Chapter 5

WBV Measurement of HEMM Operators

5.1 Introduction

The selction of study dite, subjects and procedure for WBV measurement of the HEMM operators from four opencast coal mines are presented in the last chapter. WBV measurement of the HEMM operators in the field using Human Vibration Analyzer is presented in this chapter. The calculations of WBV, daily vibration exposure, daily vibration dose value are explained. The processing of post-vibration measurement data was done using Vibration Explorer software, which is explained here. The ISO 2631- 1: 1997 and health risk evaluation is also explained in this chapter.

5.2 Calculation of WBV

Assessment of WBV and health risk was conducted in accordance with the procedures and guidelines outlined in ISO 2631-1 [32]. According to this guideline, frequency-weighted root mean square (r.m.s.) acceleration and VDV were calculated in three orthogonal axes. In order to assess the vibration which takes place in more than one direction simultaneously, ISO 2631 suggests that effect of such vibration can be calculated by considering the vector sum, a_{wv}, of three orthogonal axes. Appropriate frequency-weighting curves for axes and thereafter scaling factors for health (Kx = Ky = 1.4 and Kz = 1) were applied to each orthogonal axis. The absence or presence of transient vibration, also called shock, was evaluated by calculating the peak accelerations in orthogonal axes, which gives the crest factor. The crest factor is the ratio between the maximum peak value and the r.m.s. value for the measurement period. The more impulsive (or more random) a vibration, higher is its crest factor. Impulsive vibrations are considered to be more hazardous than non-impulsive ones. Thus, the crest factor is a good indicator of the level of harmfulness of the vibration. VDV is considered whenever the value of the crest factor exceeds 9.0.

5.2.1 Calculation of daily vibration exposure, A(8)

The frequency-weighted r.m.s. acceleration (a_w in m/s^2) values in *x*, *y*, and *z*-axes were calculated using Eq. (1) in accordance to ISO 2631-1[61]:

$$a_w = \sqrt{\frac{1}{T}\int_0^T a_w^2(t)\,dt} \tag{5.1}$$

where, $a_w(t)$ = frequency-weighted r.m.s. acceleration at time t.

The daily exposure *A*(8) was estimated from the r.m.s. acceleration in the dominant axis for the time period T. Its unit is m/s^2.

$$A(8) = a_{wd}\sqrt{\frac{T}{8}} \tag{5.2}$$

where, a_{wd}= frequency-weighted r.m.s. acceleration along dominant axis.

5.2.2 Calculation of crest factor (CF)

$$CF= \frac{\max(a_w(t))}{a_w} \tag{5.3}$$

where $\max(a_w(t))$ = maximum instantaneous peak value of the r.m.s. acceleration, a_w = frequency-weighted r.m.s. acceleration. CF is unitless.

5.2.3 Calculation of daily vibration dose value, VDV(8)

The vibration dose values (unit in m/s$^{1.75}$) in *x*, *y*, and *z*-axes were calculated using Eq. (5.4) in accordance to ISO 2631-1[61]:

$$\text{VDV} = \sqrt[4]{\int_0^T a_w^4\,(t)dt} \tag{5.4}$$

where $a_w(t)$ = frequency-weighted r.m.s. acceleration at time t,

T = measurement duration.

The daily VDV exposure for 8-hour in a working day denoted as VDV(8) was calculated using Eq. (5.5) in accordance to the ISO 2631-1. Its unit is $m/s^{1.75}$:

$$\mathbf{VDV(8)} = \boldsymbol{K_d} \times \mathbf{VDV}_{\boldsymbol{d}} \sqrt[4]{\frac{\mathbf{T_0}}{\mathbf{T_{meas}}}}$$

(5.5)

In Eq. (5.5),

K_d= k-factor of dominant axis

VDV_d = vibration dose value in dominant axis

T_0 = reference duration of 8 hours

T_{meas} = time duration over which the VDV was measured

5.3 Vibration Explorer Software

Vibration Explorer Software BZ-5623, included with Human Vibration Analyzer, Type 4447, enables the transfer of results to a PC and subsequent data manipulation. In Vibration Explorer one works with projects. A project consists of two main parts:

(i) Collection of raw measurement data. The data can be directly imported from Vibration analyzer type 4447 or taken from already existing project files. Raw data can be total measurements or logged data. The measurements only contain a set of data for each axis for the entire elapsed measurement time. In contrast, logged data provides a history of the measured vibration event in 1 s intervals. For each second, the r.m.s., VDV and Peak value are stored for each axis.

(ii) Model for the daily vibration exposure of workers. In this part of the project, the measurement data are combined and exposure durations are assigned, based on which Vibration Explorer will determine the daily exposure and indicate whether this exceeds the action or limit values given by legislation.

5.4 Results of WBV Measurement

Comparative data for the three groups of operators are given in Table 5.1

Table 5.1 Comparison of WBV exposure of 3-groups of HEMM operators

HEMM operator	N	Vibration parameter	Mean	Median	SD	Min	Max
Dumper operator	110	A(8), m/s^2	0.87	0.85	0.19	0.45	1.37
		VDV(8), $m/s^{1.75}$	24.49	23.70	5.05	14.23	36.75
		CF_Z	9.39	8.69	2.64	5.94	21.13
Drill operator	20	A(8), m/s^2	0.36	0.34	0.27	0.13	1.19
		VDV(8), $m/s^{1.75}$	14.71	12.38	13.53	3.22	49.91
		CF_Z	11.74	8.90	9.19	4.67	42.22
Shovel operator	20	A(8), m/s^2	0.43	0.36	0.14	0.29	0.78
		VDV(8), $m/s^{1.75}$	12.58	10.99	3.71	8.59	20.77
		CF_Z	9.66	9.13	3.84	6.36	23.20

Comparision of A(8) values for the three category of vehicle operators is presented in Fig. 5.1 through box plotting. It is observed that maximum median A(8) value (0.85) is for dumper operators and minimum median A(8) value (0.34) is for drill operators.

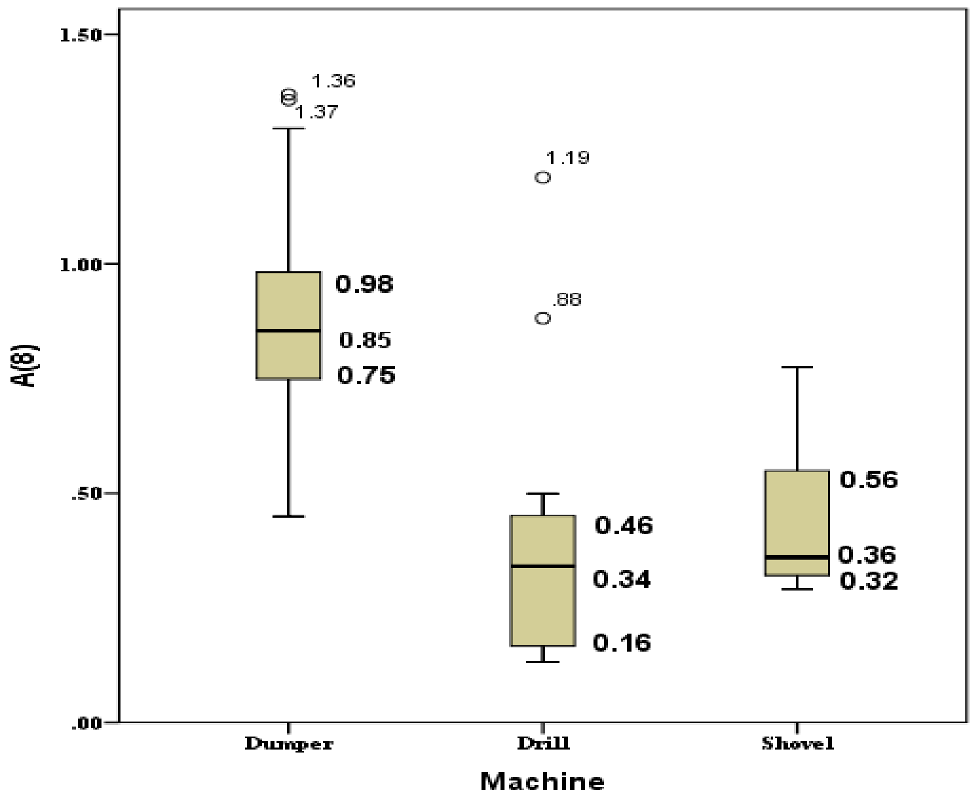

Figure 5.1 Comparison of A(8) values of HEMM operators

Comparision of VDV(8) values for the HEMM operators is presented through box plotting in Fig. 5.2. It is found that maximum median VDV(8) value (23.70) is for dumper operators and minimum median VDV(8) value (10.99) is for shovel operators.

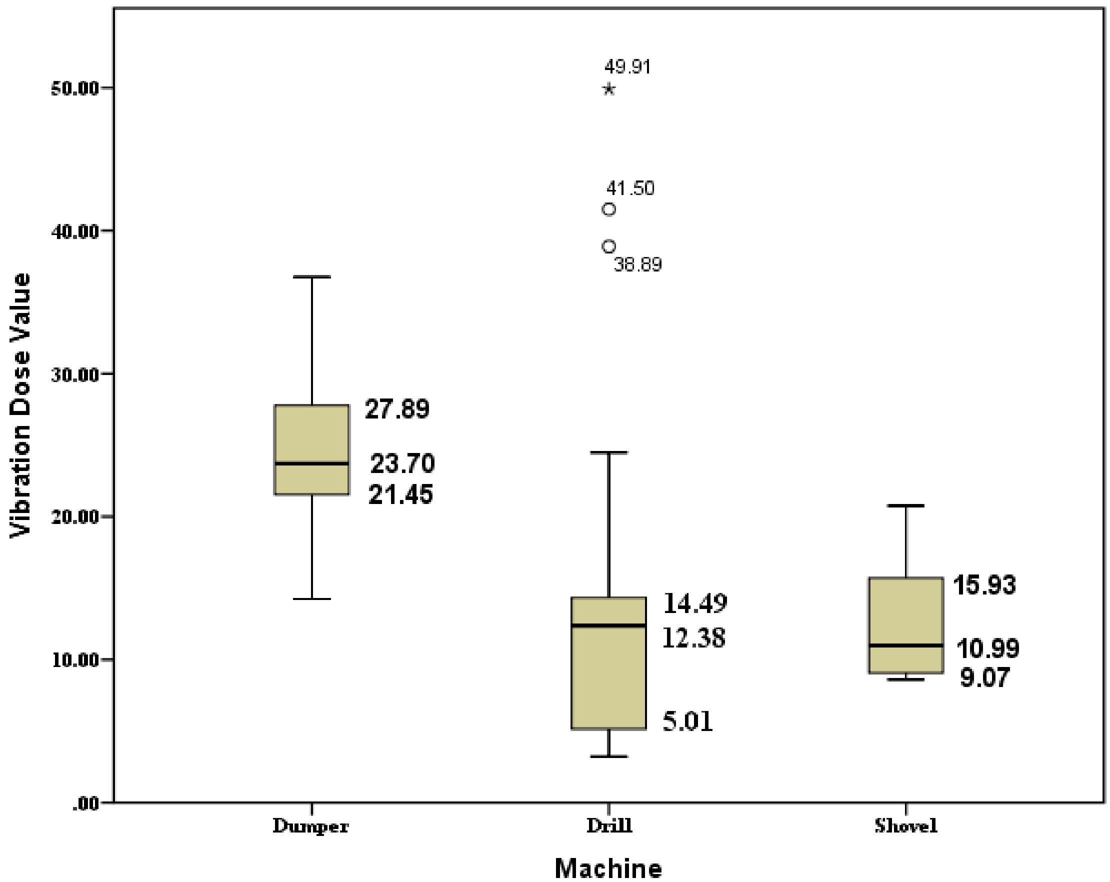

Figure 5.2 Comparison of VDV(8) values of HEMM operators

Crest factor for HEMM operators are presented in Fig. 5.3. It is found that maximum median CF value (6.13) is for dumper operators and minimum median CF value(8.69) is for shovel operators.

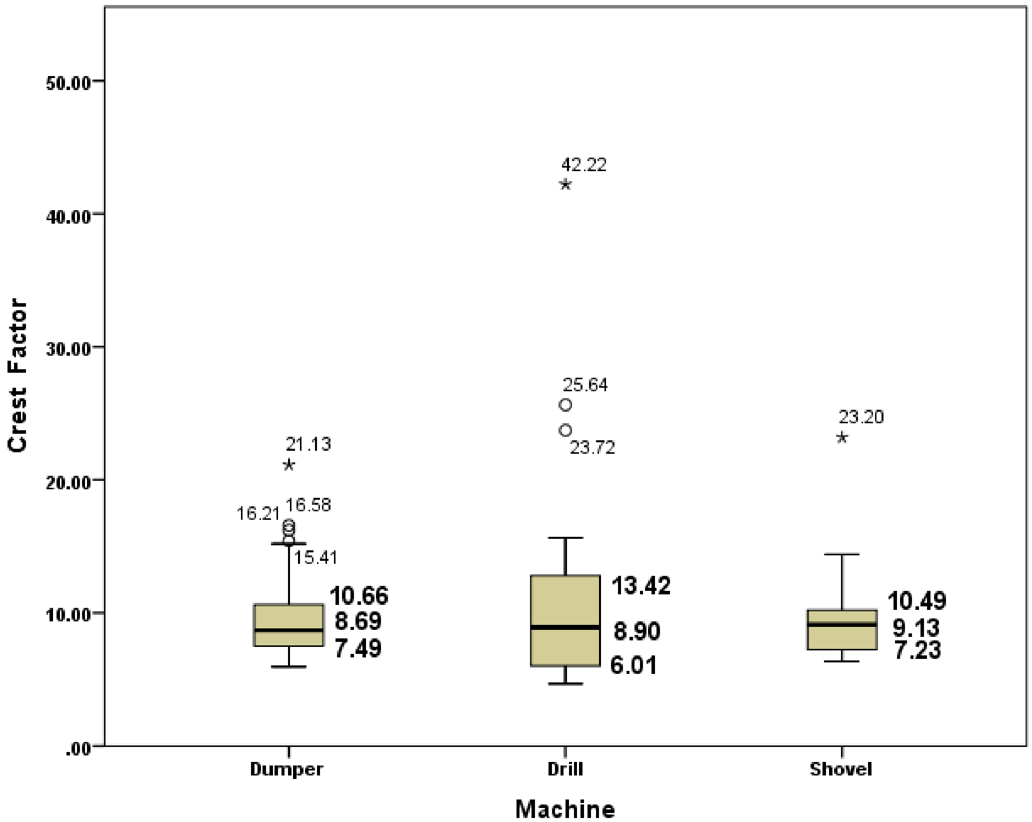

Figure 5.3 Comparison of crest factor of HEMM operators

5.5 Evaluation of Health Risks Based on ISO 2631-1(1997) Criteria

Table 5.2 summarizes the percentage of health risks of the case group based on HGCZ of ISO standard 2631-1:1997 [61], as mentioned in Table 2.6. It shows that 38% operators of the case group is exposed to likely health risk, i.e., above the upper limit of HGCZ based on A(8) value, daily frequency-weighted r.m.s. acceleration, and 61% operators are exposed to potential health risk. However, based on VDV(8), daily exposure in terms of vibration dose value, 94% operators are exposed to likely health risk, i.e. above the upper limit of HGCZ, and 6% operators are exposed to potential health risk.

Table 5.2 Percentage of subjects based on the HGCZ of ISO 2631-1: 1997

HEMM Operator	Total Number	Vibration Parameter	% of subjects at no health risk	% of subjects at potential health risk	% of subjects at likely health risk
Dumper	110	A(8)	1	61	38
		VDV(8)	0	6	94
Drill	20	A(8)	75	20	5
		VDV(8)	40	40	20
Shovel	20	A(8)	65	35	0
		VDV(8)	0	85	15

5.6 Discussion on WBV Measurement of Three Groups of Operators

It is observed from the vibration magnitude that the dumper operators of the coal mines are highly (likely) exposed to WBV compared to drill and shovel operators. The shock components were also found highest among dumper operators. The vibration exposure was lowest among drill operators. Based on the HGCZ, 94% dumper operators, 20% drill operators, and 15% shovel operators are subjected to likely health risk. The vibration magnitude is maximum in z-axis for HEMM operators.

5.7 Summary

The WBV measured according to ISO 2631-1:1997 is presented in this chapter. Calculation of A(8) and V(8) are explained. The data retrieving using Vibration Explorer software is elaborated. The comparison of WBV exposure of three groups of HEMM operators is tabulated and illustrated using box-plot. Based on the HGCZ as stated in ISO 2631-1:1997, 94% dumper operators, 20% drill operators and 15% shovel operators are subjected to likely (i.e., high) health risk. The next chapter explains the health risks concerning to the discomfort survey of the HEMM operators to understand the body regions those are likely to be affected by the WBV exposure.