

Table of Contents

Contents

Table of Contents	v
List of Figures	viii
List of Tables.....	ix
List of Symbols	xi
ABSTRACT	xii
Chapter 1: Introduction	1
1.1 Introduction	1
1.2 Scope of Research	3
1.3 Objectives of the Research.....	3
1.4 Organization of the Thesis	4
Chapter 2 : Literature Review	5
2.1 Introduction	5
2.2 Basics of Mechanical Vibration Analysis.....	5
2.3 Whole-Body Vibration.....	9
2.3.1 Magnitude.....	10
2.3.2 Frequency.....	10
2.3.3 Direction.....	11
2.3.4 Duration	11
2.3.5 Variation with time	12
2.4 Effect of WBV on Equipment Operators	12
2.5 Investigation on WBV in Mines	14
2.5.1 WBV exposure of dumper operators	16
2.5.2 WBV exposure of shovel operators.....	18
2.5.3 WBV exposure of drill machine operators.....	19
2.6 Effect of WBV on Human Health.....	21
2.7 Standards for WBV Measurement	22
2.7.1 History of development of ISO 2631-1:1997 Standards	24
2.7.2 ISO 2631-1:1997 Standard	25

2.7.3	History of development of European Union (EU) Directive 2002/44/EC.....	28
2.7.4	European Union Directive 2002/44/EC.....	29
2.8	Research Works on Prevention of WBV	29
2.9	Human Vibration Analyzer	35
2.9.1	Sensors and transducers used in Human Vibration Analyzer	35
2.9.2	Transducers	39
2.9.3	Accelerometers technology	41
2.10	Specification of Accelerometers	42
2.11	Research Gap	42
2.12	Summary	42
	Chapter 3 : Methodology	44
3.1	Introduction.....	44
3.2	Development of Methodology	44
3.3	Measurement of WBV Using Human Vibration Analyzer.....	46
3.4	Development of Questionnaire	48
3.5	Contributing Factors Affecting Whole-Body Vibration	49
3.5.1	Personal factors.....	50
3.5.2	Health-related factors.....	50
3.5.3	Machine related factors.....	52
3.6	Questionnaire for Discomfort Survey.....	53
3.7	Questionnaire for Case–Control Study	53
3.8	Statistical Methods.....	54
3.8.1	Case–control study.....	54
3.8.2	Correlation	57
3.9	Summary	58
	Chapter 4 : Case Study.....	59
4.1	Introduction.....	59
4.2	Case Study Mines and Field Visits	59
4.3	Data Collection.....	61
4.3.1	Study sites	61
4.3.2	Study subjects	61
4.4	Summary	63
	Chapter 5 : WBV Measurement of HEMM Operators	64
5.1	Introduction.....	64
5.2	Calculation of WBV.....	64

5.2.1	Calculation of daily vibration exposure, A(8)	65
5.2.2	Calculation of crest factor (CF).....	65
5.2.3	Calculation of daily vibration dose value, VDV(8).....	65
5.3	Vibration Explorer Software	66
5.4	Results of WBV Measurement.....	67
5.5	Evaluation of Health Risks Based on ISO 2631-1(1997) Criteria	70
5.6	Discussion on WBV Measurement of Three Groups of Operators.....	71
5.7	Summary	71
	Chapter 6 : Discomfort Survey	73
6.1	Introduction	73
6.2	Method	73
6.3	Discomfort Index (DI) Calculations.....	74
6.4	Results and Analysis	77
6.4.1	Effect of WBV on different parts of the body of the operators.....	78
6.4.2	Correlation analysis of HEMM operators.....	79
6.5	Summary	82
	Chapter 7 : Case–Control Study.....	83
7.1	Introduction	83
7.2	Study Design	83
7.3	Methods.....	84
7.4	Findings of Questionnaire Study.....	84
7.5	Characteristics of WBV Exposure	87
7.6	Results of Logistic Regression.....	87
7.7	Summary	89
	Chapter 8 : Conclusions	90
8.1	Introduction	90
8.2	Conclusions	90
8.3	Suggestion for Future Works	93
	References	94
	List of Publications	105

List of Figures

Figure 2.1 Sinusoidal vibration.....	6
Figure 2.2 Damped forced vibration in mechanical systems.....	7
Figure 2.3 Free body diagram of damped forced vibration system.....	8
Figure 2.4 Types of dumpers	18
Figure 2.5 Types of shovels.....	19
Figure 2.6 Types of drill machines	21
Figure 2.7 Method of evaluation and assessment of WBV according to HGCZ.....	26
Figure 2.8 Health Guidance Caution Zone of ISO	27
Figure 2.9 Line diagram of seatpad of human vibration analyser	38
Figure 3.1 Flowchart of the research work.....	45
Figure 3.2 Human vibration analyzer, Type 4447	46
Figure 3.3 Positioning of seatpad accelerometer on dumper operator's seat	47
Figure 5.1 Comparison of A(8) values of HEMM operators.....	68
Figure 5.2 Comparison of VDV(8) values of HEMM operators.....	69
Figure 5.3 Comparison of crest factor of HEMM operators.....	70
Figure 6.1 Body points and regions.....	75
Figure 6.2 Discomfort percentage and MMI for body regions of HEMM operators	77

List of Tables

Table 2.1 Investigation on WBV in mines	15
Table 2.2 Investigation of WBV exposure on dumper operators	16
Table 2.3 Investigation on drill operators	20
Table 2.4 Some parameters in the context of human response to vibration	22
Table 2.5 WBV exposure limits and their HGCZ as per ISO 2631-1:1997	28
Table 2.6 European Union Directive 2002/44/EC.....	29
Table 2.7 Accelerometer specification	42
Table 3.1 Factors and contributing parameters.....	49
Table 3.2 Personal factors of operators exposed to WBV.....	50
Table 3.3 Health-related factors of equipment operators exposed to WBV.....	51
Table 3.4 Machine related factors.....	52
Table 3.5: Contingency table of dichotomous variables with coding 0 and 1	56
Table 4.1 Method of working and machine deployment in the case study mines.....	60
Table 4.2 Distribution of total number of data collected from the mines.....	62
Table 5.1 Comparison of WBV exposure of 3-groups of HEMM operators	67
Table 5.2 Percentage of subjects based on the HGCZ of ISO 2631-1: 1997	71
Table 6.1 Distribution of discomfort in various body regions.....	78
Table 6.2 Correlation matrix for dumper operators	80
Table 6.3 Correlation matrix for drill operators	81
Table 6.4 Correlation matrix for shovel operators.....	81
Table 7.1 Descriptive statistics of personal factors of operators	85
Table 7.2 Summary of the case and control groups.....	86

Table 7.3 WBV at work posts of case group	87
Table 7.4 Results of logistic regression analysis	88