Chapter 12

Vibration transmissibility of resilient materials when loaded by a simulating mass and when gripped by the operator's hand

Jacek Zając, Piotr Kowalski
Central Institute for Labour Protection – National Research Institute

DOI: 10.54215/Noise_Control_2022_A_Digital_Monograph_Zajac_J_Kowalski_P_Vibration

Abstract
Anti-vibration gloves are made of resilient materials. International standard ISO 13753:2002 describes a method of measuring the vibration attenuation of a sample of such material. The method determines the transmissibility of the material when loaded by a mass providing a compression equivalent to gripping force exerted by the hand. The standard ISO 10819:2013 describes a laboratory method for evaluation of the vibration transmissibility of glove at the palm of the hand, which grips and pushes a test handle. This paper presents comparative results of resilient material measurements using both international standards.

Keywords: anti-vibration gloves, resilient materials, Hand-arm Vibration

1. Introduction

Anti-vibration gloves are the type of personal protective equipment most commonly used to protect against vibrations acting on the employee's upper extremities [1-3]. International ISO 10819:2013 standard describes a method of measuring vibration transmissibility of gloves worn by operators participating in tests and specifies precise evaluation criteria of anti-vibration properties thereof [4]. Resilient material constitutes the main structural component of anti-vibration gloves [4, 5]. In order to evaluate efficiency of vibration attenuation of such material, the ISO 10819:2013 standard proposes a method presented in the ISO 13753:2002 standard, which implies a means of evaluation of materials suitable for manufacture of anti-vibration gloves based on tests utilising a load of mass simulating gripping pressure used to replace an operator participating in the test [5]. The authors of the relevant publication have conducted a comparison of test results obtained for anti-vibration gloves (under ISO 10819:2013) with test results obtained for material samples which these gloves were made of (under ISO 13753:2002). The purpose of this comparison was to determine suitability of test results for resilient materials as correlation of anti-vibration properties of gloves made of such materials.

2. Tested objects

Eight types of selected anti-vibration gloves (designated with numbers 1 to 8) were subjected to the tests of vibration transmissibility of gloves used by operators. The gloves differ in the type of material used to reduce vibrations as well as in the thickness of their vibration-damping pads. Additionally, the type of material used in on the outer surface differs from glove type to type. A series of tests was performed for each type of gloves. Five gloves of each type were tested. The tested gloves are presented in Figure 1.

Figure. 1. Anti-vibration gloves used for tests

Tests of vibration transmissibility by resilient materials were conducted for 8 types of samples cut from 8 types of anti-vibration gloves tested, and specifically from the palm covering part of the glove. Three samples of each material were tested. Average thicknesses of samples tested are presented in Table 1.

Table 1. Thicknesses of the tested samples

Type of gloves	The average thickness in the palm section, mm
1	2.0 ± 0.1 mm
2	6.3 ± 0.1 mm
3	6.3 ± 0.1 mm
4	5.5 ± 0.1 mm
5	7.3 ± 0.1 mm
6	8.1 ± 0.1 mm
7	7.0 ± 0.1 mm
8	6.3 ± 0.1 mm

3. Tests of anti-vibration gloves

3.1. Test method

As per the method specified in the ISO 10819:2013 standard, mean corrected values of vibration transmissibility for gloves intended to protect against vibrations are determined: $\overline{T}_{(M)}$ and $\overline{T}_{(H)}$. These are determined during simulation of vibrations on a test handle by specifically profiled testing vibration signal comprising vibrations in the frequency range of 25-200 Hz ($\overline{T}_{(M)}$) and 200–1250 Hz ($\overline{T}_{(H)}$). Vibration transmissibility values are then calculated based on the results of measurements of acceleration of vibrations at the test handle and operator's hand.

3.2. Measurement system and test conditions

Measurement of vibration transmissibility by selected gloves was performed on a test bench meeting the requirements of ISO 10819:2013. A diagram of the test bench is presented in Figure 2.

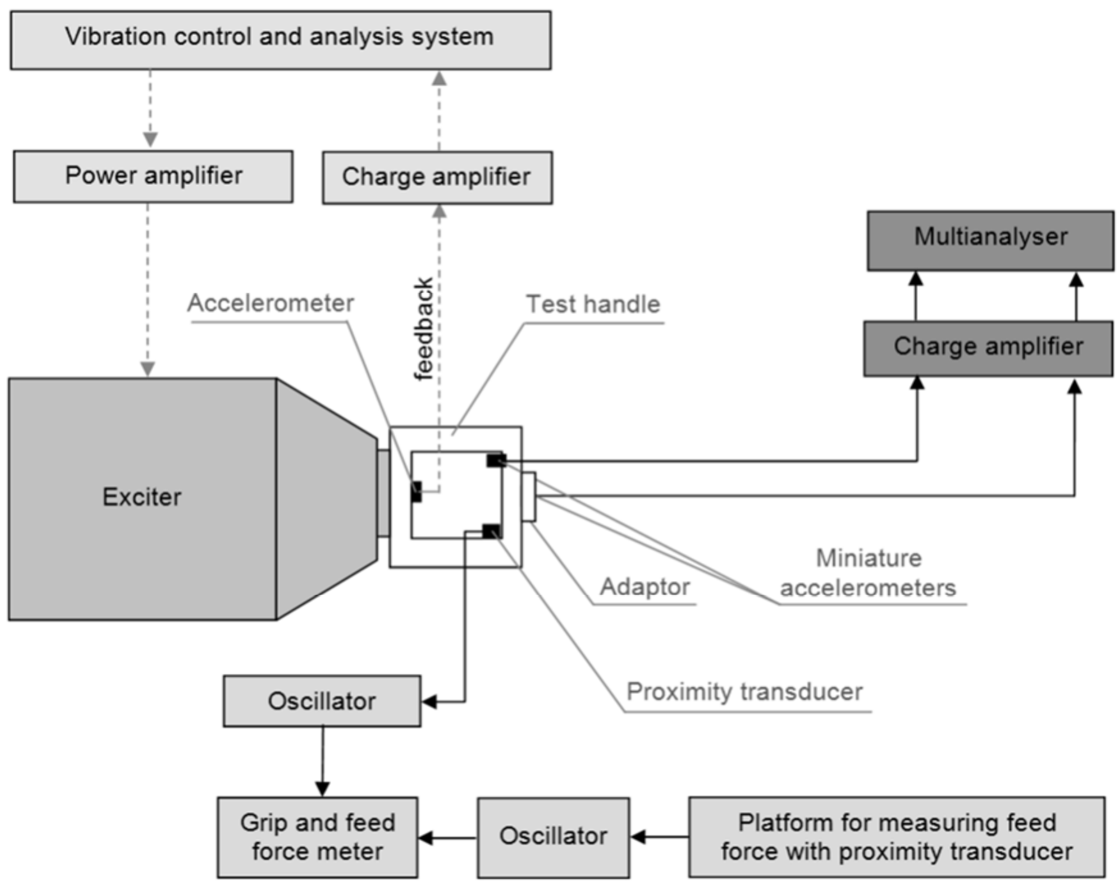

Figure. 2. Diagram of test bench used to test vibration transmissibility by gloves in accordance with ISO 10819

The test bench the glove examination was conducted on includes the following measurement instruments:

- vibration exciter, type V721, by Ling Dynamic Systems,
- power amplifier, type PA2000, by Ling Dynamic Systems,
- 2 vibration transmitters, type 4374, by Brüel & Kjær,
- vibration transmitter, type 4384V, by Brüel & Kjær,
- load amplifier, Nexus type 2692, by Brüel & Kjær,
- load amplifier, Nexus type 2692-0S, by Brüel & Kjær,
- vibration control and analysis system VibPilot, by m+p International,
- PULSE multianalyser system, type 3560C, by Brüel & Kjær,
- thermo-hygrometer, type LB-103, by LAB-EL.

Vibration acceleration in the excitation direction (one direction of measurement) was measured both on test handle (reference point) as well as operator's hand using an adapter. Vibration transmissibility values of the gloves were determined based on results of measurements of acceleration of vibrations. Before testing the gloves, measurements of vibration transmissibility of the handle-operator's hand configuration without glove for each of the 5 operators participating in the tests were made. Five pieces of each type of gloves were tested, where each piece of gloves was tested by a different operator. Each measurement was repeated three times. Measurements were performed under constant grip force value of: 50N ± 8N and feed force of 30 ± 5N at air temperature in the range of 22-24°C.

4. Tests of resilient materials

4.1. Test method

The method of testing resilient materials as in placing a sample of material on a vibration exciter plate and pressing from the top by specified in ISO 13753:2002 consists a load of mass. During the measurement, the values of vibration acceleration a_1 on the exciter plate and vibration acceleration a_2 at surface of the load are measured together with measurement of phase difference between registered signals. Based on the measured vibration acceleration values as well as the value of hand-arm impedance (specified in ISO 13753:2002), values and characteristics of vibration transmissibility for the materials tested are determined.

4.2. Measurement system and test conditions

The measurements are performed on a test bench meeting the requirements of ISO 13753:2002. A diagram of the test bench is presented in Figure 3.

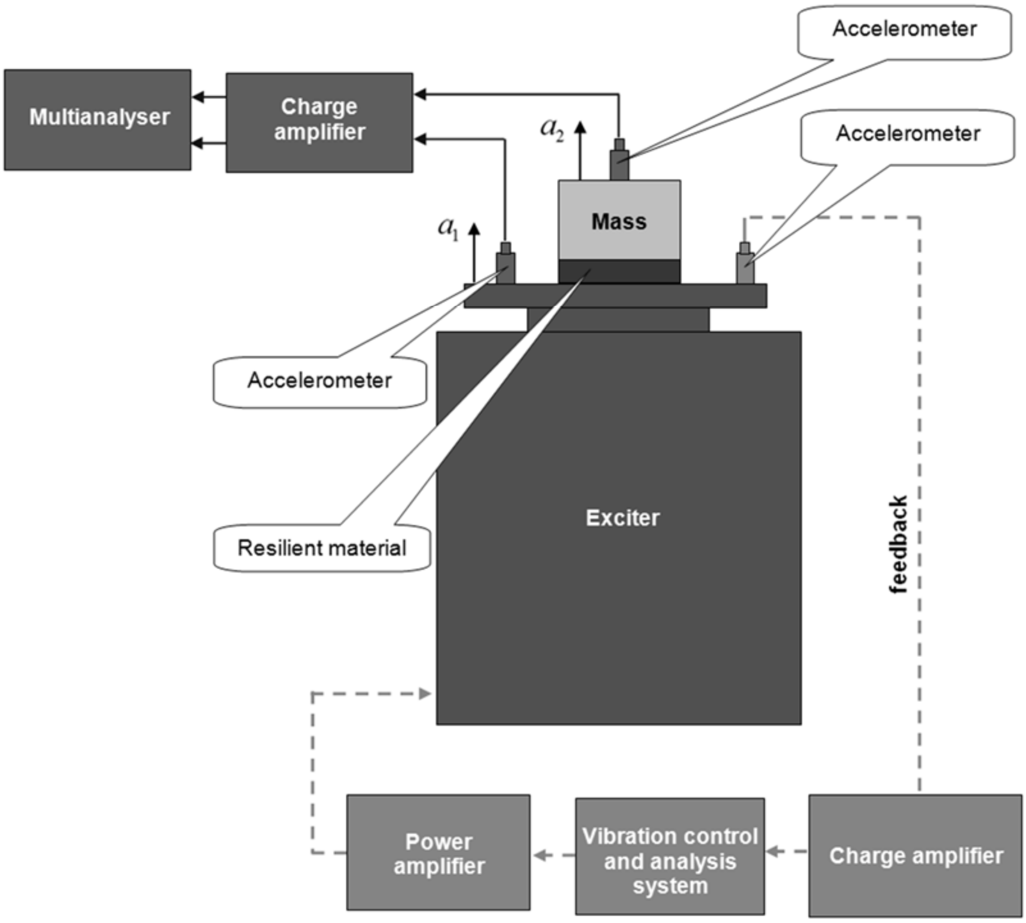

Figure 3. Diagram of test bench used to test resilient materials

The test bench for material samples tests includes the following measurement instruments:

- vibration exciter, type V721, by Ling Dynamic Systems,
- power amplifier, type PA2000, by Ling Dynamic Systems,
- accelerometer, type 4371V, by Brüel & Kjær,
- accelerometer, type 4384, by Brüel & Kjær,
- accelerometer, type 4384V, by Brüel & Kjær,
- charge amplifier, Nexus type 2692, by Brüel & Kjær,
- charge amplifier, Nexus type 2692-0S, by Brüel & Kjær,
- vibration control and analysis system VibPilot, by m+p International,
- PULSE multianalyser system, type 3560C, by Brüel & Kjær,
- thermo-hygrometer, type LB-103, by LAB-EL.

A 4294-002 calibrator by Brüel & Kjær was used for calibration of vibration measurement equipment. During measurements, ambient temperature was 23.9 ± 0.1°C, while relative humidity of air was 22.0 ± 1%. Tests were performed using a standardised cylindrical weight of radius of 45 mm and weight of 2.5 kg (Figure 4). A broadband noise of frequency range of 8-800 Hz and power spectral density of 0.08 $m^2s^{-4}Hz^{-1}$ was used as the vibration test signal.

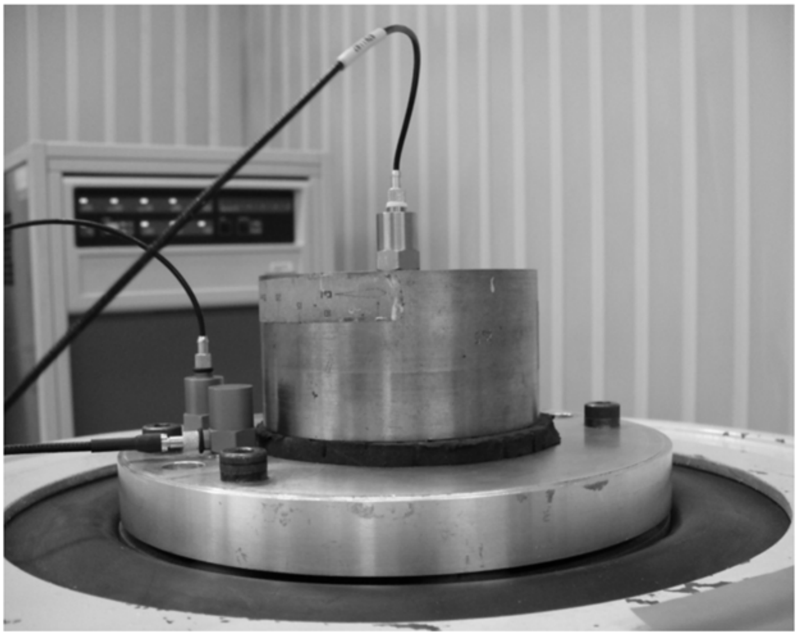

Figure 4. Sample of resilient material during measurement

5. Test results

Mean corrected values of transmissibility: $\overline{T}_{(M)}$ and $\overline{T}_{(H)}$ for the tested gloves as well as standard deviations and coefficients of variation values are presented in Table 2, whereas test results (as average values of vibration transmissibility of samples of resilient materials from the tested gloves) are presented in Table 3. Figure 5 shows frequency characteristics of vibration transmissibility of tested material samples.

Table 2. Mean corrected transmissibility, standard deviation and coefficient of variation for tested gloves in frequency range Δf_M and Δf_H

	Frequency range Δf_M			Frequency range Δf_H		
Type of gloves	$\overline{T}_{(M)}$	**Standard deviation** $s_{T(M)}$	**Coefficient of variation** $C_{V,T(M)}$	$\overline{T}_{(H)}$	**Standard deviation** $s_{T(H)}$	**Coefficient of variation** $C_{V,T(H)}$
1	0.920	0.028	0.030	1.015	0.044	0.044
2	0.756	0.031	0.041	0.583	0.025	0.043
3	0.703	0.039	0.056	0.507	0.027	0.053
4	0.721	0.038	0.052	0.573	0.039	0.069
5	0.811	0.043	0.053	0.741	0.080	0.108
6	0.794	0.050	0.063	0.650	0.033	0.051
7	0.693	0.049	0.071	0.470	0.041	0.088
8	0.707	0.043	0.061	0.534	0.063	0.119

Table 3. The values of transmissibilities calculated for tested materials

Frequency Hz	**Transmissibility (mean)**							
	Sample no.							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
10	1.02	1.02	1.02	1.06	1.04	1.04	1.05	1.02
12.5	1.02	1.02	1.02	1.06	1.04	1.05	1.06	1.02
16	1.02	1.02	1.02	1.07	1.03	1.04	1.03	1.02
20	1.00	1.02	1.02	1.02	1.01	1.01	0.98	1.02
25	0.98	1.01	1.02	0.96	0.96	0.94	0.92	1.01
31.5	0.93	0.99	0.99	0.88	0.89	0.85	0.83	0.99
40	0.89	0.95	0.95	0.81	0.83	0.77	0.75	0.95
50	0.86	0.92	0.92	0.89	0.82	0.80	0.76	0.93
63	0.87	0.92	0.91	0.83	0.87	0.77	0.72	0.92
80	0.89	0.92	0.91	0.77	0.84	0.74	0.68	0.92
100	0.88	0.91	0.90	0.64	0.77	0.67	0.63	0.91
125	0.85	0.89	0.88	0.54	0.68	0.58	0.55	0.89
160	0.82	0.89	0.87	0.48	0.62	0.53	0.50	0.88
200	0.75	0.84	0.82	0.40	0.53	0.46	0.44	0.83
250	0.66	0.74	0.71	0.37	0.46	0.40	0.39	0.73
315	0.57	0.64	0.62	0.39	0.42	0.38	0.38	0.63
400	0.51	0.57	0.55	0.49	0.43	0.43	0.42	0.57
500	0.50	0.56	0.55	0.69	0.49	0.53	0.53	0.54

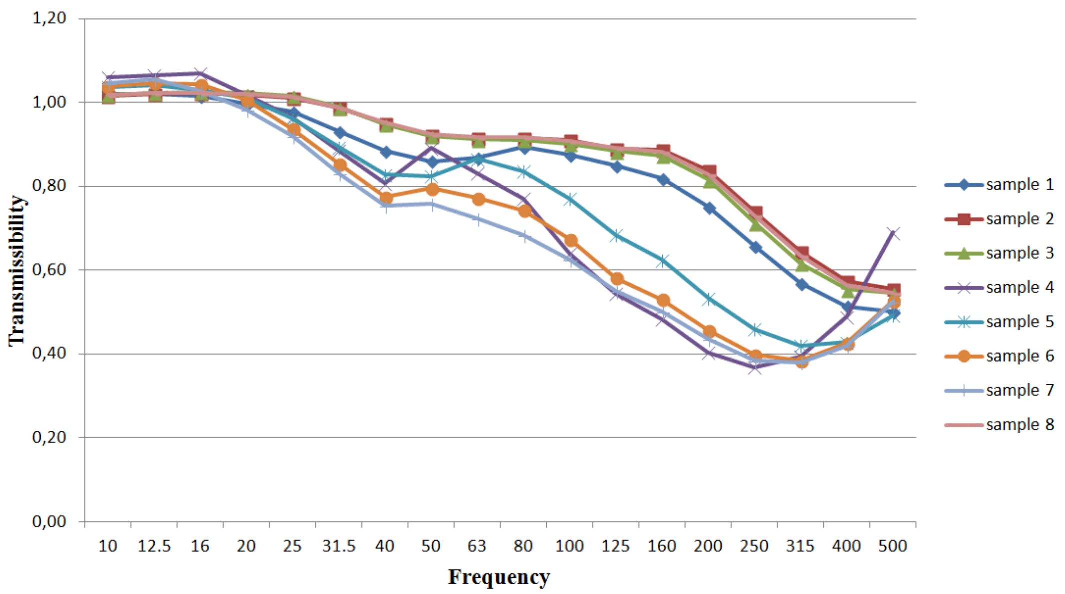

Figure 5. Transmissibility as a function of frequency calculated for tested materials

6. Conclusions

In accordance with ISO 10819, in order to be considered anti-vibration, gloves must fulfil a number of criteria. Basic requirement is that: $\overline{T}_{(M)} \leq 0.9$ and $\overline{T}_{(H)} \leq 0.6$. This requirement is met by 5 types of gloves from among the 8 tested types (gloves No 2, 3, 4, 7 and 8).

As concerns resilient materials (evaluated as per ISO 13753:2002), if vibration transmissibility for the tested material exceeds 0.6 in the whole frequency range, it is concluded that under real conditions such material does not provide attenuation for the same frequency range. Based on an analysis of the results, it was noted that none of the samples met this requirement.

Tests of material used in glove 8 would indicate that it is effective for two frequencies only: 400 and 500 Hz. However, the results obtained for this glove show that it meets all criteria of classification as anti-vibration glove. In the case of gloves 5 and 6 (not classified as anti-vibration), the material these are made of should be effective starting from frequency of 125 Hz.

The main reason for discrepancies between results of resilient materials and results of tests of gloves made of such materials may be the manner of putting a load on the samples. Pressure exerted on a tested sample by a standard loading weight (amounting to about 0.004 MPa) is almost 9 times lower than the pressure exerted by an operator (0.035 MPa). Therefore, mass of the weight should be increased so that the pressure force exerted by the weight should be as close as possible to the grip and feed force of an operator's hand. The results presented herein will be used for further tests to be conducted by Central Institute for Labour Protection – National Research Institute.

Acknowledgements

This paper was based on the results of a research task carried out within the scope of the first stage of the National Programme "Improvement of safety and working conditions" partly supported in 2014-2016 – within the scope of state services – by the Ministry of Labour and Social Policy. The Central Institute for Labour Protection – National Research Institute was the Programme's main coordinator.

References

[1] Bartkowiak G, Baszczyński K, Bogdan A, et. al. Use of Personal Protective Equipment in the Workplace. In: Salvendy G, Ed. Handbook of Human Factors and Ergonomics. 4 Ed. New Jersey:John Wiley & Sons, Inc., Hoboken; 2012. 895-909.

[2] Koton J, Kowalski P. Dobór środków ochrony indywidualnej w profilaktyce zespołu wibracyjnego [Selection of personal protection equipment for prevention of vibration syndrome]. Bezpieczeństwo Pracy. 2002;9(374):10-12.

[3] Targosz J, Adamczyk J. Badania doświadczalne wibroizolacyjnych elementów elastomerowych [Experimental studies of vibroisolating elastomer components]. Logistyka-Nauka. 2011;6:3769-3778.

[4] ISO 10819:2013. Mechanical vibration and shock – Hand-arm vibration – Measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand.

[5] PN-EN ISO 13753:2002. Drgania i wstrząsy mechaniczne – Drgania działające na organizm człowieka przez kończyny górne – Metoda wyznaczania współczynnika przenoszenia drgań materiałów elastycznych obciążonych układem ręka-ramię [Mechanical vibration and shock – Hand-arm vibration – Method for measuring the vibration transmissibility of resilient materials when loaded by the hand-arm system].