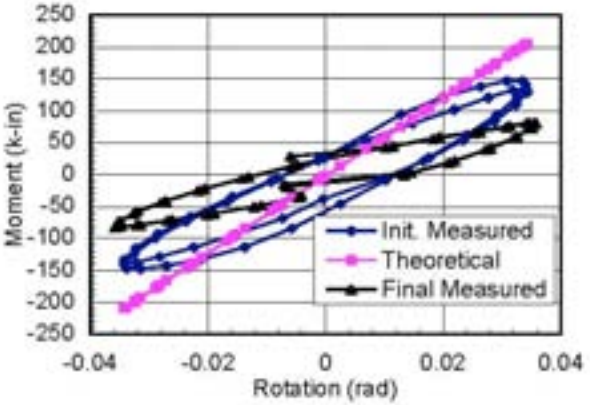
(b) Bottom

Figure A.81: CYC12-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC12-C1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	6
50%	18
75%	68
100%	6181

Rotational Stiffness

Initial Measured	40.1	k-in/%rot
Final Measured	21.3	k-in/%rot
Elastic Model	60.5	k-in/%rot

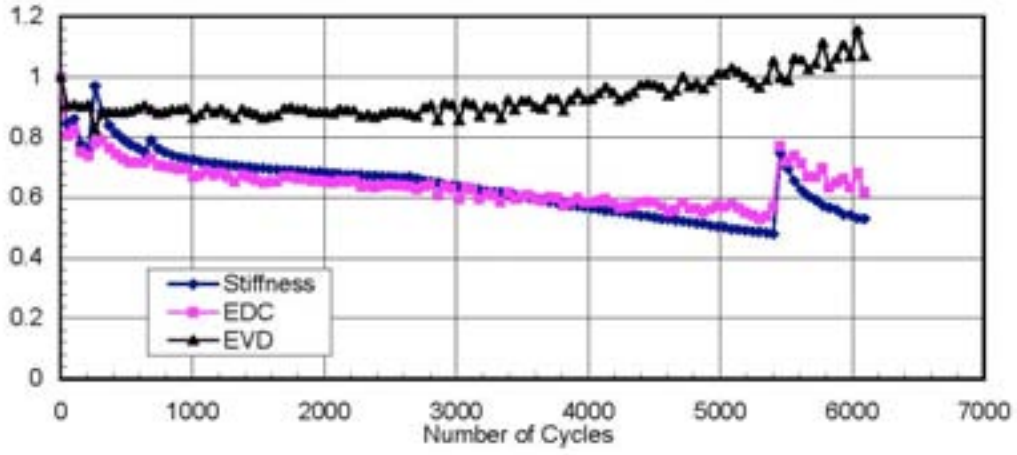
Local Nominal Shear Strains

Average Axial	5.0
Max. Rotation	1.9
Average Shear	0.0

Energy

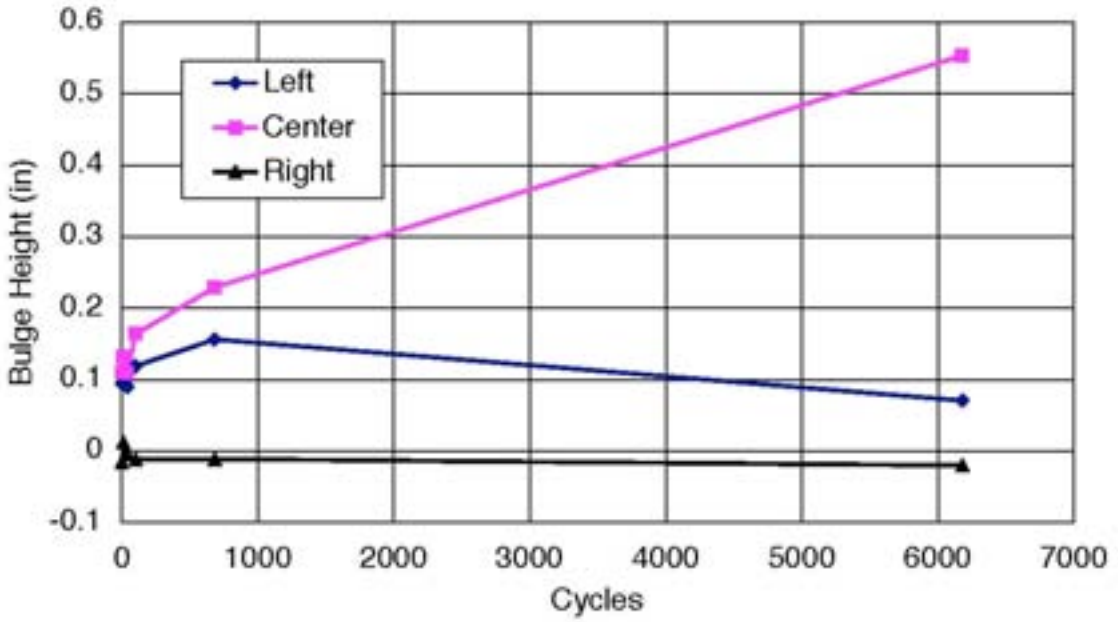
Initial EDC	4.297	k-in*rot
Final EDC	2.66	k-in*rot
Initial EVD	0.135	
Final EVD	0.145	

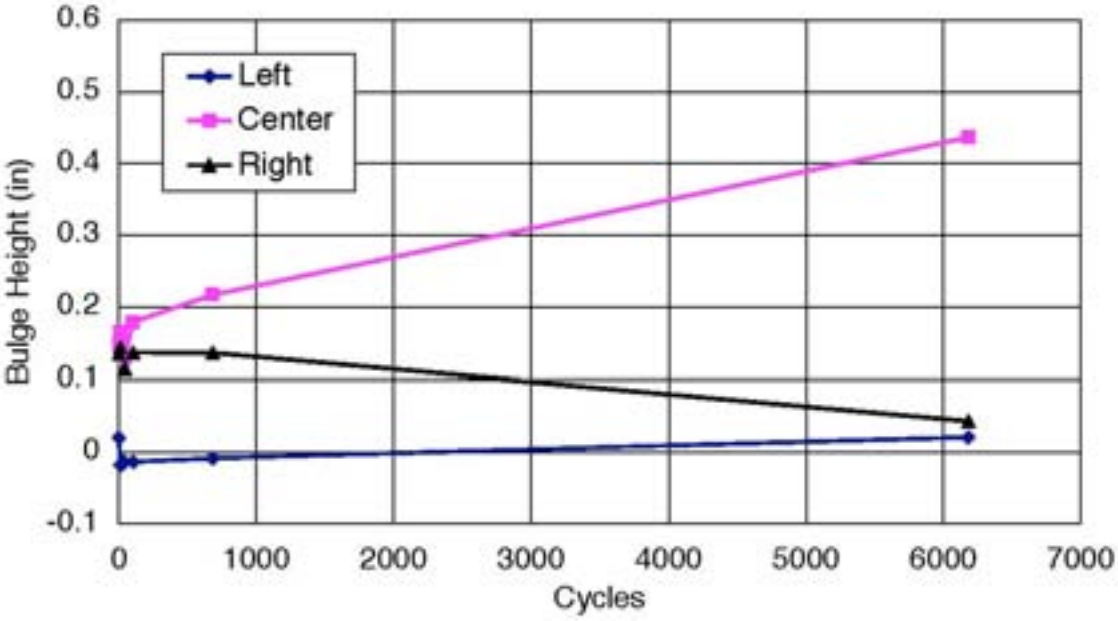
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.82: Test CYC12-C1 Summary

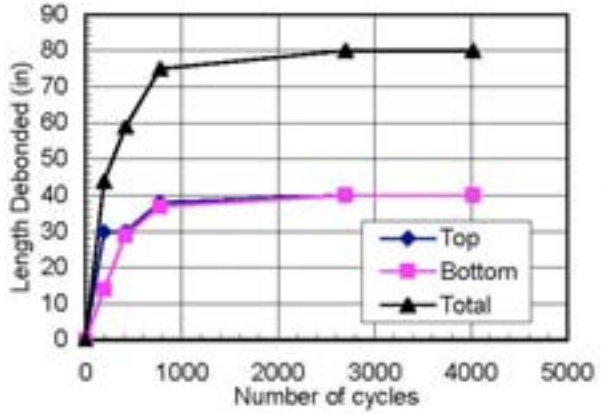




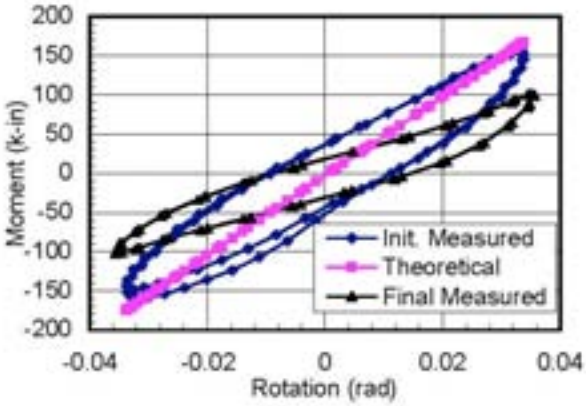
(b) Bottom

Figure A.83: CYC12-C1 Bulge Heights (a) Top of Bearing and (b) Bottom

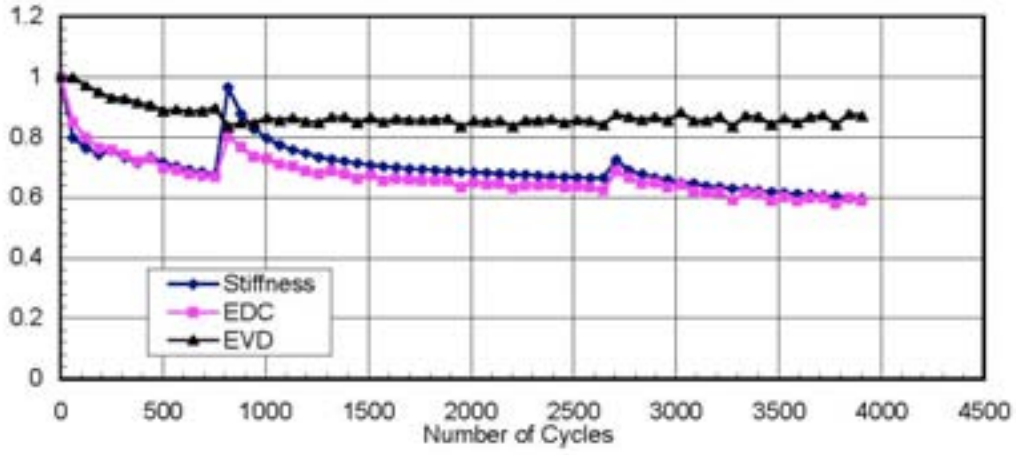
CYC12-D1



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties		
Axial Stress	$7/8\sigma_0$ = 2625 psi	
Static Rotation	0	
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad	
Shear Disp.	0	
Bearing Properties		
Area	9x22 = 198 in^2	
Aspect Ratio	2.44	
Shape Factor	6	
No. of Shims	4	
Layer Thickness	0.5 in	
Debonding Milestones (cycles)		
Initial	4	
25%	96	
50%	192	
75%	574	
100%	N/A	
Rotational Stiffness		
Initial Measured	42.5	k-in/%rot
Final Measured	25.5	k-in/%rot
Elastic Model	50.6	k-in/%rot
Local Nominal Shear Strains		
Average Axial	6.3	
Max. Rotation	1.9	
Average Shear	0.0	
Energy		
Initial EDC	4.875	k-in*rot
Final EDC	2.874	k-in*rot
Initial EVD	0.145	
Final EVD	0.127	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

Figure A.84: Test CYC12-D1 Summary

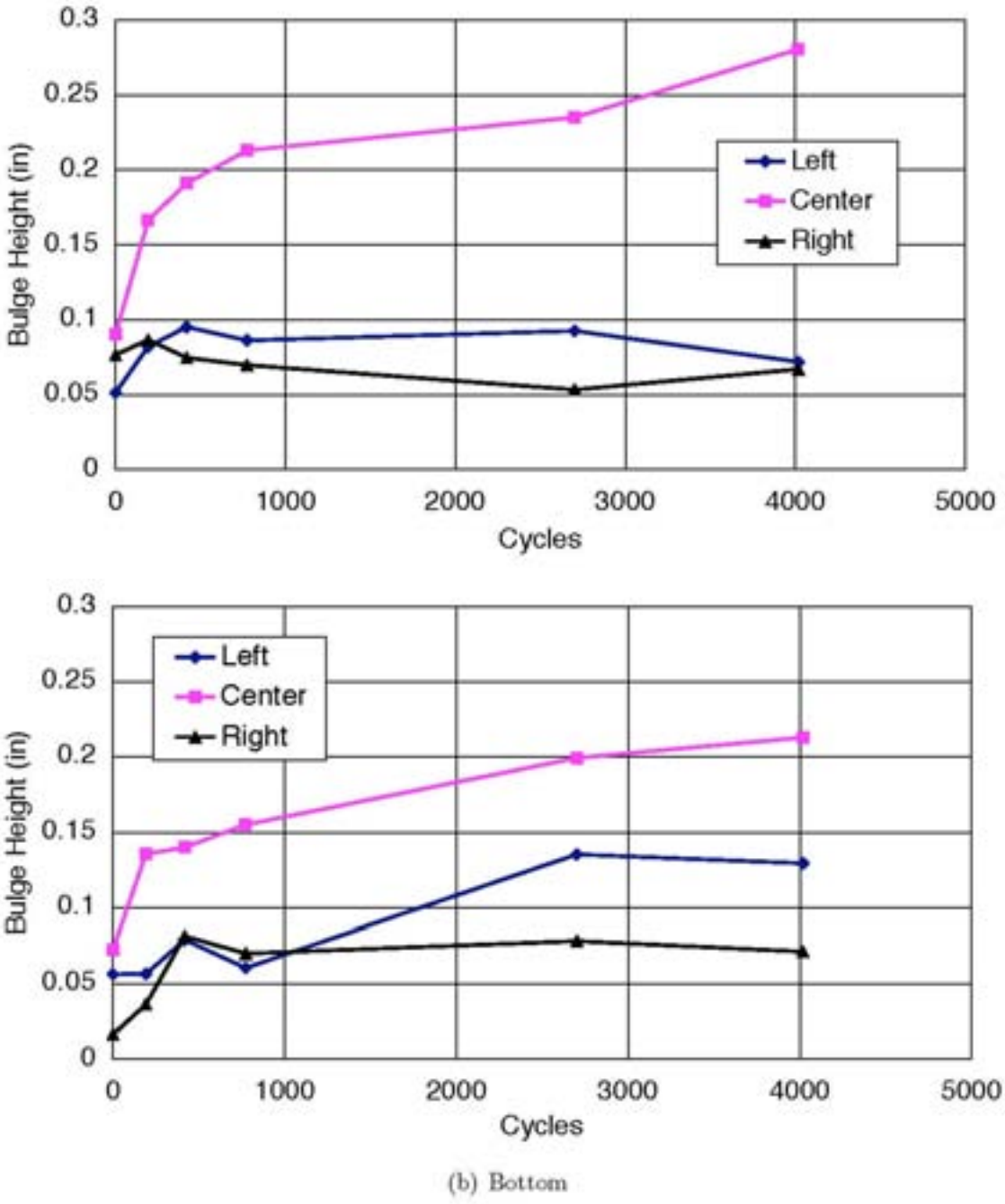
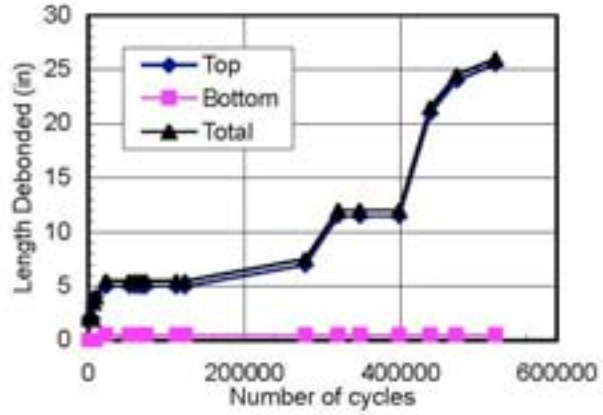
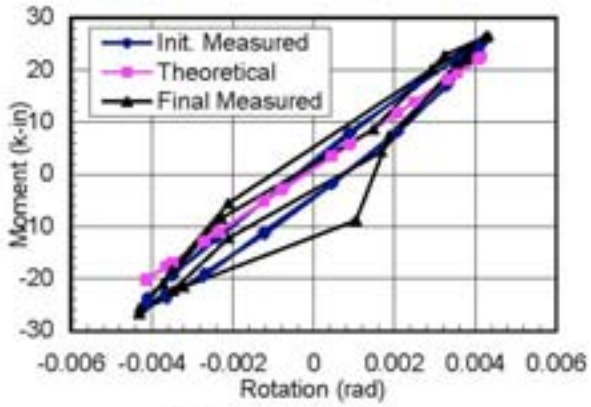


Figure A.85: CYC12-D1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC13-A1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0.02 rad
Cyclic Rotation	0.005 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	443585
50%	N/A
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	59.2	k-in/%rot
Final Measured	58.5	k-in/%rot
Elastic Model	51.4	k-in/%rot

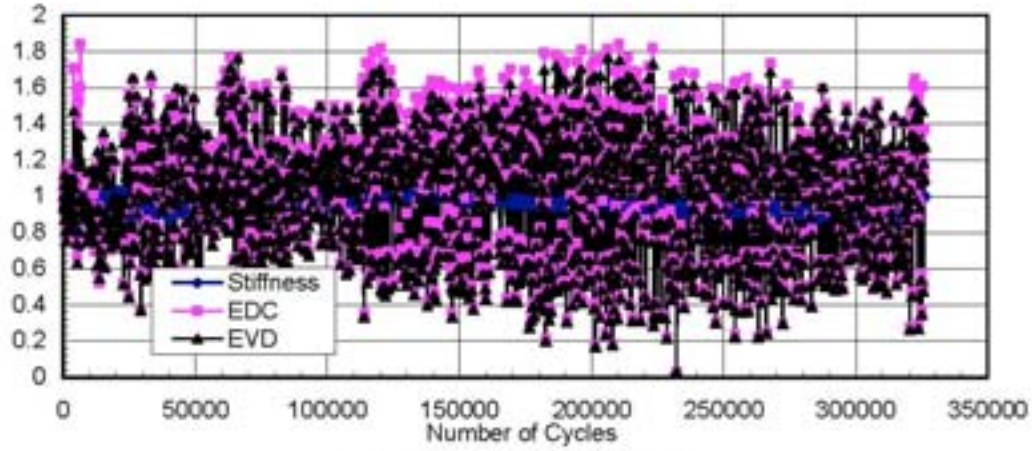
Local Nominal Shear Strains

Average Axial	4.1
Max. Rotation	0.3
Average Shear	0.0

Energy

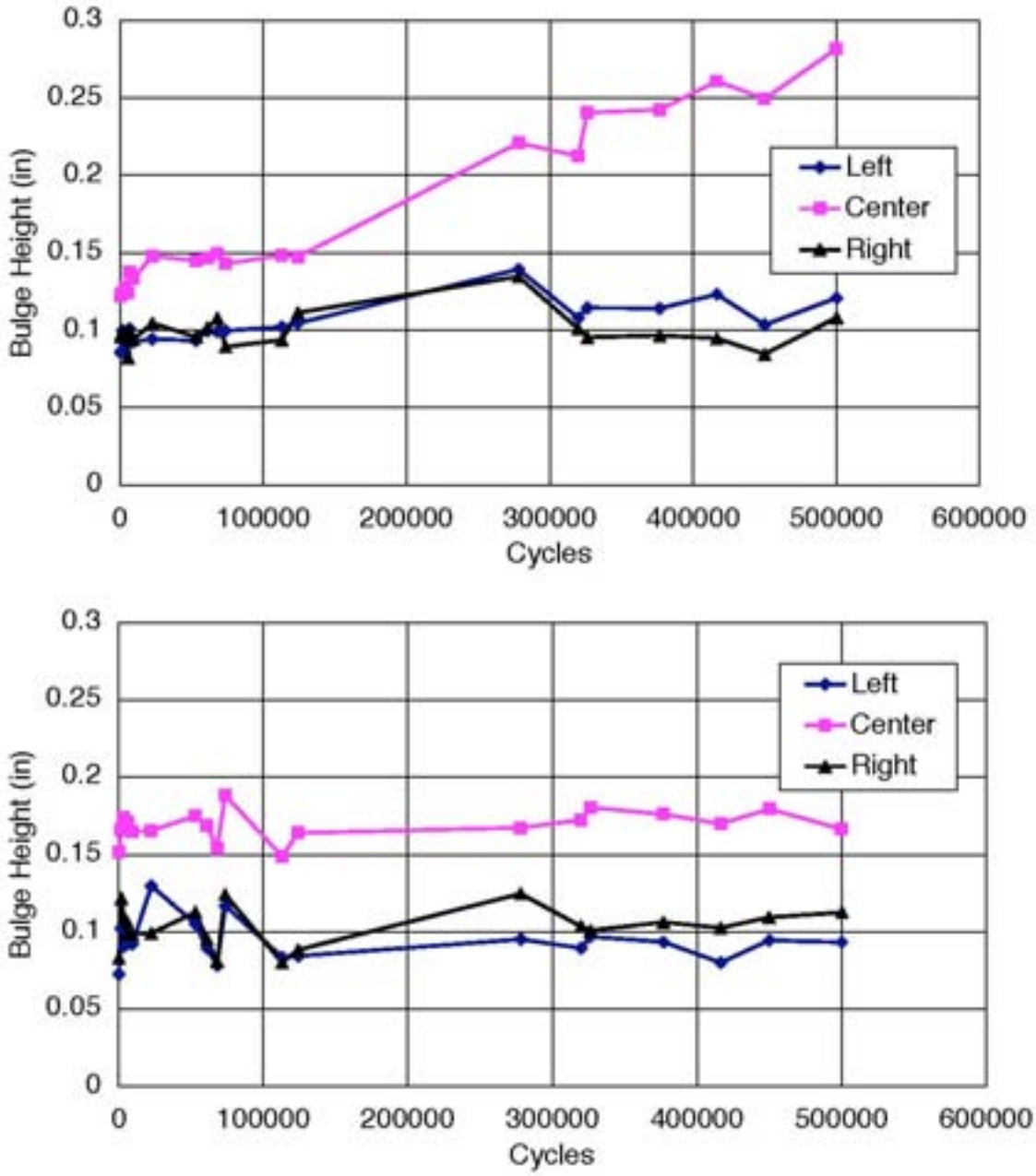
Initial EDC	0.044	k-in*rot
Final EDC	0.060	k-in*rot
Initial EVD	0.065	
Final EVD	0.084	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

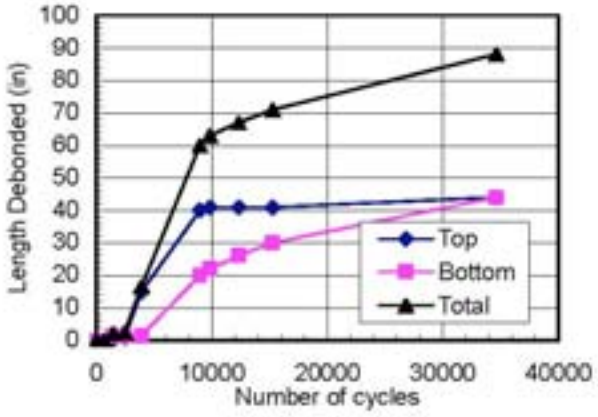
Figure A.86: Test CYC13-A1 Summary



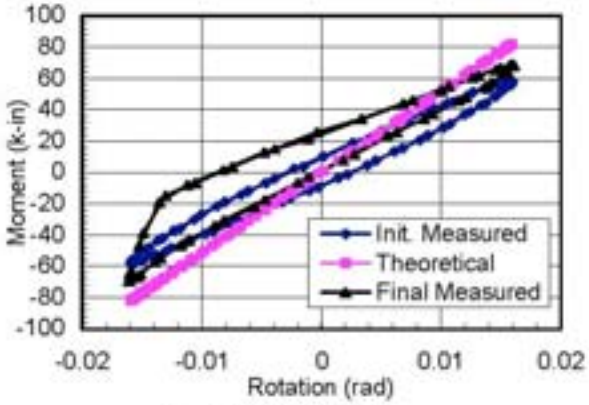
(b) Bottom

Figure A.87: CYC13-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

CYC14-A1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_{cr}$ = 1875 psi
Static Rotation	0.02 rad
Cyclic Rotation	0.0175 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	1069
25%	4530
50%	7105
75%	11709
100%	34660

Rotational Stiffness

Initial Measured	35.5	k-in/%rot
Final Measured	38.1	k-in/%rot
Elastic Model	51.4	k-in/%rot

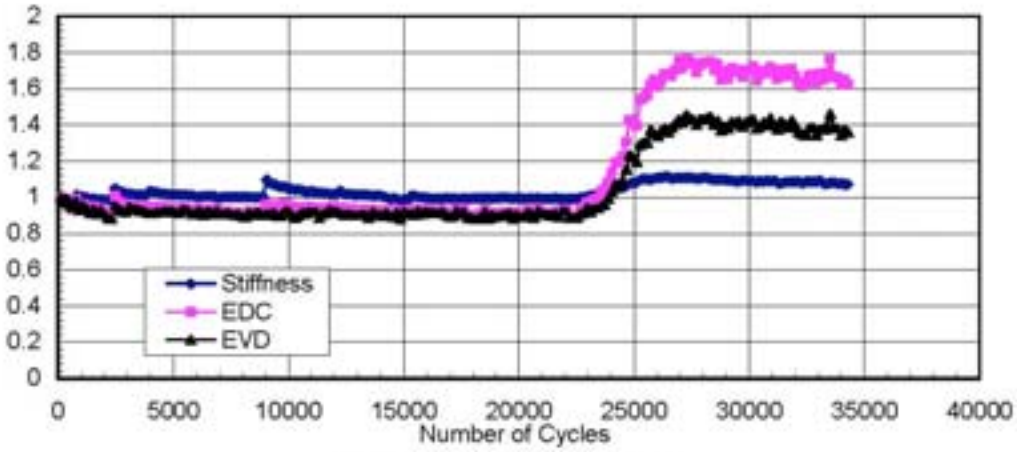
Local Nominal Shear Strains

Average Axial	4.0
Max. Rotation	0.9
Average Shear	0.0

Energy

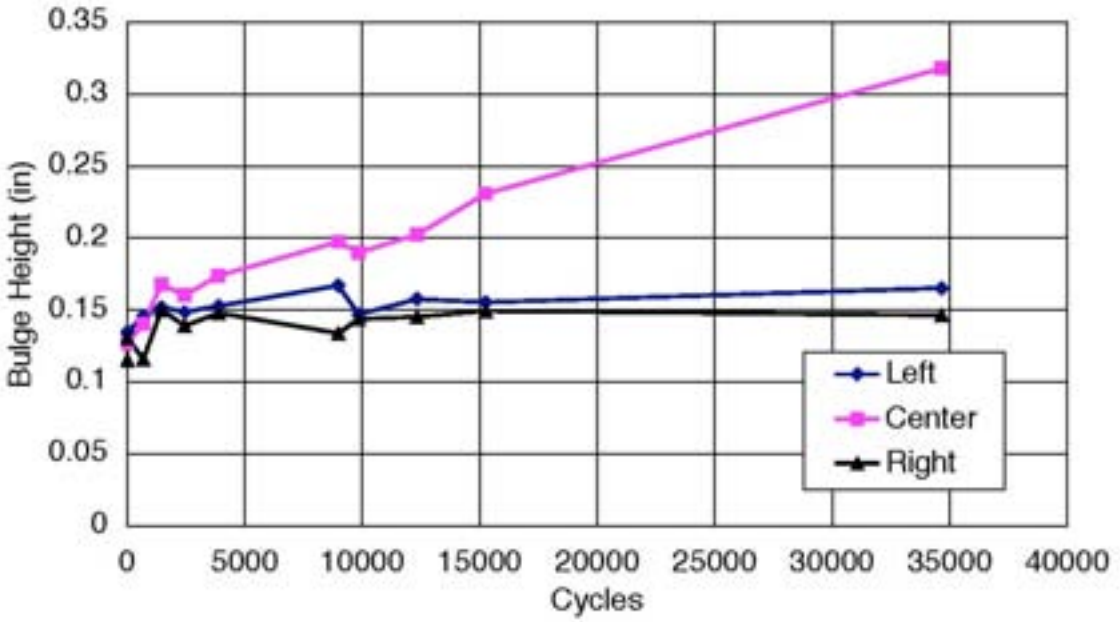
Initial EDC	0.441	k-in*rot
Final EDC	0.716	k-in*rot
Initial EVD	0.075	
Final EVD	0.102	

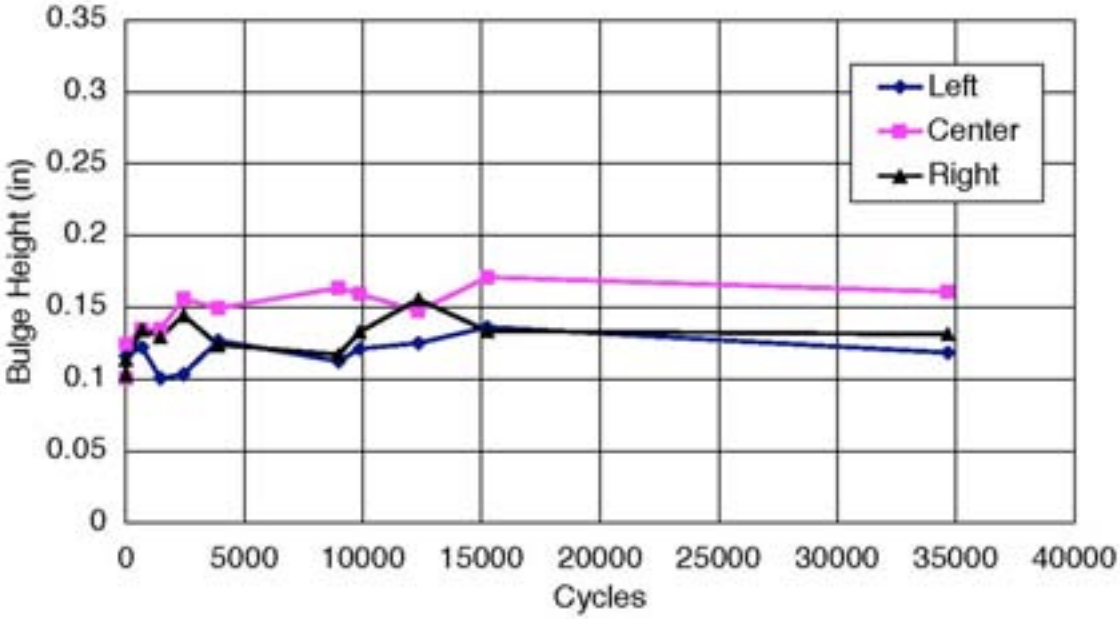
EDC = Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.88: Test CYC14-A1 Summary

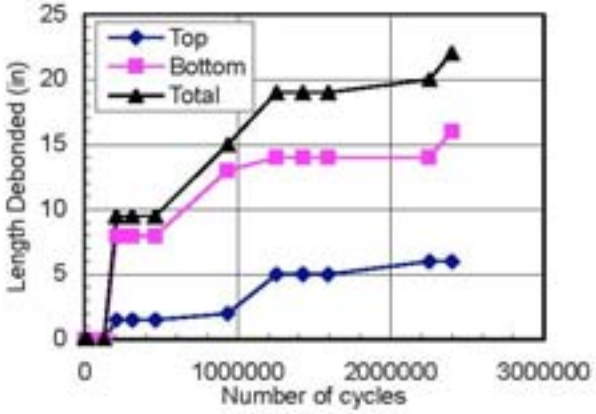




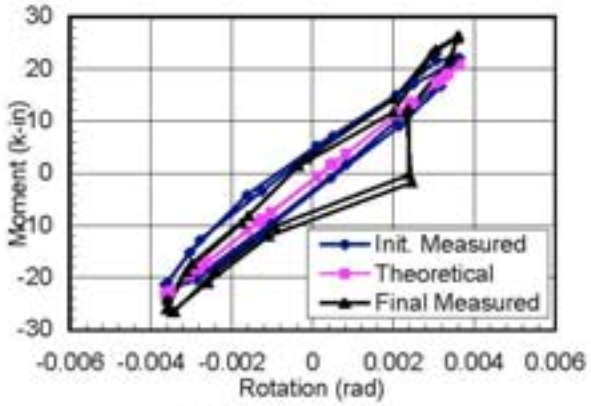
(b) Bottom

Figure A.89: CYC14-A1 Bulge Heights (a) Top of Bearing and (b) Bottom

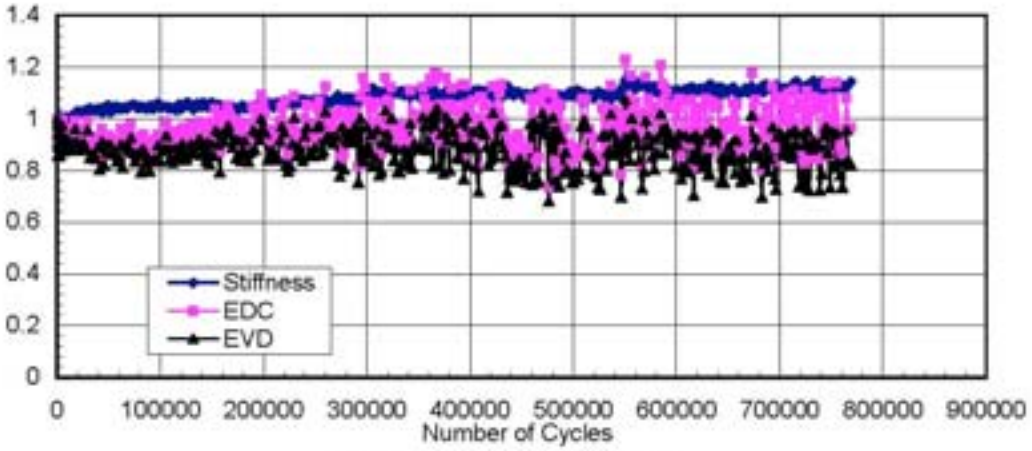
CYC15-C1



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties

Axial Stress	$5/Bo_s$ = 18755 psi
Static Rotation	0
Cyclic Rotation	0.005 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	135703
25%	2398336
50%	N/A
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	59.9	k-in/%rot
Final Measured	68.6	k-in/%rot
Elastic Model	60.5	k-in/%rot

Local Nominal Shear Strains

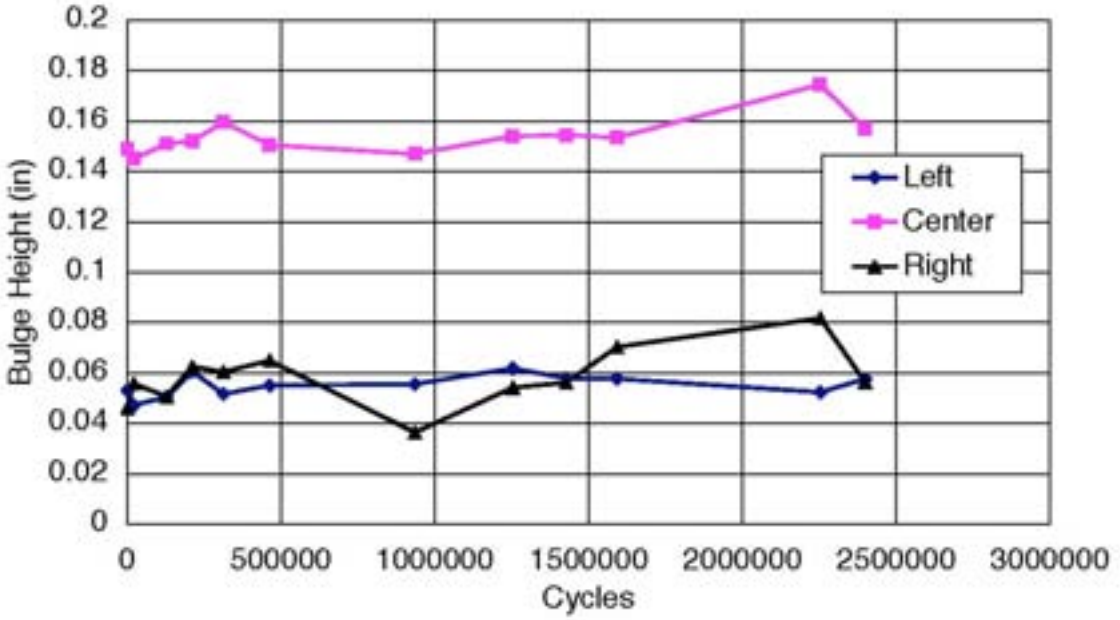
Average Axial	3.6
Max. Rotation	0.2
Average Shear	0.0

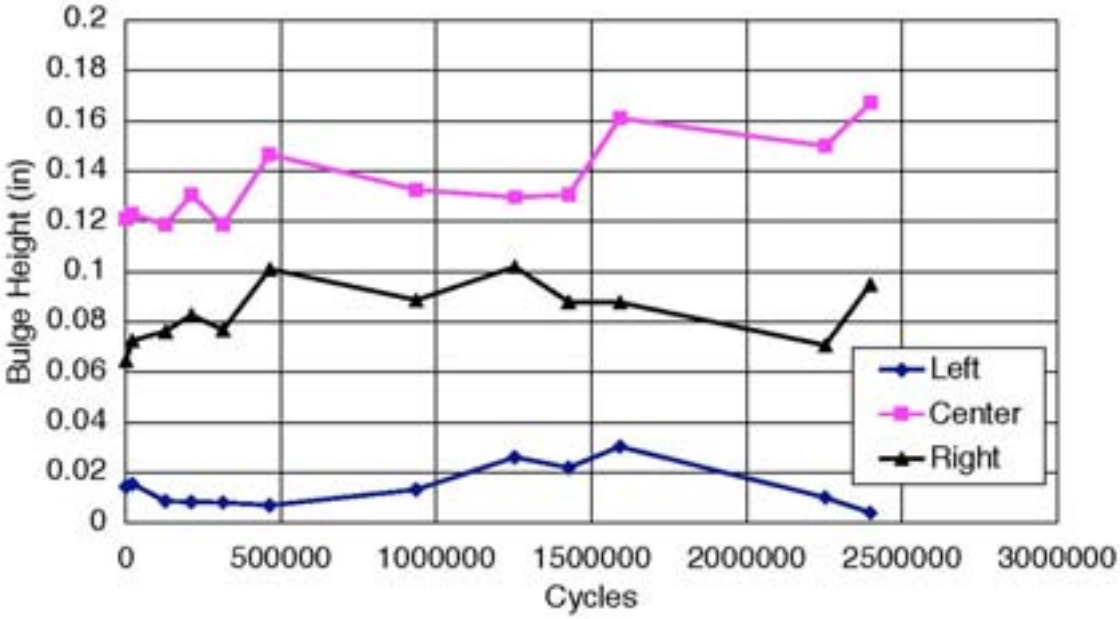
Energy

Initial EDC	0.046	k-in*rot
Final EDC	0.044	k-in*rot
Initial EVD	0.090	
Final EVD	0.074	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

Figure A.90: Test CYC15-C1 Summary





(b) Bottom

Figure A.91: CYC15-C1 Bulge Heights (a) Top of Bearing and (b) Bottom

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A.6 SHR Series

SHR1-B1

Debonding	
0 rad	0 in
0.08	0
-0 rad	0 in
-0.01	1
-0.08	1

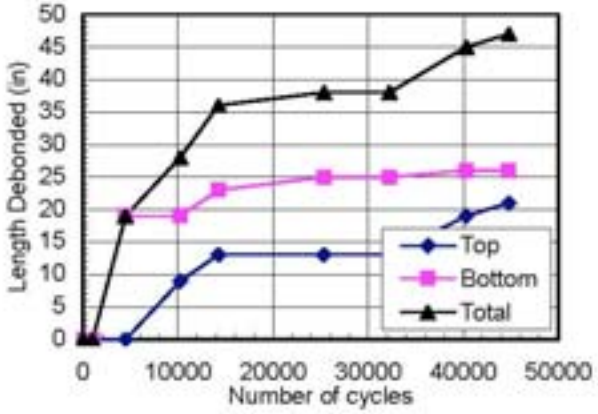
Test Properties	
Axial Stress	4GS = 2400 psi
Static Rotation	varies to 0.08 rad
Cyclic Rotation	0
Shear Disp.	50%

Bearing Properties	
Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

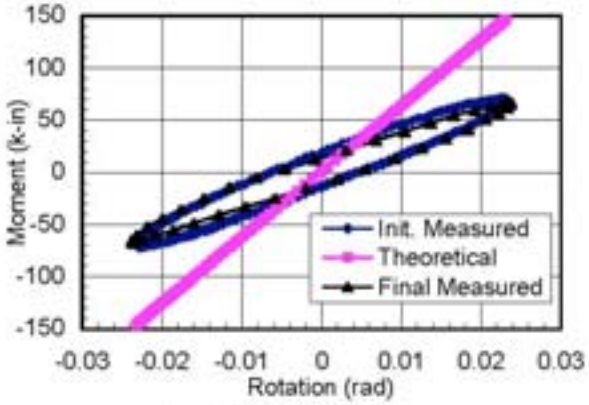
Note: Depth gauge data is not available for this test because the depth gauge could not reach to the bearing in the gap due to the shear.

Figure A.92: Test SHR1-B1 Summary

SHR3-B1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_s$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_s$ = 0.025 rad
Shear Disp.	30%

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	1215
25%	6414
50%	39163
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	29.2	k-in/%rot
Final Measured	26.8	k-in/%rot
Elastic Model	63.0	k-in/%rot

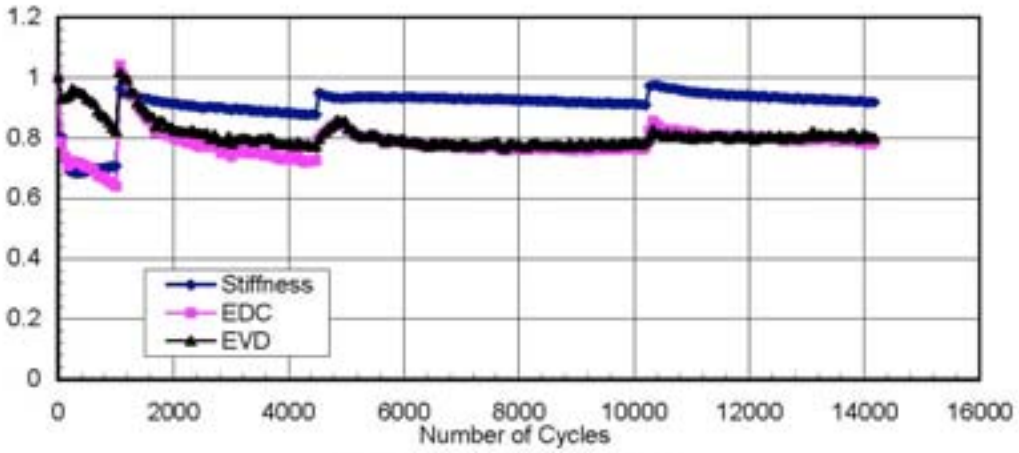
Local Nominal Shear Strains

Average Axial	3.1
Max. Rotation	1.5
Average Shear	0.3

Energy

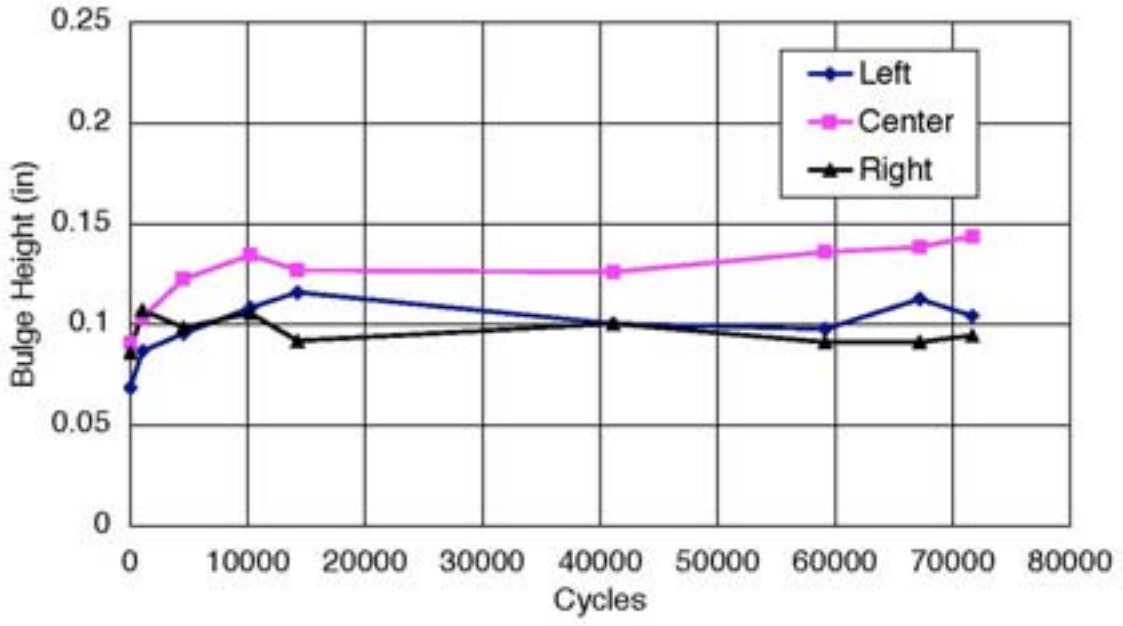
Initial EDC	1.21	k-in*rot
Final EDC	0.951	k-in*rot
Initial EVD	0.117	
Final EVD	0.094	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

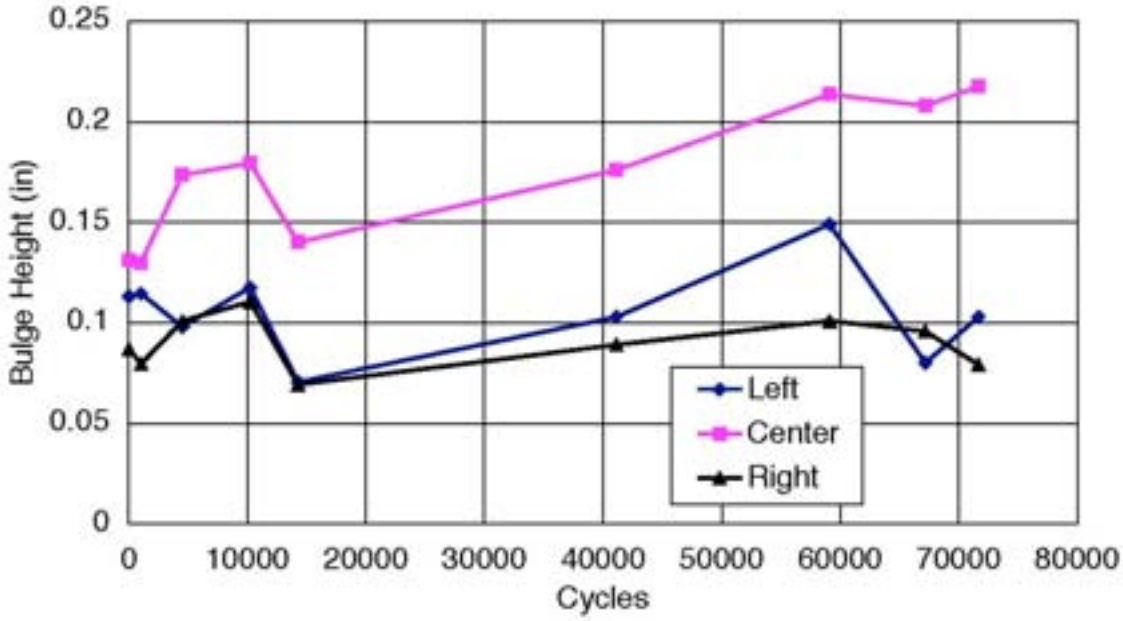


(c) Normalized Energy Values

Figure A.93: Test SHR3-B1 Summary



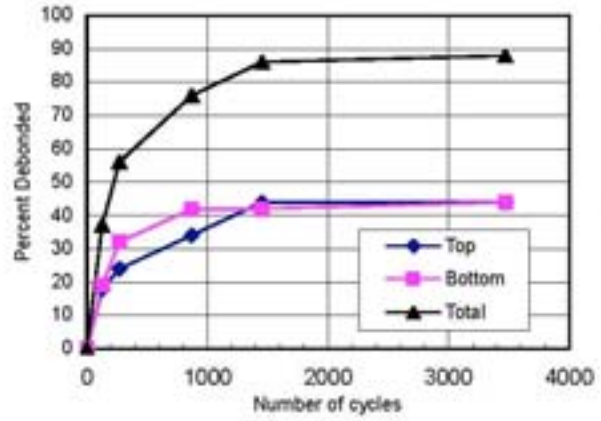
(a) Top



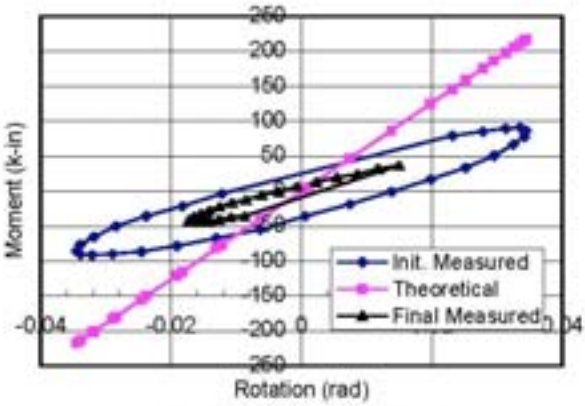
(b) Bottom

Figure A.94: SHR3-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

SHR4-B1



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	30%

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	3
25%	77
50%	181
75%	570
100%	3473

Rotational Stiffness

Initial Measured	24.3	k-in/%rot
Final Measured	25.0	k-in/%rot
Elastic Model	63.0	k-in/%rot

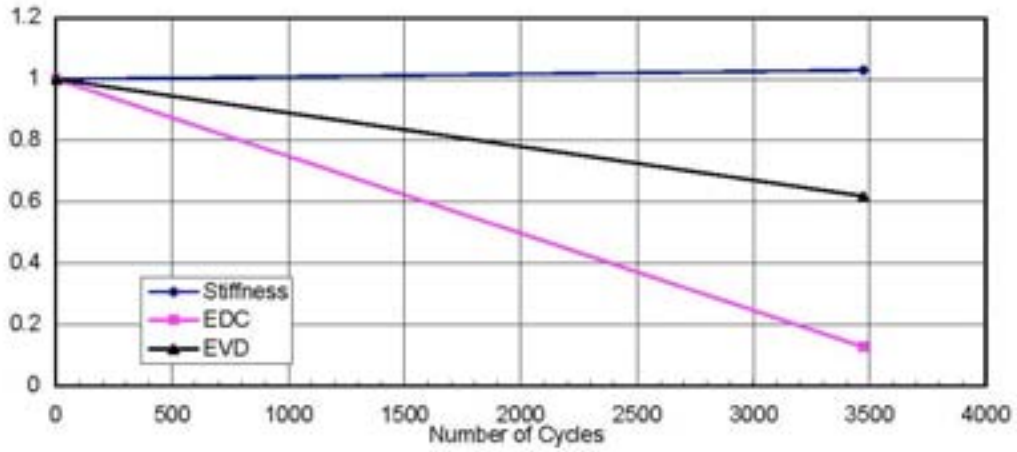
Local Nominal Shear Strains

Average Axial	3.3
Max. Rotation	1.9
Average Shear	0.3

Energy

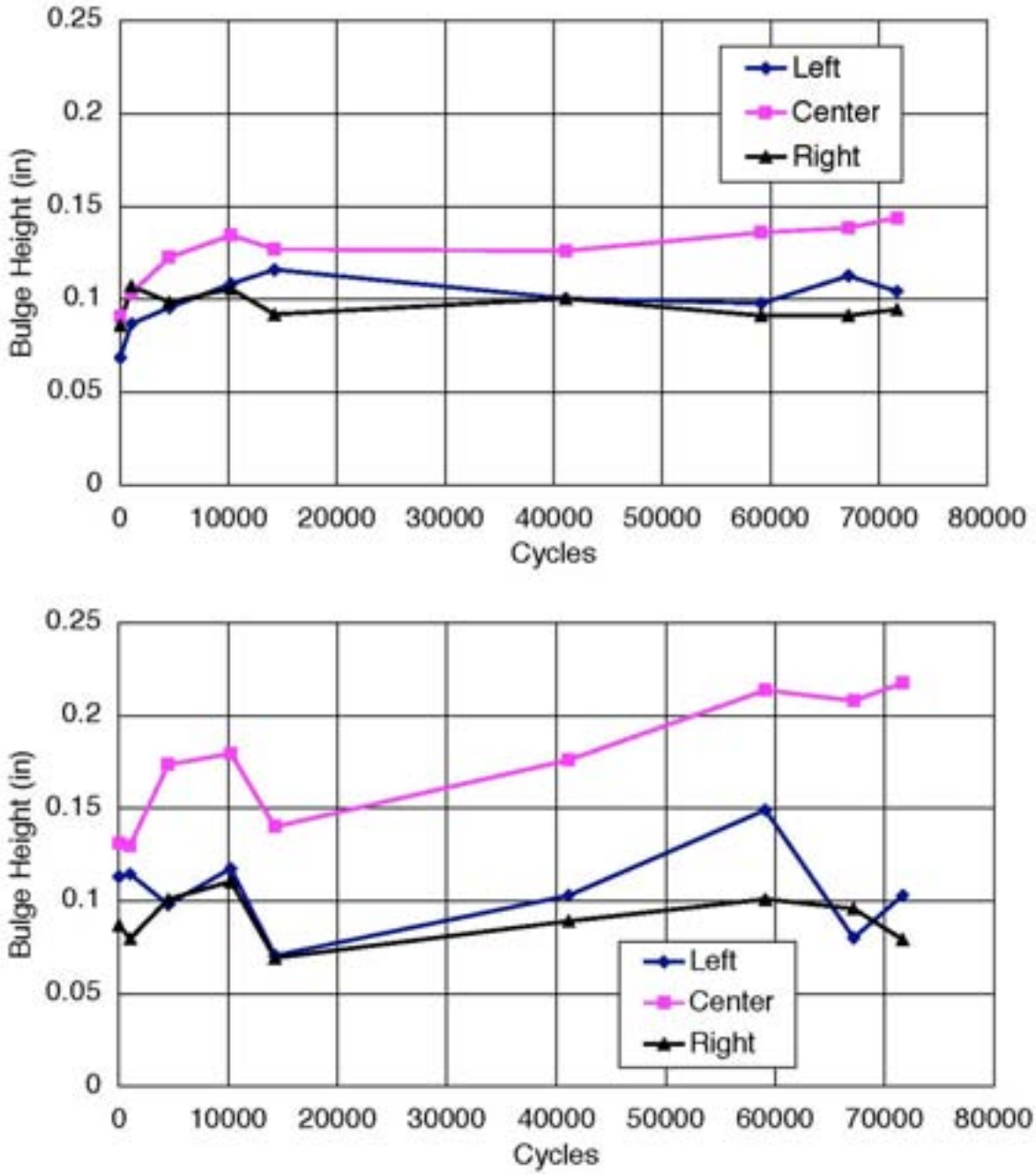
Initial EDC	1.777	k-in*rot
Final EDC	0.226	k-in*rot
Initial EVD	0.09	
Final EVD	0.056	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

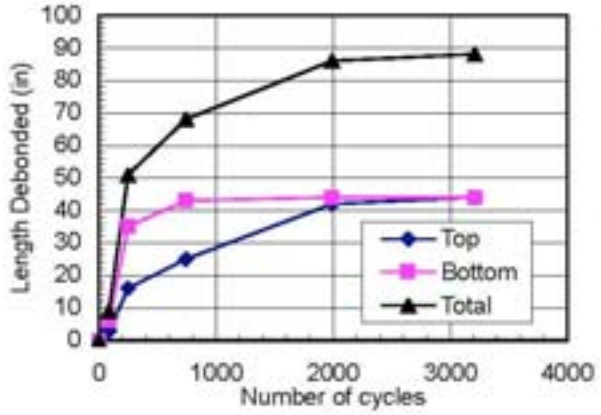
Figure A.95: Test SHR4-B1 Summary



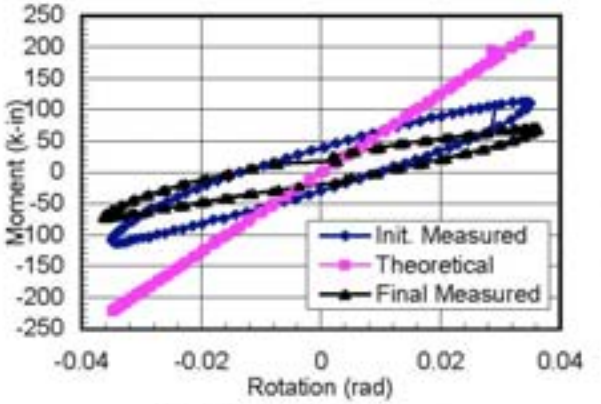
(b) Bottom

Figure A.96: SHR4-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

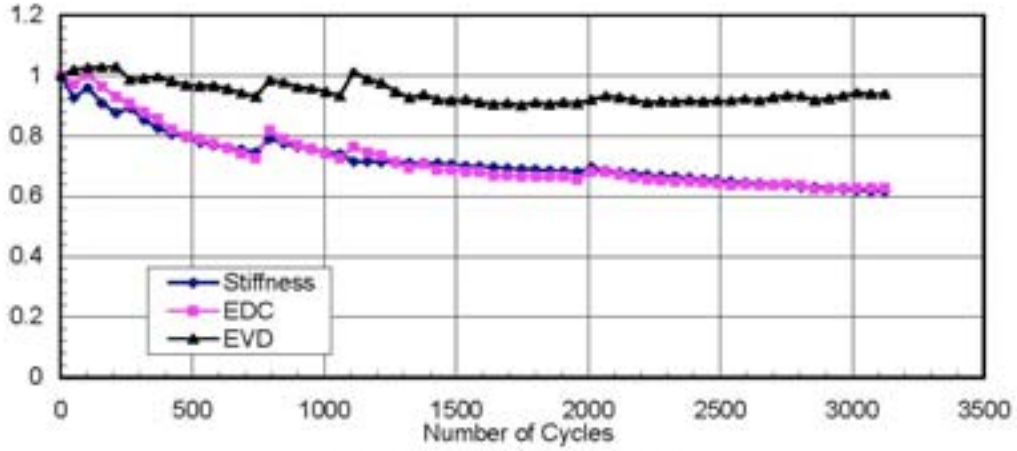
SHR5-B1



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties

Axial Stress	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	30%

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	10
25%	136
50%	222
75%	687
100%	3210

Rotational Stiffness

Initial Measured	29.9	k-in/%rot
Final Measured	18.4	k-in/%rot
Elastic Model	63.0	k-in/%rot

Local Nominal Shear Strains

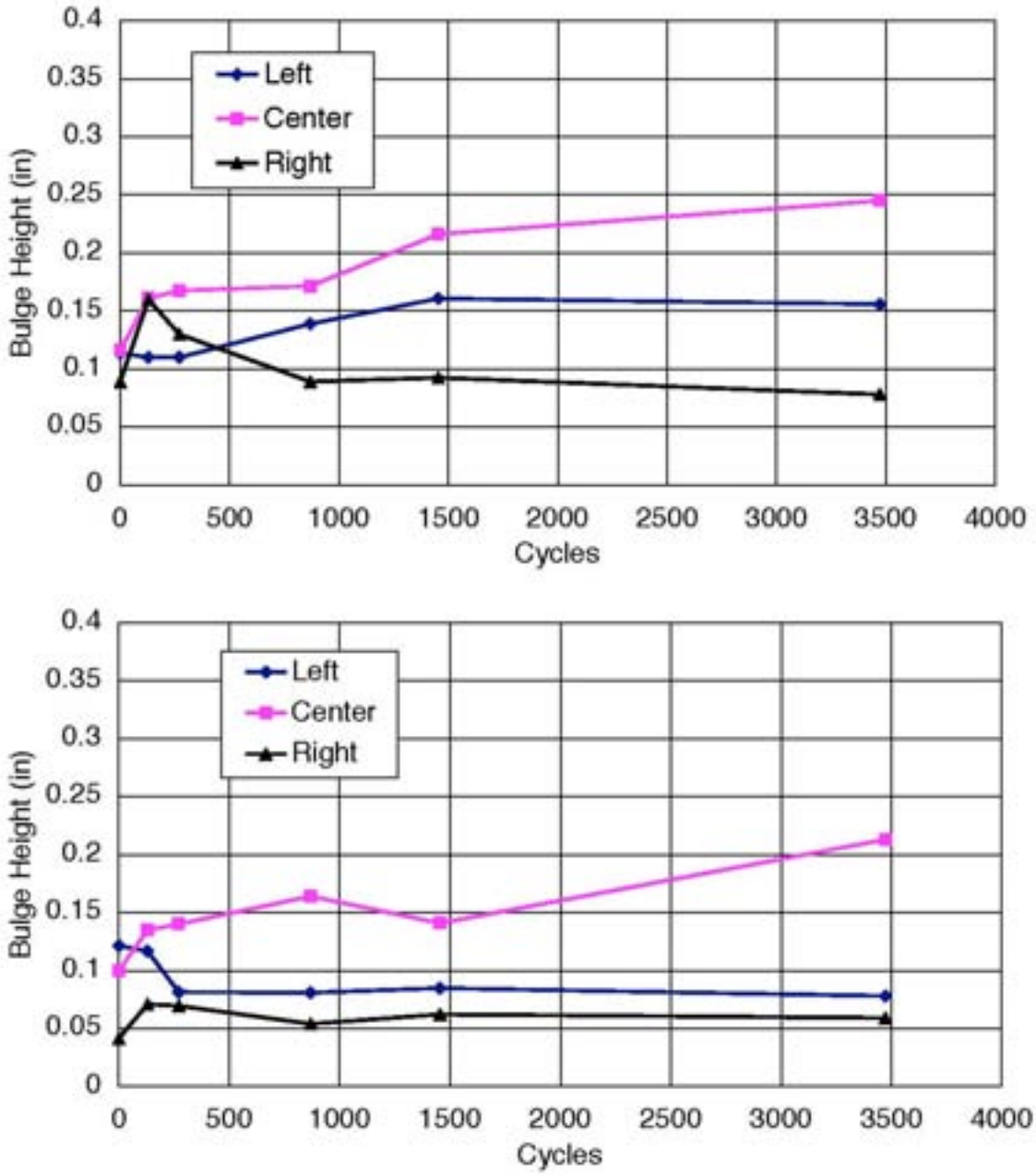
Average Axial	4.5
Max. Rotation	2.0
Average Shear	0.3

Energy

Initial EDC	3.698	k-in*rot
Final EDC	2.32	k-in*rot
Initial EVD	0.149	
Final EVD	0.14	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

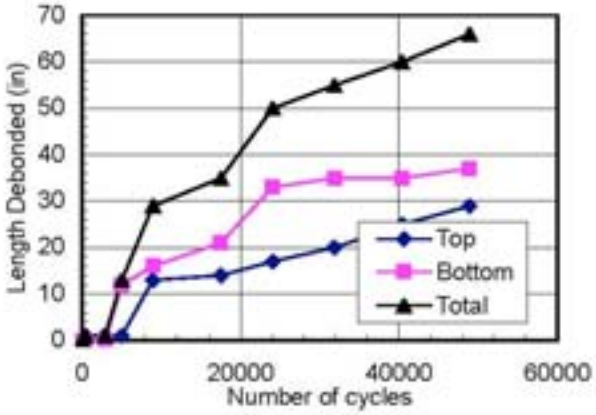
Figure A.97: Test SHR5-B1 Summary



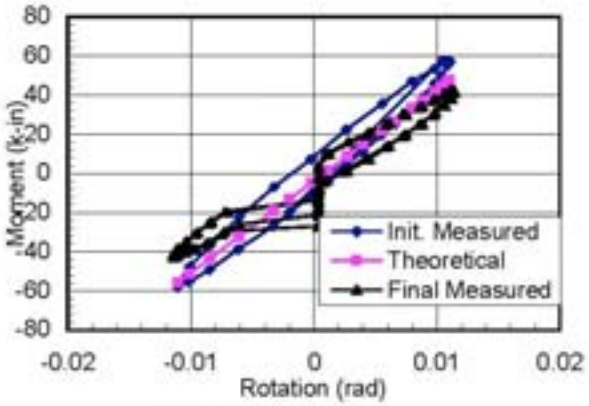
(b) Bottom

Figure A.98: SHR5-B1 Bulge Heights (a) Top of Bearing and (b) Bottom

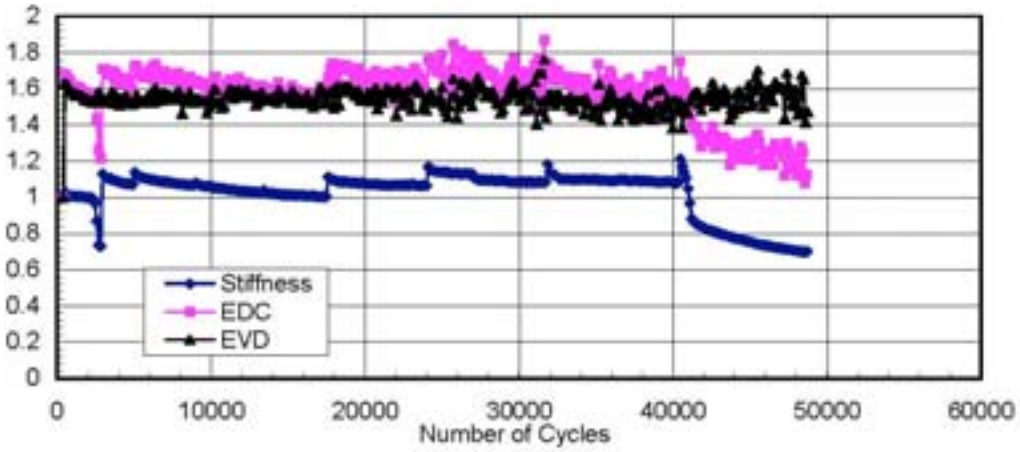
SHR6-A2



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties

Axial Stress	$7/Bc_1$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$2/B\theta_1$ = 0.0125 rad
Shear Disp.	30%

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	402
25%	7233
50%	21446
75%	48925
100%	80172

Rotational Stiffness

Initial Measured	50.8	k-in/%rot
Final Measured	35.6	k-in/%rot
Elastic Model	46.7	k-in/%rot

Local Nominal Shear Strains

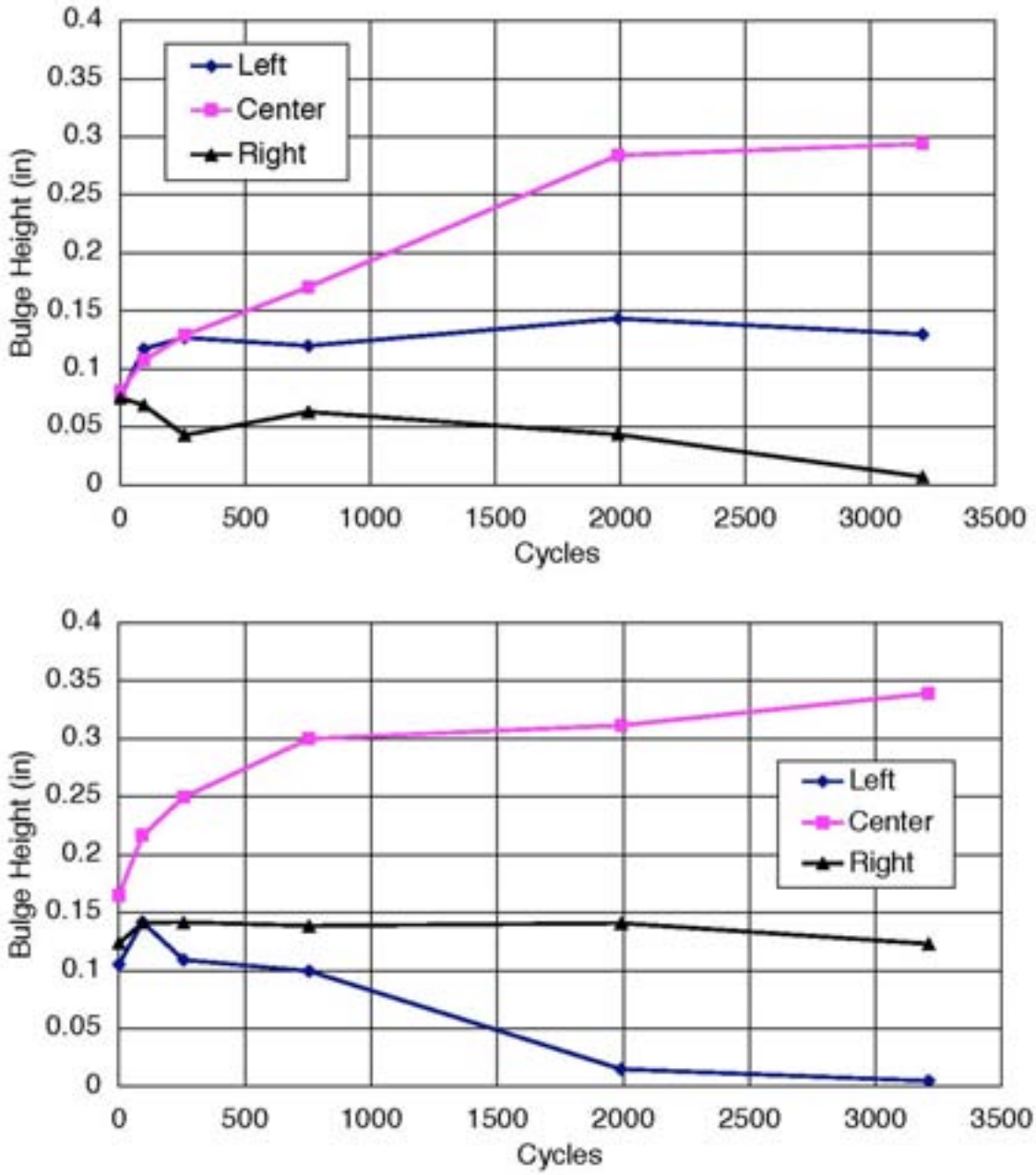
Average Axial	5.5
Max. Rotation	0.9
Average Shear	0.3

Energy

Initial EDC	0.197	k-in*rot
Final EDC	0.222	k-in*rot
Initial EVD	0.049	
Final EVD	0.072	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

Figure A.99: Test SHR6-A2 Summary



(b) Bottom

Figure A.100: SHR6-A2 Bulge Heights (a) Top of Bearing and (b) Bottom

A.7 SHF Series

SHF1-C2

Debonding
none

Shim Fracture
none

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	9
No. of Shims	5
Layer Thickness	0.375

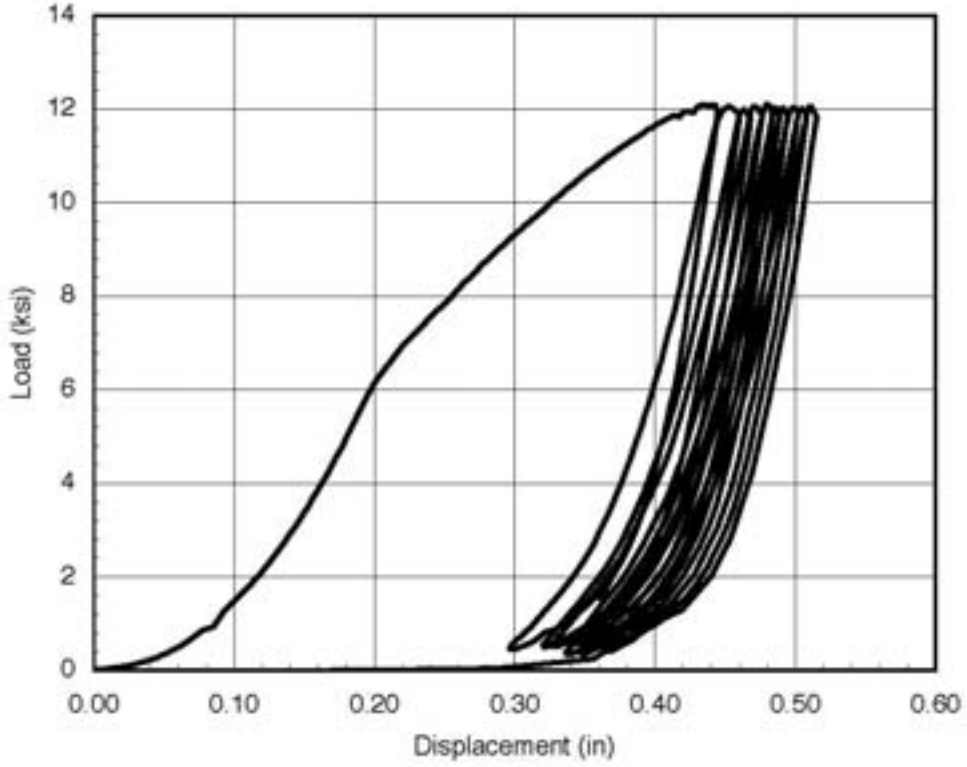


Figure A.101: Test SHF1-C2 Summary

SHF2-C2

Debonding
none

Shim Fracture
none

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	12
No. of Shims	6
Layer Thickness	0.25

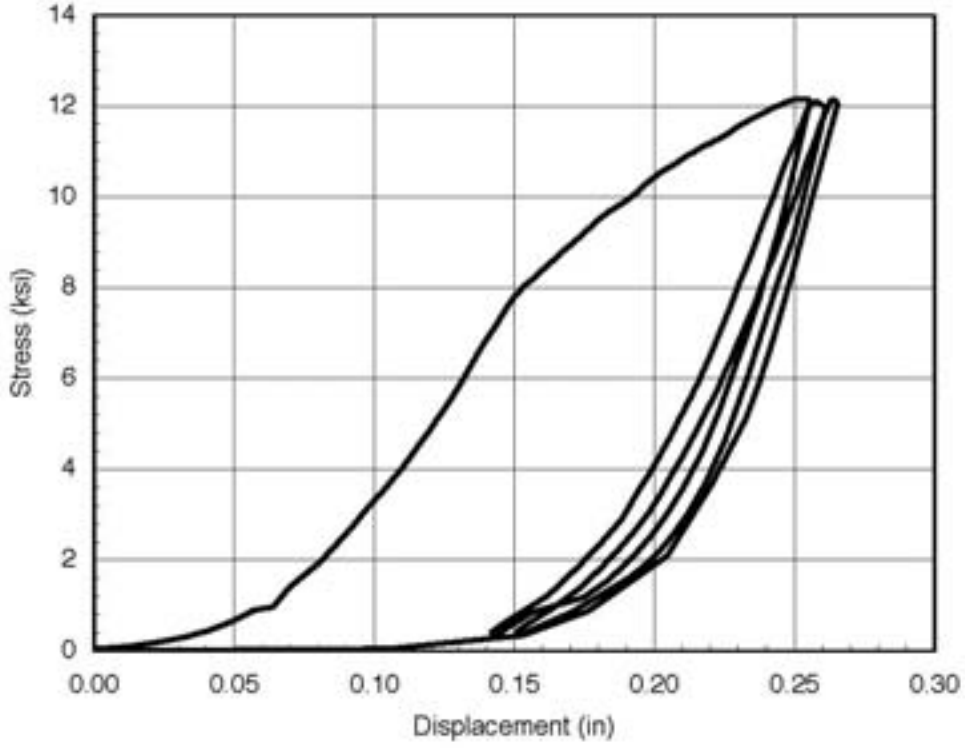
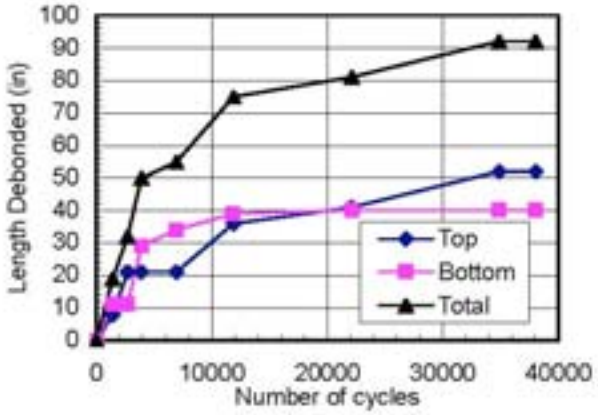
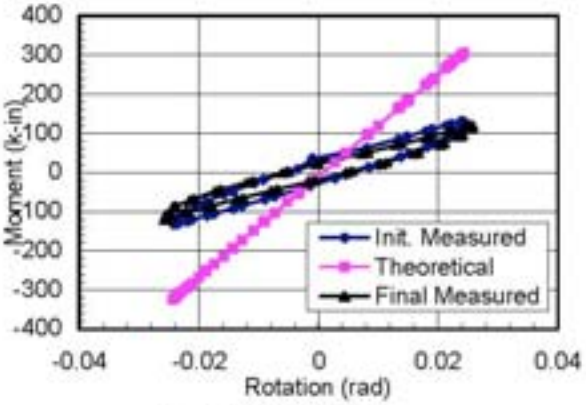


Figure A.102: Test SHF2-C2 Summary

SHF3-C2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_{cr}$ = 2510 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_r$ = 0.029 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	9
No. of Shims	5
Layer Thickness	0.375 in

Debonding Milestones (cycles)

Initial	75
25%	2777
50%	4995
75%	17796
100%	53614

Rotational Stiffness

Initial Measured	50.3	k-in/%rot
Final Measured	42.6	k-in/%rot
Elastic Model	129.0	k-in/%rot

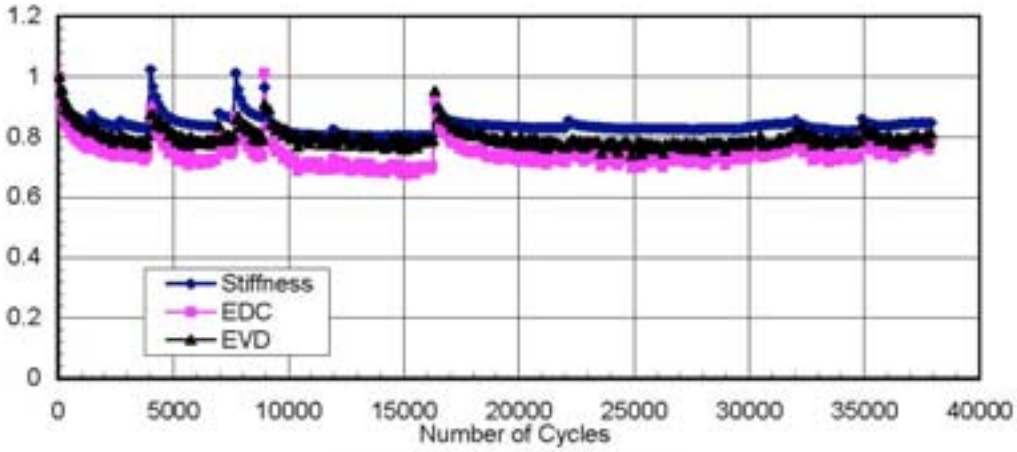
Local Nominal Shear Strains

Average Axial	2.9
Max. Rotation	1.7
Average Shear	0.0

Energy

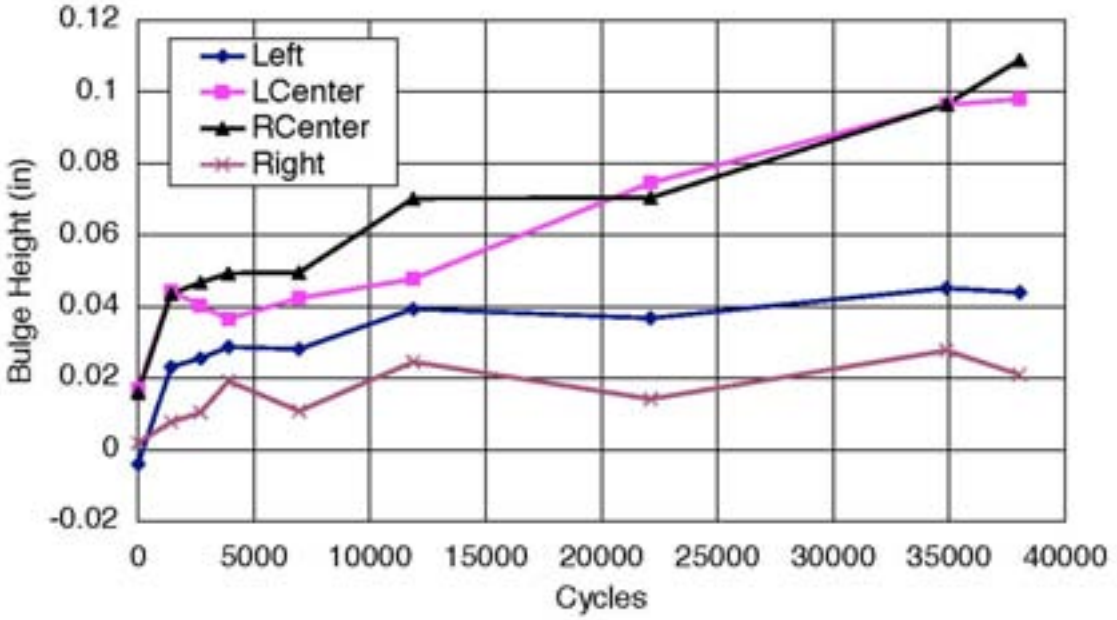
Initial EDC	2.185	k-in*rot
Final EDC	1.726	k-in*rot
Initial EVD	0.109	
Final EVD	0.089	

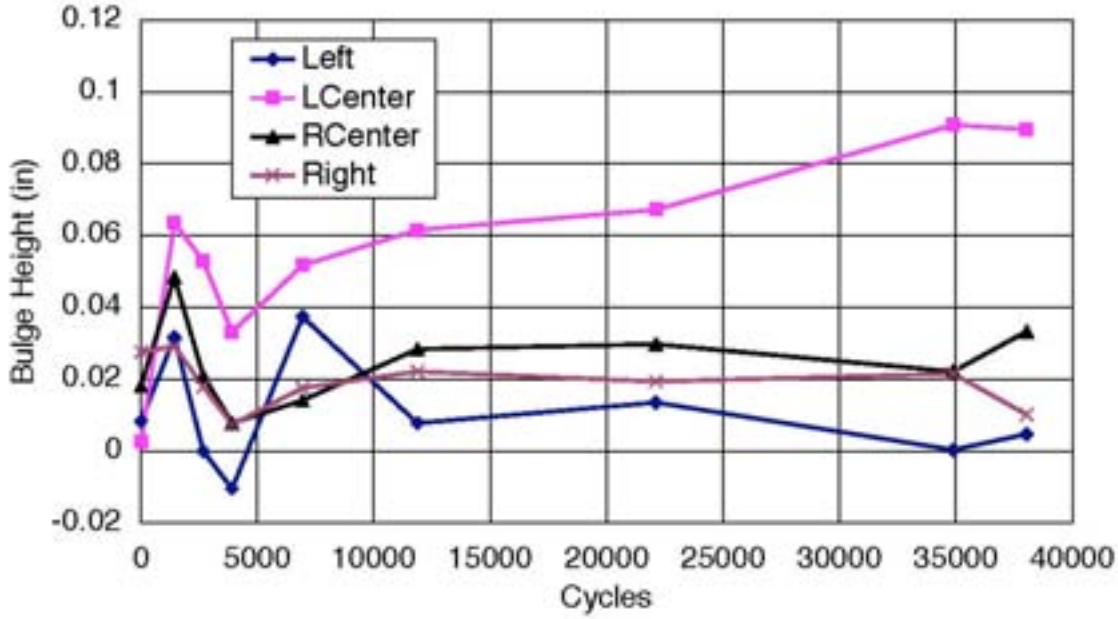
EDC = Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.103: Test SHF3-C2 Summary

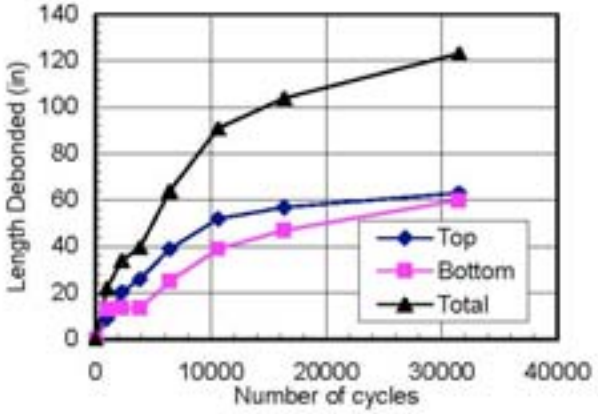




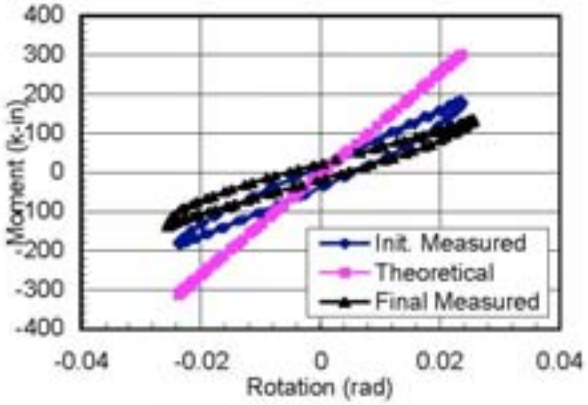
(b) Bottom

Figure A.104: SHF3-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

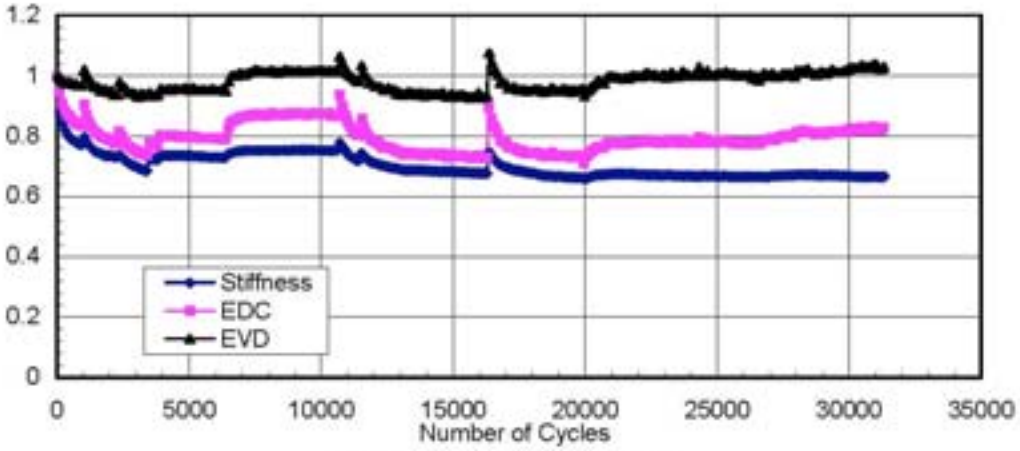
SHF4-C2



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties

Axial Stress	$7/Bo_1$ = 3343 psi
Static Rotation	0
Cyclic Rotation	$6/Bθ_1$ = 0.029 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	9
No. of Shims	5
Layer Thickness	0.375 in

Debonding Milestones (cycles)

Initial	45
25%	1996
50%	6753
75%	14135
100%	38673

Rotational Stiffness

Initial Measured	73.0	k-in/%rot
Final Measured	48.6	k-in/%rot
Elastic Model	129.0	k-in/%rot

Local Nominal Shear Strains

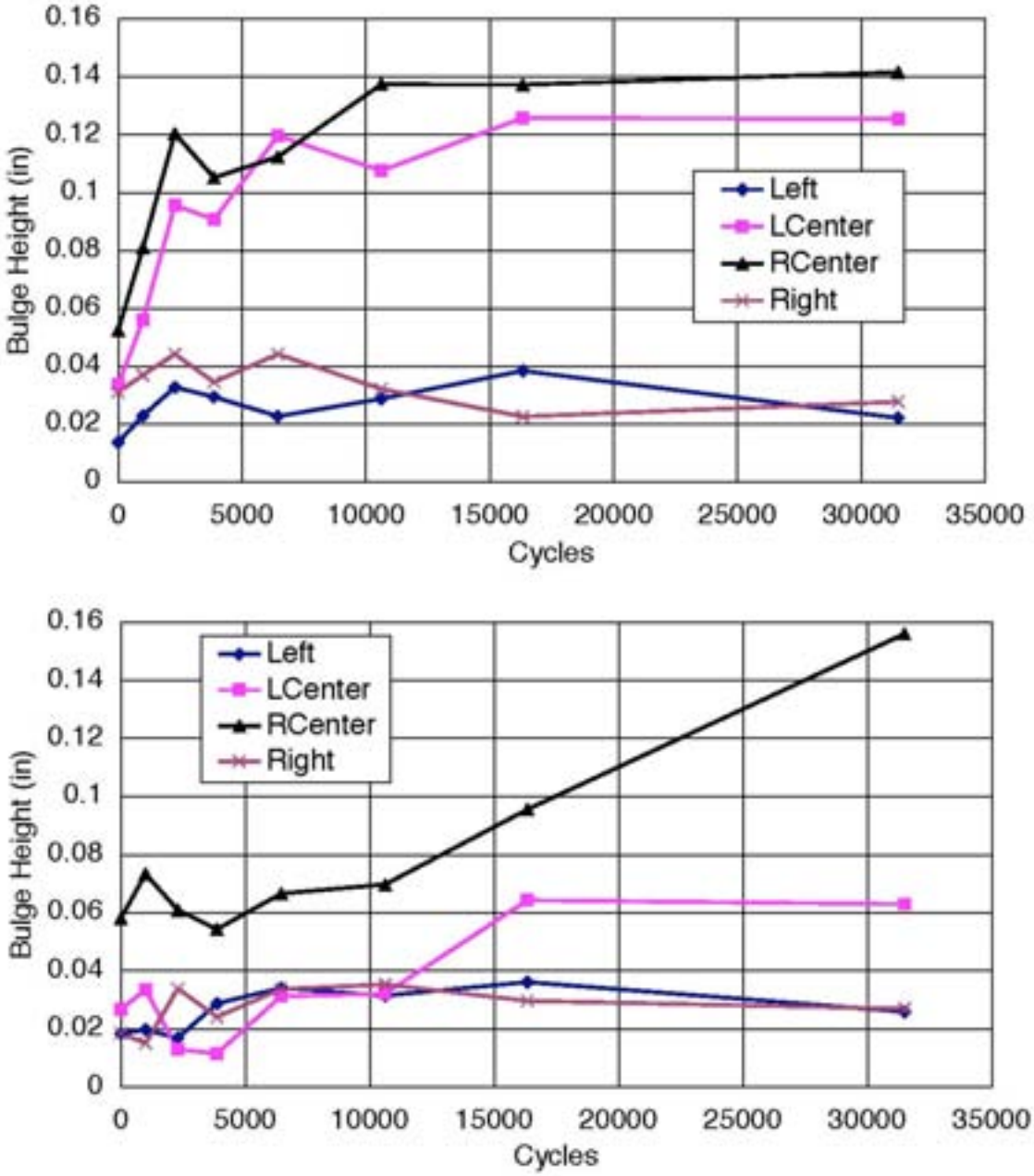
Average Axial	3.8
Max. Rotation	1.8
Average Shear	0.0

Energy

Initial EDC	2.128	k-in*rot
Final EDC	1.761	k-in*rot
Initial EVD	0.078	
Final EVD	0.08	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

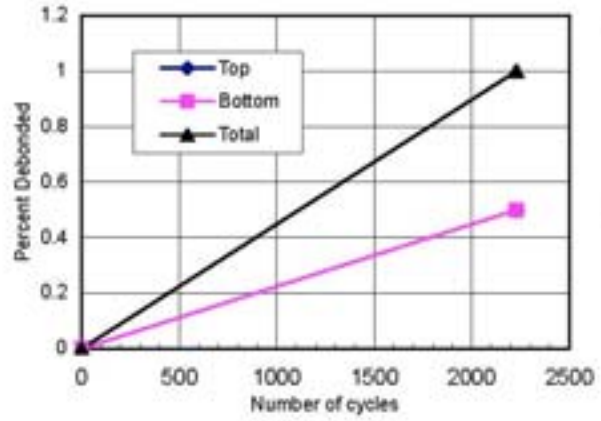
Figure A.105: Test SHF4-C2 Summary



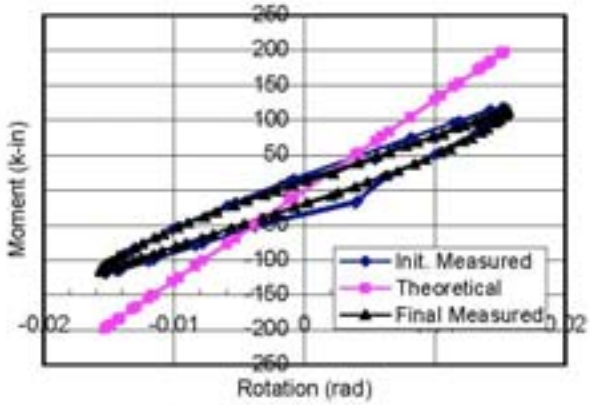
(b) Bottom

Figure A.106: SHF4-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

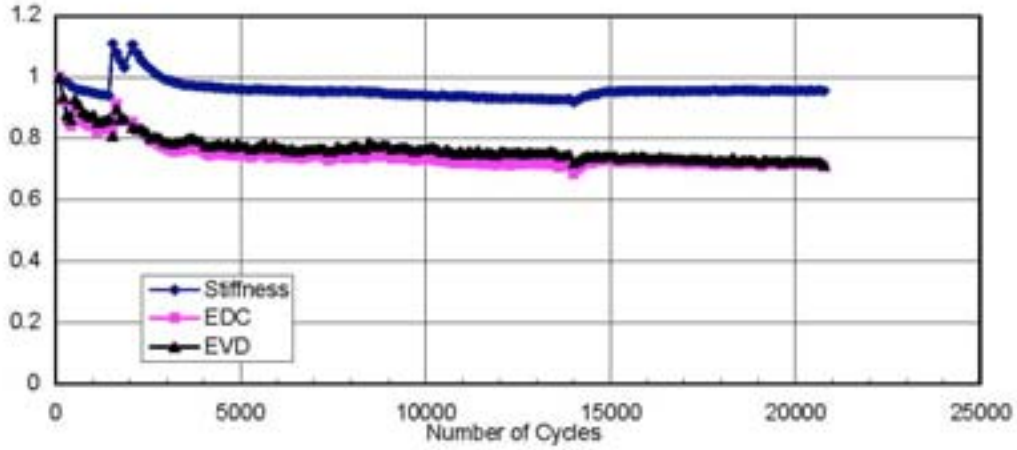
SHF5-C2



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties

Axial Stress	$7/8\sigma_0$ = 3343 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_0$ = 0.019 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	9
No. of Shims	5
Layer Thickness	0.375 in

Debonding Milestones (cycles)

Initial	2230
25%	N/A
50%	N/A
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	72.9	k-in/%rot
Final Measured	69.8	k-in/%rot
Elastic Model	129.0	k-in/%rot

Local Nominal Shear Strains

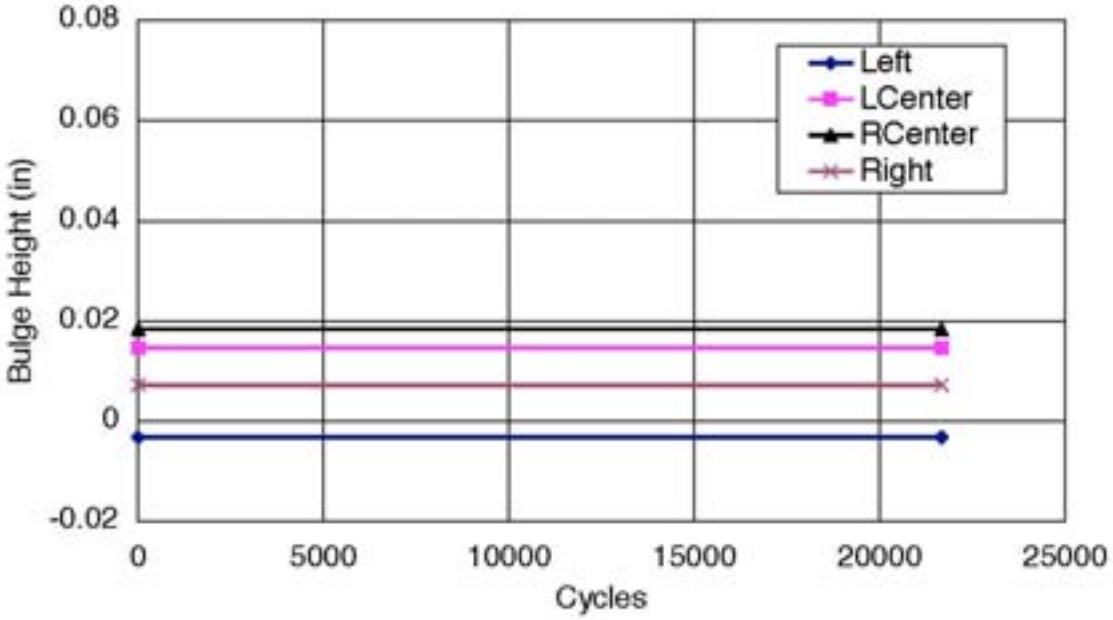
Average Axial	3.8
Max. Rotation	1.0
Average Shear	0.0

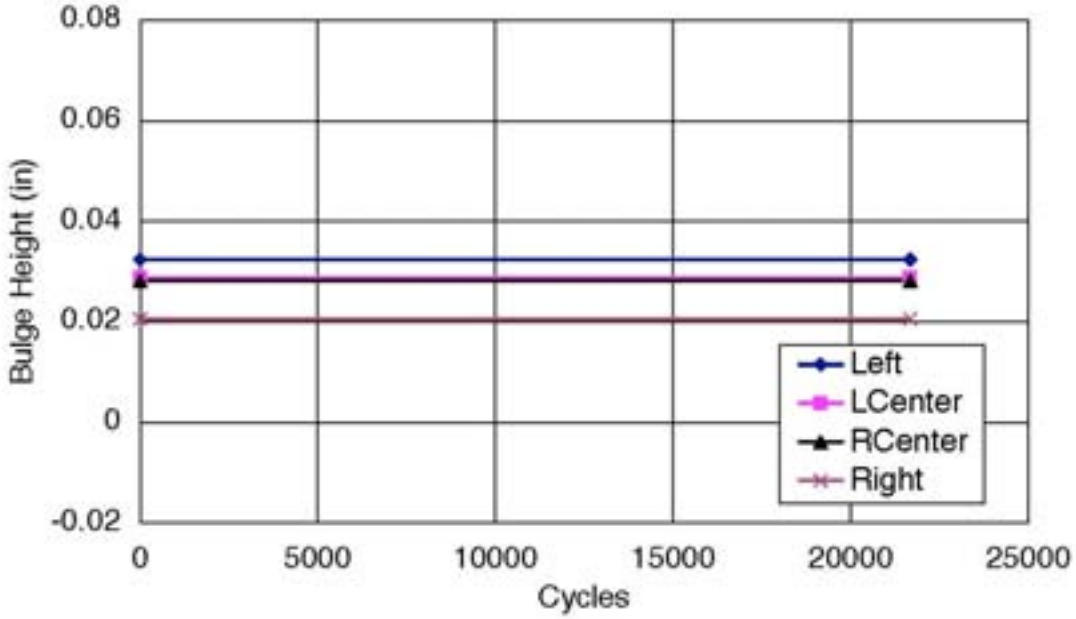
Energy

Initial EDC	1.178	k-in*rot
Final EDC	0.834	k-in*rot
Initial EVD	0.103	
Final EVD	0.073	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

Figure A.107: Test SHF5-C2 Summary

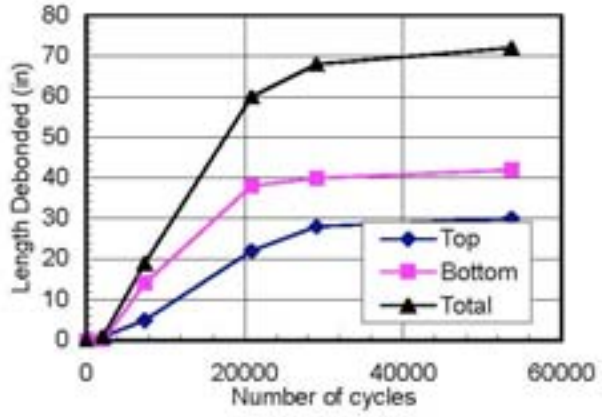




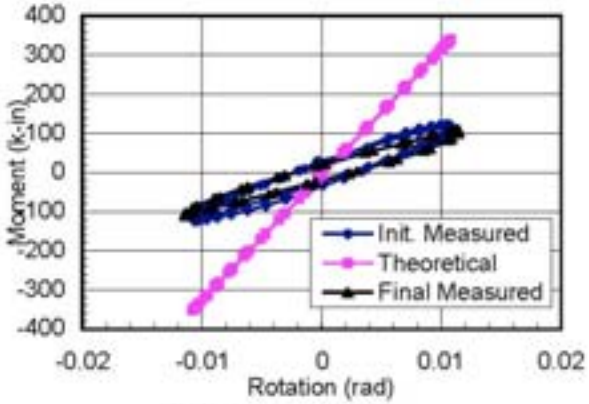
(b) Bottom

Figure A.108: SHF5-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

SHF6-C2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$5/8\sigma_0$ = 3747 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.016 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	12
No. of Shims	6
Layer Thickness	0.25 in

Debonding Milestones (cycles)

Initial	2132
25%	15611
50%	151930
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	108.5	k-in/%rot
Final Measured	90.8	k-in/%rot
Elastic Model	320.1	k-in/%rot

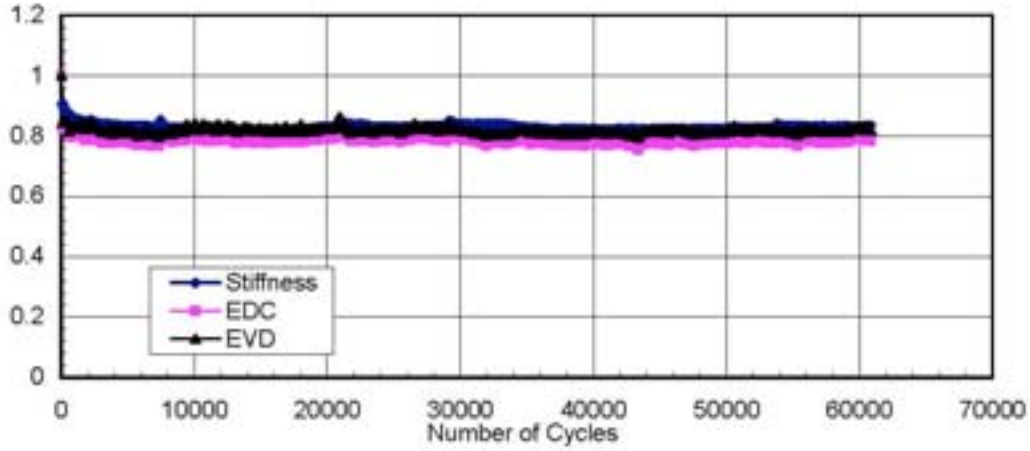
Local Nominal Shear Strains

Average Axial	3.1
Max. Rotation	1.3
Average Shear	0.0

Energy

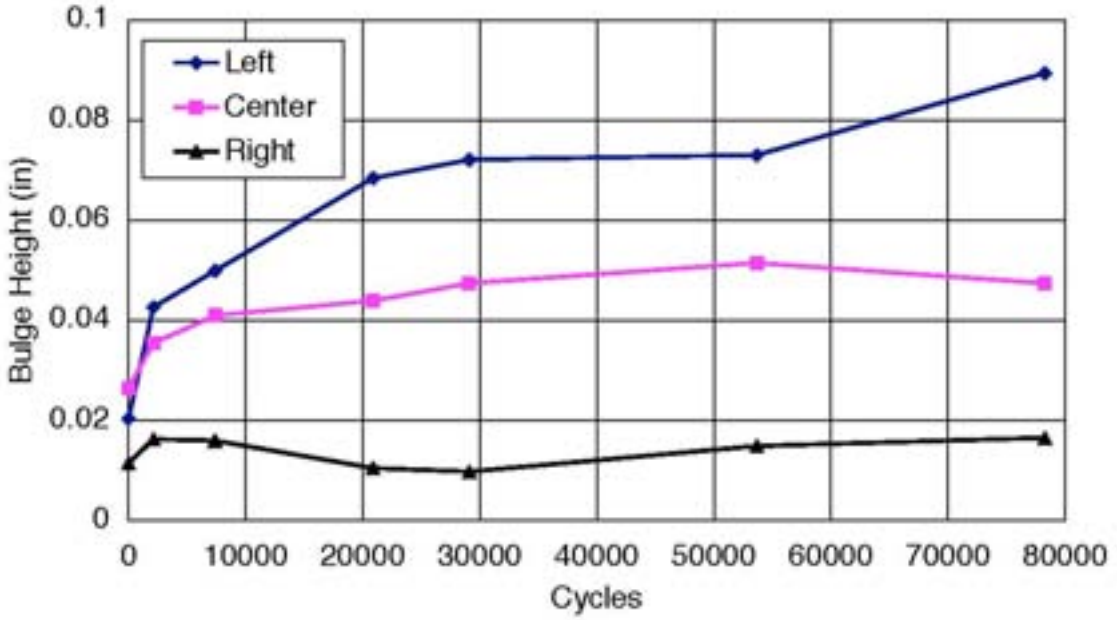
Initial EDC	0.966	k-in*rot
Final EDC	0.756	k-in*rot
Initial EVD	0.115	
Final EVD	0.094	

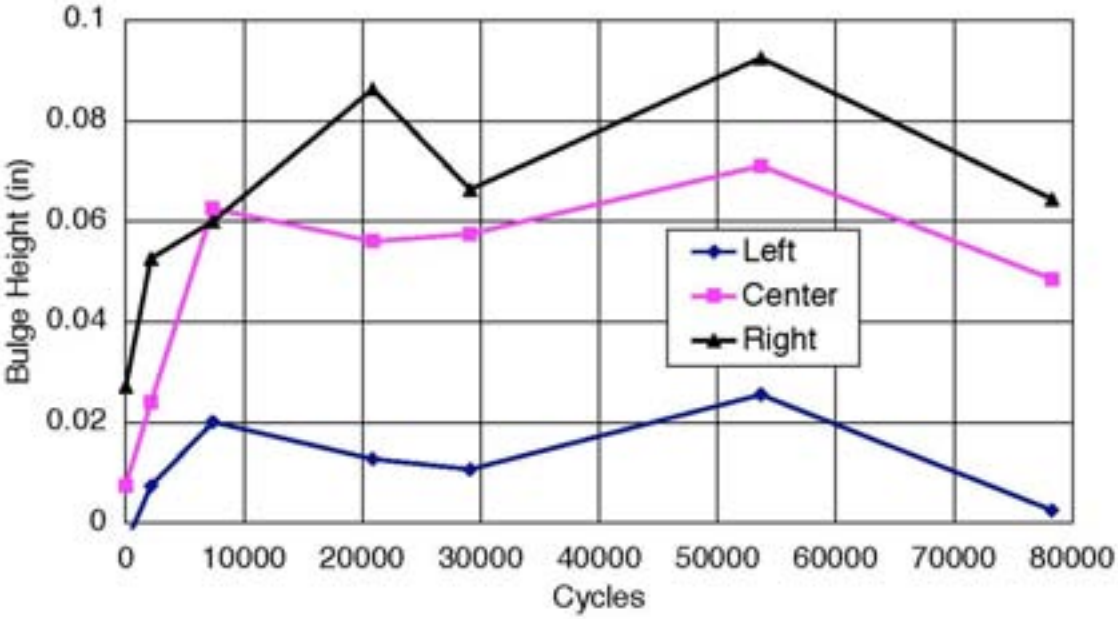
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.109: Test SHF6-C2 Summary





(b) Bottom

Figure A.110: SHF6-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

A.8 ASR Series

ASR1-C2

Debonding
none

Shim Fracture
5400 psi 1st plate

Test Properties

Axial Stress	Varies
Static Rotation	0
Cyclic Rotation	0
Shear Disp.	0

Bearing Properties

Area	9x9 = 81 in^2
Aspect Ratio	1
Shape Factor	6
No. of Shims	5
Layer Thickness	0.375

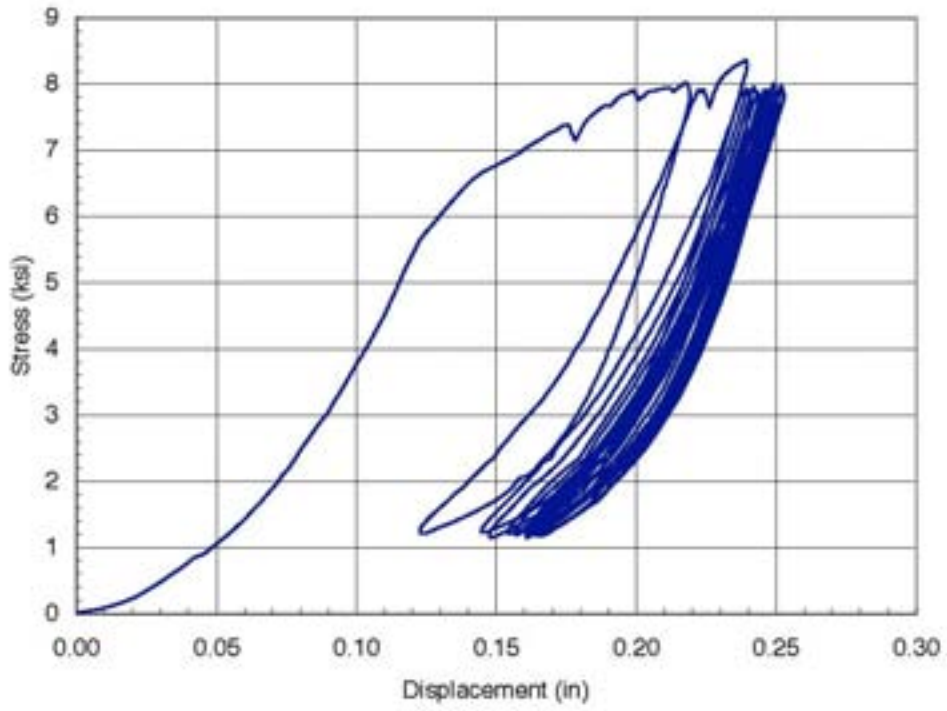
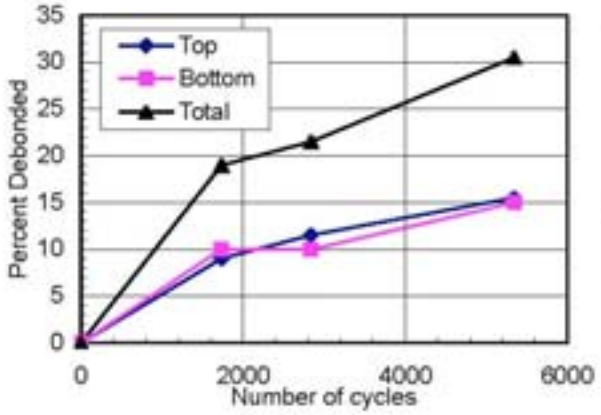
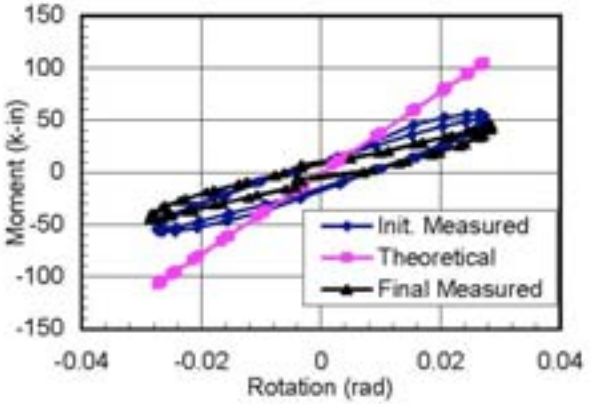


Figure A.111: Test ASR1-C2 Summary

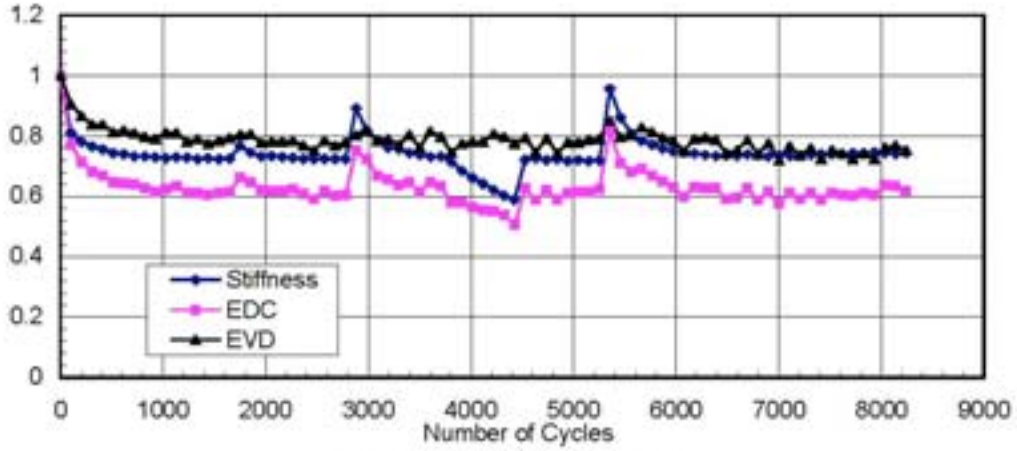
ASR2-C2



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties

Axial Stress	$5/B\sigma_0$ = 2074 psi
Static Rotation	0
Cyclic Rotation	$6/B\theta_0$ = 0.030 rad
Shear Disp.	0

Bearing Properties

Area	9x9 = 81 in^2
Aspect Ratio	1
Shape Factor	6
No. of Shims	5
Layer Thickness	0.375 in

Debonding Milestones (cycles)

Initial	91
25%	1232
50%	4369
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	19.2	k-in/%rot
Final Measured	14.3	k-in/%rot
Elastic Model	38.9	k-in/%rot

Local Nominal Shear Strains

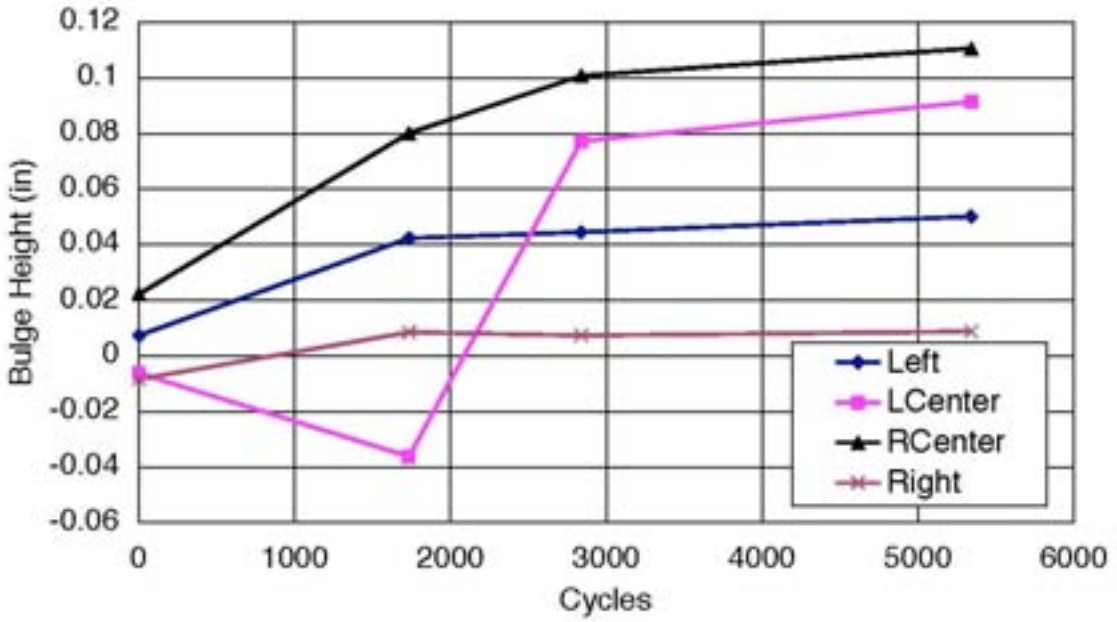
Average Axial	2.8
Max. Rotation	1.9
Average Shear	0.0

Energy

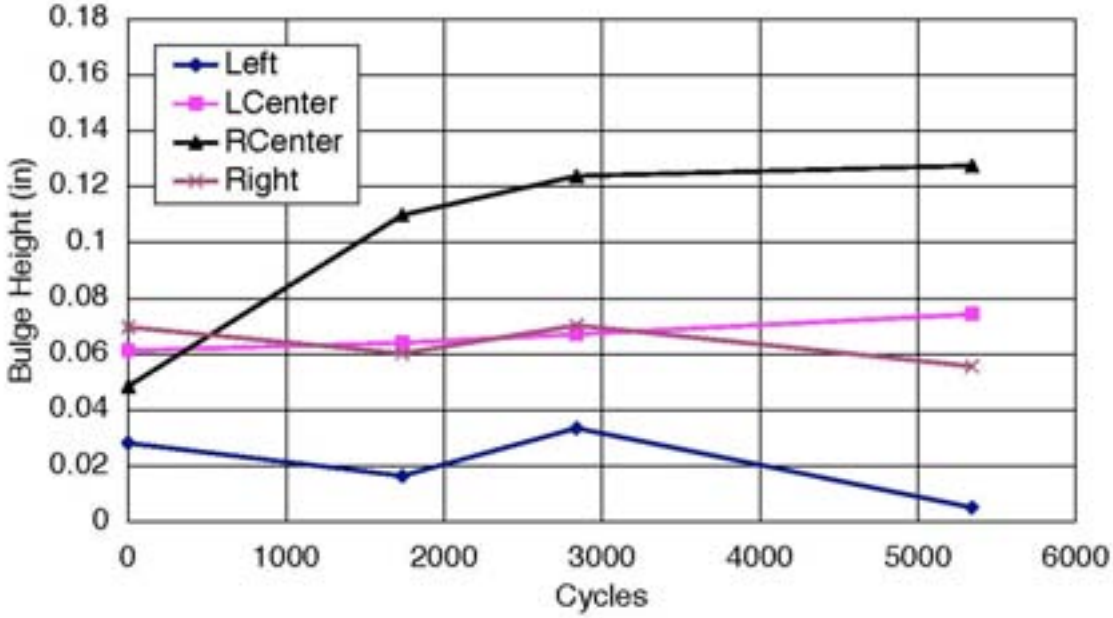
Initial EDC	1.211	k-in*rot
Final EDC	0.751	k-in*rot
Initial EVD	0.124	
Final EVD	0.112	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

Figure A.112: Test ASR2-C2 Summary

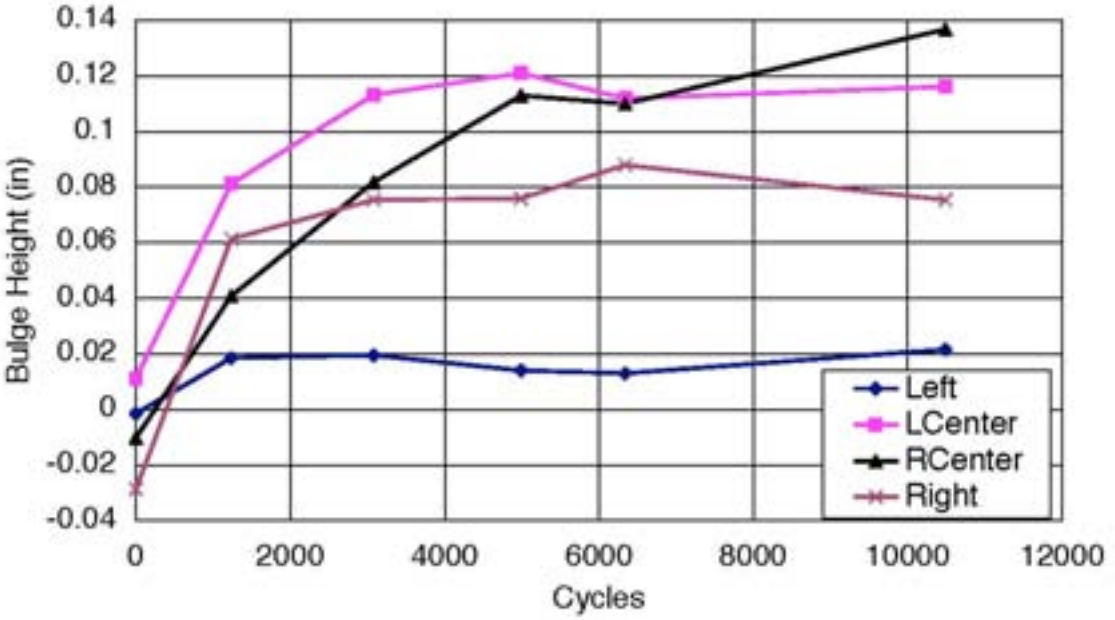


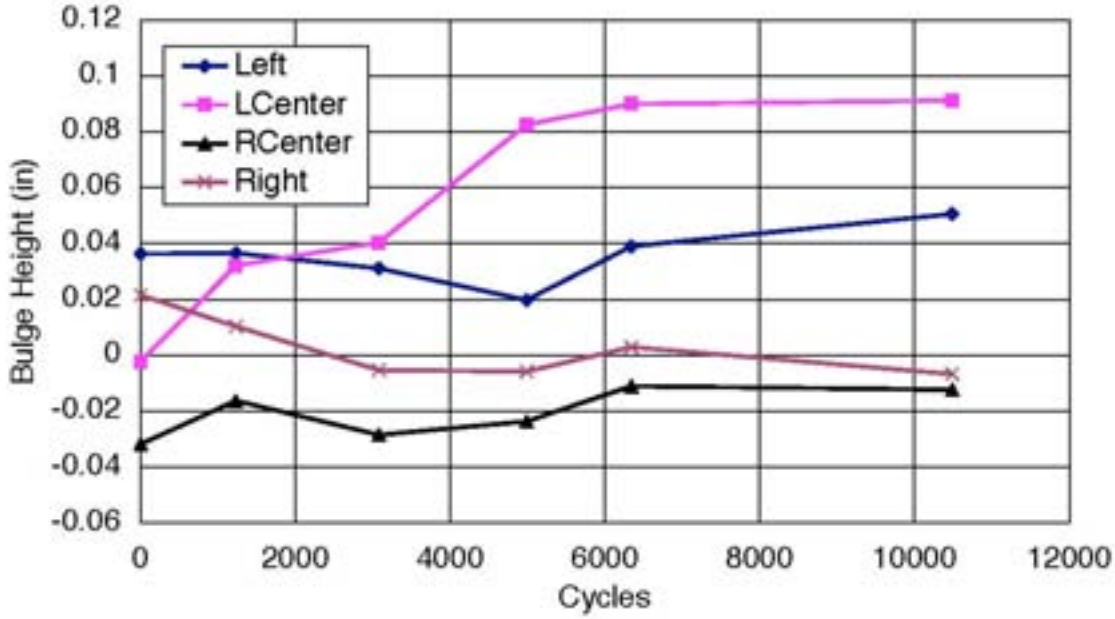
(a) Top



(b) Bottom

Figure A.113: ASR2-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

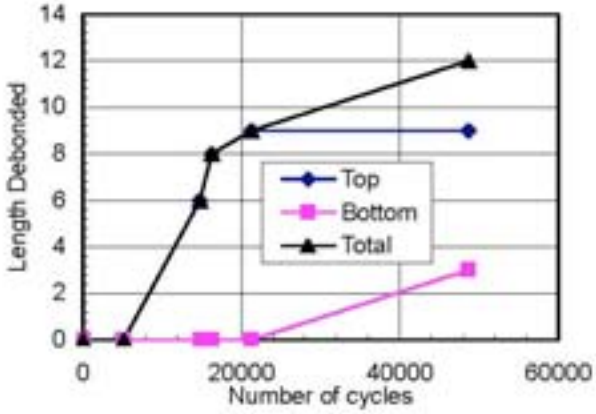




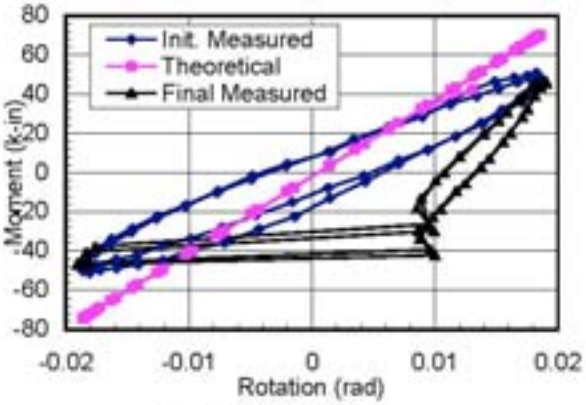
(b) Bottom

Figure A.115: ASR3-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

ASR4-C2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_y$ = 2765 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_y$ = 0.020 rad
Shear Disp.	0

Bearing Properties

Area	9x9 = 81 in^2
Aspect Ratio	1
Shape Factor	6
No. of Shims	5
Layer Thickness	0.375 in

Debonding Milestones (cycles)

Initial	6761
25%	62389
50%	N/A
75%	N/A
100%	N/A

Rotational Stiffness

Initial Measured	25.3	k-in/%rot
Final Measured	13.6	k-in/%rot
Elastic Model	38.9	k-in/%rot

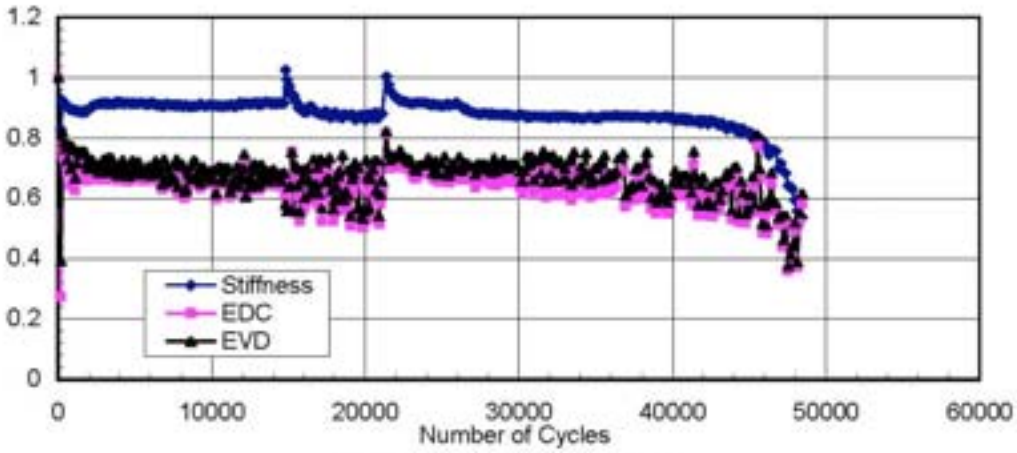
Local Nominal Shear Strains

Average Axial	4.0
Max. Rotation	1.5
Average Shear	0.0

Energy

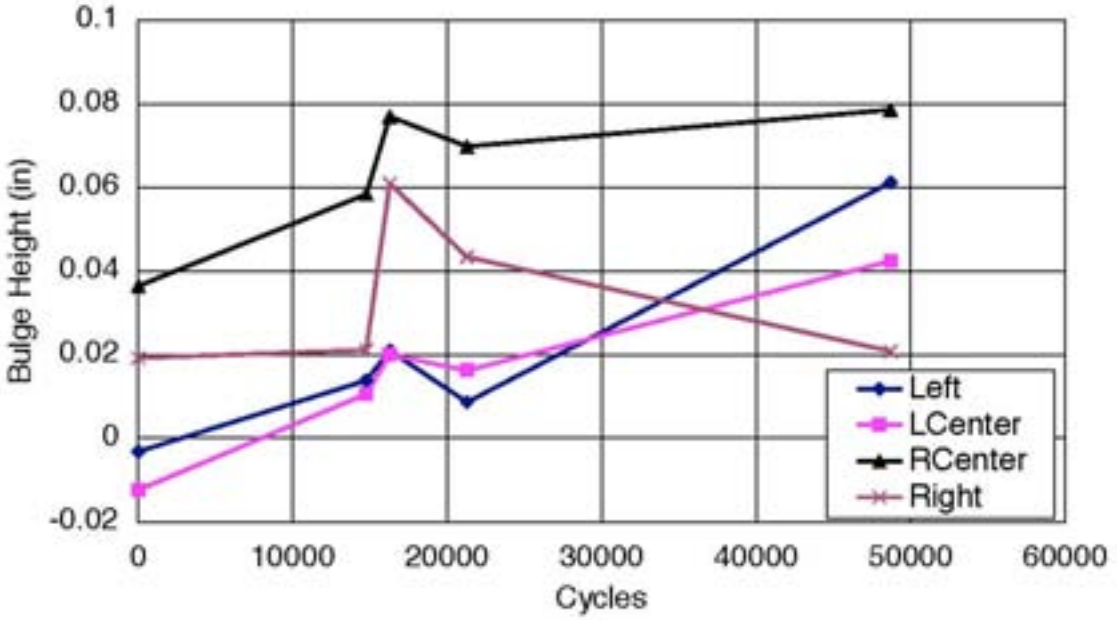
Initial EDC	0.693	k-in*rot
Final EDC	0.403	k-in*rot
Initial EVD	0.116	
Final EVD	0.072	

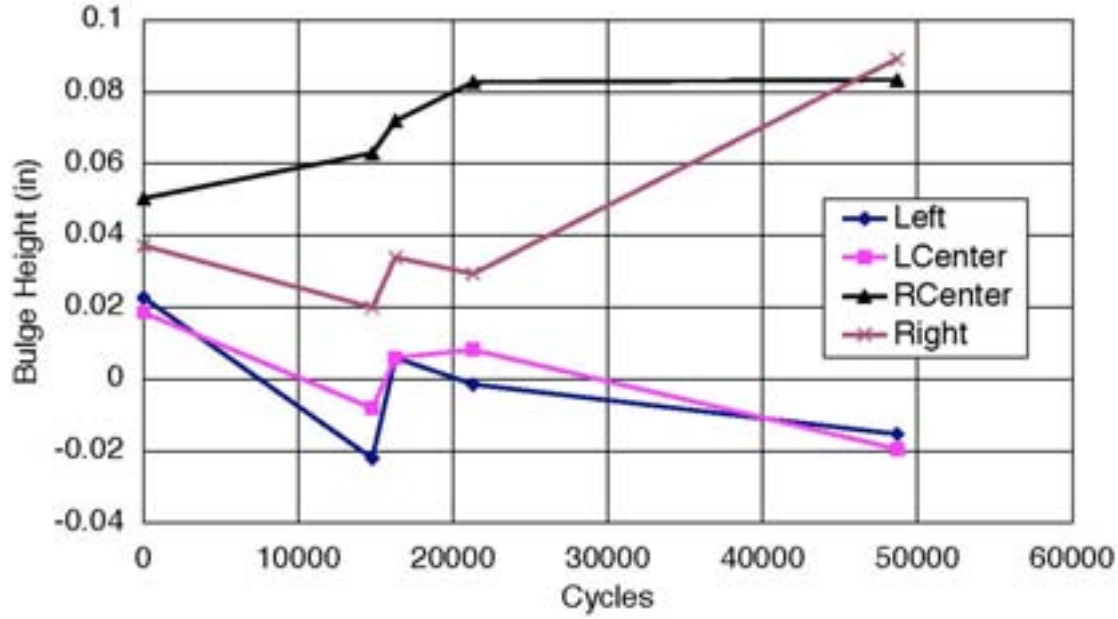
EDC = Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.116: Test ASR4-C2 Summary





(b) Bottom

Figure A.117: ASR4-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

A.9 MAT Series

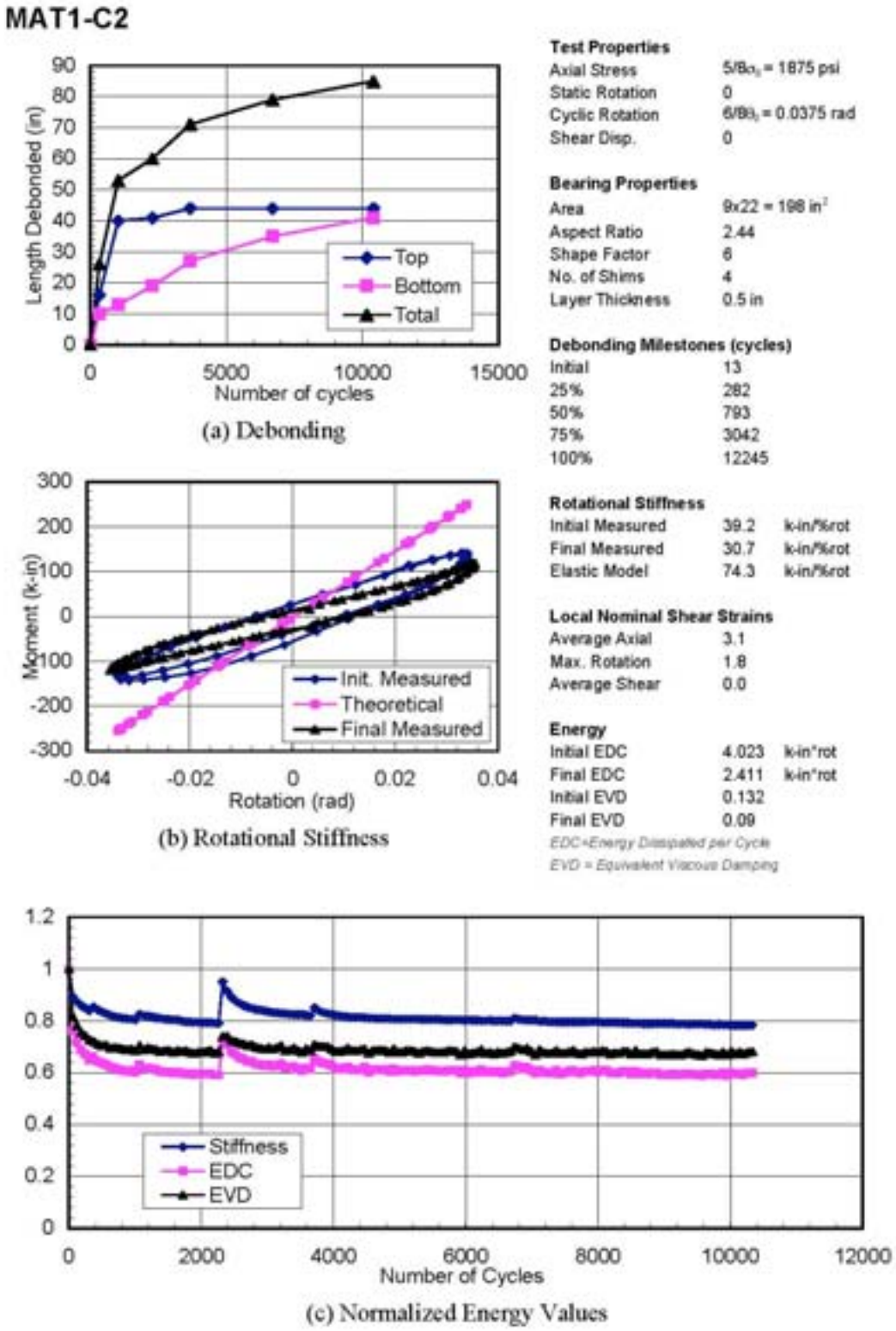
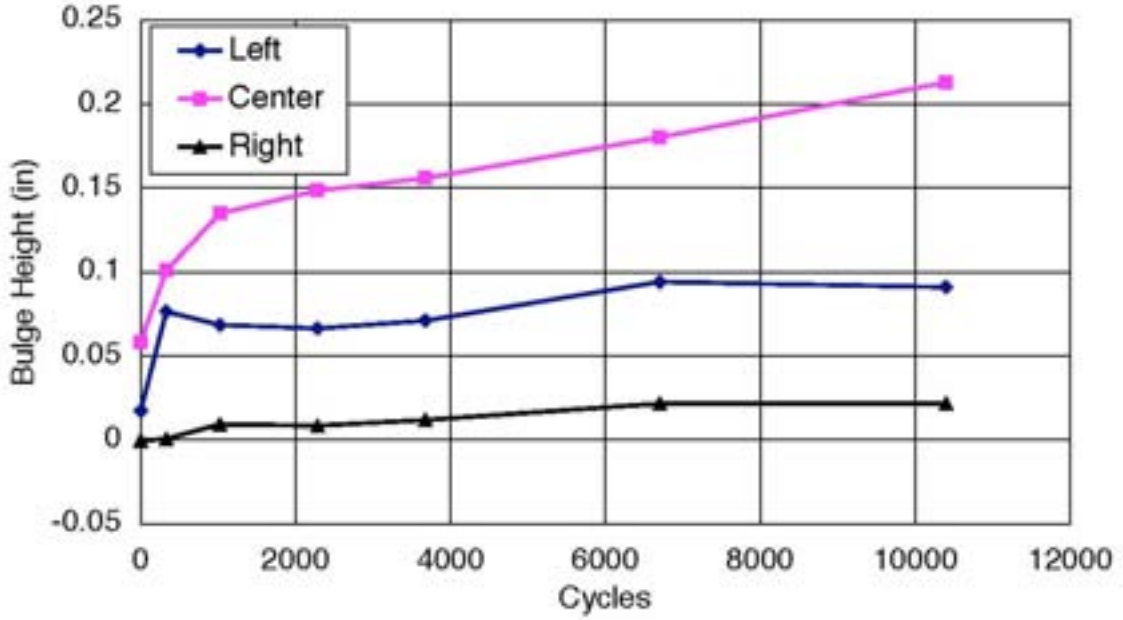
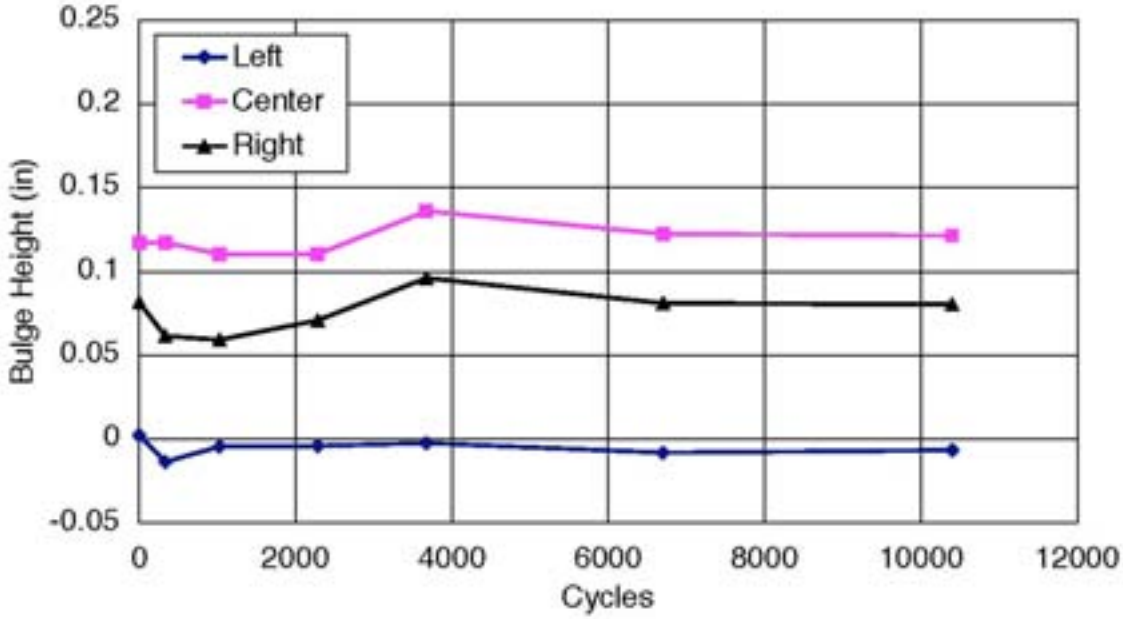


Figure A.118: Test MAT1-C2 Summary

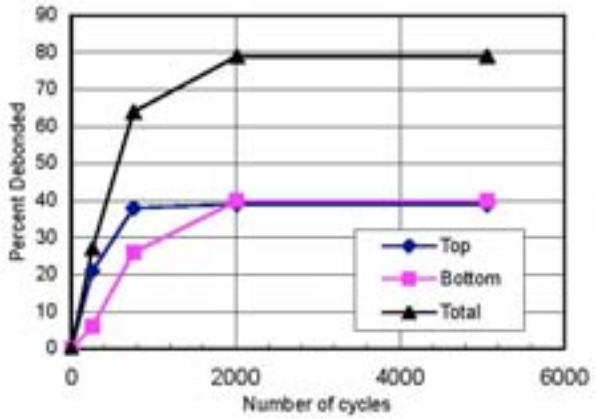




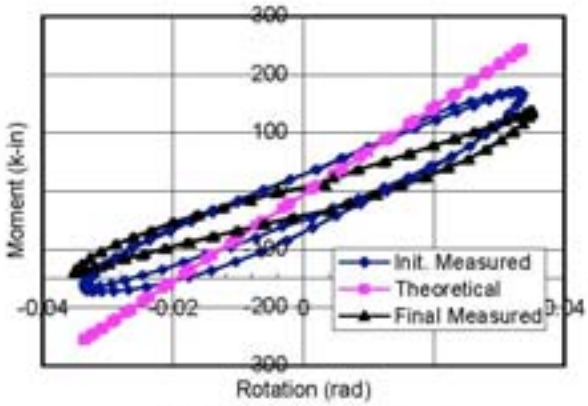
(b) Bottom

Figure A.119: MAT1-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

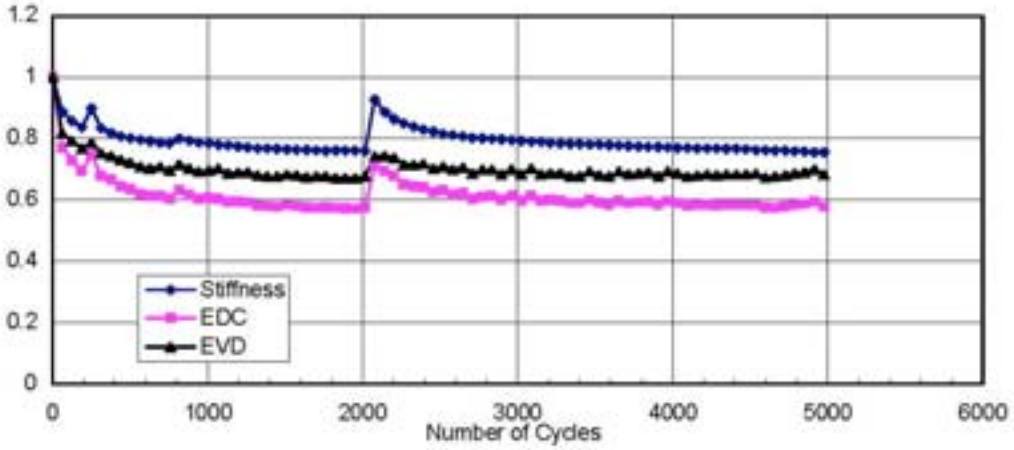
MAT2-C2



(a) Debonding



(b) Rotational Stiffness



(c) Normalized Energy Values

Test Properties

Axial Stress	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	9
25%	209
50%	486
75%	924
100%	N/A

Rotational Stiffness

Initial Measured	47.8	k-in/%rot
Final Measured	36.1	k-in/%rot
Elastic Model	74.3	k-in/%rot

Local Nominal Shear Strains

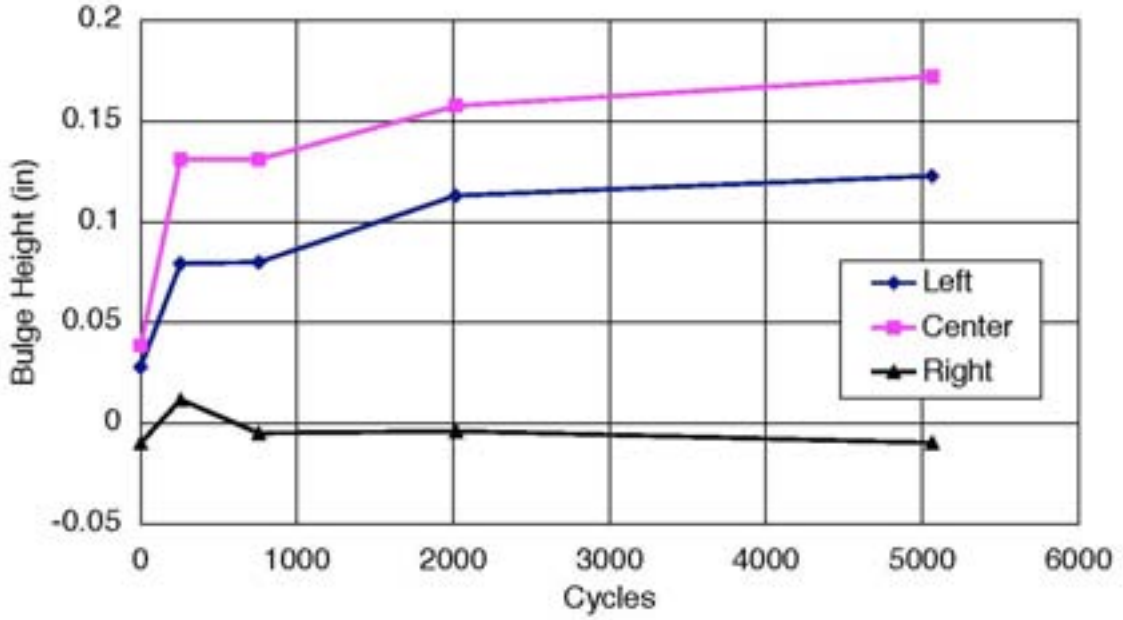
Average Axial	4.2
Max. Rotation	1.8
Average Shear	0.0

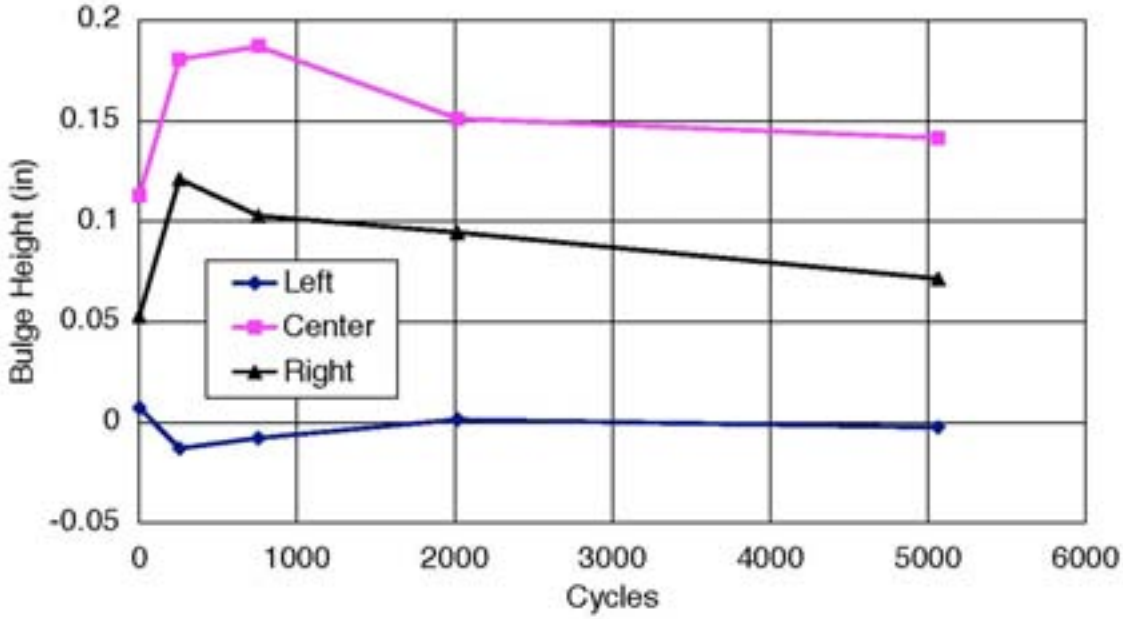
Energy

Initial EDC	4.985	k-in*rot
Final EDC	2.874	k-in*rot
Initial EVD	0.137	
Final EVD	0.094	

EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping

Figure A.120: Test MAT2-C2 Summary

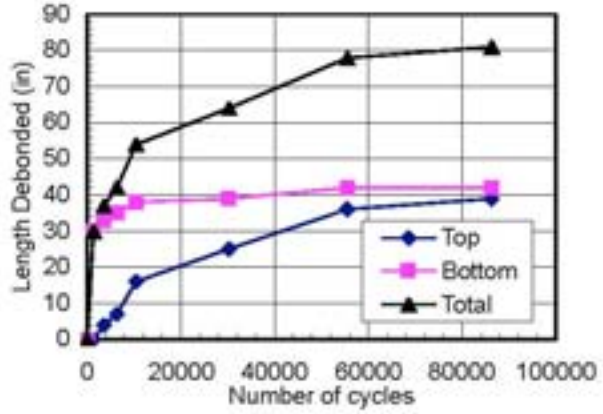




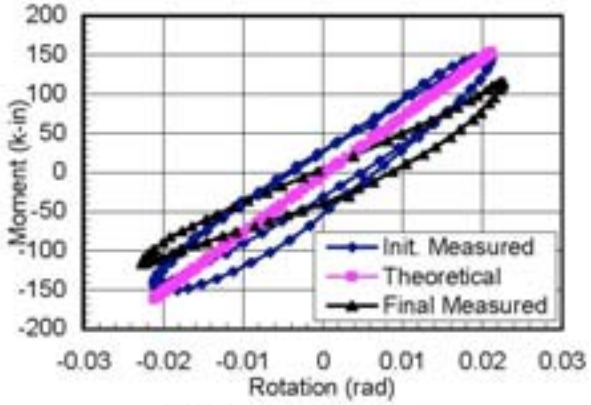
(b) Bottom

Figure A.121: MAT2-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

MAT3-C2



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Stress	$7/8\sigma_y$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$4/8\theta_y$ = 0.025 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	45
25%	999
50%	6993
75%	33837
100%	158021

Rotational Stiffness

Initial Measured	67.6	k-in/%rot
Final Measured	50.0	k-in/%rot
Elastic Model	74.3	k-in/%rot

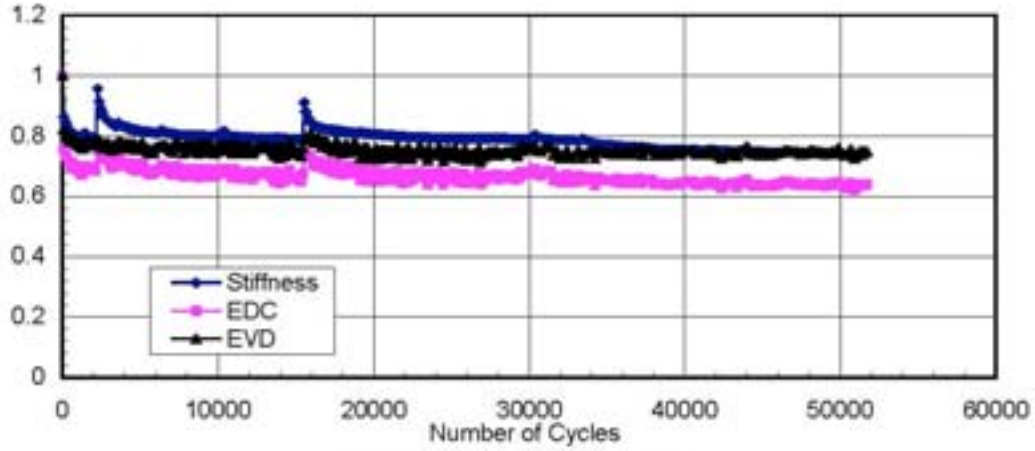
Local Nominal Shear Strains

Average Axial	4.1
Max. Rotation	1.1
Average Shear	0.0

Energy

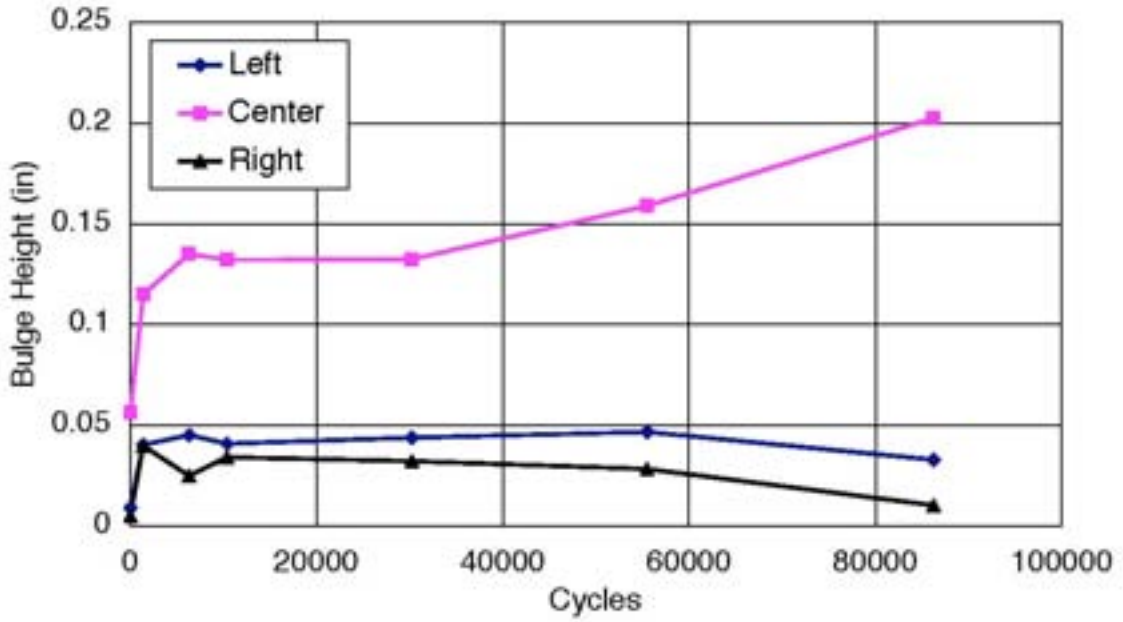
Initial EDC	2.380	k-in*rot
Final EDC	1.522	k-in*rot
Initial EVD	0.118	
Final EVD	0.089	

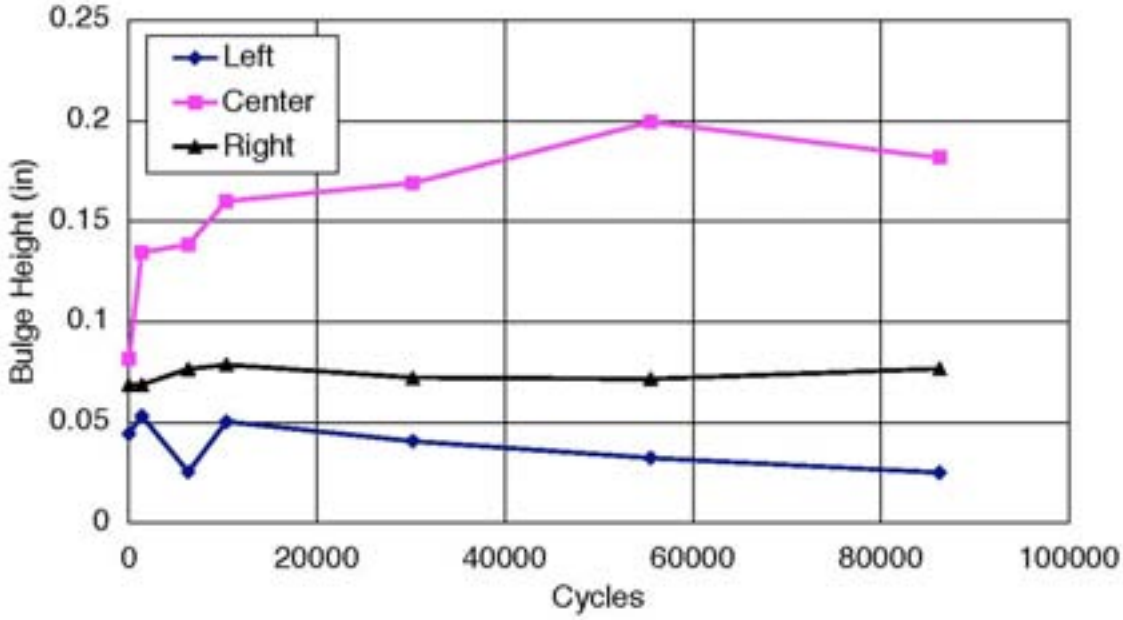
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.122: Test MAT3-C2 Summary



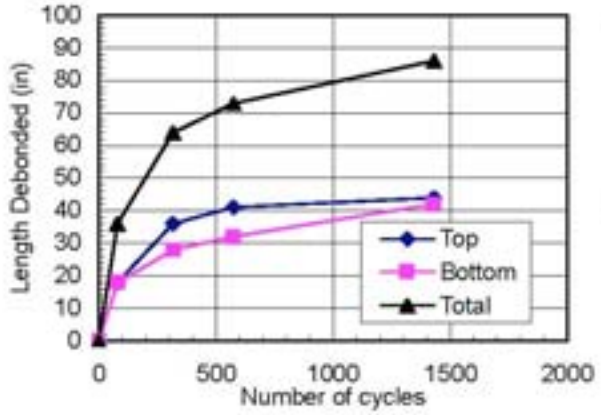


(b) Bottom

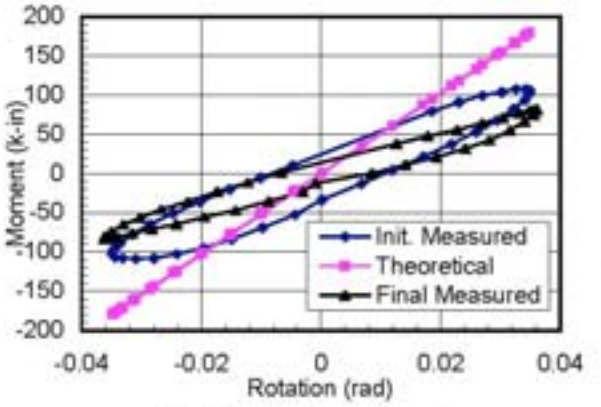
Figure A.123: MAT3-C2 Bulge Heights (a) Top of Bearing and (b) Bottom

A.10 PLT Series

PLT1-A3



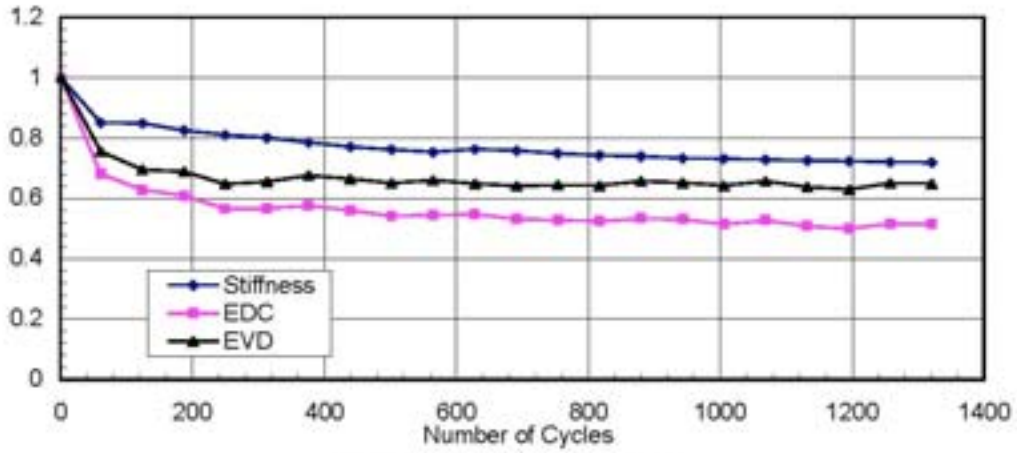
(a) Debonding



(b) Rotational Stiffness

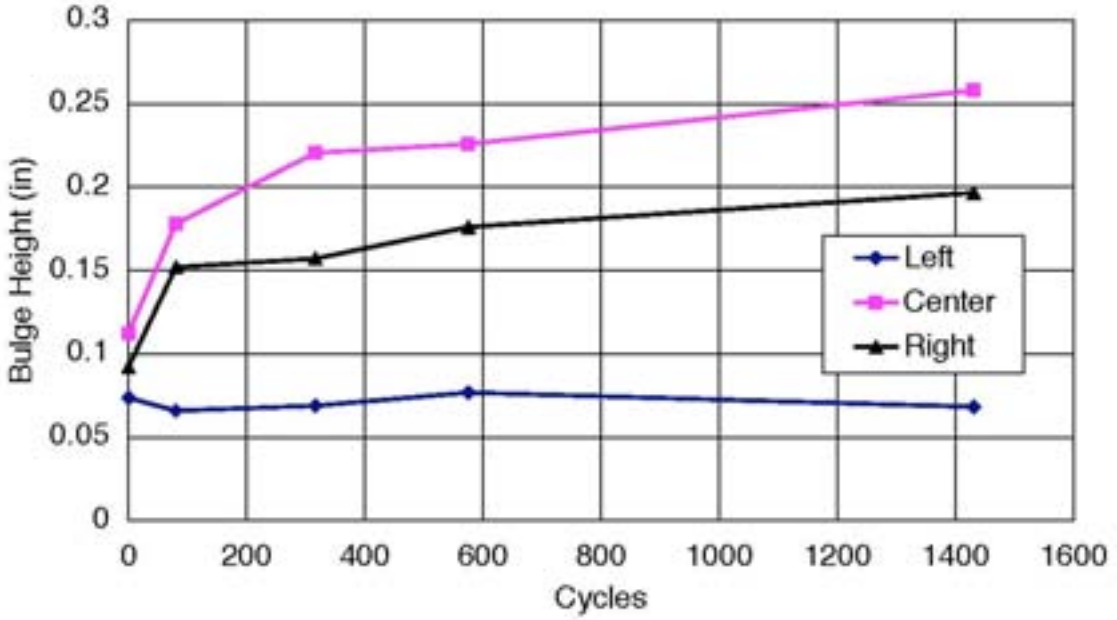
Test Properties		
Axial Load	$5/8\sigma_0$ = 1875 psi	
Static Rotation	0	
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad	
Shear Disp.	0	
Bearing Properties		
Area	9x22 = 198 in^2	
Aspect Ratio	2.44	
Shape Factor	6	
No. of Shims	4	
Layer Thickness	0.5 in	
Debonding Milestones (cycles)		
Initial	2	
25%	49	
50%	147	
75%	374	
100%	1563	
Rotational Stiffness		
Initial Measured	29.8	k-in/%rot
Final Measured	21.5	k-in/%rot
Elastic Model	51.4	k-in/%rot
Local Nominal Shear Strains		
Average Axial	4.3	
Max. Rotation	1.8	
Average Shear	0.0	
Energy		
Initial EDC	1.785	k-in*rot
Final EDC	0.918	k-in*rot
Initial EVD	0.075	
Final EVD	0.049	

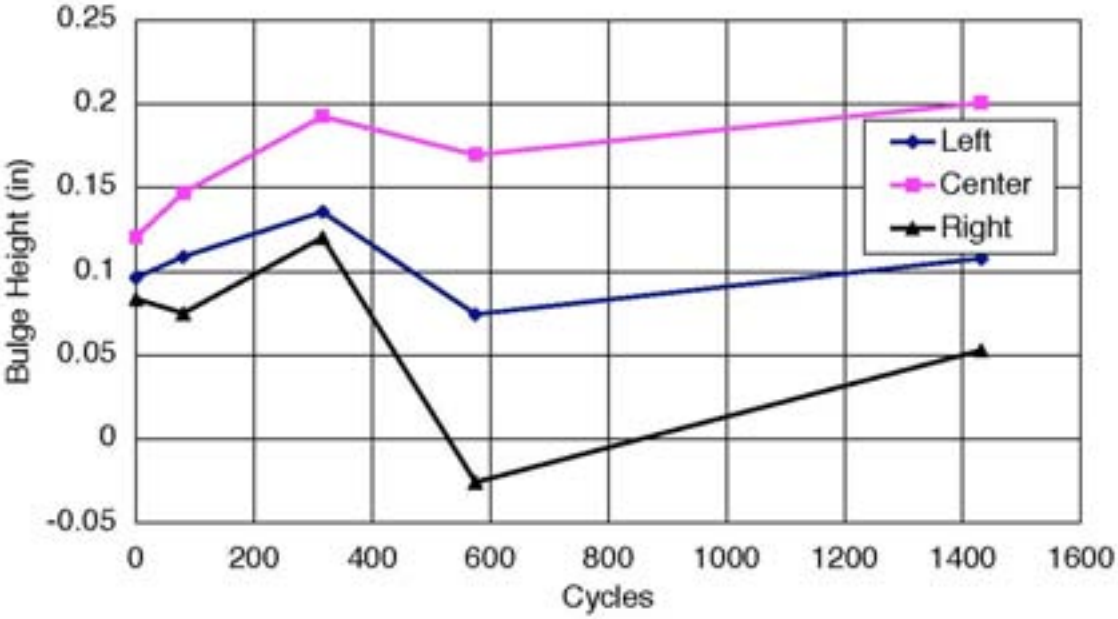
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.124: Test PLT1-A3 Summary

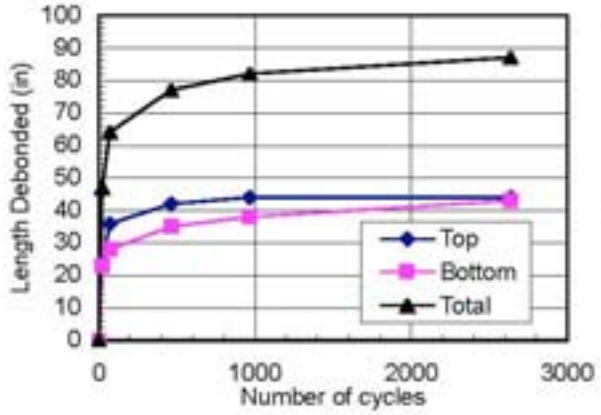




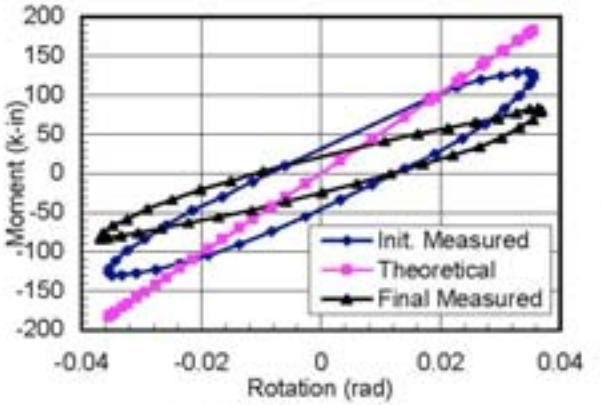
(b) Bottom

Figure A.125: PLT1-A3 Bulge Heights (a) Top of Bearing and (b) Bottom

PLT2-A3



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Load	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	10
50%	21
75%	130
100%	2971

Rotational Stiffness

Initial Measured	34.9	k-in/%rot
Final Measured	21.0	k-in/%rot
Elastic Model	51.4	k-in/%rot

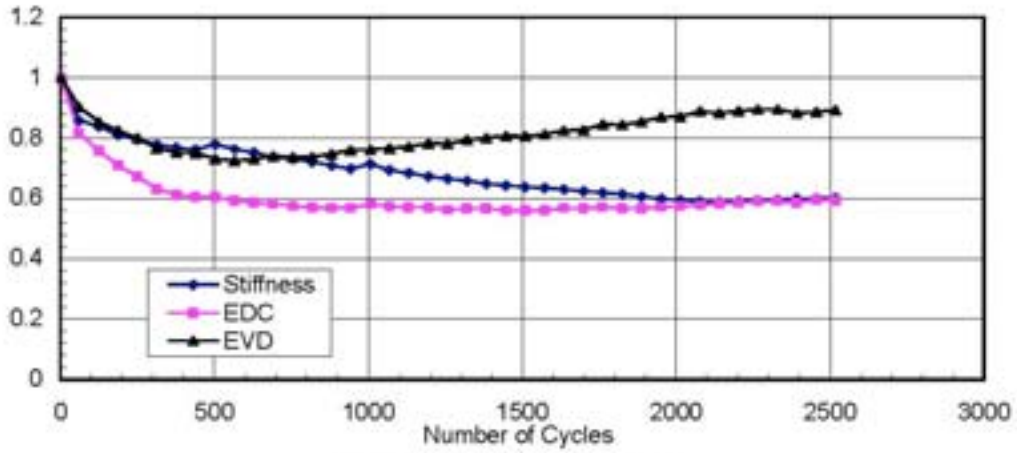
Local Nominal Shear Strains

Average Axial	5.9
Max. Rotation	2.2
Average Shear	0.0

Energy

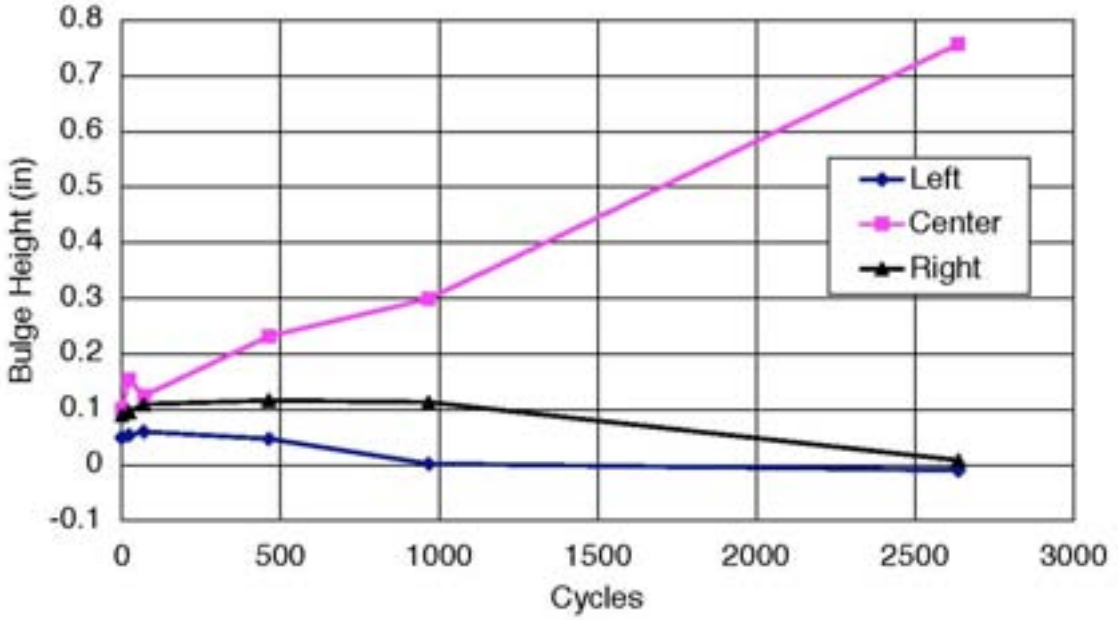
Initial EDC	2.233	k-in*rot
Final EDC	1.327	k-in*rot
Initial EVD	0.077	
Final EVD	0.069	

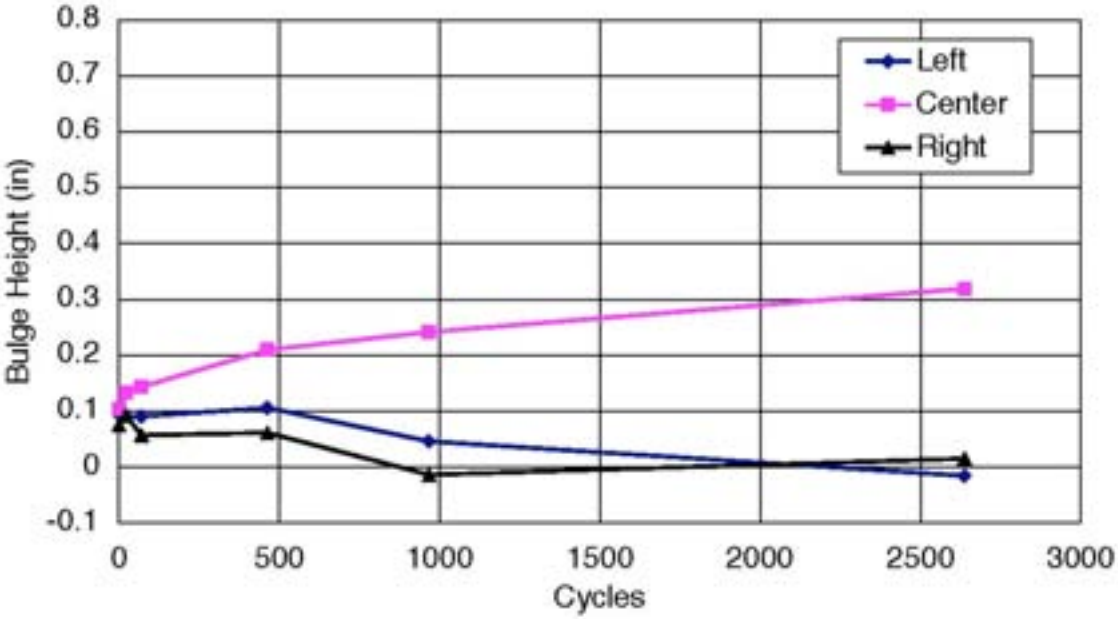
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.126: Test PLT2-A3 Summary

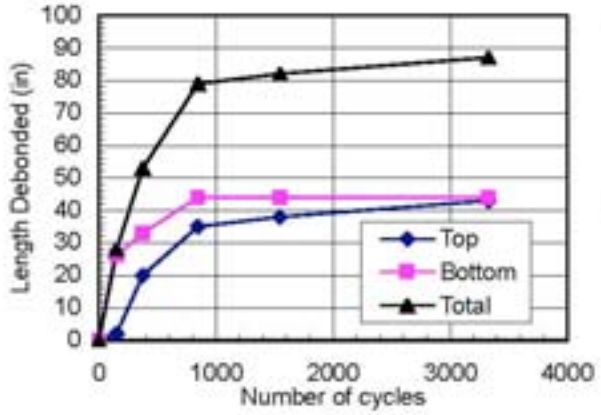




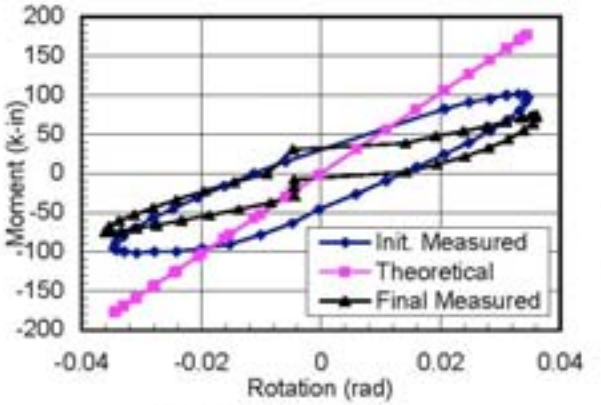
(b) Bottom

Figure A.127: PLT2-A3 Bulge Heights (a) Top of Bearing and (b) Bottom

PLT3-A3



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Load	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	5
25%	120
50%	297
75%	612
100%	3687

Rotational Stiffness

Initial Measured	27.5	k-in/%rot
Final Measured	19.0	k-in/%rot
Elastic Model	51.4	k-in/%rot

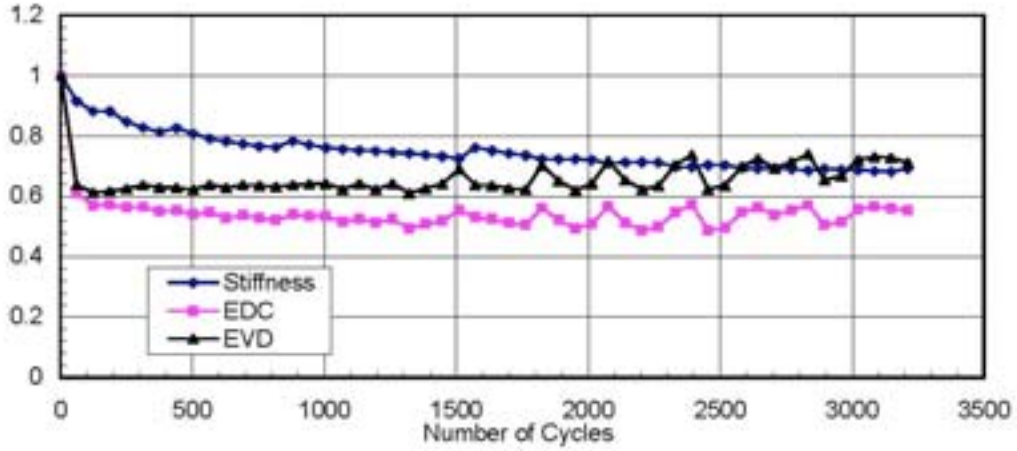
Local Nominal Shear Strains

Average Axial	4.3
Max. Rotation	1.8
Average Shear	0.0

Energy

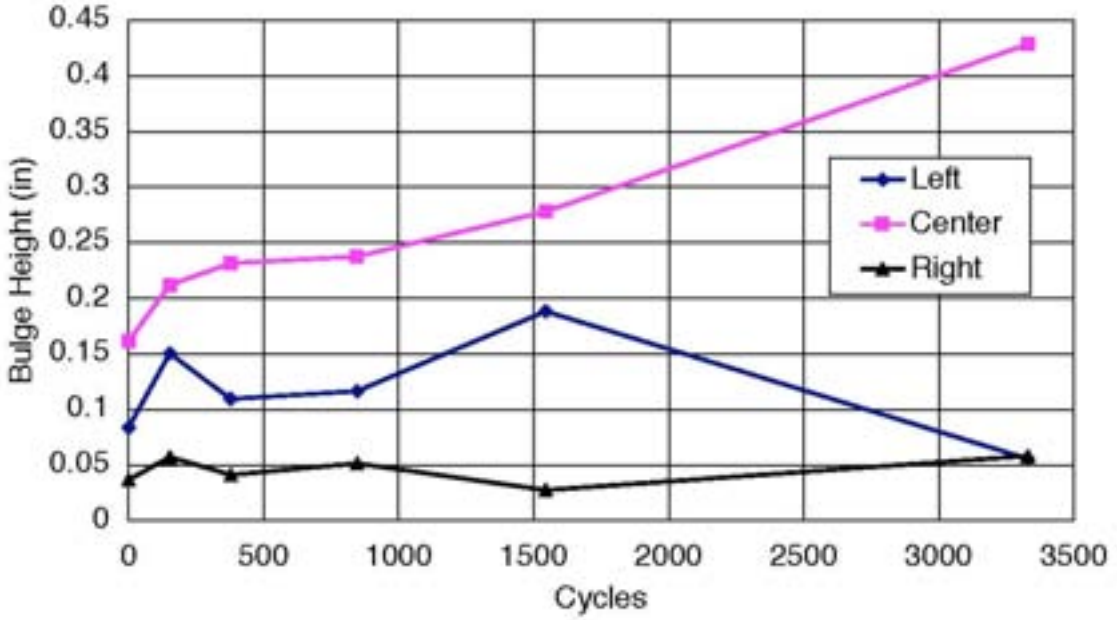
Initial EDC	2.082	k-in*rot
Final EDC	1.152	k-in*rot
Initial EVD	0.095	
Final EVD	0.067	

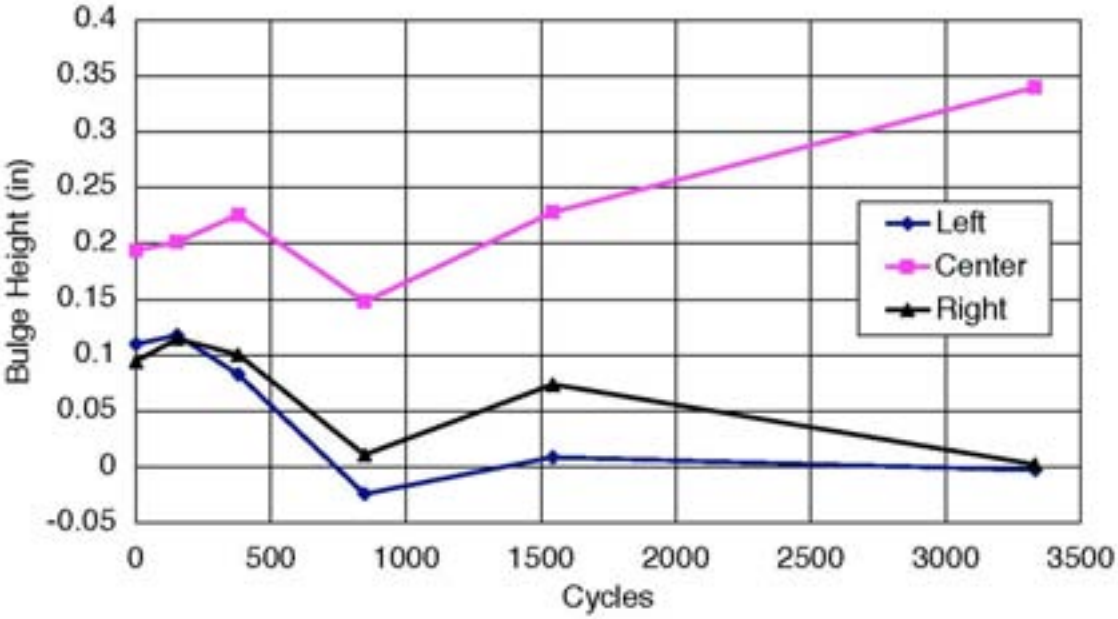
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.128: Test PLT3-A3 Summary

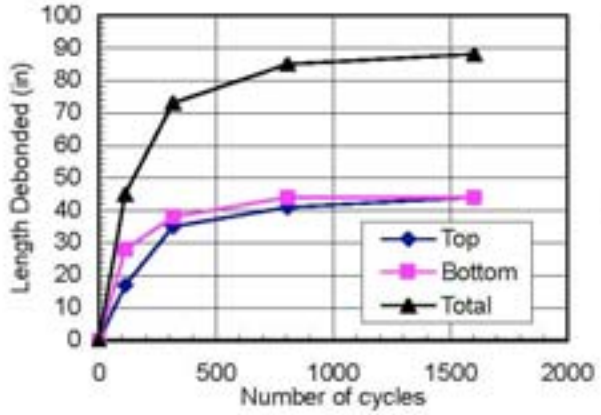




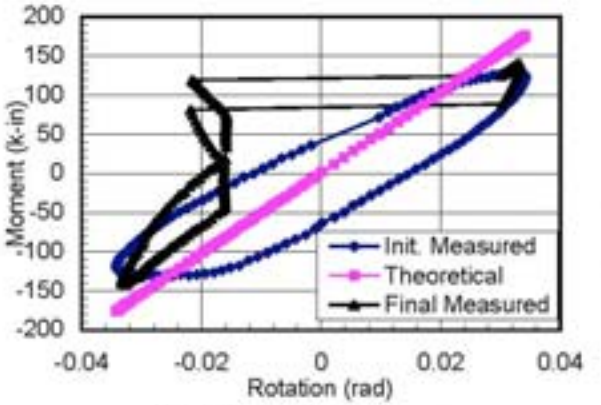
(b) Bottom

Figure A.129: PLT3-A3 Bulge Heights (a) Top of Bearing and (b) Bottom

PLT4-A3



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Load	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	3
25%	55
50%	110
75%	265
100%	1604

Rotational Stiffness

Initial Measured	35.4	k-in/%rot
Final Measured	25.2	k-in/%rot
Elastic Model	51.4	k-in/%rot

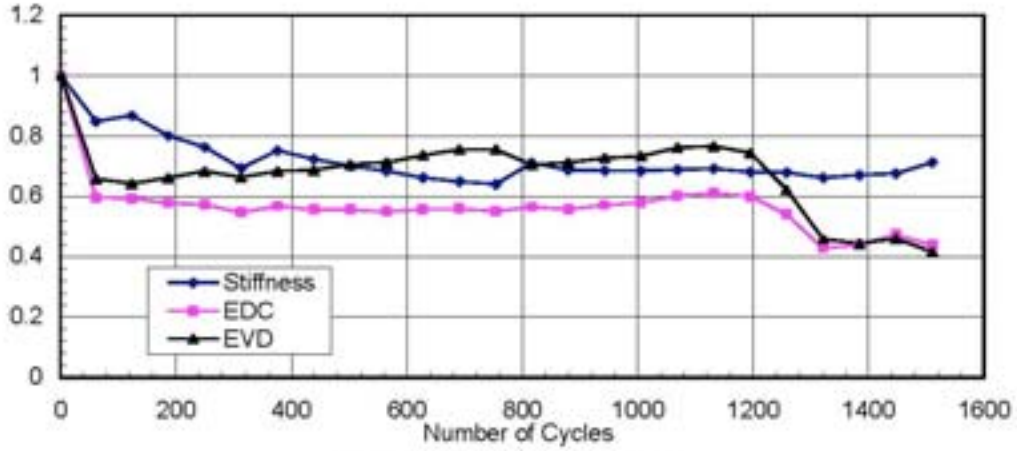
Local Nominal Shear Strains

Average Axial	6.0
Max. Rotation	1.8
Average Shear	0.0

Energy

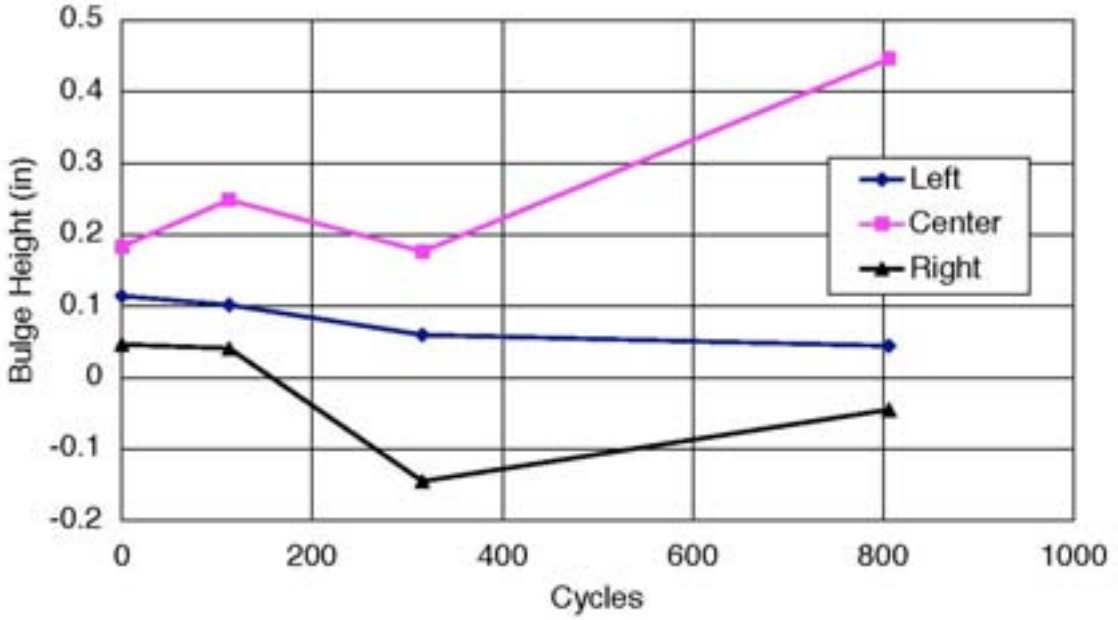
Initial EDC	2.866	k-in*rot
Final EDC	1.255	k-in*rot
Initial EVD	0.102	
Final EVD	0.043	

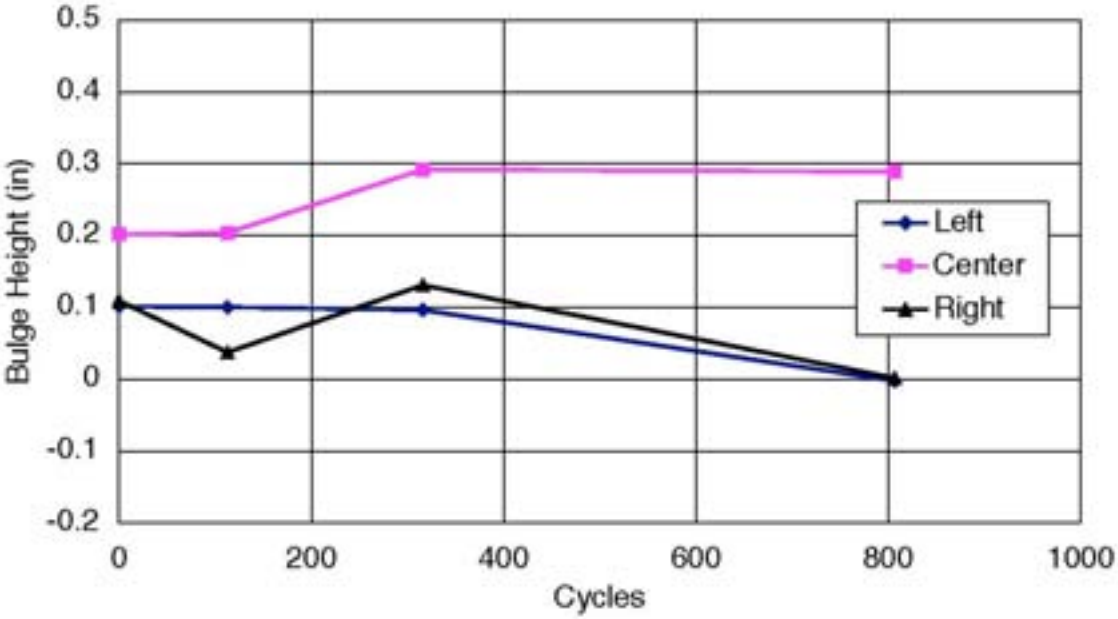
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.130: Test PLT4-A3 Summary

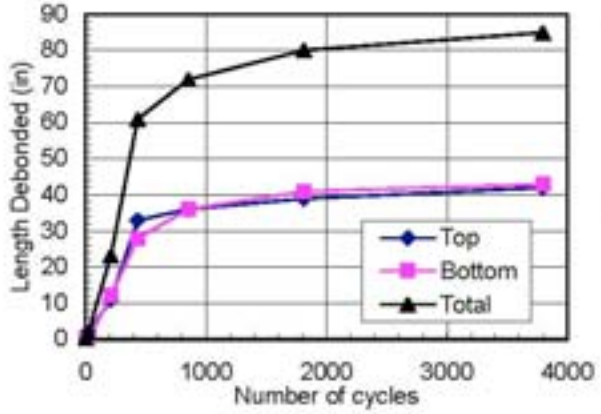




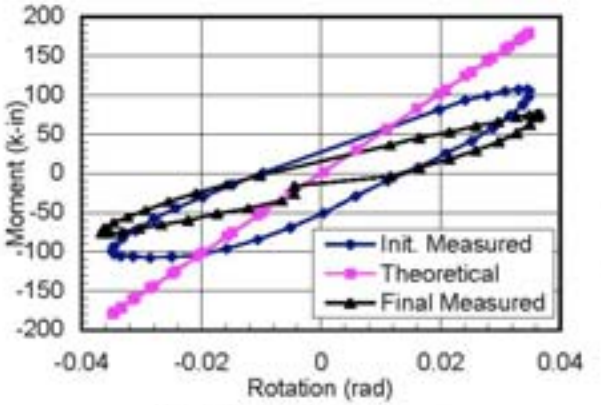
(b) Bottom

Figure A.131: PLT4-A3 Bulge Heights (a) Top of Bearing and (b) Bottom

PLT5-A3



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Load	$5/8\sigma_0$ = 1875 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	13
25%	203
50%	334
75%	624
100%	4988

Rotational Stiffness

Initial Measured	28.9	k-in/%rot
Final Measured	19.6	k-in/%rot
Elastic Model	51.4	k-in/%rot

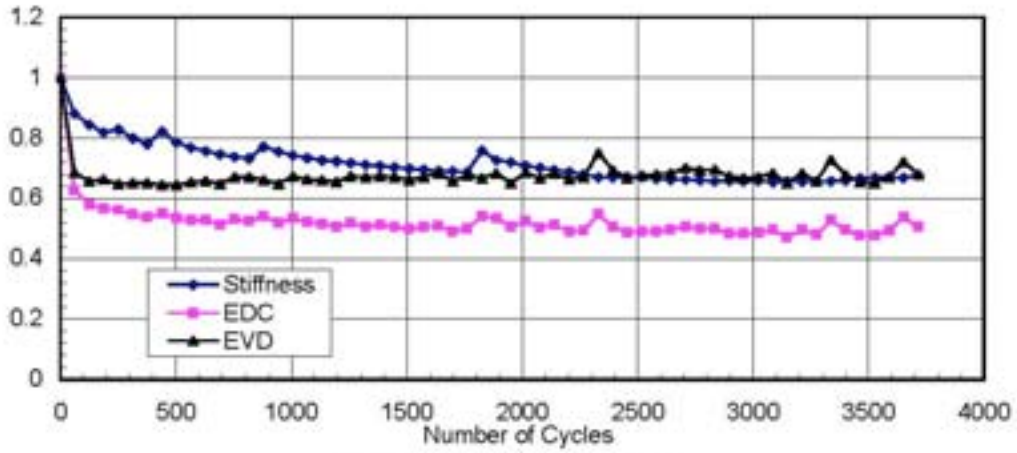
Local Nominal Shear Strains

Average Axial	4.3
Max. Rotation	1.8
Average Shear	0.0

Energy

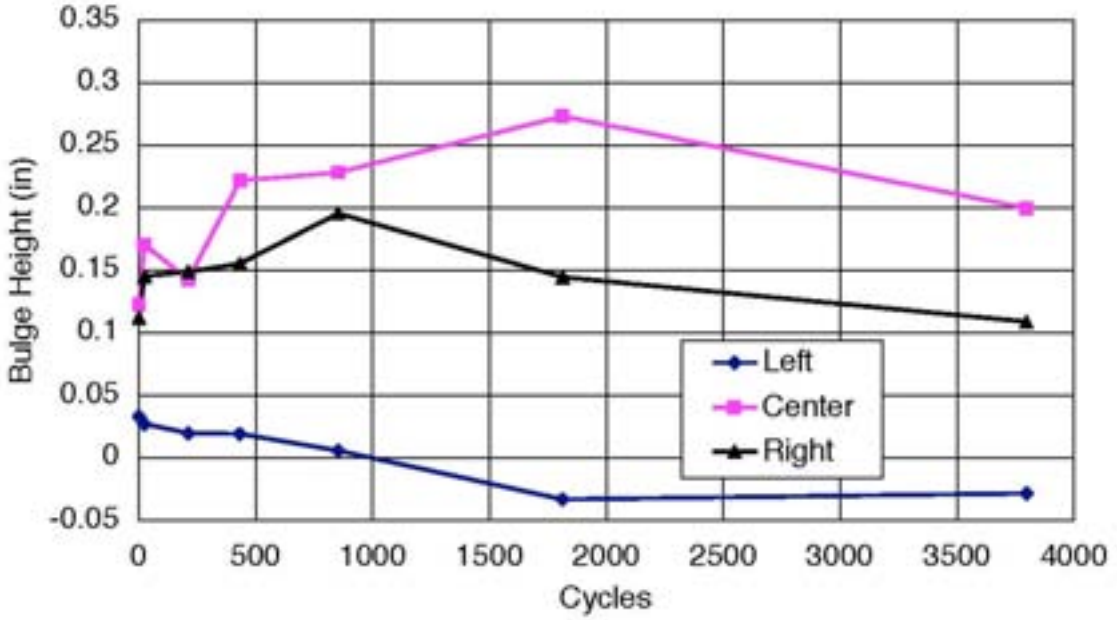
Initial EDC	2.175	k-in*rot
Final EDC	1.096	k-in*rot
Initial EVD	0.092	
Final EVD	0.062	

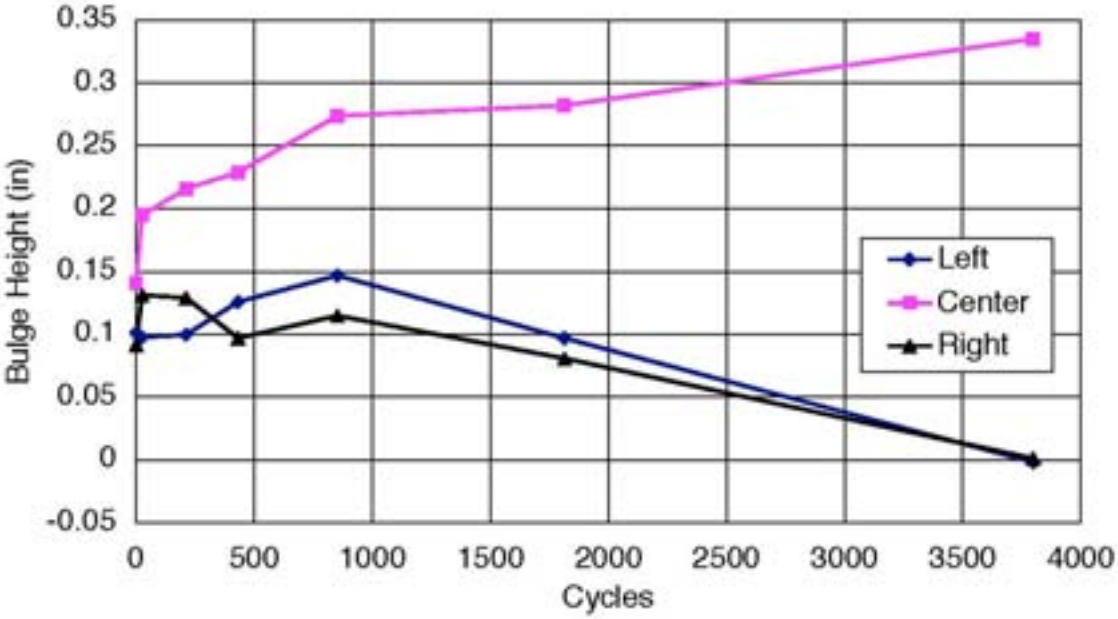
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.132: Test PLT5-A3 Summary

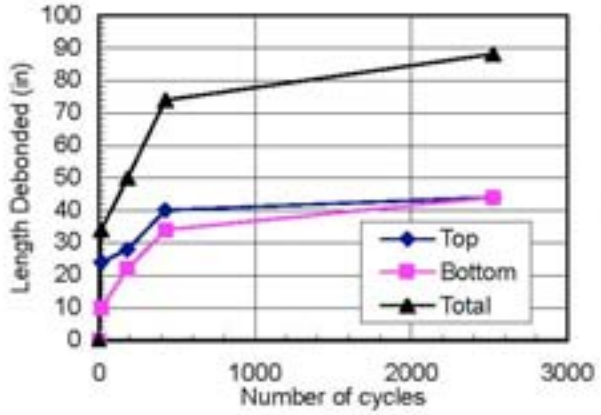




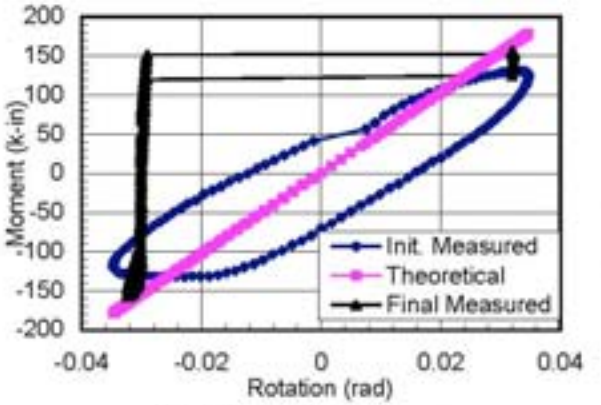
(b) Bottom

Figure A.133: PLT5-A3 Bulge Heights (a) Top of Bearing and (b) Bottom

PLT6-A3



(a) Debonding



(b) Rotational Stiffness

Test Properties

Axial Load	$7/8\sigma_0$ = 2625 psi
Static Rotation	0
Cyclic Rotation	$6/8\theta_0$ = 0.0375 rad
Shear Disp.	0

Bearing Properties

Area	9x22 = 198 in^2
Aspect Ratio	2.44
Shape Factor	6
No. of Shims	4
Layer Thickness	0.5 in

Debonding Milestones (cycles)

Initial	0
25%	10
50%	120
75%	344
100%	2524

Rotational Stiffness

Initial Measured	34.9	k-in/%rot
Final Measured	9.6	k-in/%rot
Elastic Model	51.4	k-in/%rot

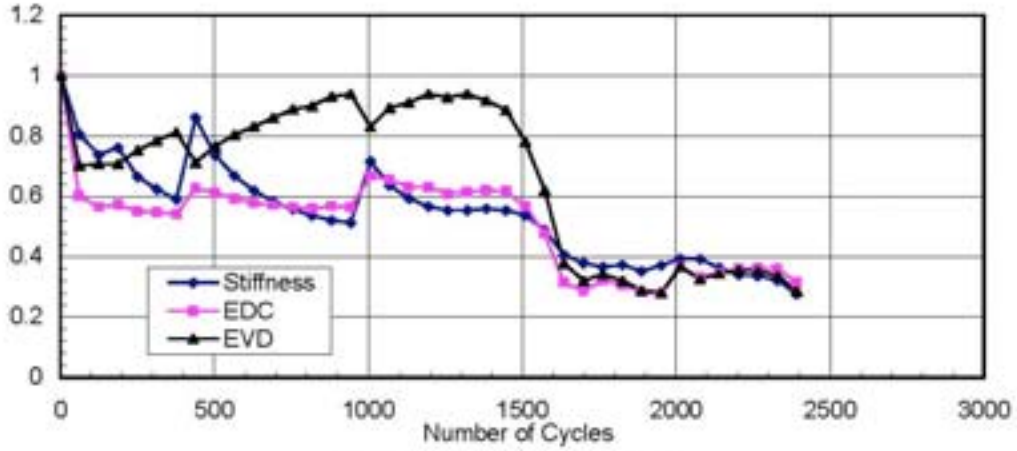
Local Nominal Shear Strains

Average Axial	6.1
Max. Rotation	1.8
Average Shear	0.0

Energy

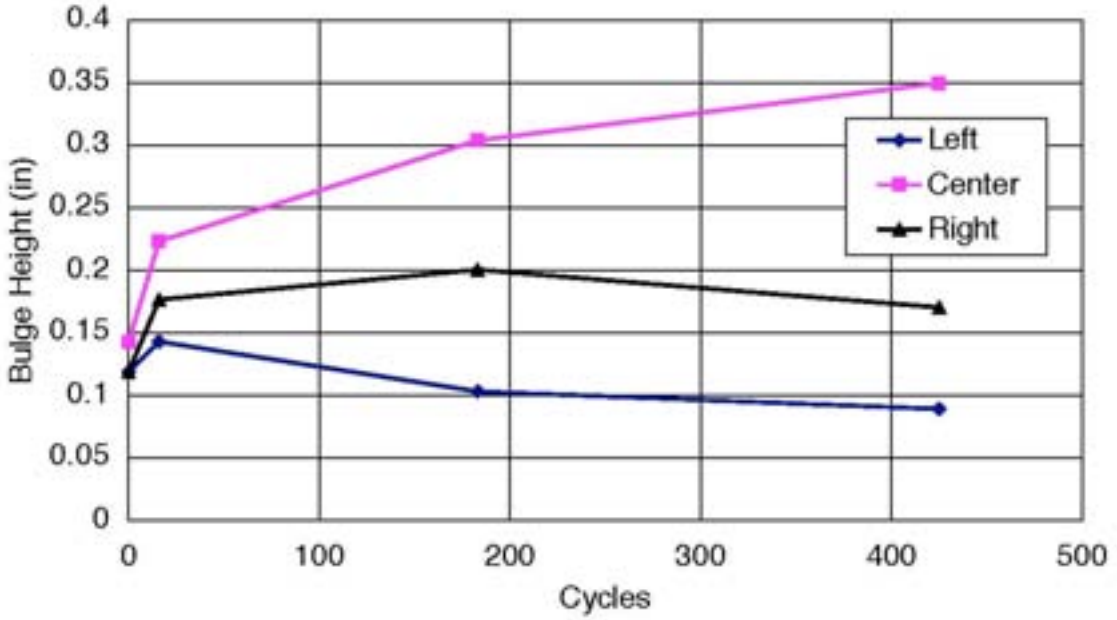
Initial EDC	3.074	k-in*rot
Final EDC	0.968	k-in*rot
Initial EVD	0.107	
Final EVD	0.03	

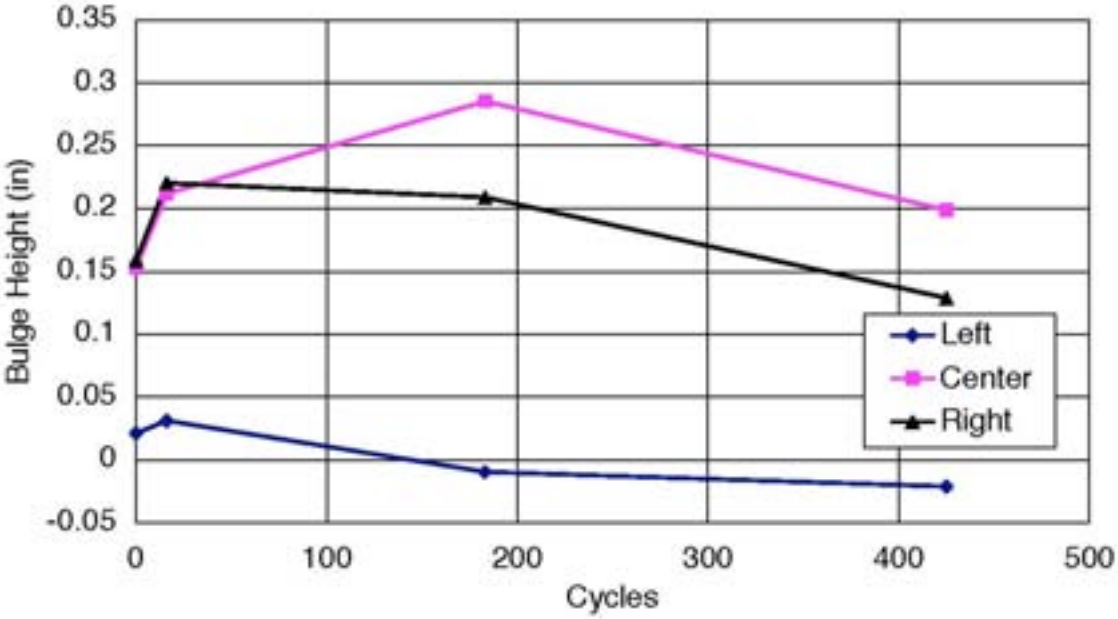
EDC=Energy Dissipated per Cycle
EVD = Equivalent Viscous Damping



(c) Normalized Energy Values

Figure A.134: Test PLT6-A3 Summary





(b) Bottom

Figure A.135: PLT6-A3 Bulge Heights (a) Top of Bearing and (b) Bottom