HAND/ARM VIBRATION MEASUREMENTS ON A DEMOLITION HAMMER WITH A SUPPORT SYSTEM

CRIQ file 670-43562

Technical report

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CRIQ DECLARATION

Testing took place on April 8, 2011, at the Client's plant.

Testing was completed and supervised by the undersigned; they attest to the accuracy of the results.

Performed by: Jacques Aubé, Technician

Supervised by: Claude Sauvageau, Eng.

This report was drafted by: Claude Sauvageau, Eng.

Total number of pages: 22, including 13 pages in appendix.

The results presented in this report refer only to the product(s) described therein.

The equipment and instrumentation used during these tests were verified and/or calibrated. The calibration certificates are retraceable to the National Research Council of Canada (CNRC) and/or to the American National Institute of Standards and Technology (NIST) standards and can be provided on request. For the standards identified in our scope of accreditation, the existing reports referencing the measurement uncertainties are available upon request.

CRIQ is ISO 9001, certificate no 008999, and this testing laboratory is accredited ISO 17025 by the Standards Council of Canada for specific tests as listed at www.scc.ca.

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1. INTRODUCTION

As requested by RNP Industries, hand/arm measurements were performed on a demolition hammer. All of the tests were performed on the same hammer, but while it was held three different ways:

- Manually
- With the PAM support system
- With the DECK support system

These tests were performed in compliance with the following standards:

- ISO 20643 standard (latest known version, 2005): Mechanical vibration – Hand-held and hand-guided machinery – Principles for evaluation of vibration emission.

- ISO 8662-5 standard (latest known version, 1992 and Amendment 1 [1999]) titled: Hand-held portable power tools – Measurement of vibrations at the handle – Part 5:: Pavement breakers and hammers for construction work.

- ISO 5349-1 standard (latest known version, 2001): Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements.

The ISO 20643 standard states that vibration measurements must be performed along the three axes and combined to obtain the overall vibration value. The ISO 8662-5 standard specifies the test method for the measurements and states that vibrations should be presented along the vertical axis only. The ISO 5349 standard indicates the weighting to apply to the vibration levels measured.

These standards call for measuring vibrations on the handle. In addition to measurements on the handle, the vibration levels were also measured using an accelerometer attached to the wrist of the person to verify the impacts of prehensile force on the vibration levels experienced by the operator. Less significant prehensile force is anticipated when using the PAM equipment.

2. EQUIPMENT SUBJECTED TO THE TEST

The tests were performed on a demolition hammer, model: CHICAGO PNEUMATIQUE CP 4611P.

The tests were performed while holding the hammer three different ways:

- Manually
- With the PAM support system
- With the DECK support system

The load source used during the test is a 60-mm-diameter steel bearing shock-absorbing device as described in the ISO 8662-5 standard. This shock-absorbing device was supplied by the Client.

3. MEASUREMENT INSTRUMENTS

The tests were performed using the following measurement instruments:

Description	Manufacturer; model	Serial number	Calibration due (yyyy/mm/dd)
Vibration analyser	LDS-Dactron: Focus II – FCS 220	5355119	2013-02-18
Triaxial accelerometer, ICP	PCB; 354C03	6498	2012-03-21
Triaxial accelerometer, ICP	PCB; 354C03	6499	2012-03-21
Accelerometer calibrator	Brüel & Kjaer; 4294	2391858	2012-03-01
Data acquisition system	Somat EDAQ	3110	2012-01-22
Load cell	Lebow; 3191-2K	162	2011-09-14
Pressure sensor	SML	5905040012	Not calibrated
Pressure calibrator	DRUCK; DPI 603	603882810	2011-12-09

The pressure sensor was verified with the pressure calibrator before the tests.

4. TEST METHOD

The hammer was held onto the shock-absorbing device during the tests. Photographs 1 to 3 in Appendix A show the test setup.

A triaxial accelerometer was installed on the equipment's handle using a screwed collar as shown on Photograph 4. The X axis corresponds to the horizontal axis from the left to the right of the operator. The Y axis corresponds to the horizontal axis from the equipment toward the operator. The Z axis corresponds to the vertical axis.

A triaxial accelerometer was installed around the operator's wrist using a bracelet as shown on Photograph 5. The X axis corresponds to the axis along the width of the wrist. The Y axis corresponds to the longitudinal axis along the arm. The Z axis corresponds to the axis which is perpendicular to the wrist's surface.

The data from both accelerometers was recorded simultaneously on the vibration analyser. After the measurements, the analysis was performed for each test, which was divided into 5 individual segments. The frequency analysis was performed for the one-third octave bands whose centre frequency is within 6.3 and 1,250 Hz. The weighting referenced in the ISO 5349-1 standard was applied, and the weighted acceleration was calculated for each axis. The combined level of the 3 axes was also calculated.

For the tests with the equipment held manually and using the DECK model, the operator was standing on a scale in order to measure feed force. For the PAM model, feed force is controlled exclusively through the pressure on the equipment, and using a scale was not necessary.

A pressure sensor provided for measuring the hammer's feed pressure.

The scale's load cell and the pressure sensor were connected to the EDAQ acquisition system.

For the hand-held hammer, the tests were performed with 3 individual operators. For the hammer connected to a support system, the test was performed with a single operator since, in these cases, one can anticipate that operator influence will be less significant. However, the tests using the PAM and DECK systems were performed with 3 different feed forces.

5. RESULTS

Overall, 15 tests were performed. For each test, 5 segments of the signal in relation to time were analysed in order to derive an average of the values for each test. The individual results of each test and the averages obtained are included in Appendix B. Tables B.1 to B.15 include the values obtained at wrist level for each of the tests. Tables B.16 to B.18 include the values obtained on the handle of the PAM system.

The standards indicate that a series of tests can be considered valid if the coefficient of variation between the individual values obtained is below 0.15 or if the root-mean-square deviation is below 0.3. The different values of Tables B.1 to B.18 indicate coefficients of variation below 0.15, except for one value in Table B.17, which is equal to 0.15. The root-mean-square deviation was calculated for this test, and a value below 0.3 is obtained, namely 0.27. The different measurements presented in Appendix B can therefore be considered valid.

The acceleration values at the handle for the hand-held hammer and the DECK system are not included herein due to the fact that the values obtained were too high vs. the capacity of the sensor used, and that the coefficients of variation obtained were much too high.

Table 1 includes the operating conditions during each test.

Table 1
Operating conditions during the tests

Test	Equipment	Operator	Operating pressure (psi)	Feed force Scale (N)	Feed force Actuator (N)	Percussion frequency (knocks/s)
1	Hand-held	1	103	178	---	15.6
2	Hand-held	1	103	231	---	15.5
3	Hand-held	1	103	178	---	15.5
4	Hand-held	2	103	200	---	15.5
5	Hand-held	2	103	173	---	12.7
6	Hand-held	3	103	200	---	14.1
7	Hand-held	3	102	489	---	14.4
8	Hand-held	3	102	222	---	14.4

Test	Equipment	Operator	Operating pressure (psi)	Feed force Scale (N)	Feed force Actuator (N)	Percussion frequency (knocks/s)
9	Hand-held	3	102	423	---	15
10	PAM	2	96	---	197	14.4
11	PAM	2	96	---	393	14.1
12	PAM	2	96	---	786	14.1
13	DECK	2	102	111	237	14.4
14	DECK	2	102	67	177	14.7
15	DECK	2	102	200	316	14.4

The percussion frequency listed in Table 1 was calculated based on the number of peaks in the pressure signal. The feed force was obtained by calculating the difference between the weight of the operator and the weight measured by the scale during the test. For the PAM and DECK systems, the force feed at the equipment level was also calculated from the pressure and diameter of the actuator that provided for adjusting this force. The difference between the obtained values of feed force from the scale and actuator from the DECK system stems from the weight of the DECK system. For the continuation of the analysis, only one of the two feed force values will be considered, namely that obtained at hammer level on the scale for Tests 1 to 9, and that obtained by the actuator for Tests 10 to 15.

The average values obtained at wrist level during each test are presented in Table 2.

Table 2
Weighted average values obtained at wrist level

Test	Equipment	Operator	Feed force (N)	X axis (m/s^2)	Y axis (m/s^2)	Z axis (m/s^2)	Combined (m/s^2)
1	Hand-held	1	178	19.31	14.41	7.48	25.24
2	Hand-held	1	231	23.19	17.51	6.72	29.92
3	Hand-held	1	178	22.44	14.00	5.72	27.07
4	Hand-held	2	200	17.90	15.76	9.71	25.77
5	Hand-held	2	173	17.76	16.33	9.70	26.01
6	Hand-held	3	200	16.06	21.52	6.19	27.58
7	Hand-held	3	489	15.44	9.96	5.35	19.15
8	Hand-held	3	222	16.89	13.79	7.76	23.17
9	Hand-held	3	423	11.72	9.75	2.64	15.48
10	PAM	2	197	1.00	1.15	1.41	2.08
11	PAM	2	393	1.54	2.46	1.82	3.43
12	PAM	2	786	0.98	1.77	0.70	2.14
13	DECK	2	237	7.76	3.84	3.73	9.43
14	DECK	2	177	4.92	3.05	4.05	7.07
15	DECK	2	316	4.05	3.56	4.14	6.81

Table 2 highlights the effect of feed force on the values obtained. For the hand-held equipment, the increased feed force provides for decreasing the acceleration measured at the wrist.

The ISO 8662-5 standard calls for feed force below 200 N during the tests. In Table 3, the values obtained at wrist level with feed force below 200 N are compared for all 3 models. For the hand-held equipment, an average of the values of Tests 1, 3, 4, 5 and 6 was derived.

Table 3
Comparison of weighted values at wrist level for feed force below 200 N

Test	Equipment	Feed force (N)	X axis (m/s^2)	Y axis (m/s^2)	Z axis (m/s^2)	Combined (m/s^2)
1, 3, 4, 5, 6	Hand-held	186	18.7	16.4	7.8	26.3
10	PAM	197	1.0	1.2	1.4	2.1
14	DECK	177	4.9	3,1	4.1	7.1

Table 3 highlights a decrease of the weighted acceleration at wrist level when the PAM and DECK systems are used.

Table 4 indicates the weighted average values obtained at the PAM system handle level.

Table 4
Weighted average values obtained at PAM system handle level

Test	Feed force (N)	X axis (m/s^2)	Y axis (m/s^2)	Z axis (m/s^2)	Combined (m/s^2)
10	197	1.95	0.63	1.59	2.60
11	393	1.56	1.78	1.87	3.02
12	786	1.17	1.53	1.93	2.73

For the combined level, the values listed in Table 4 can be compared to the value indicated on the manufacturer's data sheet, namely 13.3 m/s^2.

6. CONCLUSION

Hand/arm vibration measurements were performed on a hammer held manually and using 2 individual support systems: PAM and DECK.

Decreased vibrations were observed with the 2 systems, but more significantly so using the PAM system.

Measurements at the handle indicate combined acceleration values between 2.6 and 3 m/s² for the PAM system compared to the manufacturer's data sheet for the hand-held hammer, which lists a value of 13.3 m/s².

The measurements obtained at the wrist also point to significant decreases. For instance, for feed forces below 200 N, combined acceleration at the wrist drops from 26.3 m/s² for the hand-held hammer to 2.1 m/s² when using the PAM system and to 7.1 m/s² when using the DECK system.

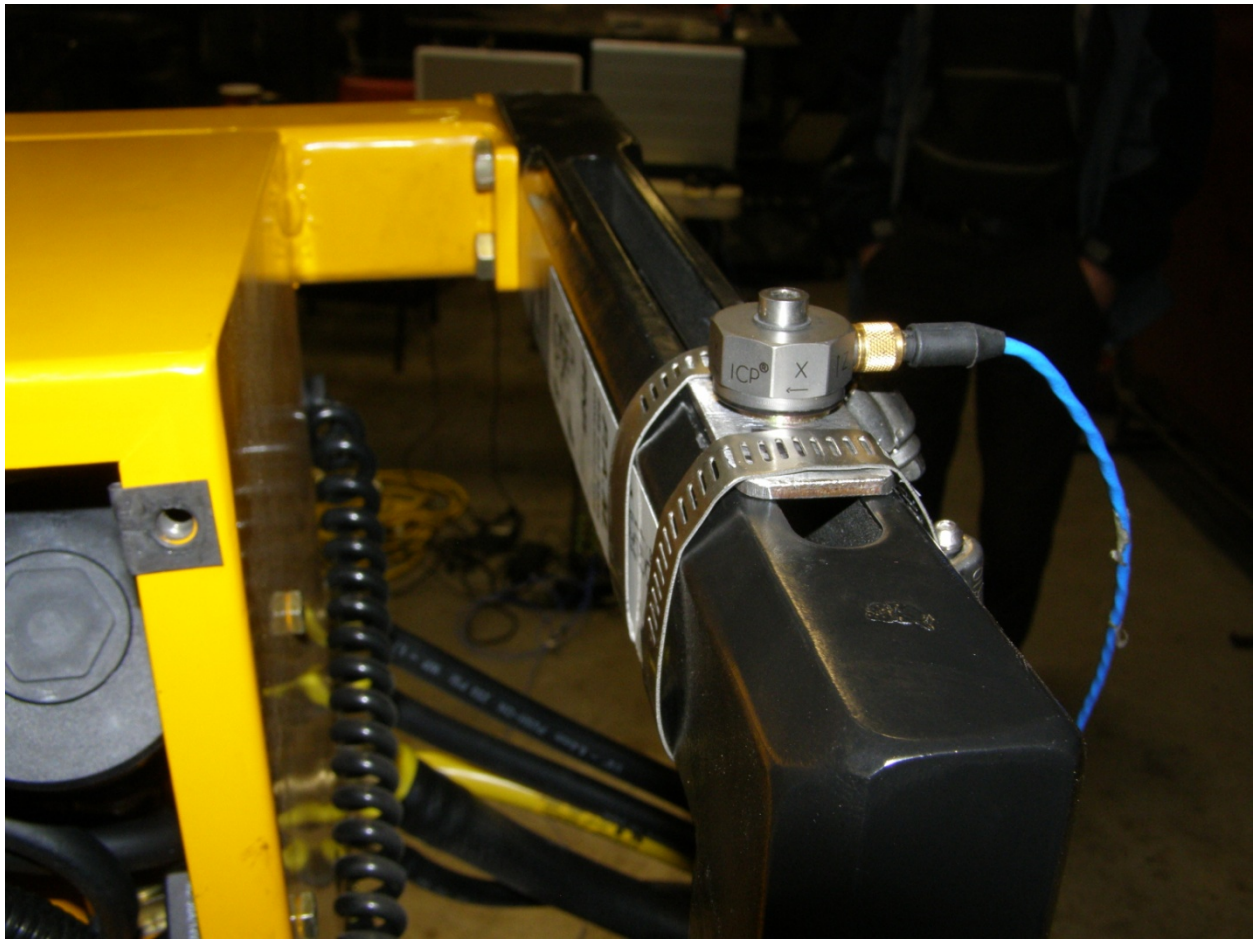
Final analysis of the results remains the Client's responsibility.

Appendix A: Photographs

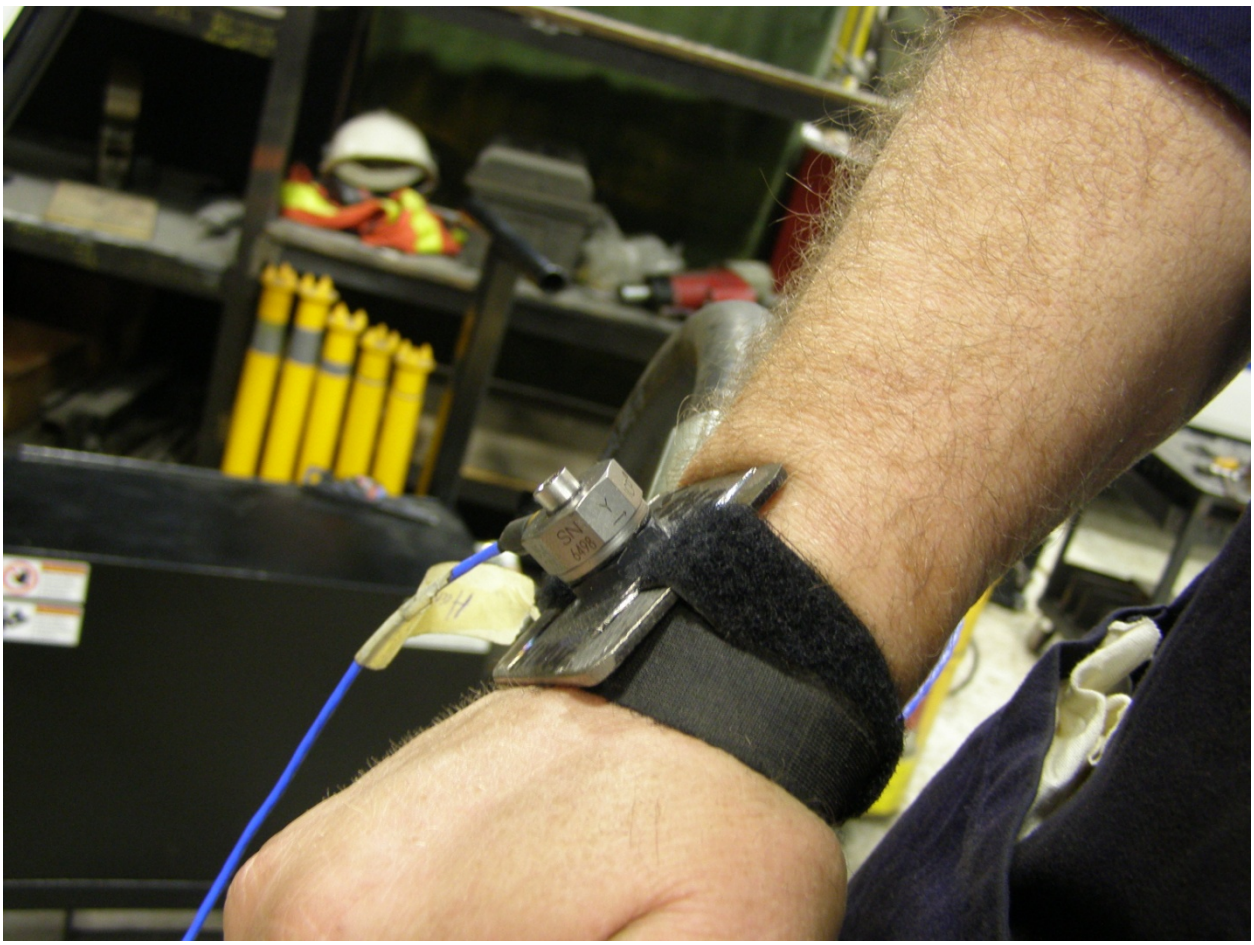
Photograph 1: Test setup with hammer

Photograph 2: Test with PAM system

Photograph 3: Test with DECK system



Photograph 4: Accelerometer setup on handle



Photograph 5: Accelerometer setup at the wrist

Appendix B: Charts of the results

Weighted accelerations – Analysis in the range from 6.3 to 1,250 Hz

Table B.1: Acceleration at wrist in m/s², Test 1

Segment	X axis	Y axis	Z axis	Combined
A	18.43	14.52	7.62	24.67
B	20.46	14.11	6.99	25.82
C	20.07	15.05	7.14	26.08
D	19.15	13.85	8.60	25.15
E	18.43	14.53	7.03	24.50
Average	19.31	14.41	7.48	25.24
Coeff. of variation	0.05	0.03	0.09	0.03

Table B.2: Acceleration at wrist in m/s², Test 2

Segment	X axis	Y axis	Z axis	Combined
A	21.16	18.10	7.04	28.72
B	26.10	15.26	5.98	30.82
C	24.62	18.13	6.49	31.26
D	24.46	17.94	6.69	31.06
E	19.60	18.15	7.42	27.72
Average	23.19	17.51	6.72	29.92
Coeff. of variation	0.12	0.07	0.08	0.05

Table B.3: Acceleration at wrist in m/s², Test 3

Segment	X axis	Y axis	Z axis	Combined
A	21.95	14.15	5.75	26.74
B	22.65	13.53	6.35	27.14
C	24.04	14.05	5.54	28.39
D	22.29	13.83	5.32	26.77
E	21.27	14.44	5.62	26.31
Average	22.44	14.00	5.72	27.07
Coeff. of variation	0.05	0.02	0.07	0.03

Table B.4: Acceleration at wrist in m/s², Test 4

Segment	X axis	Y axis	Z axis	Combined
A	16.78	15.75	9.96	25.08
B	18.91	15.15	8.40	25.65
C	19.16	15.88	10.38	26.96
D	18.20	17.60	10.28	27.33
E	16.46	14.40	9.54	23.86
Average	17.90	15.76	9.71	25.77
Coeff. of variation	0.07	0.08	0.08	0.05

Table B.5: Acceleration at wrist in m/s², Test 5

Segment	X axis	Y axis	Z axis	Combined
A	17.21	15.09	9.82	24.91
B	16.13	13.89	8.01	22.75
C	19.29	18.26	10.24	28.47
D	18.66	17.82	10.46	27.84
E	17.50	16.59	9.99	26.10
Average	17.76	16.33	9.70	26.01
Coeff. of variation	0.07	0.11	0,10	0.09

Table B.6: Acceleration at wrist in m/s², Test 6

Segment	X axis	Y axis	Z axis	Combined
A	16.97	23.49	6.58	29.71
B	17.36	23.82	7.47	30.41
C	15.03	18.02	5.71	24.15
D	16.49	20.37	5.55	26.79
E	14.44	21.90	5.63	26.82
Average	16.06	21.52	6.19	27.58
Coeff. of variation	0.08	0.11	0.13	0.09

Table B.7: Acceleration at wrist in m/s², Test 7

Segment	X axis	Y axis	Z axis	Combined
A	16.35	9.84	5.34	19.81
B	16.49	9.42	5.45	19.75
C	15.90	10.74	5.41	19.94
D	15.03	10.76	5.45	19.27
E	13.43	9.05	5.12	16.99
Average	15.44	9.96	5.35	19.15
Coeff. of variation	0.08	0.08	0.03	0.06

Table B.8: Acceleration at wrist in m/s², Test 8

Segment	X axis	Y axis	Z axis	Combined
A	17.65	13.56	7.53	23.49
B	15.46	14.92	8.60	23.15
C	17.16	13.76	7.55	23.25
D	16.98	13.17	7.63	22.80
E	17.22	13.57	7.50	23.17
Average	16.89	13.79	7.76	23.17
Coeff. of variation	0.05	0.05	0.06	0.01

Table B.9: Acceleration at wrist in m/s², Test 9

Segment	X axis	Y axis	Z axis	Combined
A	11.72	9.76	2.64	15.48
B	11.73	9.46	2.44	15.27
C	12.13	10.43	2.81	16.24
D	11.77	9.40	2.75	15.31
E	11.26	9.71	2.54	15.08
Average	11.72	9.75	2.64	15.48
Coeff. of variation	0.03	0.04	0.06	0.03

Table B.10: Acceleration at wrist in m/s², Test 10

Segment	X axis	Y axis	Z axis	Combined
A	1.02	1.15	1.40	2.08
B	0.97	1.12	1.45	2.07
C	1.08	1.25	1.41	2.18
D	0.82	1.05	1.31	1.87
E	1.09	1.21	1.48	2.20
Average	1.00	1.15	1.41	2.08
Coeff. of variation	0.11	0.07	0.04	0.06

Table B.11: Acceleration at wrist in m/s², Test 11

Segment	X axis	Y axis	Z axis	Combined
A	1.74	2.41	1.76	3.45
B	1.74	2.53	1.76	3.54
C	1.36	2.28	1.86	3.24
D	1.52	2.66	1.82	3.57
E	1.34	2.41	1.92	3.36
Average	1.54	2.46	1.82	3.43
Coeff. of variation	0.13	0.06	0.04	0.04

Table B.12: Acceleration at wrist in m/s², Test 12

Segment	X axis	Y axis	Z axis	Combined
A	1.02	1.70	0.65	2.09
B	1.05	1.84	0.71	2.23
C	1.08	1.84	0.76	2.26
D	0.92	2.02	0.67	2.31
E	0.86	1.44	0.71	1.82
Average	0.98	1.77	0.70	2.14
Coeff. of variation	0.10	0.12	0.06	0.09

Table B.13: Acceleration at wrist in m/s², Test 13

Segment	X axis	Y axis	Z axis	Combined
A	8.05	3.95	4.06	9.84
B	7.84	3.63	3.42	9.29
C	7.68	4.22	3.80	9.55
D	7.53	3.17	3.59	8.92
E	7.68	4.22	3.80	9.55
Average	7.76	3.84	3.73	9.43
Coeff. of variation	0.03	0.12	0.07	0.04

Table B.14: Acceleration at wrist in m/s², Test 14

Segment	X axis	Y axis	Z axis	Combined
A	4.80	2.73	4.07	6.86
B	4.76	3.23	3.95	6.98
C	4.71	3.31	3.63	6.81
D	5.18	3.13	4.47	7.53
E	5.14	2.85	4.12	7.18
Average	4.92	3.05	4.05	7.07
Coeff. of variation	0.05	0.08	0.08	0.04

Table B.15: Acceleration at wrist in m/s², Test 15

Segment	X axis	Y axis	Z axis	Combined
A	4.23	3.44	3.99	6.76
B	3.51	3.69	4.07	6.52
C	4.01	3.80	4.25	6.97
D	4.37	3.18	4.19	6.83
E	4.13	3.67	4.22	6.95
Average	4.05	3.56	4.14	6.81
Coeff. of variation	0.08	0.07	0.03	0.03

Table B.16: Acceleration at handle in m/s², Test 10

Segment	X axis	Y axis	Z axis	Combined
A	1.99	0.66	1.63	2.65
B	1.98	0.60	1.60	2.62
C	1.85	0.67	1.55	2.50
D	1.98	0.58	1.63	2.63
E	1.96	0.67	1.56	2.60
Average	1.95	0.63	1.59	2.60
Coeff. of variation	0.03	0.07	0.02	0.02

Table B.17: Acceleration at handle in m/s², Test 11

Segment	X axis	Y axis	Z axis	Combined
A	1.49	1.45	1.91	2.82
B	1.51	1.53	1.90	2.87
C	1.40	2.02	1.78	3.03
D	1.75	1.93	1.85	3.20
E	1.64	1.96	1.90	3.19
Average	1.56	1.78	1.87	3.02
Coeff. of variation	0.09	0.15	0.03	0.06

Table B.18: Acceleration at handle in m/s², Test 12

Segment	X axis	Y axis	Z axis	Combined
A	1.11	1.47	2.03	2.74
B	1.06	1.37	1.79	2.49
C	1.12	1.35	1.86	2.56
D	1.30	1.77	2.09	3.03
E	1.27	1.69	1.89	2.84
Average	1.17	1.53	1.93	2.73
Coeff. of variation	0.09	0.12	0.06	0.08