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STUDY OF THE ENVIRONMENTAL NOISE POLLUTION IN PRODUCTION ECONOMICAL ACTIVITIES

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Abstract: *The paper presents results of a study of the environmental noise pollution in sewing and metal working manufacture and the harvester in agriculture. Indiscrete method for noise measurements were created. They are characterized by high precision, wide range of determination of the noise and large sample size of measured values. A probabilistic method for noise pollution assessment is introduced. Seven groups of indicators were used. The method is approbated in practice. The results show large coverage and accuracy.*

Key words: *noise pollution, production, economics, action, assessment.*

INTRODUCTION

Risk assessment of industrial noise requires precise characterization of pollutions in the occupational environmental systems. For this purpose an indiscrete method for noise imissions measurements and probabilistic methods for evaluation were created.

The assessment of environmental noise requires accurate determination of emissions and imission control. The reason is in the complex mathematical algorithms to assess risk, requiring precise information obtained in the measurement noise. The time of occurrence of sudden changes are with the order of milliseconds to seconds. Therefore, to analyze and evaluate the noise objectively it is necessary to use appropriate measurement method and the results to be processed in a way that takes into account the random nature of unexpected change. This necessitates the need to implement indiscrete methods for analysis and risk assessment [4]. Up to now, the methods used to measure noise are characterized by a large dispersion and significant time consumption that limits their field of application beyond the needs of information provision in the risk of environmental noise.

The purpose of this work is to establish an environmental noise pollution in sewing and metal working manifacture and the harvester in agriculture. The study allow solving three main tasks: 1) A virtual device for indiscrete noise measurement creation, 2) Determination of the criteria for analysis and evaluation of noise polltion, 3) Experimental study, methods testing and their capabilities analysis.

METHODS

To solve the first problem a device was used to collect data – NI DAQ 6210 [2,3,4]. It was adapted to the program LabView 8.5. DAQ 6210 and connects to the computer platform. A virtual instrument for measuring noise that comes completed to an analogue sound level meter SL 401, is connected to the device input - a1. From the Start menu in Windows it is selected All programs/National Instruments LabView 8.5. A dialog box opens. It starts Blank VI, representing the workspace, which includes measuring modules. In the block diagram of the window where are elements that are necessary for the programming. A dropdown menu of the program functions is activated. Input instruments are chosen and DAQ assistant for unit control. The parameters of the device, the number of measurements and the frequency of the reported measurement results are adjusted. The system is calibrated. This is done using the drop-down menu. DAQ device allows operation at 250 kS/s. In practice it is necessary to use much lower frequency. A module converting the measurement of volts (V) in relative units - decibels (dB) was developed. It is done using mathematical module Formula. For this purpose DAQ device is set to the frequency 250 kS/s. This yields a maximum amount of data in one period of oscillation of the membrane of the acoustic calibrator Robotron 05 000. It also generates a reference signal with a frequency of 1000 Hz and amplitude 94 dB. Since the length of the period was 0,001 s, then at the selected frequency, the number of measurements can be arbitrary, but more than 250. With a recording block the measured values are saved in a text file. To determine the voltage that occurs when the support sound pressure is assumed a linear relationship between the pressure in Pascals (Pa) and voltage in volts (V) is adopted. Voltage corresponding to a threshold pressure value was obtained 0,000000527 V. From the drop down menu and the tools Signal analysis is activated the module Filter. Select - a broadband filter. The lower and upper cut-off frequency must be determined. The lower frequency 500 Hz is chosen and the upper - from 5000 to 10000 Hz simulating the A-weighted SPL, which is embedded in the sound-level meter standard IEC 651. Select type of Chebyshev FIR filter with exponent of 1. The input filter is connected to the output of the module Filter, and the filter - to the output of the modules for registration and visualization of the results.

The data recording uses the module Write to measurement file. It records the data directly into ".lmv" file which is supported in Excell. It is possible to set the parameters of the file and the behaviourof the program in duplicate files. In the survey it was selected the text file format ".lmv" with one column, and if there are more than one file, the program selects the next file name and file number by turns. The output module is associated with a Table. On the front panel the table appears with drop-down menu and it is set to 9 columns and 2 rows. It is able to set the accuracy of results, the size of the table, fonts and etc. To record the data of an octave, the measurement unit is connected to the data recording module.

The described virtual instrument is applied for measurements and analyzing of the imission noise. Individual measurements are carried out according to private standards. The system makes a measurement on set of the parameters and records a sum of two files-one with the data of measurements of the overall noise level, where is recorded and the values - RMS, Mean and Peak of the diagram displayed on the monitor, and one with different frequencies and octaves.

Working on the second and the third tasks a definition of the criteria for analysis and assessment of environmental noise and implementation of an experimental investigation is implemented. They are applied in the experimental study of noise emission from tree objects-sewing manufacture, metal working manufacture and the acriculture during harvest with rotary combine machine. The choice of the object to study is made on the basis of its popularity as a source of noise pollution of the environment. In the research is essential the selection of measuring point. As shown in some of our research, choosing the measurement point influence significantly on the analysis and evaluation of noise and can be heavily influenced results obtained [6]. In making indiscrete measurements, the location and the number of measurement points are chosen according to the Bulgarian state standard. Pollution immission characteristics are based on standards EN ISO 11201:1995 [1] and EN ISO 11204:1995 + AC 1997 [2]. The emission characteristics are determined on the basis of ISO 1999:2004 [3]. To analyze accurately the results of measurements of noise pollution in sewing, metal working manufacture and agriculture the procedure is adopted to a system of characteristics. It includes: Group I. Distribution laws of the measured values of imissions. Group II. Mean values: Im_{sr}, dBA - averaged A-weighted level of the sound pressure of imissions: $Im_{sr\,min}$ - minimal mean value A-weighted level of the sound pressure of imissions; $Im_{sr\,max}$ - the maximum mean value of A-weighted level of the sound pressure of imissions; $\Delta Im_{sr} = Im_{sr\,max} - Im_{sr\,min}, dBA$ - range the mean values of A-weighted level of the sound pressure of imissions; Group III. Standard deviation: $\sigma_{Im\,min}$-minimum value of the deviation from the mean value of the imission; $\sigma_{Im\,max}$-maximum deviation of the imission values; Group IV. Variance: $\sigma_{Im\,min}$ minimum-value of the variance of noise imissions; $\sigma^2_{Im\,max}$ - maximum value of the variance of noise imissions; $\Delta\sigma^2{}_{Im\,max} = \sigma^2{}_{Im\,max} - \sigma^2{}_{Im\,min}$ - maximum range of the variance of noise imisisons;Group V. Amplitude:

Im_{min}, dBA - the minimum amplitude of the A-weighted sound pressure level of noise imissions; Im_{max}, dBA - maximum amplitude of the A-weighted sound pressure level of noise imissions; $\Delta Im = Im_{max} - Im_{min}, dBA$ - maximum range of the amplitude in all imissions measurements; Group VI. Coefficient of variation of the mean values: $K_v[Em]_{min} / K_v[Im]_{min}$ - minimum value of the coefficient of variation for imissions; $K_v[Em]_{max} / K_v[Im]_{max}$ - maximum value of the coefficient; $\Delta K_v[Im]_{max} = K_v[Im]_{max} - K_v[Im]_{min}$ - highest range of the coefficient of variation within the all imissions measurements; Group VII. Number of exceedings: $N_{Im\,pr_{max}}$ - maximum value of rated A-weighted sound pressure level of noise imissions; $T_{Im\,pr_{max}}, s$ - the maximum time of exceeding the rated A-weighted sound pressure immission level. The program *Risk 4.5* is used for the first group parameters determination. It checks 16 law types of distribution of discontinuous and continuous random variables. Distribution laws are ranked systematically. The first law in the range is acquired. The law parameters are determined.

RESULTS AND DISCUSSIONS

Experimental studies have been made in tailoring workshop "Heros" in Ruse and metal working manufacture in the University of Ruse There were 100 attempts measured at three points. In any attempt the program software registers 20 000 measurements at three sampling rates: I- $f_s = 10\,kHz;$ II - $f_s = 15\,kHz;$ III - $f_s = 20\,kHz$. The measurement time of each record is determined by the relationship: $t = n_s / f_s$, where f_s is the sampling rate, kHz; n_s - number of measured values of the noise imissions. At a constant number of values for each measurement, the sample rate determines the length of the each measurement: I- $t = 2\,s;$ II - $t = 1{,}33\,s;$ III -$t = 1\,s$. The position and the number of measurement points are selected accordingly to the Bulgarian state standard BDS ISO 1999:2004, rejecting BDS 15204:1980, used in some stages of the work. Analyzing the results a strong influence of the measuring point's position was established. Therefore, preliminary trials and determinations of the microphone localization were made. The data analysis (Tables 1 and 2) show

Table 1

Parameters of noise pollution in sewing manufacture (*L*-logistic distribution law; *B*-Beta distribution; W - distribution Weibul; *N*-normal distribution)

Parameters	Measurement points								
	I1			I2			I3		
	10*kHz*	15*kHz*	20*kHz*	10*kHz*	15*kHz*	20*kHz*	10*kHz*	15*kHz*	20*kHz*
Distribution law, % from all the investigations in brackets	*L* (72) *B* (28)	*L* (69) *B* (30) *W* (1)	*L* (68) *B* (31) *W* (1)	*L* (65) *B* (33) *W* (2)	*L* (65) *B* (32) *W* (3)	*L* (67) *B* (32) *W* (1)	*L* (58) *B* (41) *W* (1)	*L* (61) *B* (39)	*L* (58) *B* (42)
$Im_{sr\,min}$	64.57	63.85	64.29	66.77	66.33	65.00	64.05	61.26	61.74
$Im_{sr\,max}$	71.19	74.85	73.56	77.68	77.86	75.37	68.55	70.43	70.18
$\Delta Im_{sr}, dBA$	6.63	11.01	9.27	10.91	11.54	10.38	4.51	9.17	8.45
$\sigma_{Im\,min}$	10.01	9.00	9.30	8.98	8.88	9.45	9.97	9.81	9.84
$\sigma_{Im\,max}$	10.78	10.51	10.77	10.45	10.90	11.33	10.82	10.61	10.60
$\sigma^2_{Im\,min}$	100.2	80.91	86.47	80.52	78.85	89.25	99.28	96.14	96.72
$\sigma^2_{Im\,max}$	116.21	110.29	115.81	108.95	118.65	128.36	117.03	112.54	112.29
$\Delta\sigma^2{}_{Im\,max}$	16.02	29.38	29.35	28.44	39.81	39.11	17.75	16.40	15.58
Im_{min}, dBA	0.02	0.01	0.02	0.05	0.01	0.04	0.01	0.02	0.01
Im_{max}, dBA	99.2	98.57	99.84	107.37	112.91	110	94.56	94.73	92.61
$\Delta Im, dBA$	99.18	98.56	99.82	107.33	112.91	109.97	94.56	94.72	92.60
$K_v\,[Im]_{min}$	14.07	12.15	9.61	11.56	9.52	9.66	14.79	9.20	14.33
$K_v\,[Im]_{max}$	16.08	16.19	16.15	15.31	15.24	15.73	16.62	16.73	16.49
$\Delta K_v\,[Im]$	2.01	4.05	6.55	3.76	5.73	6.07	1.83	7.54	2.16
$N_{Im\,pr_{max}}$	484	942	1097	3207	3539	1642	240	249	220
$TI_{m\,pr_{max}}, s$	0.05	0.07	0.06	0.33	0.24	0.09	0.03	0.02	0.02

considerable dynamics in the results of measuring Table 2 noise in both proceedings. The laws of distribution of A-weighted sound pressure levels indicate priority distribution logistics law. In clothing production this law shall be established in 58-72% of the trials and in metal working manufacture at 65-76%. Rarely immission obey the Weibul distribution -an average of 1 to 3% for both procedures. Beta distribution is found in approximately 30-33% of the trials. Only one of the trials demonstrated a normal distribution. That is the evidence that conventional assumptions about normal distributions laws are not true, if they are not proven experimentally. Minimal average immission values $Im_{sr\,min}$ are related order - 61,74-66,72 to 66, 72 in tailoring manufacture and 59,67-74,55 dBA in metal working. The same is at the maximum values $Im_{sr\,max}$ of the averages. The same applies to the interval of averaged values of ΔIm_{sr} -от 4,51 to 11,32 and 7,83-12,32 dBA. It is interesting to see the minimal and maximal measured values and their accuracy of the determination.

Table 2

Parameters of noise imissions in metal working manufacture (*L*-logistic distribution law; *B*-Beta distribution; W - distribution Weibul; *N*-normal distribution)

Parameters	Measurement points								
	I1			I2			I3		
	10*kHz*	15*kHz*	20*kHz*	10*kHz*	15*kHz*	20*kHz*	10*kHz*	15*kHz*	20*kHz*
Distribution law, % from all the investigations in brackets	*L* (68) *B* (30) *W* (2)	*L* (70) *B* (30)	*L* (72) *B* (28)	*L* (68) *B* (30) *W* (1)	*L (76)* *B (24)*	*L (72)* *B (26)* *W (2)*	*L (66)* *B (34)*	*L (65)* *B (31)* *W (3)*	*L (67)* *B (33)*
$Im_{sr\,min}$	73.73	73.62	73.58	74.3	74.53	69.24	67.12	59.48	67.1
$Im_{sr\,max}$	80.3	95.9	78.75	88.48	84.93	84.08	70.59	70.37	71.22
$\Delta Im_{sr}, dBA$	6.57	22.28	5.17	14.19	10.41	14.85	3.47	10.9	4.12
$\sigma_{Im\,min}$	9.97	9.87	9.92	9.86	9.85	9.84	9.97	9.83	9.95
$\sigma_{Im\,max}$	11.05	13.02	10.53	12.07	10.46	11.09	11.9	14	10.43
$\sigma^2_{Im\,min}$	99.21	97.3	98.25	97.1	96.96	96.76	99.27	96.49	98.97
$\sigma^2_{Im\,max}$	121.93	169.42	110.82	145.57	109.28	122.95	141.4	196	108.65
$\Delta\sigma^2{}_{Im_{max}}$	22.73	72.13	12.58	48.48	12.33	26.2	42.14	99.52	9.68
Im_{min}, dBA	0.12	0.04	0.02	0.01	0.01	0.02	0.02	0.01	0.03
Im_{max}, dBA	109.23	119.26	102.74	112.48	109.79	108.85	105.81	109.1	93.11
$\Delta Im, dBA$	109.12	119.23	102.73	112.48	109.79	108.84	105.8	109.1	93.08
$K_v\,[Im]_{min}$	9.83	12.95	12.86	12.09	9.72	12.44	14.42	9.32	9.34
$K_v\,[Im]_{max}$	13.25	13.38	13.69	13.14	13.63	13.06	14.83	14.84	14.55
$\Delta K_v\,[Im]$	3.43	0.44	0.83	1.06	3.91	0.63	0.42	5.52	5.22
$N_{Im\,pr_{max}}$	7432	16073	5883	2422	11686	10616	54	2128	589
$TI_{m\,pr_{max}}, s$	0.75	1.08	0.3	0.25	0.78	0.54	0.01	0.15	0.03

With the proposed method it was registered values up to 4-5 and more decimal places and values, close to zero. These values are 0,01-0,05 *dBA* in clothing manufacture which, by traditional methods of measurement can not be identified. The same ifact is watched and for the maximal values. In the sewing production maximum immission reaches 112,91, and in the metal working workshop - 119,23 *dBA*. The lowers value of the maximum range of the coefficient of variation within the trial is measured at the point I2 and sampling rate of 15 *Hz* in metal working noise imissions. The values are $K_v\,[Im]_{max}$=55,2%. Naturally, the maximum range of variability is $\Delta\sigma^2{}_{Im_{max}} == 99{,}52$. These results highlight the variability in the nature of the noise because there is more concentration of machine tools in a work zone. The number of exceeding of values of A-weighted sound pressure levels in metal working manufacture is changing in a very large range, from 54 to 16073. These exceeding have such accuracy that can not be determined by the conventional methods of measurement. In sewing production the exceeding $N_{Im\,pr_{max}}$ are less - from 220 to 3539.

Table 3

Parameters of noise emissions and imissions of combine CASE 2288 (*L*-logistic distribution law; *B*-Beta distribution)

	Emmisions			Immisions		
Parameters	10*kHz*	15*kHz*	20*kHz*	10*kHz*	15*kHz*	20*kHz*
Distribution law, % from all the investigations in brackets	*L* (76) *B* (24)	*L* (71) *B* (29)	*L* (67) *B* (33)	*L* (84) *B* (6)	*L* (87) *B* (3)	*L* (81) *B* (19)
$Em_{sr\,min} / Im_{sr\,min}$	89.92	89.71	89.42	72.78	72.09	72.68
$Em_{sr\,max} / Im_{sr\,max}$	93.07	92.28	91.97	75.67	78.35	76.9
$\Delta Em_{sr}, dBA / \Delta Im_{sr}, dBA$	3.16	2.57	2.56	2.89	6.26	4.23
$\sigma_{Emmin} / \sigma_{Immin}$	9.9	9.94	9.93	9.86	9.75	9.6
$\sigma_{Emmax} / \sigma_{Immax}$	10.43	10.44	10.43	10.4	10.41	10.48
$\sigma^2_{Emmin} / \sigma^2_{Immin}$	97.94	98.68	98.49	97.13	94.92	92.06
$\sigma^2_{Emmax} / \sigma^2_{Immax}$	108.6	108.87	108.58	108.11	108.34	109.68
$\Delta\sigma^2{}_{Emmax} / \Delta\sigma^2{}_{Immax}$	10.67	10.2	10.1	10.99	13.43	17.62
$Em_{min}, dBA / Im_{min}, dBA$	0.11	0.06	0.01	0.01	0.05	0.01
$Em_{max}, dBA / Im_{max}, dBA$	114.36	115.57	113.3	113.29	119.09	114.82
$\Delta Em, dBA / \Delta Im, dBA$	114.25	115.52	113.29	113.29	119.05	114.82
$K_v[Em]_{min} / K_v[Im]_{min}$	10.76	10.78	10.96	13.03	12.56	12.56
$K_v[Em]_{max} / K_v[Im]_{max}$	11.14	11.31	11.25	13.83	12.83	13.46
$\Delta K_v[Em] / \Delta K_v[Im]$	0.39	0.53	0.30	0.81	0.27	0.9
$N_{Em\,pr_{max}} / N_{Im\,pr_{max}}$	16582	16283	16114	2571	5336	3832
$T_{Em\,pr_{max}}, s / T_{Im\,pr_{max}}, s$	1.66	1.09	0.81	0.26	0.36	0.2

Similarly it was obtained and the exceedings time. Values $TI_{m\,pr_{max}}$ from 0,1-0,2 to 0,24-1,08 s were registered. The maximum single value of the amplitude of sound pressure is measured at point I1 of metal working manifacture at 15 kHz with values between 15,15-119,15 dBA.

The object of the study is to the noise of a rotary combine harvester CASE 2388 with parameters. The emission characteristics are determined on the basis of ISO 1999:2004 [3]. During the immission measurement it is selected one measuring point in the cab of the machine at a height $0{,}8\,m$ upon the level of the seat and $0{,}1\text{m}$ head away from the operator [6]. Emission tests were performed at selected points from the corpus of the machine, located away from the foundation, satisfying the condition of distance 1m from the body. Its axis is directed towards working bunker, which has the largest share in the emitted noise.

There were 100 attempts, made at three measurement points. In any attempt are 20,000 measurements at three sampling rates - f_s: I- $f_s = 10\,kHz;$ II - $f_s = 15\,kHz;$ III- $f_s = 20\,kHz$. At a constant number of values for each measurement, the sample rate determines the length of recording meanings: I- $t = 2\,s;$ II - $t = 1{,}33\,s;$ III - $t = 1\,s$. Data analysis

(Table 3) shows significant results in the dynamics of measurement noise. The laws of distribution of A weighted sound pressure levels indicate priority distribution on logistics law. This law is established in 67-87% of attempts. This is a proof that conventional assumptions about normal distributions laws are not true, if are not demonstrated experimentally.

An interest is there with the minimum and maximum measured values and the accuracy of the determination. The proposed method amounts to 4-5 record and more decimal places and levels close to zero. These values are from 0.01 to 0.110, which by conventional measurement methods can not be identified. The same goes for the amount of the maximum value of the immissions, that reached *114,82 dBA.*

The lowest value of the maximum range of the coefficient of variation within the experiments in immission is observed at a sampling rate $20\,kHz$. It reaches values $K_v\,[Im]_{max}$=90 %. The maximum range of the variance is $\Delta\sigma^2{}_{Im_{max}} = 17{,}62$. These results underscore the uneven nature of the noise. The number of exceedings of the levels of A-weighted sound pressure levels $N_{Im\,pr_{max}}$ vary in a very wide range, from 2571 to 16 582. These exceedings with such accuracy can not be determined by conventional method. Similar results are received and for the time of overruns $TI_{m\,pr_{max}}$. Registered values are in the range from 0.2 to 1.66 *s*. The maximum single value of the amplitude of the sound pressure is measured at pollution in point at frequency $f_s = 15\,kHz$ - 119,0 *dBA*.

CONCLUSION

We can make the following conclusions: 1) Proposed methods for measuring and assessing of noise pollution have high accuracy, high resolution and unlimited measuring range; 2) Introduced by seven groups of parameters they completely describe the process of pollution levels and present most accurate their dynamic evolution over the time; 3) Comparisons of the features offered do not create difficulties, since all calculations are carried out numerically and the final results are tabulated. Indeed, comparing their findings is subjective. Errors cannot be admitted because the quantitative characteristics were obtained as accurate and objective indicators of pollution levels of the industrial noise; 4) The method has successfully been probated in the measurement and evaluation of noise generated in the environment of sewing and metal working manifacture and the harvester in agriculture. All calculations are carried out numerically, and the final results are tabulated, which minimizes subjective mistakes; 5) The quantitative characteristics obtained are accurate and objective indicators of environmental noise.

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