2010 International Conference on Measuring Technology and Mechatronics Automation

Active Noise Control System of Central Pump House In Mine Tunnel

FAN Jing
Department of Electronics and Electrical Engineering
Nanyang Institute of Technology
Henan , China
E-mail: fanjing8886@yahoo.com.cn

***Abstract*—A new way which can reduce environment noise underground in mine tunnel is produced. By analysis of the noise in central water pump house, point out that noise underground is mainly consist of base frequency and harmonic frequency coming from electric motor and transformer, with its frequency coverage below 650Hz . Acoustic spread environment in mine tunnel is similar to that in duct. Therefore, it is suitable to reduce noise by active noise control method. According to installation situation of equipment and noise distribution characters, feed forward FXLMS algorithm is used. Simulated results based on Matlab proved that there is an average of 13dB reduction using active noise control system.**

Keywords-Mine tunnel;Central pump house; Active noise control;feed forward FXLMS

I. INTRODUCTION

With the increase of electrical and mechanical equipments in coal mine, underground environmental noise pollution becomes more and more serious, and does a great harm to the health of the miners .Some documents show that noise level of Chinese main coal mines in most workplace exceed the required standards. Fushun Coal Mining Administration conducted a survey of miners who exposed to noise, and results showed that 59% of production workers exposed to high-decibel noise, 76% of workers contacted with noise are over 90 dB, 24% are over 100 dB, 3.8% workers lost hearing[1]. In the current safety context, noise pollution underground is still not paid enough attention, but it is a very urgent problem need to be solved.

The traditional way to acoustic noise control is focus on using passive techniques such as enclosures, barriers, and silencers to attenuate the undesired noise. Document[2] using acoustic enclosures etc. to control noise of coal mine air shaft axial flow fan. Document[3] using isolator to reduce air shaft noise of centrifugal fan. These passive silencers are valued at high frequencies. However, they are relatively large, costly, and ineffective at low frequencies. In order to obtain good results, we must increase the thickness of the material, which results high cost and too large size of system. Therefore it is difficult to realize.

Active Noise Control technology is the greatest potential method for noise reduction. By tracking and identifying the source of the noise, it creates the phase contrast signal with same frequency, and appropriate amplitude. This signal outputs through audio device and interferes the original noise. And so, this method can attenuate the noise within the region. The technology is very effective in reduction of low-frequency noise, and the equipment constitutes is simple and practical. Over the last decade, with the digital computer and integrated circuit technology, it has been widely studied and applied [4] [5] [6]. Active Noise Control of pipeline has been researched for many years. Because of its structural features, the transmission of sound waves in pipeline can be simplified to one dimensional problem. Active Noise Control technology has advantages of small energy loss, relatively simple algorithm, better effect. There are already many successful applications around the world.

Noise is very serious in underground central pump room because power of water pump motor often exceeds 1000KW, and the work noise is often more than 90dB. While talking with workers in the underground pump house, the workers in water pump room often complain the noise, which seriously affects the efficiency of work and workers' health. The pump house structure, which can be approximated as a "channel" .By sampling and analyzing the noise of the pump house , the noise mainly concentrated in low frequency range, and this is the ideal band for active noise control.

II. ENVIRONMENTAL NOISE ANALYSIS OF A CENTRAL PUMPING STATION

A central pumping station in coal mine have serious environment noise, where electrical and mechanical equipment are relatively concentrated. The place which author collected data is underground more than 800 meters and it is adjacent to the central transformer substation. Pumping station is about 3 meters high,with arch-shaped cross section. There are 6 sets 1200KW high-voltage motors as the driving force in the pumping station. See layout in Figure 1 below.

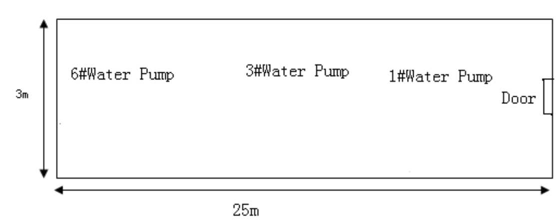

Figure 1. Pump position in pumping station

978-0-7695-3962-1/10 $26.00 © 2010 IEEE
DOI 10.1109/ICMTMA.2010.595

Pump noise is too large to talk with the workers normally. The measurement data show that the noise is about 95dB, exceed the national level A of "Industrial& Enterprise Noise health standards". Long-term noise will impact on workers' hearing. United States NOISH report shows that 90% of miners who suffer from noise have hearing problems after the age of 50 .The author uses laptop and a microphone to collect noise data in the pump room, and uses Matlab to convert the time-domain data into frequency-domain data by FFT transform. The distribution of its spectrum is showed in Figure 2.

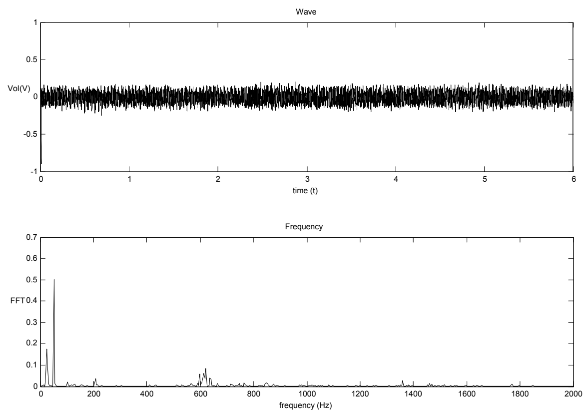

Figure 2. Environment noise in pump house and its frequency spectrum

By analysis of the frequency spectrum, it is found that the noise in the pump house is mainly caused by the motor rotation, and is closely related with the motor speed, and includes its harmonic components. In addition, 50HZ power frequency noise and its harmonics are also noteworthy. There are also more complex frequency components may be related to the space environment and machine resonance. From figure 2, the peak points of the main frequency are: 23HZ, 51Hz, 102Hz, 207Hz, 433Hz, 621Hz. Major frequency at low frequencies are helpful to eliminate active noise.

III. PRINCIPLE OF ADAPTIVE NOISE CONTROL

Active noise control is achieved by using acoustic interference theory, which uses man-made offset sound field to overlap with the original sound field. In order to decrease noise of controlled area, it is required that the original sound field and offset sound field have excellent match character. Mine tunnel is much more like a pipeline, it is a 1-dimensional structure, and Active Noise Control is most easily applied to 1-dimensional duct environment. Therefore, it should be able to achieve better results in mine tunnel.

Further analysis in pump station shows that the acoustic noise is varying in time and frequency, so adaptive algorithm is needed. The most common form of adaptive filter is the transversal filter using the leastmean-square (LMS) algorithm. However, the LMS algorithm can't apply for ANC directly, compensation filter is needed in practice, that becomes the filtered–X least-mean-square (LMS) algorithm[6]. The stability of the algorithm has been studied in documents[7]. Compensation filters have been designed in documents [8], which also made theoretical analysis of the transfer function amplitude and phase error to the controller performance. Since FXLMS algorithm can be implemented by either feedforward or feedback, we decide to adopt feedforward algorithm because it is easy to get noise reference signal in pumping room. The basic working principle shows in Figure 3.

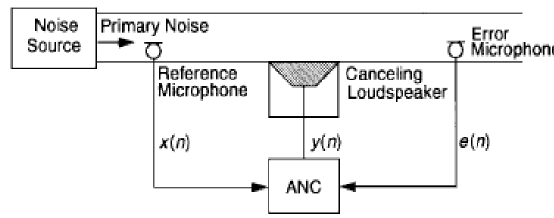

Figure 3. Single-channel FX LMS adaptive controller

See figure 3, feedforward adaptive active noise cancellation system requires two acoustic sensors. The left sensor installed in the pump house near the machine, is used to provide reference signals d(n) to the adaptive filter, the right side of the sensor is used to test de-noising errors and provide error signals e(n) to the LMS algorithm for updating filter coefficients. Because of the unknown channel H, compensation must be introduced. Namely, being FXLMS algorithm. The system structure diagram is shown in Figure 4.

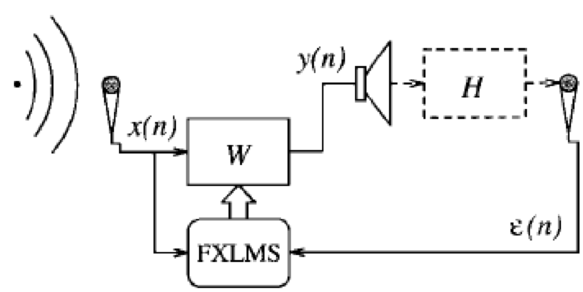

Figure 4. Feedforward ANC system using the FXLMS algorithm

Where, x(n) is the reference signal from the pump noise, through the filter W, to be y(n). In order to ensure system stability, this type of filter is FIR, the filter coefficient w changes over time, in accordance with minimum mean square criterion.

$$X(n) = [x(n), x(n-1), \cdots, x(n-N+1)]^T$$

N-order FIR filter weights

$$W(n) = [w_1(n), w_2(n), \cdots, w_N(n)]^T$$

Then the filter output is:

$$y(n) = \sum_{i=1}^{N} w_i(n)x(n-i+1) = X^T(n)W(n)$$

$w_i(n)$ is the filter coefficients, N is the filter length. Estimation error as follows:

$$e(n) = d(n) - y(n) = d(n) - X^T(n)W(n)$$

According to the minimum mean-square criterion, the best filter performance function $E(e^2(n))$ should be minimal. Using the Widrow-Hoff learning algorithm and using the error signal for each iteration of the instantaneous squared value of the minimum mean-square value of an alternative method to estimate the gradient $\nabla(n)$ of error function. That is

$$\hat{\nabla}(n) = [\frac{\partial e^2(n)}{\partial w_0(n)}, \frac{\partial e^2(n)}{\partial w_1(n)}, \cdots \frac{\partial e^2(n)}{\partial w_m(n)}]^T$$

Written in vector form, there is

$$w(n+1) = w(n) + 2u(n)e(n)x(n) \quad (1)$$

Where u(n) is the convergence step size of time n. In practice, this step is not too large, otherwise the system is unstable. If too small, the system also slows the speed of convergence .In actual system, it is appropriate to take 0.01-0.1 [9].

In active noise control, the error signal e(n) is after the output signals y(n), then through a special transfer function H to get. The transfer function features include a reconstruction filter, power amplifiers, AD converters, and acoustic channel from the speaker to the error collect sensor. Therefore, the impact of the impact function h(n) must be taken into account [10]. Then the actual e(n) should be:

$$e(n) = d(n) - y(n) = d(n) - h(n) * y(n) \quad (2)$$

Put (2) into (1), get the final FXLMS algorithm for adaptive iteration formula:

$$w(n+1) = w(n) + 2u(n)[d(n) - h(n) * y(n)]x(n)$$

Note that here * denotes convolution.

IV. EXPERIMENTAL RESULTS AND PERFORMANCE ANALYSIS

FXLMS Active Noise Control Model Using was built based on Matlab [11], and noise data collected from a central underground pump room was input to this model. Hence, this algorithm can be carried out in laboratory. The simulation results are shown in Figure 5.

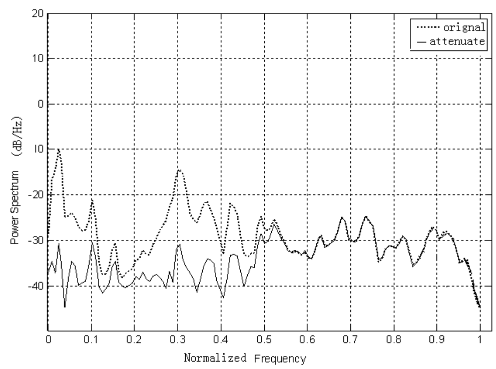

Figure 5. Normalized frequency spectrum (Orignal signal vs. Attenuated signal)

In Figure 5, data1 dotted line is normalized frequency spectrum prior to elimination of noise. Data2 is the normalized frequency spectrum after elimination of noise. In contrast to power spectrums we can see, at 23Hz, the ambient noise reduction of about 18dB, and reduction 20dB at 51Hz, 10dB at 102Hz, 15dB at 207Hz, 7dB at 433Hz, 0dB at 621Hz. The average reduction figure of these key frequencies is 13dB.

V. CONCLUSION

Environment noise pollution in coal mine seriously endangers the health of miners. By studying pumping station in underground environment, it can be found that underground roadway space is good for active noise control. Environmental noise spectrum analysis in the pump room confirmed that the noise is mainly below 650Hz and suitable for using the feedforward FXLMS algorithm. The simulation results based on matlab show that active noise control program is able to reduce noise an average of 14 db in the pump house and its effect is obvious.

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