REMUNOM
ISSN 2178-6925

Received: 17/08/2026 - **Accepted:** 21/09/2026
Vol: 13.20
DOI: 10.66104/xw4avs62
Pages: 1-18

A RISK OF HAVS FROM USING GRINDERS IN METAL SHEET CUTTING

O RISCO DA VMB UTILIZANDO ESMERILHADEIRAS NO CORTE DE CHAPAS METÁLICAS

EL RIESGO DE SÍNDROME DE VIBRACIÓN MANO-BRAZO (HAVS) AL UTILIZAR AMOLADORAS ANGULARES PARA CORTAR CHAPAS METÁLICAS

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Abstract

Studies indicate that excessive exposure to vibration can cause harm to the human body. Consequently, the use of rotary tools may pose health risk to operators, especially in the absence of a damping system. This study aims to quantify hand-arm vibration (HAV) generated by grinders during the cutting of metallic materials. Three grinder models were tested for cutting ASTM 1100 H14 aluminum sheets, SAE 1020 carbon steel, and AISI 304L stainless steel, collecting vibration data using the Vib008 dosimeter. Inferential analysis employed the Kruskal-Wallis test for independent samples to evaluate HAV levels, along with the Mann-Whitney U test for independent samples, with a

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confidence level of $p < 0.05$. HAV results indicate that in Group ES-I, HAV for manufacturer “A” was 12.33 m/s², 148% above the TL; for manufacturer “B,” it was 11.39 m/s², 127% above the TL; and for manufacturer “C,” it was 10.62 m/s², 112% above the TL. In Group ES-II, HAV for manufacturer “A” was 7.55 m/s², 50% above the TL; for manufacturer “B,” 7.83 m/s², 56% above; and for manufacturer “C,” 6.91 m/s², 38% above the TL. Acceleration values in the x, y, and z axes, as well as total acceleration, indicate they exceed the tolerance limit of 5 m/s². According to the results, exposure to vibration in Group ES-I could cause Raynaud's phenomenon in 10% of exposed workers over an average period of 2.5 years, and in Group ES-II over 3.75 years. The results suggest that the grinders used on-site for metal cutting pose a health risk to workers, necessitating corrective measures such as limiting usage time and recommending the replacement with anti-vibration models to achieve and maintain acceptable vibration levels.

Keywords: HAV, metal sheet cutting, grinders, Raynaud's phenomenon.

Resumo

Estudos indicam que uma excessiva exposição à vibração pode provocar danos ao organismo humano. Consequentemente, o uso de ferramentas rotativas pode apresentar risco à saúde dos operadores, principalmente se não houver um sistema de amortecimento. O objetivo desta pesquisa é quantificar a vibração de mãos e braços (VMB) gerada por esmerilhadeiras no corte de materiais metálicos. Para tanto, ensaiou-se três modelos de esmerilhadeiras na tarefa de corte chapas de Alumínio ASTM 1100 H14, aço carbono SAE 1020 e aço inox AISI 304L, para obtenção dos dados sobre a vibração, a partir de dosímetro Vib008 Na análise inferencial utilizou-se o teste de Kruskal-Wallis para amostras independentes para avaliar a VMB e o teste U de Mann-Whitney de amostras independentes, com um nível de confiança de $p < 0,05$. Os resultados de VMB indicam que no grupo ES-I, a VMB para o fabricante “A” foi de 12,33 m/s², 148% acima do LT; para o fabricante “B” foi de 11,39 m/s², 127% acima do LT e para o fabricante “C” foi de 10,62 m/s², 112% acima do LT. No grupo ES-II, a VMB para o fabricante “A” foi de 7,55 m/s², 50% acima do LT, para o fabricante “B” foi de 7,83 m/s², 56%, e para o fabricante “C” foi de 10,62 m/s², 38% acima do LT. Os valores de aceleração nos eixos x, y e z e a aceleração total indicam que estão acima do limite de tolerância, de 5 m/s². De acordo com os resultados, os valores de exposição à vibração para o grupo ES-I podem causar a síndrome de Raynaud em 10% dos trabalhadores expostos em um período médio de 2,5 anos e para o grupo ES-II de 3,75 anos. Conclui-se que as esmerilhadeiras utilizadas na obra para o corte dos metais oferecem risco à saúde do trabalhador, sendo necessária a adoção de medidas corretivas.

Palavras-chave: VMB, corte de chapas metálicas, esmerilhadeiras, síndrome de Raynaud.

Resumen

Los estudios indican que la exposición excesiva a vibraciones puede causar daños al cuerpo humano.

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En consecuencia, el uso de herramientas rotativas puede entrañar riesgos para la salud de los operarios, especialmente si carecen de sistemas de amortiguación. El objetivo de esta investigación es cuantificar las vibraciones transmitidas al sistema mano-brazo (HAV) generadas por amoladoras angulares durante el corte de materiales metálicos. Para ello, se probaron tres modelos de amoladora cortando chapas de aluminio ASTM 1100 H14, acero al carbono SAE 1020 y acero inoxidable AISI 304L; los datos de vibración se recopilaron mediante un dosímetro Vib008. El análisis inferencial empleó la prueba de Kruskal-Wallis para muestras independientes para evaluar las HAV, seguida de la prueba U de Mann-Whitney para muestras independientes, con un nivel de confianza de $p < 0,05$. Los resultados de las HAV indican que, en el grupo ES-I, los niveles de vibración fueron de 12,33 m/s² (148 % por encima del límite de tolerancia) para el fabricante "A", 11,39 m/s² (127 % por encima del límite) para el fabricante "B" y 10,62 m/s² (112 % por encima del límite) para el fabricante "C". En el grupo ES-II, los niveles de HAV fueron de 7,55 m/s² (50 % por encima del límite) para el fabricante "A", 7,83 m/s² (56 % por encima del límite) para el fabricante "B" y 10,62 m/s² (38 % por encima del límite) para el fabricante "C". Los valores de aceleración en los ejes x, y y z, así como la aceleración total, indican niveles que superan el límite de tolerancia de 5 m/s². Según los resultados, los niveles de exposición a vibraciones del grupo ES-I podrían provocar el síndrome de Raynaud en el 10 % de los trabajadores expuestos en un periodo promedio de 2,5 años, y en 3,75 años para el grupo ES-II. Se concluye que las amoladoras utilizadas en el lugar de trabajo para el corte de metales representan un riesgo para la salud de los trabajadores, lo que hace necesaria la adopción de medidas correctivas.

Palabras clave: vibraciones mano-brazo (HAV), corte de chapa, amoladoras angulares, síndrome de Raynaud.

1. Introduction

Hand-arm vibration (HAV) exposure occurs when an individual handles a vibrating tool, such as a powered surgical instrument, floor polisher, jackhammer, riveting gun, motorcycle handlebar, or other tools (MANSFIELD, 2005 apud MEDEIROS, CATAI and ROMANO, 2024).

Various portable and motorized equipment are used in metal construction processes, exposing workers to vibration and posing health risks. A study indicated that among a group of 75 workers, 66% exhibited symptoms resulting from vibration exposure (COSTA at al., 2012).

Vibration is considered a harmful agent present in various work activities. Whole-body vibration (WBV) is generated by moving vehicles (buses, tractors, or agricultural machinery) and transmitted to the entire body, whereas HAV is generated

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by motorized tools (electric, combustion, or pneumatic) and absorbed by the hands and arms (BERNARD, 1997).

In the hands and arms, hazardous effects include episodic numbness tingling, finger blanching, pain, and reduced grip strength and dexterity (GRIFFIN, 1990).

It is estimated that nearly two million people worldwide are at risk due to vibration, which can lead to an inability to perform work effectivelym. Certain HAV effects have well-established occupational connections, such as secondary Raynaud's phenomenon (vibration-induced white finger), digital neuropathy, and carpal tunnel syndrome (PALMER and BOVENZI, 2015 apud MEDEIROS, CATAI and ROMANO, 2024).

The pathophysiological mechanisms in vibration-exposed workers are complex, but the response may represent an exaggerated central sympathetic vasoconstrictor reflex triggered by prolonged vibration exposure, along with local changes in digital vessels such as muscular wall thickening, endothelial damage, and functional receptor alterations (OLSEN, 1987).

Users of vibrating power tools often experience finger tingling. Initially, symptoms are transient and disappear quickly after use. However, prolonged high exposure levels can lead to persistent symptoms such as insomnia. In advanced stages, clinical examinations may reveal abnormalities in light touch, temperature sensation, and pinprick sensitivity (PALMER and BOVENZI, 2015 apud MEDEIROS, CATAI and ROMANO, 2024).

To assess hand-arm vibration over a period, the root mean square (r.m.s.) value was used as a function of time in the "j" direction, which may correspond to the orthogonal axes "x", "y", or "z". Alternatively, it can be the square root of the sum of the mean squares measured along the three orthogonal axes "x", "y", and "z". This can be obtained using a triaxial accelerometer, which integrates and provides the r.m.s. values.

The average acceleration was adopted, which is obtained by calculating the root mean square (r.m.s.) value of the signals from each sample. The discrete signals are calculated according to Equation 1.

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$$r.m.s\,(a_w) = \sqrt{\frac{1}{T}\int_0^T a_w^2\,(t)dt} \qquad [m/s^2] \qquad \text{Equation 1}$$

Where T is the duration of the measured exposure, and $a_w(t)$ is the frequency-weighted acceleration at time t.

The total vibration value (a_{hwx}) to which the arm system is exposed can be calculated using Equation 2 by taking the square root of the sum of the squares of the frequency-weighted accelerations a_{wx}, a_{wy}, and a_{wz} along the axes:

$$a_{hwx} = \sqrt{a_{wx}(8)^2 + a_{wy}(8)^2 + a_{wz}(8)^2} \quad [m/s^2] \qquad \text{(Equação 2)}$$

Where:

- ahvx is the total acceleration or the sum of the three axes;
- aw is the frequency-weighted acceleration of the “x”, “y”, and “z” axes;
- total vibration value in m/s².

The assessment of HAV is based on calculating the normalized daily exposure value for an 8-hour reference period, expressed as the square root of the sum of the squares — that is, the total value A(8) for an eight-hour workday. However, if the measured daily vibration exposure A(8) differs from an 8-hour duration, the equivalent exposure for an 8-hour period can be determined using the expression in Equation 3.

$$A(8) = a_{hv,eq}\sqrt{\frac{T}{T_0}} \qquad [m/s^2] \qquad \text{(Equation 3)}$$

Where:

- T is the total daily duration of vibration exposure;
- To is the reference duration of 8 hours (480 minutes).

The European Union adopts an action value of 2.5 m/s² and an exposure limit of 5.0 m/s², as established by Directive 2002/44/EC (EUROPEAN COMISSION, 2002), as shown in Table 1.

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Table 1. Acceleration values established by Directive 2002/44/EC

Action level A(8) – *Recommended*	**Exposure limit A(8)** – *Not acceptable*
>2.5 m/s²	>5.0 m/s²

Based on the daily exposure value of acceleration A(8) collected in the field, the working time during which 10% of workers may develop Raynaud's phenomenon due to exposure to hand-arm vibration (HAV) can be calculated using Equation 2,

$$D_y = 31.8 \times A_8^{-1.06} \text{ [years]} \qquad \text{Equation 2}$$

Where D_Y represents the number of years of exposure required for 10% of workers exposed to hand-arm vibration (HAV) to potentially develop Raynaud's phenomenon.

A (8) – Daily exposure normalized to an 8-hour period.

T - Total daily duration of exposure to vibration ahv,

T_0 - Reference duration of 8 hours (28,800 seconds).

Thus, ISO 5349-1 provides a predictability of the occurrence of HAVS over the years, allowing the Occupational Health and Safety sector to adopt mitigating measures for vibration in work activities (ISO, 2001).

2. MATERIALS AND METHODS

2.1. Tested Equipment

Three grinder models available in the workplace were randomly tested, GA-9020, D28491 and GWS-22-180, with the following nominal characteristics: 220 V electrical supply, 2200 W power, 6500 to 8500 rpm rotation, and a mass between 4200 g and 5800 g, according to the experimental design in Figure 1.

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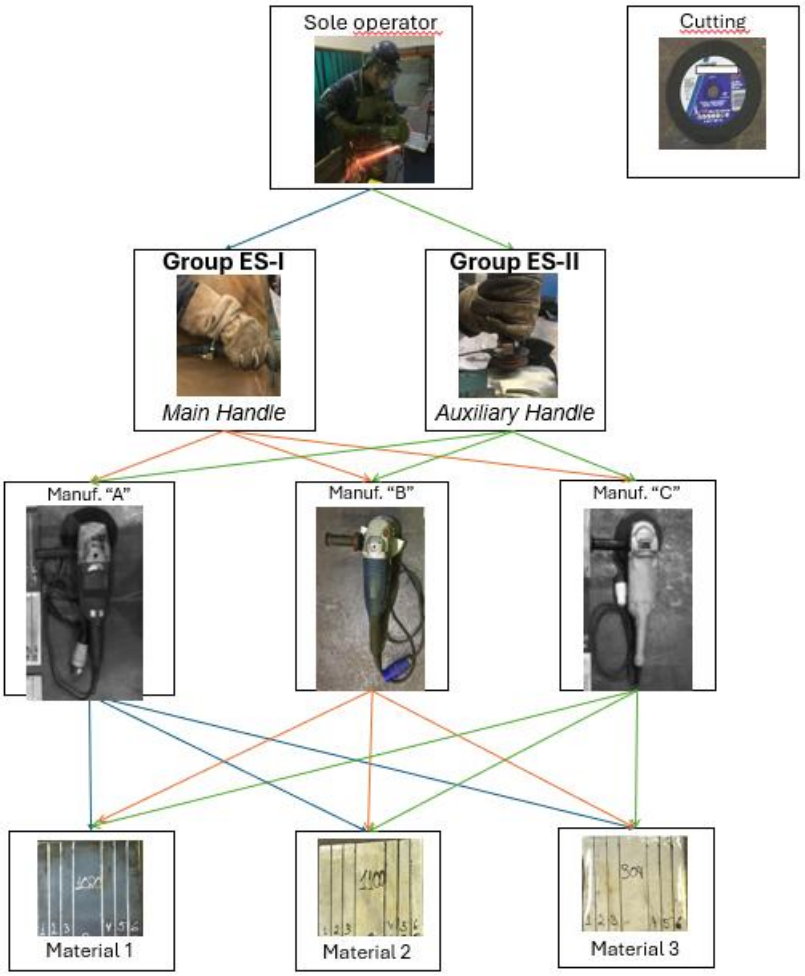

Figure 1. Experimental designer

Therefore, tests were conducted using four angle grinders from Manufacturer A (Makita), four from Manufacturer B (Bosch), and four from Manufacturer C (DeWalt). The equipment was operated by a single 55-year-old male with 20 years of experience as a boilermaker. Cuts were made on the three selected materials, with measurements taken at the main handle (Group ES-I) and the secondary handle (Group ES-II).

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2.2 Tested Materials

Twenty-seven plates measuring 250 mm x 250 mm with a thickness of 9.53 mm were prepared—featuring six 25 mm sections and a central 40 mm space for mounting—from three different materials: SAE 1020 carbon steel, ASTM 1100 H14 aluminum, and AISI 304L stainless steel; these were cut into 132 pieces with a minimum width of 50 mm. SAE 1020 carbon steel offers a favorable combination of strength and ductility and is widely used in the construction of metal structures. Aluminum is an extremely lightweight, soft, and versatile metal that exhibits high corrosion resistance (due to a natural protective oxide layer) as well as excellent thermal and electrical conductivity. Type 304 stainless steel is a versatile austenitic alloy composed of approximately 18% chromium and 8% nickel; it offers excellent corrosion resistance and is easily formed and welded (NUNES and KREISCHER, 2010). Thus, the study encompassed the three primary metals used in the mechanical construction and assembly industry.

ASTM 1100 H14 aluminum has a tensile strength of 105 MPa, a yield strength of 25 MPa, a minimum elongation of 22%, and a hardness of 23 HB. SAE 1020 carbon steel has a tensile strength of 405 MPa, a yield strength of 345 MPa, a minimum elongation of 131%, and a hardness of 131 HB. 304L stainless steel has a tensile strength of 770 MPa, a yield strength of 350 MPa, a minimum elongation of 65%, and a hardness of 160 HB.

2.3 Vibration Analyzer

To collect the vibration signal, the VIB008 occupational vibration dosimeter from the brand 01 dB was used, along with the tri-axial accelerometer model AP2042, also from 01 dB, with a sensitivity of (± 5%) and 0.661 mV/ms^2. This device captures the physical vibration signal and provides individual acceleration values along the x, y, and z axes.

For sensor coupling to the angle grinders, adapters provided by 1dB were used, attached to the main and auxiliary handles to ensure greater rigidity in the accelerometer mounting, as shown in Table 2.

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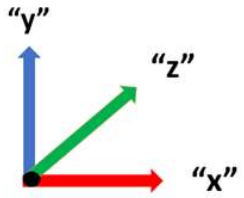
Table 2. Accelerometer Mounting on Tools – “x”, “y”, and “z” Axes

Work	**Group ES-I**	**Group ES-II**	*Axis Positions*
	Main Handle	*Auxiliary Handle*	
			

Thus, the positioning and mounting of the accelerometer were kept rigid for the execution of the tests.

2.4. Statistical Methods

Statistical analysis included median, standard deviation, and standard error calculations. The Shapiro-Wilk test was used to test sample normality, with a confidence level of $p < 0.05$. The Kruskal-Wallis test for independent samples and the Mann-Whitney U test for independent samples were used for inferential analysis.

Whenever necessary, the samples were stratified to determine the significance of the factors affecting vibrations within a specific frequency range. The statistical software SPSS (IBM© SPSS Statistics, version 22.0) was used to process the results.

3. RESULTS AND DISCUSSION

3.1. Safe use Acceleration Analysis – Group ES-II

The data presented in this study refers to total acceleration (A_t), which represents the actual vibration level to which the operator is exposed while cutting metal sheets. In Brazil, NR-15 (Unhealthy Activities and Operations), Annex 8, addresses whole-body and hand-arm vibration as unhealthy activities; the standard is based on calculating the daily exposure value normalized to an 8-hour reference period—accounting for other operator activities such as breaks, material preparation and clamping, and changing cutting discs on grinders—

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expressed as the root sum of squares, the A(8) value for an eight-hour shift, which is lower than the total vibration; Equation 3.

Since the study aims to evaluate the performance of the equipment (grinders), daily vibration exposure A(8) was set equal to the At (total acceleration) value; however, differences in operator skills—along with variations in tasks such as preparing and securing material, installing new cutting discs, and employer-mandated breaks—result in significant differences that make a direct comparison of the grinders unfeasible.

3.2. Total Acceleration Analysis A_t in Group ES-I

In group ES-I, 66 tests were analyzed: 22 cases using grinders from manufacturer “A” without a vibration reducer on the main handle, 22 cases using grinders from manufacturer “B”, and 22 cases using grinders from manufacturer “C”, with the accelerometer mounted on the main handle, as shown in Table 3.

Table 3. Sample Size of Group ES-I

Group	Manufacturers	Cases
ES-I	Manuf. “A”	22
	Manuf. “B”	22
	Manuf. “C”	22
	Total	66

In group ES-I, during the load tests involving metal cutting with grinders from manufacturer “A”, a total acceleration of 12.33 m/s² was estimated, with a standard deviation of 2.32 m/s² and a standard error of 0.49 m/s². When using tools from manufacturer “B”, the total acceleration was 11.39 m/s², with a standard deviation of 1.65 m/s² and a standard error of 0.35 m/s². With tools from manufacturer “C”, the total acceleration was 10.62 m/s², with a standard deviation of 1.13 m/s² and a standard error of 0.24 m/s², as shown in Figure 2.

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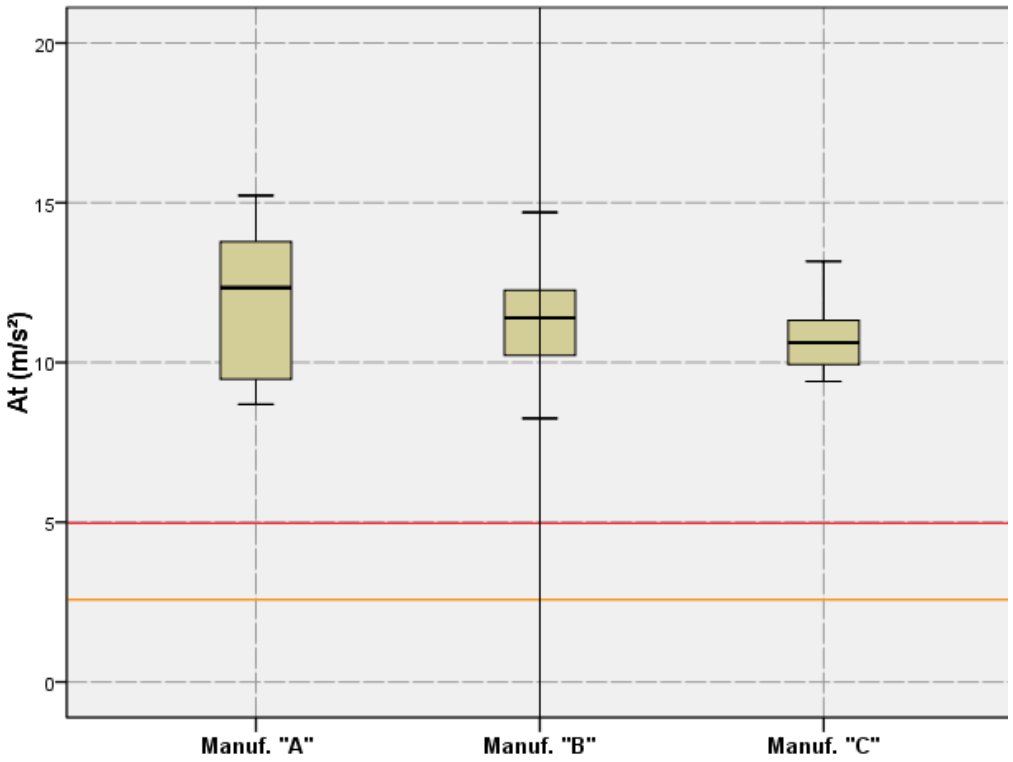

Figure 2. Boxplot of total acceleration A_t in group ES-I

Considering the worst-case scenario — where the total acceleration (At) over an eight-hour continuous workday, A(8). The total acceleration, A_t, during metal cutting with grinders from manufacturer “A” in no-load tests was estimated at 148% above the tolerance limit. Using grinders from manufacturer “B”, the total acceleration A(8) was estimated at 127% above the tolerance limit. With grinders from manufacturer “C”, the total acceleration A_t was estimated at 112% above the tolerance limit.

According to the European Community, the criterion adopted for measuring occupational vibration is total acceleration, with two threshold values for an A(8) workday: the action limit of 2.5 m/s² and the tolerance limit of 5.0 m/s².

Thus, HAV in grinders from manufacturers A, B, and C, assessed at the main handle, indicated high-risk situations (A(8) > 5.0 m/s²), requiring immediate intervention through the introduction of rest breaks for exposed workers, while awaiting the implementation of technical measures to reduce exposure conditions to

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below A(8) = 5.0 m/s². Table 4 presents the result of the Kruskal-Wallis test, with p = 0.32 at a 5% significance level; the null hypothesis was retained.

Table 4. Kruskal-Wallis Test Result for Group ES-I

Manufacturers	p-value	α	Decision
The distribution of acceleration A_t is the same among manufacturers “A”, “B”, and “C”	0,32	0,05	Null hypothesis retained

Therefore, according to the result of the Kruskal-Wallis test, there are no differences among the grinders from manufacturers “A”, “B”, and “C”.

Based on the weighted acceleration results, the maximum exposure time for circular saws from manufacturer “A” was calculated at 225 minutes, with a standard deviation of 53 minutes and a standard error of 11 minutes. Using tools from manufacturer “B”, the maximum exposure time was 210 minutes, with a standard deviation of 34 minutes and a standard error of 7 minutes. Using tools from manufacturer “C”, the maximum exposure time was 225 minutes, with a standard deviation of 22 minutes and a standard error of 5 minutes. Thus, the tools from manufacturers “A”, “B”, and “C” can be used for up to 3 hours of work.

For an estimated use of 480 minutes, according to the criteria of ISO 5349-1:2001[16] (ISO, 2001a), using the grinder from manufacturer “A”, the time until the onset of white finger syndrome (D_Y) was calculated at 2.6 years, with a standard deviation of 0.65 years and a standard error of 0.14 years. Using the grinder from manufacturer “B”, D_Y was calculated at 2.4 years, with a standard deviation of 0.41 years and a standard error of 0.08 years. Using the grinder from manufacturer “C”, D_Y was calculated at 2.6 years, with a standard deviation of 0.27 years and a standard error of 0.05 years, as shown in Table 5.

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Table 5. Results of Maximum Exposure Time and Dy for Group ES-I

Manufacturers	**Maximum Exposure Time (min)**	***Dy (years)***
Manuf. “A’	225	2.6
Manuf. “B”	210	2.4
Manuf. “C”	225	2.6

Therefore, when comparing the average D_Y for the grinders studied, group ES-I, according to ISO 5349-1:2001 (ISO, 2001b), using the Equation 2, the task of cutting metallic materials using grinders from manufacturers “A”, “B”, and “C” indicated a 10% risk of workers developing white finger syndrome within 2 years and 6 months.

According to Medeiros, Catai, and Romano (2024), the use of angle grinders equipped with vibration-damping systems indicated a 10% risk of workers developing white finger syndrome within four years.

This represents a 60% increase in the time it takes for the first symptoms of white finger syndrome to appear. While the tool market offers models both with and without damping systems—and despite the price difference—worker comfort and health must be considered when purchasing new equipment.

3.3. Acceleration Analysis – Group ES-II

Considering the worst-case scenario — where the total acceleration (At) over an eight-hour continuous workday, A(8). During metal cutting with grinders from manufacturer “A”, the total acceleration was estimated at 7.55 m/s^2, with a standard deviation of 1.36 m/s^2 and a standard error of 0.28 m/s². Using tools from manufacturer “B”, the total acceleration was 7.83 m/s², with a standard deviation of 0.43 m/s² and a standard error of 0.09 m/s². With tools from manufacturer “C”, the total acceleration was 6.91 m/s², with a standard deviation of 0.81 m/s² and a standard error of 0.17 m/s², as shown in Figure 3.

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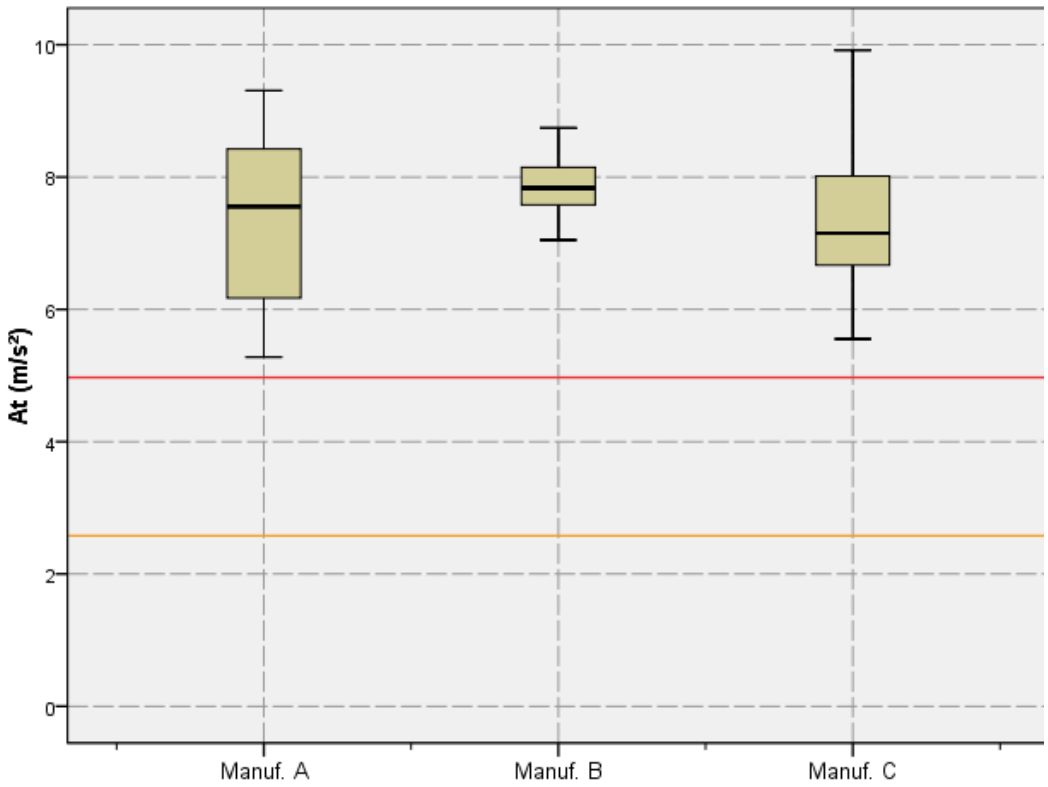

Figure 3. Boxplot of total acceleration A_t in group ES-II

The total acceleration A_t during metal cutting using grinders from manufacturer "A" in no-load tests was estimated at 50% above the exposure limit. With grinders from manufacturer "B", the total acceleration A(8) was estimated at 56% above the exposure limit. With grinders from manufacturer "C", the total acceleration A_t was estimated at 38% above the exposure limit.

Thus, HAV in grinders from manufacturers "A", "B", and "C", without vibration dampers and assessed at the auxiliary handle, indicated high-risk situations (A(8) > 5.0 m/s²), requiring immediate intervention through the introduction of rest breaks for exposed workers, while awaiting tools that reduce HAV to levels below A(8) = 5.0 m/s².

Table 6 presents the result of the Kruskal-Wallis test with p=0.03 at a 5% significance level; the null hypothesis was rejected.

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Table 6. Kruskal-Wallis Test Result for Group ES-II

Mounting Method	**p-value**	**α**	**Decision**
The distribution of total acceleration A_t is the same among manufacturers “A”, “B”, and “C”	0,03	0,05	Null hypothesis rejected

Therefore, according to the Kruskal-Wallis test result, differences were observed among the grinders from manufacturers “A”, “B”, and “C”.

For the “A” and “B” pair, the p-value was 0.99 on the “x” axis; 0.84 on the “y” axis; and 0.40 for A_t; the null hypothesis was retained. On the “z” axis, the p-value was 0.03; the null hypothesis was rejected. For the “A” and “C” pair, the p-values were 0.25 on the “x” axis, 0.45 on the “y” axis, 0.12 on the “z” axis, and 0.59 for A_t; the null hypothesis was retained for all variables. For the “B” and “C” pair, the p-values were 0.99 on the “x” axis, 0.84 on the “y” axis, and 0.31 for A_t; the null hypothesis was retained. For the variable a_{whz} on the “z” axis, the p-value was 0.3, as shown in Table 7.

Table 7. Results of the Mann-Whitney U Test for Group ES-II

Pairs	**a_{whx}**	**a_{why}**	**a_{whz}**	**A_t**	**Consideration**
Manuf. “A” vs Manuf. “B”	0.99	0.84	0.03	0.31	Null hypothesis retained for a_{whx}, a_{whx} and A_t; rejected for a_{whz}.
Manuf. “A” vs Manuf. “C”	0.25	0.45	0.12	0.59	Null hypothesis retained for all variables
Manuf. “B” vs Manuf. “C”	0.47	0.22	0.58	0.01	Null hypothesis retained for a_{whx}, a_{whx}, and a_{whz}; rejected for A_t.

Based on the weighted acceleration results, the maximum exposure time for circular saws from manufacturer “A” was calculated at 318 minutes, with a standard deviation of 64 minutes and a standard error of 13 minutes.

Using tools from manufacturer “B”, the maximum exposure time was 306 minutes, with a standard deviation of 17 minutes and a standard error of 4 minutes.

REMUNOM
ISSN 2178-6925

Received: 17/08/2026 - **Accepted:** 21/09/2026
Vol: 13.20
DOI: 10.66104/xw4avs62
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With tools from manufacturer “C”, the maximum exposure time was 335 minutes, with a standard deviation of 44 minutes and a standard error of 9 minutes. Thus, tools from manufacturers “A”, “B”, and “C” can be used for up to 4 hours of work.

According to the ISO 5349-1:2001 standard, the time until the onset of white finger syndrome using grinders from manufacturer “A” is 3.72 years, with a standard deviation of 0.81 years and a standard error of 0.17 years. With grinders from manufacturer “B”, it is 3.58 years, with a standard deviation of 0.21 years and a standard error of 0.04 years. With grinders from manufacturer “C”, it is 3.95 years, with a standard deviation of 0.58 years and a standard error of 0.12 years, as shown in Table 8.

Table 8. Results of Maximum Exposure Time and Dy for Group ES-II

Manufacturers	**Maximum Exposure Time (min)**	***Dy (years)***
Manuf. “A’	317	3.72
Manuf. “B”	306	3.58
Manuf. “C”	335	3.95

Therefore, when comparing the average Dy for the grinders studied, group ES-II, according to ISO 5349-1:2001, using the Equation 2, the task of cutting metallic materials using grinders from manufacturers “A”, “B”, and “C” indicated a 10% risk of workers developing white finger syndrome within 4 years.

Thus, under these conditions and in accordance with the European Directive 2002/44/EC (EC, 2002), corrective measures should be adopted, such as limiting the daily usage time of grinders by workers, changing manufacturing processes, and implementing preventive measures like conducting regular occupational health exams. Monitoring the health of workers, given the risk of HAVS, allows for early identification of health issues and, through temporary removal from exposure, helps reduce damage caused by HAVS.

REMUNOM
ISSN 2178-6925

Received: 17/08/2026 - **Accepted:** 21/09/2026
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DOI: 10.66104/xw4avs62
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4. CONCLUSIONS

The study confirmed that weighted acceleration values exceed the tolerance limit, making it impossible to comply with Directive 2002/44/EC without implementing engineering modifications to the product and/or process.

The results indicate that weighted acceleration per x, y, and z axes remained below 1.65 m/s², not causing health issues related to occupational vibration exposure. However, during metal cutting, acceleration values in the x and y axes were found to be twice the action limit and close to the tolerance limit.

The Kruskal-Wallis test for independent samples on the x, y, and z axes indicates that the accelerations on the left hand (handle) are similar. The task of cutting metallic materials presents a similar risk to workers' health. This demonstrates that the weighted acceleration on the x, y, and z axes exceeds both the Action Limit and the Exposure Limit.

Analysis of weighted acceleration in the x, y, and z axes in the main handle shows that vibration in the y-axis is twice as high as in the x and z axes, posing a greater health risk. Median weighted acceleration values in the y-axis remained above 11 m/s², which is 200% higher than the tolerance limit. The Kruskal-Wallis test confirmed no significant differences in acceleration between the x, y, and z axes.

Total acceleration in the left hand (handle) was measured at 7 m/s², 140% above the tolerance limit of 5.0 m/s². Analysis of total acceleration in the right hand (key) indicates that values exceeded the tolerance limit even under no-load conditions. During metal cutting, total acceleration exceeded 12 m/s², 250% above the tolerance limit established by Directive 2002/44/EC.

These findings confirm that controlling grinder usage time is necessary to mitigate HAV exposure risks. Even with the replacement of grinders with anti-vibration systems, the risk of HAVS remains.

Declarations

Conflict of Interest: The authors declare that they have no conflict of interest.

REMUNOM
ISSN 2178-6925

Received: 17/08/2026 - **Accepted:** 21/09/2026
Vol: 13.20
DOI: 10.66104/xw4avs62
Pages: 1-18

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