A New Approach to Noise Measurement and Analysis in an Industrial Facility

Conference Paper *in* Conference Record - IEEE Instrumentation and Measurement Technology Conference · May 2014

DOI: 10.1109/I2MTC.2014.6860886

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A New Approach to Noise Measurement in an Industrial Facility

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***Abstract*—This paper presents a new approach to study and measure the noise present in a industrial plant. This first experience was made in a national footwear industry enviroment and the results shows how this problem is harmful to worker health. A change on the way of think about an deal with high noise levels is requisited to reach a sustainable workplace.**

I. Introduction

A vibratory motion can be propagated in elastic media with suficient energy and modify some physical properties of it. If this motion occurs in the air it is known as sound [1]. Noise can be described as a sound that brings harmfull effects in a human [2]. A sum of nonperiodical or periodical (with different intensities, frequencies and amplitudes) sinoidal waves can be considered noise as well [3]. All people lives with inconvenient sounds daily. However, some people are exposed to high levels of noise for many hours in a day. Excessive exposure can became health issues in a close future to this people. On a industrial enviroment motors, fans, transformers and compressors generate noise that can be harmfull to worker's health. This equipments are large used in industry and generate a noise which power levels concetrates in a range of low frequencies (Low Frequency Noise) [3].

Much can be done to mitigate noise problems. There is no simple solution like turning down the volume of a sound source [4]. To control noise, some aspects have to be take in account. This aspects will determinate if the solution is possible or not to be made. The first to be observed is legal regulations. Technical standards imposes proper noise levels to different enviroments to protect people health [5]. The economical aspect have to be observed also. Many solutions are discarded or changed because financial limitation.

II. Low Noise Frequency Effects on Health

The human auditory system and, as well as, physical and mental activities are affected by noise. Each of it suffer in a different way. One of audiologic effect is the Noise Induced Hearing Loss (NIHL). This occupational disease starts with the cronic exposure to high levels of sound pressure. This cenario causes temporary listening changes and if the cronical exposure persists irreversible hearing changes. The firt case is known as Temporary Threshold Shift (TTS), and the second as Permanent Threshold Shift [7]. A person who is affected by a TTS, restores his hearing capability after a auditory rest (in a silnce room). The time needed to restore depends of how much damage were done to the auditory system (less damage, less time). If this same person do not care about his health and continue exposed to high noise levels, it can be victim of a PTS. Initially affects one or more frequencies between 3 kHz and 6 kHz range [3].

Low frequency noise can produce not auditory effects also. Experiments with low frequency sound stimulus show that range of frequencies can affect human body [8]. For example, a constant level of noise (107 db) makes a human chest vibrates between 30 Hz and 80 Hz so intense that modulate the voice for a lower tone [8]. Beyond this effects, noise acts in other organic functions as: alarm reactions, neurovegetative reactions. For the first ones, occurs increase of cardio and respiratory frequency, increase of blood pressure (and other symptoms) like as if the person were in danger. As neurovegetative reaction can be cited disgestive disorder, variations on circulatory dynamic, anguish, increase of respiratory amplitude, neurological disorder, hormone disorder.

Exist a subjective relation between high LFN levels and noise sensibility [6]. This relation still motivate reasechers to find a way to minimize the noise effects by knowing who is more sensible to noise and directing this people to areas less noisy [9][10][11]. However, the subjectivity limits broad application of this approach, regardless of existence some preponderant factors[11].

III. Methodology

This work presents a new approach to noise problem in a specific location (industry). The proposed methodology do not intends to acheive a better signal-to-noise ratio. Works like [12] and [13] addresses this problem. The nature of noise produced by industrial machinery is aimed. There are many sources of noise on a industrial enviroment and a specific treatment of each source is not pratical [14]. Therefore, understand the nature of industrial noise can be a asset to control this noise problems.

The Brazilian Labor and Employment Ministry (*Ministério do Trabalho e Emprego* – MTE) regulates acceptable levels of noise exposure to industrial workers (as others jobs categories) [3]. If a company exceeds this levels it is punished according to the Regulatory Norm 15 (*Norma Regulamentadora* – NR) [15]. The methodology used by MTE to determine the noise level on a enviroment is present on appendix 1 of NR 15 [15] but this method do not covers spectral analysis of noise measured.

The noise analysis comprehends two stages. The first one consists on use the ABNT standard (NBR 10151:2000). This is a similar approach to the MTE's method. It consists on measuring the noise with a Sound Level Meter (SLM) adjusted to fast response and A weighting [16]. The second is the proposal method. An adapted methodology presented by Bendat and Piersol in [17] is used.

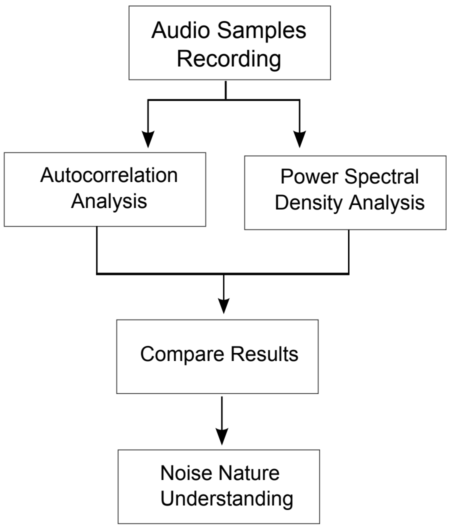

Fig. 1. Proposed methodology to understand noise nature.

To colect sample data and measure using SLM were chosen four sites. At each site there fan sets (all existing fans at studied factory were own manufacturing). As first as second methods were stablished some parameters for posterior comparison:

- ten seconds measures / samples;
- five measures / samples at each site;
- measure instantaneous power levels;
- calculate equivalent power level;

IV. Data Analysis

A. Sound Level Meter Approach

Before colect sound samples, noise levels were measured in selected points using a sound level meter. For best comprehension about colected data, were evaluated average values and standard deviation of each minimum and maximum values measured even as instantaneous values. Futhermore, the equivalent sound level was also calculated, using the Equation 1:

$$L_{Aeq} = 10 \log \frac{1}{n} \sum_{i=1}^{n} 10^{\frac{L_i}{10}}, \qquad (1)$$

where L_i is the sound pressure level, in dB(A), read in fast response for every 5 s, during noise masurement time and n is the number of readings. The colected and calculated values were arranged on Tables I, II, III, IV.

TABLE I. First measurement with Sound Level Meter

First Measurement				
Meas. Pts.	**Min. (dB(A))**	**Max. (dB(A))**	**Meas. (dB(A))**	**Leq (dB(A))**
1	93,6	96,3	94,5	
2	93,6	95,9	94,8	
3	93,6	97	94,5	94,71
4	93,9	96,1	95,1	
5	93,6	95,9	94,6	
Average	**93,7**	**96,2**	**94,7**	
Std. Dev.	**0,1**	**0,5**	**0,3**	

TABLE II. Second measurement with Sound Level Meter

Second Measurement				
Meas. Pts.	**Min. (dB(A))**	**Max. (dB(A))**	**Meas. (dB(A))**	**Leq (dB(A))**
1	92,6	95,1	93,6	
2	92,8	95,4	93,9	
3	92,5	95,6	93,8	94,08
4	93,3	96,1	94,8	
5	93,2	95,4	94,2	
Average	**92,9**	**95,5**	**94,1**	
Std. Dev.	**0,4**	**0,4**	**0,5**	

At all observed points the sound power level exceeds the maximum threshold forced by ABNT 10151:2000 (70 dB(A)) as can be observed on the tables presented. In compliance to NR 15, a worker only can be exposed to such levels for 2 hours, without individual protection equipment. The use of this type of equipment becomes needfull to this factory, as can be seen. The noise levels on this enviroment was noticiable. For all fan sets, the power levele measured overpasses 90 dB(A). The second part of this work aimed to understand the noise nature to solve the noise problem. The result obtained with this new approach were also compared with known methodology.

B. Signal Processing Approach

For each of fan assemblies, were generated two Power Spectral Density (PSD) graphs for best representation of the frequency range studied (0 Hz to 1.2 kHz). The Figures 2 and 3 are examples of PSD graph of measured audio sample. If this two figures be observed together, high noise values are concentrated at low frequency range. A vibration at this frequency range can acts directly over industry workers and create a body vibration thats harmful [8], [9] and [10]. Noise level

TABLE III. Third measurement with Sound Level Meter

Third Measurement				
Meas. Pts.	**Min. (dB(A))**	**Max. (dB(A))**	**Meas. (dB(A))**	**Leq (dB(A))**
1	91,3	97,4	94,5	
2	91,3	96,6	94,0	
3	92,0	97,2	93,3	94,25
4	92,2	97,6	95,5	
5	91,2	98,2	93,6	
Average	**91,6**	**97,4**	**94,2**	
Std. Dev.	**0,5**	**0,6**	**0,9**	

TABLE IV. Fourth measurement with Sound Level Meter

Fourth Measurement				
Meas. Pts.	**Min. (dB(A))**	**Max. (dB(A))**	**Meas. (dB(A))**	**Leq (dB(A))**
1	92,0	95,1	94,0	
2	91,4	94,8	93,2	
3	92,1	94,5	93,9	93,6
4	92,8	96,3	94,2	
5	91,4	94,2	92,5	
Average	**91,9**	**95,0**	**93,6**	
Std. Dev.	**0,6**	**0,8**	**0,7**	

peaks occurs between 80 Hz a 180 Hz. At high frequencies (over 500 Hz), the levels of noise are similar. On Table V peak values are consolidated. The Equivalent Sound Level (L_{eq}) were calculated and the results are consolidated on Table V as well. Comparing the traditional measurement approach with this proposal initiative, both results are comparable.

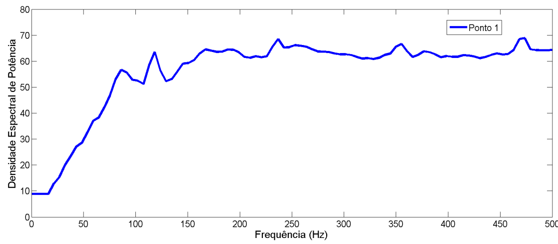

Fig. 2. Power spectral density graph of colected audio at first site to 0 – 500 Hz frequency range.

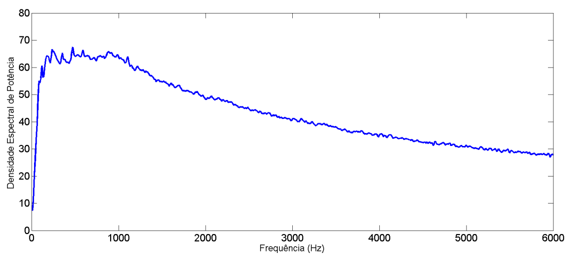

Fig. 3. Power spectral density graph of colected audio at first site to 0 – 6 kHz frequency range.

TABLE V. MEASURED DATA OBTAINED AT ALL SITES

Measurements				
Meas. Pts.	Freq. (Hz)	Peak		Leq (dB(A))
		Freq. (Hz)	Power (dB(A))	
1	0 - 500	473,73	68,80	94,5
	500 - 1200	586,78	67,26	
2	0 - 500	236,86	71,72	93,9
	500 - 1200	942,08	66,67	
3	0 - 500	468,34	69,18	94,2
	500 - 1200	586,78	66,89	
4	0 - 500	231,48	70,88	93,1
	500 - 1200	1017,44	66,54	

V. CONCLUSION

The scenario was studied show some intriguing results. The appearing of characteristics that belongs to a sine function on autocorrelation function added to Gaussian noise needed further studies. The preliminar indentification of noise nature enables future application of specific mitigation techniques [3]. The actual Brazilian legislation do not covers all needed aspects of noise as seen on this paper. The existence of high levels of LFN in this industry can harm workers and cause future medical sick leaves. Other steps of this research are the development of a mathematical model to predict the behaviour of this measured noise and indentify which frequencies are prejudicial to human health.

ACKNOWLEDGMENT

The authors would like to thank the Federal University of Campina Grande and the Instituto de Estudos Avançados em Comunicações to provide all infrastructure needed to achieve the results of this paper.

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