QUANTIFICATION AND COMPARISON OF SELECTED MATERIAL PROPERTIES FOR ANTI-FATIGUE MATS TO INVESTIGATE VIBRATION TRANSMISSION REDUCTION POTENTIAL

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1. INTRODUCTION

It is common for workers in many industries to experience vibration transmitted to the feet while standing. It has recently been suggested that this exposure can lead to a condition beginning to be known as vibration induced white foot[1]. Vibration induced white finger or hand-arm vibration syndrome (HAVS), which is common in occupations such as mining, forestry and construction, results in many of the same symptoms in the hands that can be observed in the lower extremities in the case of vibration induced white foot. Although vibration at the feet can be considered to be whole-body vibration (WBV), the effects can have more in common with HAVS[2] particularly if the dominant frequency of the foot-transmitted vibration is in the range known to be associated with the development of HAVS.

Anecdotal evidence has suggested that the use of anti-fatigue mats may be beneficial in reducing vibration exposure to the feet; however, little is known about the mat material properties in the context of vibration reduction. Therefore, the purpose of this preliminary study was to quantify selected material properties. These can be used to determine vibration properties using 2 physiologically-based loads and loading rates for 5 commonly used anti-fatigue mats, to begin to determine if they could be successful in reducing vibration transmission.

2. METHODS

The mats tested included:

1. 3M Safety-Walk Cushion Matting 5100 (3M, Canada),
2. Tilecote Sponge Mat (Style 46948, Seton, Canada),
3. KMB-1100 General Purpose Mat with Bevel Edge (GO Resiliant, Canada),
4. 3M Nomad Scraper Matting 8150 Backed (3M, Canada) and
5. 3M Nomad Scraper Matting 8100 Unbacked (3M, Canada).

Twenty-four, approximately equal small samples were cut from each mat and weighed. Samples were then compression tested using an Instron universal testing machine (Model 4204, Instron, Norwood, MA) (Figure1). Each sample was tested at one of two speeds ramping up to one of two maximum forces. The slow speed (0.000833 m/s) was chosen to represent how a mat would be loaded if a subject stepped onto it slowly. The fast speed (0.005 m/s) was chosen because it was the highest speed the Instron could produce without overshooting the maximum force constraints, and was intended to represent the loading on a mat of a subject stepping onto it quickly. The low and high forces were selected to represent 0.5(Body Weight) and 1.5(Body Weight) for a 50 percentile sized male, respectively. The two maximum forces were determined by finding the area of the sole of a shoe that would be in contact with the ground for a 50 percentile sized male. This, together with the Body Weight of a 50 percentile male, was used to determine how much force should be placed on the mat samples based on the cross sectional area of the compression platen being used.

Testing was randomized on the basis of speed, force and mat type in order to avoid order effects. The variables determined for each sample included Young's Modulus (E) (MPa), stiffness (k) (kN/m), natural frequency (fn) (Hz) and displacement (Δd) (mm).

Figure 1. Experiment Setup

3. RESULTS

Means and standard deviations for all variables and experiment conditions are presented in Table 1. Factorial ANOVA (Minitab 16, State College, PA) results revealed significant differences ($p \leq 0.05$) between mats and speeds for all variables. Bonferroni post-hoc procedures revealed that the faster speed resulted in higher values for E, Δd, k and fn whereas the higher force condition resulted in larger Δd. The following differences were observed between mats (numbers refer to mat types defined in the methods):

E	(3,2)>(1,4,5);
Δd	5>(1,4,3,2); 1>(4,3,2); 4>(3,2);
k	3>(2,1,4,5); 2>(1,4,5);
fn	3>(2,1,4,5); 2>(1,4,5).

A number of significant two-way interactions were observed. A (mat type)*(speed) interaction was found for E, k and fn, whereas a (mat type)*(force interaction) was observed for Δd. These interactions revealed that mat types do not all follow the same trend for different loading speeds and forces.

4. DISCUSSION AND CONCLUSIONS

Further work is needed but the results from this study suggest that some mats may be better than others at reducing vibration transmission to the feet. This study showed that when mats were compressed at a higher speed, they exhibited higher stiffness. It stands to reason that when a material is compressed faster, it will provide more resistance. It was also determined that at a higher force, all mats showed a larger displacement. The 3M Safety-Walk showed the highest stiffness followed by the GO Resilient mat. While the higher stiffness results in a higher fn, this may not always be desirable depending on how the mat will be used. As an example, a worker standing on a mat for long periods of time may wish to have a less stiff mat from a comfort perspective. While the predicted resonant frequencies of the mats were all well above the known resonant frequencies of the ankle (4-8 Hz, 12.5 Hz and 25-63 Hz[3]) and the whole body (9-16 Hz[4]), it would be none the less important to know the vibration characteristics of the input vibration to the matting in order to avoid using a mat whose resonant frequency is the same as the input vibration. Given the viscoelastic nature of the mats, future work is needed to quantify damping, stress relaxation and creep properties.

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Table 1. Young's Modulus (E), Stiffness (k), Displacement (Δd) and Natural Frequency (fn) expressed by Mat Type, Force (Low=0.5*50th%ile Male Body Weight; High=1.5*50th%ile Male Body Weight) and Speed (Slow=0.000833 m/s; Fast=0.005 m/s) (n=3) (mean±SD)

Mat Type	Force	Speed	E (MPa)	k (kN/m)	Δd (mm)	fn (Hz)
Seaton Tilecote Sponge Mat	Low	Slow	1.07 ± 0.07	460.89 ± 55.32	5.36 ± 0.53	193.80 ± 11.87
		Fast	4.16 ± 3.17	1773.83 ± 1449.77	5.83 ± 0.37	360.73 ± 148.97
	High	Slow	1.45 ± 0.61	610.96 ± 217.94	7.29 ± 0.18	221.21 ± 38.33
		Fast	4.60 ± 1.46	2032.99 ± 645.11	7.68 ± 0.16	403.78 ± 67.69
GO Resilient KMB-1100	Low	Slow	11.46 ± 2.49	3544.86 ± 851.83	1.03 ± 0.06	504.21 ± 59.29
		Fast	33.21 ± 19.03	12558.50 ± 8034.61	1.83 ± 0.04	910.41 ± 346.62
	High	Slow	7.50 ± 1.55	2631.06 ± 946.99	1.66 ± 0.24	432.00 ± 75.58
		Fast	36.71 ± 17.24	12078.33 ± 6247.00	2.11 ± 0.22	915.67 ± 231.57
3M Safety-Walk Cushion Matting	Low	Slow	14.56 ± 9.43	7041.39 ± 2509.66	0.91 ± 0.23	775.23 ± 135.02
		Fast	56.40 ± 14.75	21908.34 ± 5244.35	2.01 ± 0.52	1374.00 ± 172.30
	High	Slow	17.55 ± 1.05	6657.71 ± 497.57	1.68 ± 0.16	761.03 ± 28.74
		Fast	34.57 ± 13.22	13597.99 ± 5176.55	2.45 ± 0.28	1072.93 ± 222.02
3M Nomad Scraper Matting 8150	Low	Slow	0.33 ± 0.17	152.37 ± 15.17	5.21 ± 0.13	129.71 ± 6.38
		Fast	1.87 ± 0.20	706.41 ± 24.85	4.87 ± 0.15	279.48 ± 4.92
	High	Slow	0.99 ± 0.37	403.83 ± 134.27	6.56 ± 0.45	209.28 ± 35.99
		Fast	3.74 ± 1.07	1404.08 ± 459.29	7.34 ± 0.24	390.09 ± 68.29
3M Nomad Scraper Matting 8100	Low	Slow	0.44 ± 0.13	129.35 ± 29.39	5.50 ± 0.56	123.71 ± 14.58
		Fast	1.05 ± 0.30	393.58 ± 124.76	6.05 ± 0.59	214.75 ± 36.40
	High	Slow	0.76 ± 0.06	238.32 ± 19.95	8.85 ± 0.53	168.60 ± 6.98
		Fast	2.50 ± 0.16	832.57 ± 75.39	8.36 ± 0.25	315.09 ± 14.43