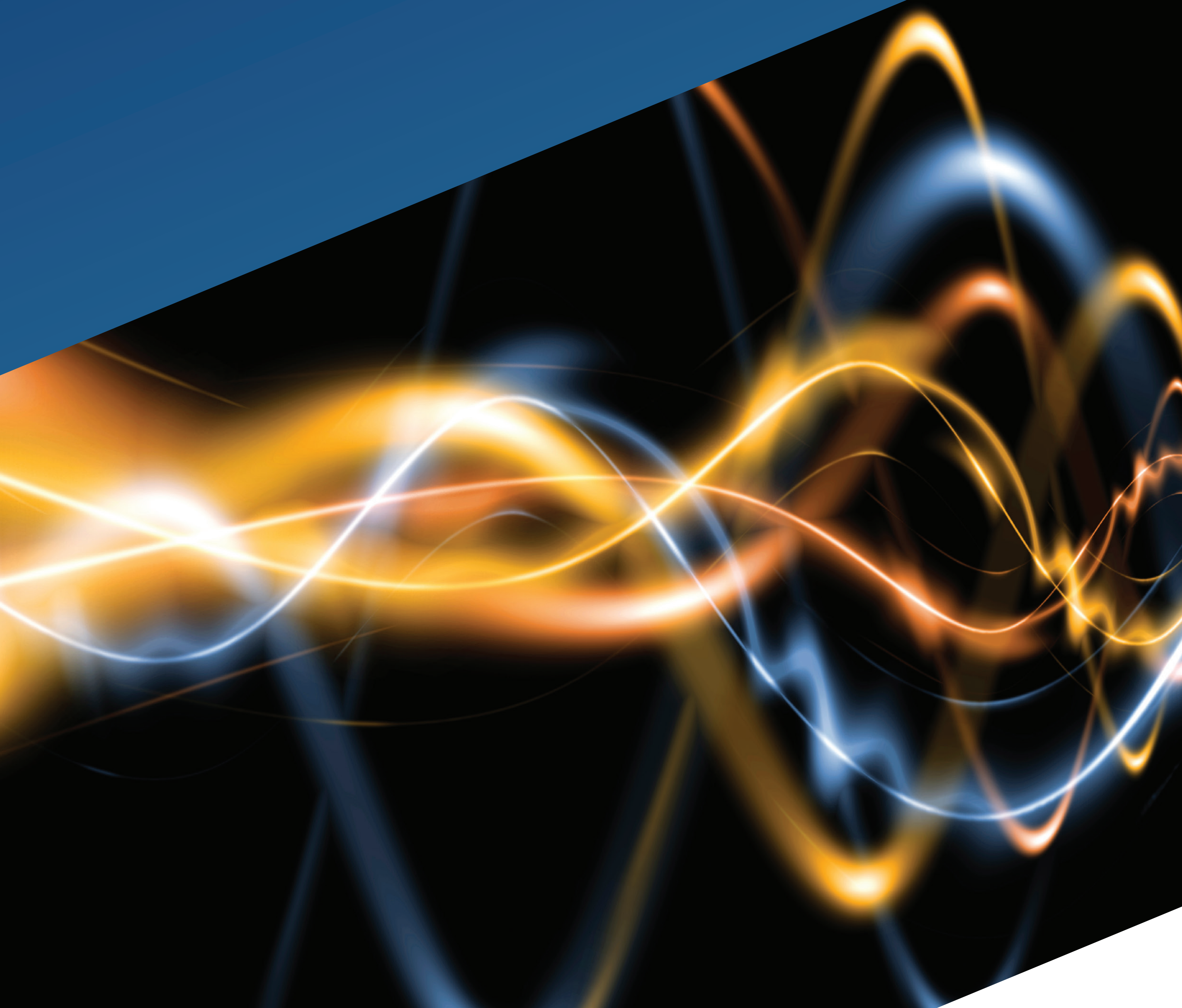
Cranfield University

HRV2017

52nd Human Response to Vibration Conference & Workshop

Covering all aspects of sound, shock and vibration effects



Cranfield University at the
Defence Academy of the United Kingdom,
Shrivenham, Wiltshire, SN6 8LA

HRV 2017

HRV2017: 52nd Human Response to Vibration Conference & Workshop

Cranfield Forensic Institute,
Shrivenham
SN6 8LA, UK

www.cranfield.ac.uk/CFI
www.hrv2017.co.uk

ISBN 978-1-9998301-0-6

Committee members

Prof Peter Zioupos	(Biomechanics, CU)
Dr Gareth Appleby-Thomas	(Dynamic Response, CU)
Dr Thiru Thirulogasingam	(Vibration, CU)
Dr Mike Gibson	(FEA & Simulations, CU)
Mr Constantinos Franceskides	(Rapid prototyping models, CU)
Prof Amer Hameed	(Engineering Systems, CU)
Dr Hugh Goyder	(Energy Dissipation in Dynamics, CU)
Col Peter Mahoney	(Anaesthesia, Visiting Prof CU)
Col Jon Clasper	(Trauma & Orthopaedics, Visiting Prof Imperial)
Dr Gurmail Paddan	(Acoustics & Vibration, INM Gosport)
Dr Ya Huang	(Whole body vibration, Ports)
Prof Michael Griffin	(Human factors, ISVR, Soton)

Endorsed by the ESB

European Society of Biomechanics

Sponsored by

Shock Mitigation · Brüel & Kjær BEYOND MEASURE · SVANTEK · HVlab · DJB Instruments SENSING ENGINEERING INNOVATION · SKYDEX · shawcity LIMITED LIFE-SAVING SOLUTIONS

HRV2017: 52nd Human Response to Vibration Conference & Workshop

Cranfield Forensic Institute, Shrivenham SN6 8LA, UK
www.cranfield.ac.uk/CFI

THE IMPACT OF CONTACT FORCE ON THE ACCURACY OF HAND-ARM VIBRATION MEASUREMENT

Jacek Kuczyński
Marketing Manager - Svantek Sp. z o.o.
Warsaw, 04-872 Poland
jkuczynski@svantek.com.pl

Piotr Kowalski, Ph.D. (Eng.)
Central Institute for Labour Protection – National Research Institute
Department of Vibroacustic Hazards,
Warsaw, Poland
e-mail: pikow@ciop.pl

Abstract

Measurement of hand-arm vibration with the use of a hand mounted sensor ensures achieving the most representative measurements, taken at the point of contact of hand with a vibrating tool. When measuring vibration on a hand, simultaneous measurement of contact force verifies whether the force magnitude is sufficiently rigid. The contact force also provides information on operator's work schedule and may help to instruct operators if they are using excessive or too little force when working with hand-held tools. Additionally, by knowing both the coupling force value and the vibration acceleration, it is possible to calculate actual vibration energy dose that has been transferred to a hand. The accuracy of vibration measurements using hand-arm adapters has been tested in 240 measurements in total, performed at the Polish National Research Institute at the Central Institute for Labour Protection. The impact of coupling force on vibration magnitudes has been assessed with Svantek's SV106 human vibration meters and SV105AF hand-arm adapters (push force thresholds in tests were: 0 N, 20 N, 50 N, 100 N). The results proved that measurements taken with hand-arm adapters provide correct vibration results regardless of contact force changes and type of vibration signal. The study has also indicated that it is necessary to define a minimum force threshold in order to mitigate the uncertainty related to the contact between hand and a vibrating tool.

1. Introduction

1.1. Micro Electro-Mechanical Systems

In recent years accelerometers based on MEMS technology (Micro Electro-Mechanical Systems) became an alternative to piezoelectric sensors. MEMS transducers are widely used in micro-mechanical systems in the automotive, computer and audio-visual industries. Construction of MEMS consists in a moving mass of resistant boards placed on a mechanical suspension system frame of reference. As a result of movement (such as vibration) there is a change in the capacitance between the moving and the fixed plates (which form capacitors).

The advantage of MEMS is their dimensions that can vary from only a few microns to millimetres, which makes them a milestone in miniaturization. The list of the advantages of MEMS-based sensors is long and includes **low cost**, low power consumption, small size, **resistance to mechanical shocks**, full electromagnetic compatibility and **no DC-shift effect**.

Introduction of MEMS accelerometers broke the barrier created by piezoelectric accelerometers in hand-arm vibration measurements. First of all, it reduced the cost of the complete system. Secondly, their small size allowed for being attached to human hands without any distraction to the performance of everyday activities even underneath anti-vibration gloves, therefore giving the true results of vibration exposure. Additionally, their size gave the opportunity to install a force sensor next to the accelerometer, thus enabling measurement of the contact force simultaneously to tri-axial acceleration assessment. This constituted a strong basis for the creation of improved methods of hand-arm vibration assessment and new hand-arm vibration measurement standards.

Photo 1 Hand-arm vibration adapter with tri-axial MEMS accelerometer and contact force sensor installed

1.2. Use of hand-arm vibration adapters in accordance to ISO 5349

Before MEMS sensors were introduced to the market, hand-arm vibration measurements were performed with piezo-electric sensors typically mounted on tools. The location of sensors was chosen not as recommended by the ISO – at the point of contact with hand, but, in order to avoid damages, at the point most convenient and safe for the sensor itself. The introduction of MEMS hand-arm vibration adapters with force measurement capabilities solved that problem, and enabled measurement exactly at the point of contact between the hand and the vibrating surface.

At the same time the use of hand-arm vibration adapters raised a question on the accuracy of vibration measurements **in function of the contact force.** To answer this question 240 measurements were performed at the Polish National Research Institute at the Central Institute for Labour Protection. The impact of the coupling force on the vibration magnitudes has been assessed with Svantek's SV106 human vibration meters and SV105AF hand-arm adapters (push force thresholds in tests were: 0 N, 20 N, 50 N, 100 N).

2. Testing object and measurement performance

2.1. Measurement instrumentation and localisation of measurement points

Instrumentation used to generate and control test signals:

- vibration exciter, Ling Dynamic Systems V721, nr id. NA2/30/31,
- vibration accelerometer, Brüel & Kjaer 4374, nr id. NA2/11,
- amplifier NEXUS, Brüel & Kjaer 2692, nr id. NA2/62,
- power amplifier, Ling Dynamic Systems PA 2000, Nr id. NA2/26,
- signal generator Brüel & Kjaer 1054, nr id. NA2/25,
- computer nr id. NA2/63,
- analyser PULSE, Brüel & Kjaer 3560C, Nr id. NA2/84.

Instrumentation used for force measurements:

- force meter, PI-W Movir MSZN-1, Nr id. NA2/32,
- push force platform, CIOP PIB, Nr id. NA2/34,
- testing handle, CIOP PIB, Nr id. NA2/33,
- optic sensor, Sensor, CW 18/80, Nr id. NA2/43,

The study has been performed with two **SV 106** (Svantek Sp. z o.o., 2017), SVANTEK's human vibration level meters meeting the ISO 8041:2005 requirements, and designed to perform measurements in accordance with ISO 5349-1 and ISO 5349-2 standards, with special SV 105AF hand-arm adapters mounted on handles of vibration exciters. During the measurement, the instrument was battery powered. Two SV 105AF units, marked as A and B hand-arm adapters, have been attached with a tape and beeswax to ensure the repeatability of measurements. One of the adapters (A) has been used for measurement with the operator, while the second one (B) as the reference. Both measurement points were located on testing handle. During measurements, point A was located at the point of contact of operator's hand with the handle. Point B has been located below the zone of contact of hand with the testing handle. As the reference the accelerometer Brüel & Kjaer 4374, nr id. NA2/11 and PULSE Brüel & Kjaer 3560C, Nr id. NA2/84 analyzer have been used. The reference accelerometer has been also attached to the handle.

Photo 2 SV 106 meters with sensors and the reference accelerometer installed on the vibration exciter handle.

2.2. Contact force

Contact forces between the hand and the vibrating surface are: the push/pull force and the gripping force. The need of simultaneous assessment of contact forces and vibration magnitudes has been universally recognized and reflected in ISO 15230 standard.

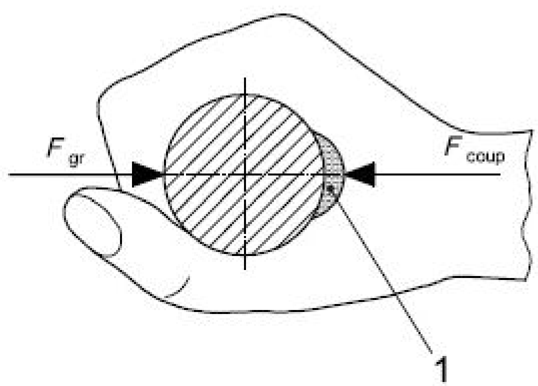


Figure 1 Example of contact forces measurement given by ISO 15230

During the experiment the push force has been measured with the use of special platform at the Polish National Research Institute at the Central Institute for Labour Protection, using PI-W Movir MSZN-1 meter and CW 18/80 sensor. Push force thresholds in tests were: 0 N, 20 N, 50 N, 100 N.

2.3. <u>The measurement goal and method</u>

The goal of the experiment was to perform measurements of vibration acceleration on a testing handle with the use of SV 106 meters described in p. 2.1 with the presence of the different push forces applied by the operator and evaluation of these forces on the vibration results.

The method of the study was to measure the weighted vibration acceleration in the direction parallel to vibration generated on a testing handle with the simultaneous use of two measurement sets described in p. 2.1. The vibration generated on a handle was compliant to ISO 10819:2013 standard.

Adapter A was tested under defined push forces applied by **10 different operators,** whereas adapter B was used as the reference without use of push forces.

Two testing signals were used in the study:

- Vibration signal 1 – simulated signal of vibration accelerations generated by the vibration hammer,
- Vibration signal 2 – simulated signal of vibration accelerations generated by the angle grinder

Measurements of hand-arm vibration were performed in accordance to standards **ISO 5349-1:2001** Mechanical vibration -- Measurement and evaluation of human exposure to hand-transmitted vibration -- Part 1: General requirements and **ISO 5349-2:2001** Mechanical vibration -- Measurement and evaluation of human exposure to hand-transmitted vibration -- Part 2: Practical guidance for measurement at the workplace.

Photo 3 Position of the operator on platform during the measurements.

3. Measurement results

3.1. Differences between vibration values measured with applied forces and the reference values

Tables below presents measurement results of the weighted vibration acceleration in accordance to the method described in p.2.3 measured for the selected force thresholds: 0 N, 20 N, 50 N, 100 N.

Table 1. Measurement results of the weighted vibration acceleration at push force: 0 N

PUSH FORCE 0 N							
Operator No	Test No	Test Signal 1			Test Signal 2		
		Value of vibration acceleration measured with meter A [m/s2]	Value of vibration acceleration measured with meter B [m/s2]	Ratio of the value of vibration acceleration measured with meter A against meter B	Value of vibration acceleration measured with meter A [m/s2]	Value of vibration acceleration measured with meter B [m/s2]	Ratio of the value of vibration acceleration measured with meter A against meter B
1	1	10,20	10,30	0,990	6,71	6,81	0,985
	2	10,60	10,50	1,010	6,61	6,69	0,988
	3	10,60	10,50	1,010	6,65	6,72	0,990
2	1	10,70	10,60	1,009	6,74	6,88	0,980
	2	10,40	10,40	1,000	6,63	6,73	0,985
	3	11,00	10,90	1,009	6,68	6,70	0,997
3	1	10,40	10,40	1,000	6,60	6,55	1,008
	2	10,80	10,70	1,009	6,71	6,62	1,014
	3	10,70	10,60	1,009	6,58	6,52	1,009
4	1	10,60	10,60	1,000	6,66	6,75	0,987
	2	10,20	10,20	1,000	6,75	6,85	0,985
	3	10,50	10,40	1,010	6,66	6,78	0,982
5	1	10,90	10,80	1,009	6,75	6,86	0,984
	2	10,90	10,80	1,009	6,69	6,78	0,987
	3	10,40	10,80	0,963	6,73	6,86	0,981
6	1	10,50	10,40	1,010	6,75	6,79	0,994
	2	10,80	10,70	1,009	6,78	6,78	1,000
	3	10,80	10,70	1,009	6,78	6,78	1,000
7	1	10,20	10,20	1,000	6,72	6,60	1,018
	2	10,40	10,50	0,990	6,79	6,69	1,015
	3	10,20	10,30	0,990	6,68	6,59	1,014
8	1	10,90	10,80	1,009	6,78	6,73	1,007
	2	10,80	10,70	1,009	6,85	6,78	1,010

	3	11,00	10,90	1,009	6,77	6,71	1,009
9	1	11,00	11,00	1,000	6,79	6,75	1,006
	2	11,00	10,90	1,009	6,82	6,77	1,007
	3	11,00	10,90	1,009	6,89	6,83	1,009
10	1	11,10	11,00	1,009	6,82	6,71	1,016
	2	11,10	11,00	1,009	6,85	6,75	1,015
	3	11,20	11,10	1,009	6,82	6,75	1,010
Average Value		**10,70**	**10,65**	**1,004**	**6,73**	**6,74**	**1,000**
Standard Deviation		**0,30**	**0,26**	**0,010**	**0,08**	**0,09**	**0,013**

Table 2. Measurement results of the weighted vibration acceleration at push force: 20 N

PUSH FORCE 20 N							
Operator No	Test No	Test Signal 1			Test Signal 2		
		Value of vibration acceleration measured with meter A [m/s^2]	Value of vibration acceleration measured with meter B [m/s^2]	Ratio of the value of vibration acceleration measured with meter A against meter B	Value of vibration acceleration measured with meter A [m/s^2]	Value of vibration acceleration measured with meter B [m/s^2]	Ratio of the value of vibration acceleration measured with meter A against meter B
1	1	10,40	10,40	1,000	6,61	6,60	1,002
	2	10,20	10,20	1,000	6,66	6,64	1,003
	3	9,95	10,10	0,985	6,58	6,57	1,002
2	1	10,30	10,40	0,990	6,70	6,71	0,999
	2	10,40	10,60	0,981	6,69	6,68	1,001
	3	10,30	10,40	0,990	6,76	6,78	0,997
3	1	10,10	10,10	1,000	6,58	6,71	0,981
	2	10,20	10,30	0,990	6,64	6,77	0,981
	3	10,10	10,20	0,990	6,56	6,69	0,981
4	1	10,20	10,20	1,000	6,60	6,77	0,975
	2	10,20	10,30	0,990	6,66	6,87	0,969
	3	10,30	10,30	1,000	6,55	6,71	0,976
5	1	10,00	10,20	0,980	6,55	6,76	0,969
	2	10,20	10,30	0,990	6,57	6,77	0,970
	3	10,10	10,20	0,990	6,63	6,82	0,972
6	1	10,30	10,40	0,990	6,69	6,76	0,990
	2	10,10	10,10	1,000	6,80	6,81	0,999
	3	10,30	10,40	0,990	6,78	6,75	1,004
7	1	10,40	10,40	1,000	6,78	6,61	1,026

	2	10,60	10,70	0,991	6,85	6,68	1,025
	3	10,40	10,50	0,990	6,74	6,58	1,024
8	1	10,50	10,50	1,000	6,68	6,74	0,991
	2	10,80	10,80	1,000	6,68	6,74	0,991
	3	10,60	10,60	1,000	6,71	6,76	0,993
9	1	10,50	10,60	0,991	6,72	6,63	1,014
	2	10,40	10,40	1,000	6,78	6,67	1,016
	3	10,30	10,40	0,990	6,85	6,71	1,021
10	1	10,60	10,60	1,000	6,80	6,72	1,012
	2	10,70	10,70	1,000	6,72	6,72	1,000
	3	10,70	10,70	1,000	6,75	6,73	1,003
Average Value		**10,34**	**10,40**	**0,994**	**6,69**	**6,72**	**0,996**
Standard Deviation		**0,22**	**0,20**	**0,006**	**0,09**	**0,07**	**0,017**

Table 3. Measurement results of the weighted vibration acceleration at push force: 50 N

PUSH FORCE 50 N							
Operator No	Test No	Test Signal 1			Test Signal 2		
		Value of vibration acceleration measured with meter A [m/s²]	Value of vibration acceleration measured with meter B [m/s²]			Value of vibration acceleration measured with meter A [m/s²]	Value of vibration acceleration measured with meter B [m/s²]
1	1	9,99	9,89	1,010	6,55	6,58	0,995
	2	10,10	10,10	1,000	6,58	6,65	0,989
	3	9,92	9,91	1,001	6,65	6,68	0,996
2	1	10,10	10,30	0,981	6,65	6,68	0,996
	2	9,85	10,00	0,985	6,70	6,75	0,993
	3	9,87	10,00	0,987	6,63	6,67	0,994
3	1	10,00	10,00	1,000	6,55	6,69	0,979
	2	9,78	9,87	0,991	6,65	6,72	0,990
	3	9,85	10,10	0,975	6,58	6,75	0,975
4	1	10,20	10,30	0,990	6,48	6,73	0,963
	2	10,20	10,40	0,981	6,54	6,75	0,969
	3	9,93	10,00	0,993	6,56	6,78	0,968
5	1	10,10	10,20	0,990	6,50	6,76	0,962
	2	9,79	9,94	0,985	6,59	6,80	0,969

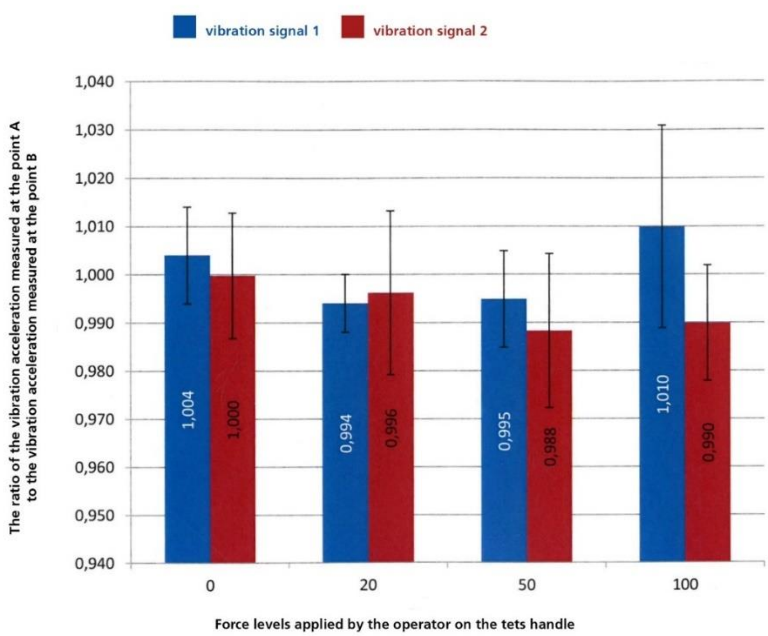
	3	10,20	10,40	0,981	6,53	6,78	0,963
6	1	9,87	9,97	0,990	6,66	6,77	0,984
	2	10,10	10,00	1,010	6,63	6,75	0,982
	3	9,83	9,78	1,005	6,63	6,82	0,972
7	1	10,50	10,50	1,000	6,75	6,65	1,015
	2	9,98	9,98	1,000	6,62	6,60	1,003
	3	9,97	9,87	1,010	6,65	6,61	1,006
8	1	10,30	10,30	1,000	6,58	6,65	0,989
	2	10,60	10,70	0,991	6,61	6,69	0,988
	3	10,30	10,30	1,000	6,52	6,61	0,986
9	1	10,40	10,50	0,990	6,74	6,63	1,017
	2	10,40	10,50	0,990	6,69	6,62	1,011
	3	10,40	10,40	1,000	6,75	6,63	1,018
10	1	10,60	10,60	1,000	6,61	6,65	0,994
	2	10,40	10,40	1,000	6,65	6,69	0,994
	3	10,500	10,40	1,010	6,65	6,72	0,990
Average Value		**10,13**	**10,19**	**0,995**	**6,62**	**6,70**	**0,988**
Standard Deviation		**0,25**	**0,25**	**0,010**	**0,07**	**0,07**	**0,016**

Table 4. Measurement results of the weighted vibration acceleration at push force: 100 N

PUSH FORCE 100 N							
Operator No	Test No	Test Signal 1			Test Signal 2		
		Value of vibration acceleration measured with meter A [m/s²]	Value of vibration acceleration measured with meter B [m/s²]			Value of vibration acceleration measured with meter A [m/s²]	Value of vibration acceleration measured with meter B [m/s²]
1	1	10,20	10,10	1,010	6,64	6,58	1,009
	2	10,20	10,20	1,000	6,52	6,60	0,988
	3	10,20	10,20	1,000	6,46	6,65	0,971
2	1	10,40	10,40	1,000	6,63	6,65	0,997
	2	10,10	10,10	1,000	6,68	6,68	1,000
	3	10,20	10,20	1,000	6,61	6,58	1,005
3	1	9,95	9,93	1,002	6,55	6,61	0,991
	2	9,74	9,75	0,999	6,54	6,78	0,965
	3	9,72	9,67	1,005	6,55	6,65	0,985
4	1	9,93	9,95	0,998	6,48	6,61	0,980
	2	9,89	8,89	1,112	6,52	6,65	0,980
	3	9,92	9,87	1,005	6,57	6,69	0,982
5	1	10,40	10,20	1,020	6,43	6,61	0,973

	2	10,20	10,10	1,010	6,49	6,68	0,972
	3	10,40	10,30	1,010	6,53	6,61	0,988
6	1	10,10	9,93	1,017	6,52	6,68	0,976
	2	10,20	10,10	1,010	6,46	6,63	0,974
	3	10,10	9,99	1,011	6,51	6,67	0,976
7	1	10,30	10,30	1,000	6,61	6,64	0,995
	2	9,82	9,74	1,008	6,49	6,52	0,995
	3	10,30	10,10	1,020	6,52	6,54	0,997
8	1	10,20	10,10	1,010	6,56	6,58	0,997
	2	10,40	10,30	1,010	6,55	6,58	0,995
	3	10,20	10,20	1,000	6,47	6,50	0,995
9	1	10,30	10,20	1,010	6,61	6,59	1,003
	2	10,20	10,00	1,020	6,70	6,67	1,004
	3	10,30	10,20	1,010	6,56	6,53	1,005
10	1	10,40	10,40	1,000	6,58	6,58	1,000
	2	10,30	10,30	1,000	6,57	6,58	0,998
	3	10,10	10,10	1,000	6,58	6,59	0,998
Average Value		**10,16**	**10,06**	**1,010**	**6,55**	**6,62**	**0,990**
Standard Deviation		**0,20**	**0,29**	**0,021**	**0,06**	**0,06**	**0,012**

The graph below presents the **ratio** of averaged results for 30 measurements for each force threshold at point A against the results at point B together with the standard deviation. The results from vibration signal 1 are marked in blue and vibration signal 2 in red.



Graph 1 The ratio of vibration values measured with the applied force against to the reference values with no force applied.

3.2. The impact of contact force on measured vibration values.

On the basis of the conducted study it has been defined that differences between measured vibration accelerations in points A and B for push forces in the range of 0 – 100 N **do not exceed 1.2%** which means that the **effect of the push force applied is irrelevant to the measured vibration values**.

3.3. The minimum contact force threshold required for the accurate vibration acceleration measurements.

Additional measurements with hand-arm adapters without the use of beeswax nor mounting tape were performed to evaluate **the effect of changes of the coupling of the adapter** to the testing handle. It has been noted that for **force thresholds below 20 N** it was necessary to ensure that the coupling between adapter and testing handle was sufficient to prevent the breaks in a continuous contact during the measurements.

4. Conclusion

The conducted study proves that the effect of changes of the force thresholds applied by the operator are **irrelevant** to the measured vibration acceleration values. This assumption is valid for the forces above **threshold of 20 N**, below which it is necessary to ensure the **correct coupling** between hand-arm adapter and vibrating surface. Together with the force level drop below 20 N, the uncertainty related to the coupling increases rapidly. However it is necessary to note that in practise, for tools generating high vibration amplitudes, the threshold of 20 N may not guarantee the perfect coupling, therefore higher threshold levels should be established.

5. Summary

At the time the ISO 5349 standard was introduced it was practically impossible to perform force measurements together with tri-axial vibration measurements due to limitations in hardware.

At the moment very small force transducers can be fitted right next to the MEMS-technology-based vibration accelerometer in a form of hand-arm adapter as specified by ISO 5349-2 and ISO 10819 standards. In comparison to the technique of mounting sensor on a tool, the use of contact force allows defining the actual vibration exposure, whereas mounting on a tool bears the uncertainty of including into tests the periods when there was no contact with the operator’s hand.

As it has been proven, the use of hand-arm adapters provides the same accuracy of vibration amplitudes as in case of standard piezoelectric vibration sensors mounted on a tool, but additionally offers the advantage of the best possible location of the measurement point – exactly at the point of transmission of the vibration signal to the hand of an operator and provides information on the actual exposure to the vibration.

6. References

PhD (Eng.) Piotr Kowalski (2017), Measurement Report on Laboratory Study of the Influence of The Contact Forces of the Svantek Hand-Arm Vibration Adapter with the Testing Handle Simulating the Hand-Arm Vibration, on the Results of Measurements of Vibration Acceleration. Polish National Research Institute at the Central Institute for Labour Protection.

International Organization for Standardization (1996) Mechanical vibration and shock -- Hand-arm vibration -- Measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand, ISO 10819.

International Organization for Standardization (2007) Mechanical vibration and shock -- Coupling forces at the man--machine interface for hand-transmitted vibration, ISO 15230.

International Organization for Standardization (2001) Mechanical vibration. Measurement and evaluation of human exposure to hand-transmitted vibration. General requirements, ISO 5349-1.

International Organization for Standardization (2001) Mechanical vibration. Measurement and evaluation of human exposure to hand-transmitted vibration -- Part 2: Practical guidance for measurement at the workplace, ISO 5349-2.

International Organization for Standardization (2005) Human response to vibration -- Measuring instrumentation, ISO 8041.

Svantek Sp. Z o.o. (2017) SV 106 Human Vibration Level Meter); http://svantek.com/lang-en/product/8/sv_106_human_vibration_meter___analyser.html#about

Endorsed by

European Society of Biomechanics

The European Society of Biomechanics (ESB) was founded at a meeting of 20 scientists from 11 countries in Brussels on May 21, 1976. Biomechanics is defined as "The study of forces acting on and generated within a bwody and of the effects of these forces on the tissues, fluids or materials used for diagnosis, treatment or research purposes". The primary goal of the ESB is *"To encourage, foster, promote and develop research, progress and information concerning the science of Biomechanics"*.

https://esbiomech.org

Sponsored by

Shock Mitigation delivers subject matter expertise to increase efficiency for professional maritime organisations operating fast boats. The company offers specialist training, consultancy and strategic product development, plus an independent overview relevant to end user organisations, OEM boat builders and equipment manufacturers. Knowledge is shaped by experience and understanding the factors that are driving the changes for employers and operators in the commercial and military marine sector worldwide. The objective is to improve the overall approach to crew safety and the operational performance of boats and equipment for the professional sector.

www.shockmitigation.com

Brüel & Kjær Sound and Vibration Measure-ments A/S supplies integrated solutions for the measurement and analysis of sound and vibration. As a world-leader in sound and vibration measurement and analysis, we use our core competences to help industry and governments solve their sound and vibration challenges so they can concentrate on their primary task; efficiency in commerce and administration.

www.bksv.co.uk

Svantek UK Ltd is the UK subsidiary of Svantek in Poland, a world leading manufacturer of noise and vibration monitoring instrumentation.

www.svantek.com/

HVLab instruments and software have been developed through research on human responses to vibration conducted in the Institute of Sound and Vibration Research at the university of Southampton. The instruments and software are used in medical, industrial, research and educational establishments for health surveillance medical diagnosis and fundamental research.

www.southampton.ac.uk/hvlab/

DJB Instruments UK Ltd has been the only British manufacturer of both Charge and IEPE (Voltage) output piezoelectric accelerometers for over 40 years and is well known for innovative world leading products such as water cooled high temperature accelerometers testing up to 900°C and the world's smallest IEPE ultra-miniature accelerometer at just 0.19grams. We design, manufacture, assemble and calibrate on site with worldwide distribution for companies in the aerospace, automotive, industrial and engineering fields. Our latest research and development program has led to a ground breaking new wireless piezoelectric accelerometer technology which will further advance our range and offerings for human vibration, sports science and medical applications.

www.djbinstruments.com

SKYDEX® is a global leader in impact mitigation and cushioning solutions. Installed in 23,000 military vehicles and 6,000 marine craft, SKYDEX's proprietary technology is engineered to excel in the harshest and most demanding conditions. By customizing their technologies to meet specific market requirements, SKYDEX maximizes product and end-user performance. SKYDEX is dedicated to Protecting Things That Matter®

www.skydex.com

Shawcity is totally focused on enabling customers working in Environmental, Occupational Hygiene and Health & Safety applications to achieve the highest levels of monitoring performance by constantly sourcing the best new technology for the UK and Ireland.

We offer an extensive range of monitoring detection including portable products for: VOCs; Benzene; Ground Gas; Single Gas; Confined Space; Multigas; Mercury; Fixed Gas Detection Systems; Sound, Noise and Vibration; Air Quality; Dust and Heat Stress.

With the best instruments on the market from a range of manufacturers available to HIRE or BUY, each order is tailored to your specific requirements to provide individual solutions.

Perhaps most importantly, thanks to our close links with leading manufacturers our technical team provides you with training, support and advice for the lifetime of your instrument for total peace of mind. We offer a complete solution, with our manufacturer-trained and approved engineers providing in-house servicing and calibration.

http://www.shawcity.co.uk/

Cranfield Forensic Institute
Cranfield Defence and Security
Shrivenham SN6 8LA

E: info@hrv2017.co.uk
www.hrv2017.co.uk

Cranfield short courses:

E: courses.shrivenham@cranfield.ac.uk
T: +44 (0)1793 785810
www.cranfield.ac.uk

Cranfield Masters' courses:

E: enquiries@cranfield.ac.uk
T: +44 (0)1234 758008
www.cranfield.ac.uk

ISBN 978-1-9998301-0-6
9 781999 830106 >