Research on the optimization method of selecting hearing protectors in power station

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Abstract. In order to explore the noise reduction effect and application of different hearing protectors in different workplaces in a power station, so as to facilitate to select differently suitable hearing protectors to staff based on needs. This paper uses principal component analysis and evaluation according to the insertion loss test results of 112 kinds of hearing protectors. Combined with the field test results of 10 workplaces in a power station, it is found that 112 kinds of hearing protectors mostly are suitable in 7 working places. People need to select suitable hearing protectors specifically in other 3 places. At the same time, this paper can provide reference for the selection of hearing protection in other different working places.

Keywords: power station, hearing protectors, principal component analysis.

1. Introduction

With the deepening of reform and opening up and the rapid development of the national economy, the construction of power station has also entered a period of rapid development. Because the power station has the characteristics of high water head, large capacity, high speed of the unit, two-way operation of water flow and changing frequency of working conditions, the noise is quite obvious, which will have a great impact on the personnel working in the factory area. Long-term work is highly likely to lead to permanent hearing loss and even severe occupational deafness in a high-noise environment without effective protection [1, 2]. At present, many countries have listed occupational deafness as one of the important occupational diseases [3, 4]. Therefore, people working in the high noise area of power station need hearing protection to avoid the risk of hearing loss. In this paper, we tested the insertion loss of 112 kinds of hearing protectors on the market, then we picked out the more suitable hearing protectors in 10 kinds of workplaces in the power station using principal component analysis method. At present, there are many kinds of hearing protectors that can be purchased, workers have some confusion when choosing them, and they often cannot find the most suitable hearing protectors. In order to help workers make the best choice according to the needs of the workplace and protect their hearing, this research work has been carried out.

2. Characteristics and analysis of power station noise

In this paper, there are different workplaces in this power station, the environment noise is measured separately in order to fully understand the noise situation of power station and select the best noise protection equipment. The noise exposure value in the working place is mainly measured, and the test time is from March 21th to March 23th in 2018. Under the operating condition of each unit, the ventilation facilities should operate normally. The noise level of the operating condition of each unit are shown in Table 1.

From Table 1, it can be seen that there are 10 testing places which are more than 85 dBA. The spectrum measurement and analysis of the 10 workplaces under operating conditions are shown in Fig. 1.

Table 1. The noise level of the operating condition of each unit

No.	Workplaces	Testing places	dB(A)	No.	Places	Points	dB(A)
1	Generator layer	#1 Generator layer	78.4	18	Water turbine layer	#1 Outdoor water turbine	85.2
2		#1 Generator interior	94.6	19		#1 Indoor water turbine	93.6
3		#2 Generator layer	77.3	20		#2 Outdoor water turbine	84.8
4		#3 Generator layer	76.8	21		#2 Indoor water turbine	93.7
5		#4 Generator layer	72.3	22		#3 Outdoor water turbine	83.2
6		Installing room	68.9	23		#3 Indoor water turbine	91.5
7	Wind tunnel layer	#1 Outdoor wind tunnel	82.6	24	Main electrical wire Hall	#1 Main electrical wire hall	79.8
8		#2 Outdoor wind tunnel	84.2	25		#2 Main electrical wire hall	76.0
9		#3 Outdoor wind tunnel	83.7	26		#3 Main electrical wire hall	76.1
10		#4 Outdoor wind tunnel	81.7	27	Transformer chamber	#1 Transformer chamber	82.7
11	Volute layer	#1 Outdoor draft tube cone	82.9	28		#2 Transformer chamber	84.7
12		#1 Indoor draft tube cone	84.4	29		#3 Transformer chamber	85.5
13		#2 Outdoor draft tube cone	85.1	30		Cable interlayer	72.0
14		#2 Indoor draft tube cone	87.9	31		SFC room	70.7
15		#3 Outdoor draft tube cone	85.5	32		LCU room	68.2
16		#3 Indoor draft tube cone	88.7	33		LCU switching room	65.0
17		#4 Ball valve area	84.7	34		GIS room	71.0

3. Selection of hearing protections

3.1. Preliminary screening of hearing protectors

We tested 112 kinds of hearing protectors insertion loss, they are all selected randomly from the market. During the test, we referred to the following standards: ISO 4869-3:2007 "Acoustics-Hearing protectors – Part 3: Measurement of insertion loss of ear-muff type protectors using an acoustic test fixture" and ISO 4859-2:1994 "Acoustics-Hearing protectors – Part 2: Estimation of effective A-weighted sound pressure levels when hearing protectors are worn" [5, 6].

We tested using the instruments by B&K 4128C Head and Torso Simulators, using the pink noise as the noise source. The sound pressure levels were tested with [1] the hearing protector and without the hearing protector, respectively. The results of errors are insertion loss, that is:

$$L_{l,Aeq} = 10\log \sum_{i=1}^{33} 10^{(L_{p,i}-L_{e,i})/10}, \tag{1}$$

where $L_{l,Aeq}$ is the equivalent continuous A-weighted sound pressure level after wearing hearing protectors when workplaces are tested. $L_{p,i}$ is the actual test of each frequency band sound level in different workplaces. $L_{e,i}$ is the insertion loss of each frequency band sound level of different kinds of hearing protectors, i is 33 frequency bands.
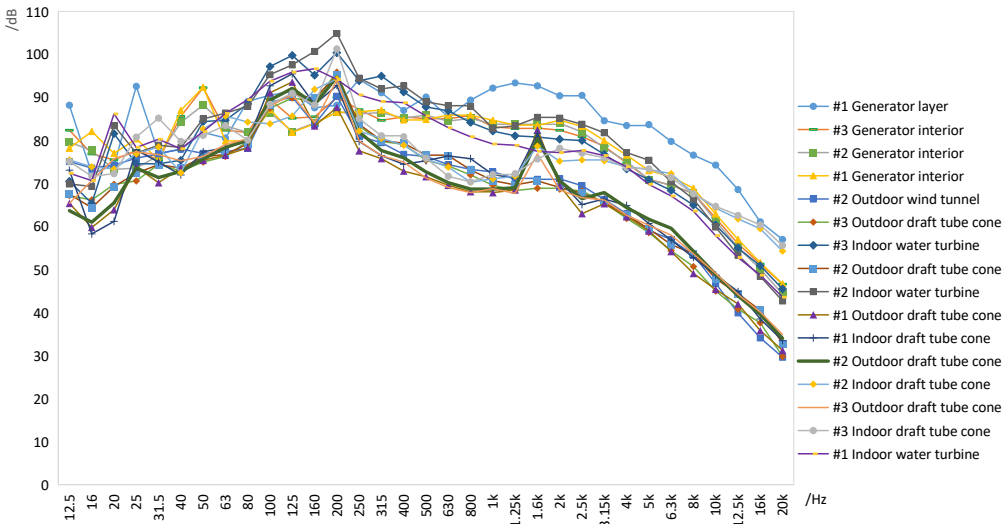

Fig. 1. The spectrum of 1/3 octave of noise in 10 working places

The steps of testing are:

(1) The sound pressure level at the microphone is tested using PLUSE 7758 when Head and Torso Simulators are not inserted the hearing protector.

(2) Place the hearing protectors in the Head and Torso Simulators' ear canal in sequence, and ensure the hearing protectors is located in the center of the microphone (as shown in Fig. 2).

(3) After about 30 s, the sound pressure level is tested again using PLUSE 7758 when Head and Torso Simulators are inserted the hearing protector.

(4) Repeat steps (1)-(3) three times with the same hearing protectors, the average value of three times is used to calculate the insertion loss.

Fig. 2. The contrast of before and after hearing protectors insertion

The equivalent continuous A-weighted sound pressure level can be obtained by weighting the insertion loss of each frequency band. Based on GB/T 23466-2009 "Guidelines for selection of hearing protectors", the effective value of the weighted sound pressure level is between 75 dB(A)-80 dB(A) after the operator is protected by the hearing protector. While less than 70 dB(A) indicates that the hearing protectors are overprotective, and the more than 80 dB(A) are

lack of protection [4]. The Eq. (1) is used to calculate the equivalent continuous A-weighted sound pressure level with hearing protectors in each test place. There are 24 kinds of hearing protectors, the equivalent continuous A-weighted sound pressure level are between 75 dB(A)-80 dB(A) after wore, as shown in Table 2.

Table 2. The better testing results of different brands in the different workplaces

No.	testing places	The better testing results of the Brands
1	#1 generator interior	Lian Zhi Pi, 3M, Quies, Deltaplus-conifit, Shi Da, Xing Gong, Nan Ji Ren, Black Forest Soft, Mack's-aqua-block, De Bei Nuo, Ju Li, Jin Xiu Yue Dian, Mei Bai
2	#1 outdoor water turbine	Shi Da, Xing Gong
3	#1 indoor water turbine	Venitex-conicfit06, Lian Zhi Pi, Quies, Deltaplus-conifit, Sai Er Bi, Ju Jia Jia, Pluggerz-sleep
4	#2 indoor water turbine	Venitex-conicfit06, Lian Zhi Pi, Quies, Deltaplus-conifit, Ohropax-color, Ohropax-mini-soft, Ohropax-classic, Mack's, Nan Ji Ren, Mack's-earammo, Ju Jia Jia, Ju Li, Jin Xiu Yue Dian, Pluggerz-diy, Mei bai
5	#3 indoor water turbine	Venitex-conicfit06, Lian Zhi Pi, Quies, Deltaplus-conifit, Ohropax-color, Ohropax-mini-soft, Shi Da, Ohropax-classic, Mack's, Nan Ji Ren, Mack's-earammo, Ju Jia Jia, Ju Li, Jin Xiu Yue Dian, Mei Bai
6	#2 outdoor draft tube cone	Shi Da, Xing Gong, Sai Er Bi
7	#2 indoor draft tube cone	Lian Zhi Pi, Quies, Xing Gong, Sai Er Bi, Pluggerz-sleep
8	#3 outdoor draft tube cone	Shi Da, Xing Gong, Sai Er Bi
9	#3 indoor draft tube cone	Xing Gong, Sai Er Bi
10	#3 transformer chamber	–

3.2. Statistical analysis

Principal component analysis (PCA) is a multivariate statistical method that transforms multiple indexes into a few comprehensive indexes based on the idea of dimensionality and the principle of minimizing the loss of data information [7].

In this paper, the insertion loss of each central frequency band of 24 kinds of hearing protectors is analyzed by PCA method, as shown in Table 3 and Table 4.

Table 3. Communalities

Frequency	Initial	Extraction
31.5 Hz	1.000	0.783
63 Hz	1.000	0.772
125 Hz	1.000	0.937
250 Hz	1.000	0.952
500 Hz	1.000	0.940
1000 Hz	1.000	0.910
2000 Hz	1.000	0.940
4000 Hz	1.000	0.853
8000 Hz	1.000	0.641
16000 Hz	1.000	0.612

Table 4. Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loading		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	6.990	69.899	69.899	6.990	69.899	69.899
2	1.349	13.492	83.391	1.349	13.492	83.391
3	.636	6.361	89.752			
4	.426	4.265	94.017			
5	.254	2.540	96.557			
6	.207	2.067	98.623			
7	.087	.868	99.492			
8	.028	.282	99.774			
9	.014	.135	99.909			
10	.009	.091	100.00			

According to Table 3, it can be obtained that the principal component coefficients extracted in each frequency band are all more than 0.5, which indicates that the extracted principal components have a higher degree of interpretation of each variable. According to Table 4, two principal components were extracted in this calculation analysis. The characteristic root of the first principal component is 6.990, the variance contribution rate is 69.899 %. And the characteristic root of the second principal component is 1.349, the variance contribution rate is 13.492 %. The cumulative variance contribution rate of the two principal components is 83.391 %. It is further indicated that the extraction of the two principal components is appropriate.

Table 5. Component matrix*

Frequency	Component		Frequency	Component	
	1	2		1	2
31.5 Hz	–0.055	0.883	1000 Hz	0.936	–0.185
63 Hz	–0.856	0.200	2000 Hz	0.968	–0.061
125 Hz	0.967	0.036	4000 Hz	0.906	0.180
250 Hz	0.956	–0.196	8000 Hz	0.800	–0.026
500 Hz	0.952	–0.186	16000 Hz	0.477	0.620
* 2 components extracted					

As shown in Table 5, the correlation coefficient between the first principal component and frequencies from 63 Hz to 8000 Hz are all close to 1, this indicate that there are more hearing protectors with noise reduction range from 63 Hz to 8000 Hz in the tested hearing protectors. Similarly, there are more hearing protectors with noise reduction range with frequency bands of 31.5 Hz and 16000 Hz in the second principal component.

Each principal component can be weighted and summed according to the characteristic root of each principal component:

$$F = [u_1/(u_1 + u_2)] \times F_1 + [u_2/(u_1 + u_2)] \times F_2, \tag{2}$$

where F_1 and F_2 are two principal component functions respectively, u_1 and u_2 the characteristic roots of the two principal components respectively. According to Eq. (2), the ranking of principal component score and comprehensive score of 24 kinds of hearing protectors can be determined, as shown in Table 6.

We can see from the Table 6 that in the comparison of each brand of hearing protection in this study, the hearing protection of Xing Gong brand is more representative among 63-8000 Hz, and Pluggerz-sleep brand's hearing protection is more representative in 31.5 Hz and 16000 Hz.

Combined with the above principal component analysis, it can be concluded that among the 112 kinds of hearing protection devices tested, most of the hearing protection devices are more suitable for the 7 sites studied: #1 generator layer, #1 outdoor water turbine, #1 indoor water

turbine, #2 outdoor draft tube cone, #2 indoor draft tube cone, #3 outdoor draft tube cone and #3 indoor draft tube cone.

Table 6. The ranking of principal component score and comprehensive score of 24 kinds of hearing protectors

Brands	Rank the score of principal component 1	Rank the score of principal component 2	Rank the comprehensive score	Brands	Rank the score of principal component 1	Rank the score of principal component 2	Rank the comprehensive score
Venitex-conicfit06	5	24	9	Black Forest-soft	20	10	20
Lian Zhi Pi1#	7	18	8	Mack's-aquablock	14	13	13
3M-1270	16	21	16	De Bei Nuo	24	7	24
Quies	4	9	4	Mack's-earammo	18	12	18
Deltaplus-conifit	3	23	6	Sai Er Bi	8	8	5
Ohropax-color	23	15	23	Ju Jia Jia	15	6	14
Ohropax-mini-soft	22	14	22	Ju Li	12	16	10
Shi Da	2	11	2	Jin Xiu Yue Dian	10	22	12
Xing Gong	1	3	1	Pluggerz-Sleep	6	1	3
Ohropax-classic	13	20	15	Pluggerz-diy	9	2	7
Mack's	11	19	11	Mei Bai	21	4	21
Nan Ji Ren	19	5	19	Lian Zhi Pi2#	17	17	17
Note: The score ranking only shows the representation of the two principal components of each brands and has nothing to do with the noise reduction effect							

4. Conclusions

According to the test analysis in this paper, it can be seen that the working environment and noise intensity of the power station are different. In the 10 of the 34 sites tested, the noise is too high, which is not conducive to workers' work and affects the physical and mental health of workers, so it is necessary to effectively protect the situation.

By testing the insertion loss of 112 kinds of hearing protectors, 24 kinds of hearing protectors with better noise reduction effect were selected. The principal component analysis of the 24 kinds of hearing protectors were carried out and find out the most representative hearing protectors. Most of the 112 kinds of hearing protectors tested are suitable for the 7 workplaces. The other 3 workplaces need to be targeted to choose the suitable hearing protectors. This study also provides a reference for other workplaces to choose the type of hearing protectors.

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