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Influence of Absorption and Insulation Properties for Phonic Treatment of Public Works Equipment

This study presents the problem of designing, manufacturing and testing of some protective systems made from composite materials which can simultaneously perform the next requirements: noise absorption for middle and high range frequencies, noise insulation for low frequencies, vibration damping in order to avoid noise transmission by structure and finally, modularity and adaptability for using to different types of public works equipment, also for other technological equipment with a high level of noise, vibration and mechanical shocks. Decreasing of sound and vibration global level inside and/or outside the public works equipment's cabin as well as the reduction the noise pollution or the pollution due to the vibration and mechanical shocks on construction site is an actual matter, especially for the countries –last became members of EU; these countries must harmonize theirs national legislations regarding the environment pollution and the labor protection with the EU Directives. The article presents the experimental data of four composite structures with noise absorption and insulation features and three case studies of global level noise reduction inside the cabin for a vibrating compactor, a crawler excavator and a frontal loader.

Keywords: *phonic treatment, composite structures, noise insulation*

1. Introduction

In the framework of the sustainable technology, innovation and sustainable development are very interactive with each other. At the same time, innovations lead to a direct reduction in production costs for companies, therefore companies' competitiveness increases in national and international arena.

The goal of using innovative composite structures in the public work equipment is to simultaneously decrease global level of noise and vibrations into cabin and to dissipate the energy of the emitted sound in environment. These properties can be assured if the structure of sandwich composites is made up of one layer of material in order to insulate the low frequency noise, one layer of porous material in order to absorb the medium and high frequency sound and one layer of soundproofing material [1-3].

Taking into consideration the usual noise levels of different types of civil work equipment and the EU Directives [4-6] requests, it can appreciate that the acoustic performances of soundproofing treatments of the cabins and of the cases must be characterized by the values from Table 1.

Table 1. Requiring acoustic performances for the composite

Acoustic property	Den.	Unit	Frequency range [Hz]	
			400-1000	1000-4000
Sound absorption coefficient	α	%	30-40	40-90
Sound transmission loss	ΔL	dB	20-30	30-40

2. Characteristics of the studied materials

The project "Modular protective systems from sound absorbent and sound insulation composite materials for civil works equipment" developed within the Programme V "Innovation" of Ref. [7] proposes some types of composite materials in order to assure the required values for the acoustic properties (table 2). The base materials used to build the composite structures with their physic and mechanic properties are done in the table 2.

Table 2. Base materials properties

Material	**Description**	**Structure**	**Thick.** [mm]	**Density** [kg/m^2]
PC10	Cork	composite	1	0,360
PC30	Cork	composite	3	1,200
PST10	Polystyrene	close cell low density foam	1	0,130
PST5	Polystyrene	close cell low density foam	0,5	0,060
PST20	Polystyrene	close cell low density foam	2	0,250
PSTM5	Polystyrene	close cell low density foam + Alu foil	0,5	0,240
PVC8	Polyvinyl	high density foil	0,8	1,120
PVC10	Polyvinyl	high density foil	1	1,400
PVCT10	Polyvinyl	textile reinforced PV foil	1	1,150
PVC15	Polyvinyl	cellulose background PV foil	1,5	1,650
PES20	Polyester	open cell foam	2	0,600
PES50	Polyester	open cell foam	5	1,500
PESM40	Polyester	open cell foam with Alu foil	4	1,250
PESMV150	Polyester	open cell foam + Alu + PV textile reinforced	15	4,500
MTT20	Textile + latex	textile reinforced latex	2	2,300

3. Sound absorption coefficient. Experimental results

The experimental data was determined using acoustic standing waves method [8-10], for 1/3 octave bandwidth. Figure 1 a, b, c shows the variations of α coefficients of the base materials and composite materials (table 2), plotted for sound frequencies between 100Hz and 3200 Hz.

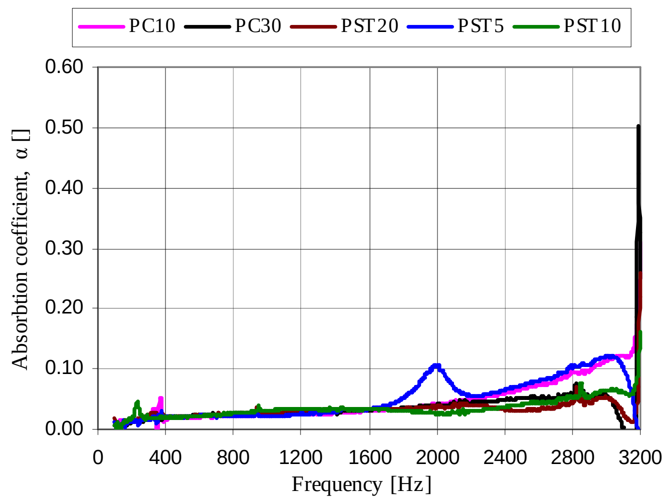

Figure 1. a) Sound absorption coefficient: PC10, PC30, PST20, PST5, PST10

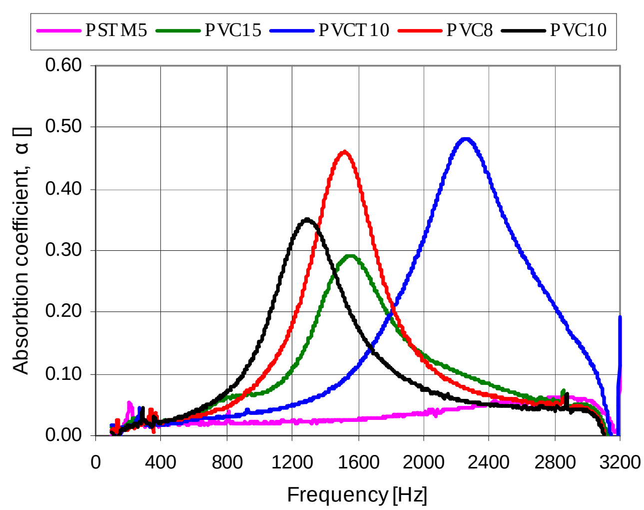

Figure 1. b) Sound absorption coefficient: PSTM5, PVC15, PVCT10, PVC8, PVC10

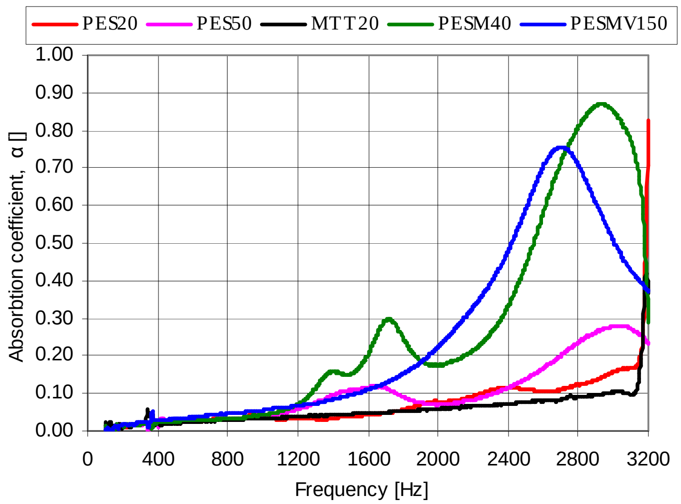

Figure 1. c) Sound absorption coefficient: PES20, PES50, MTT20, PESM40, PESMV150

The values of these coefficients were determinate with Kundt's Tube Bruël&Kjær type 4206 (acoustic standing waves method) for the frequency bandwidth 100÷3200Hz, with an increment pitch of 4Hz. The experiment data were acquainted and processed by Bruël&Kjær PULSE Platform type 7758.

According to plotted diagrams from Figure1, we can take some conclusions:

- for low and middle-low frequency bandwidth of noise ($f < 800Hz$), the sound absorption coefficient α is smaller than 20%, no matter of type of composite structure;
- for middle frequency bandwidth of noise ($800Hz < f < 2000Hz$), the sound absorption coefficient α is growing fast, with values from 15% to 70% (with maxim values for frequencies around 1,2÷1,5 kHz);
- for high frequency bandwidth of noise ($f \geq 2000Hz$), the sound absorption coefficient α is growing (from 20% to 95%) for all types of composite structures excepting PST 20 and PSTM5 (for which the coefficient α is almost constant, with the smallest value of 12÷13%);
- for entire frequencies domain, the sound absorption coefficient α is bigger how much more the material structures is thicker.

4. Cabin's phonic treatment for frontal loader MMT45 – case study

According to Ref. [2] and [11-14], the main acoustic features of the self propelled public work equipment cabins (see fig. 2) are:

-the equivalent phonic absorbent surface A [m^2]
-the average absorption coefficient α_{med}
-the global sound level loss ΔL [dB]
-the phonic absorption constant R_α [m^2]

Figure 2. Frontal loader MMT 45

The equivalent absorption area of the construction equipment cabin (with/without phonic treatment) can be calculate as follows:

$$A = \sum_{i=1}^{n} \alpha_i S_i \ , \qquad (1)$$

where: S_i is the area of the surface number i

α_i - the absorption coefficient of the surface S_i

The calculus relation for the average sound absorption coefficient α_{med} of the cabin is

$$\alpha_{med} = \frac{\sum \alpha_i S_i}{\sum S_i} \qquad (2)$$

The calculus relation for the global sound level reduction/loss ΔL is

$$\Delta L = 10 \lg \frac{A}{A_0} , \qquad (3)$$

where: A is the equivalent absorption area of the cabin after the phonic treatment

A_0 - equivalent absorption area of the cabin without the phonic treatment

The phonic absorption constant of the cabin is function of the total surface $\sum S_i$ and the average absorption coefficient α_{med} as follows:

$$R_\alpha = \frac{\alpha_{med}}{1-\alpha_{med}} \sum_{i=1}^{n} S_i \quad (4)$$

In order to calculate the reduction of the global noise level inside the cabin of the frontal loader MMT45, it considers the next dimensional and acoustic features:

$S_1 = 3.8m^2$ - glass surface area

$S_2 = 1.7m^2$ - uncoated steel sheet surface area

$S_3 = 4.7m^2$ - phonic treated surface area with composite structures

$\alpha_1 = 0{,}03$ - organic glass sound absorption coefficient (average value)

$\alpha_2 = 0{,}08$ - steel sound absorption coefficient (1mm thickness sheet).

Figure 3. Determining the level of noise in the cabin of MMT45, in charge (without acoustic treatment)

With the above values for areas and sound absorption coefficients, we can calculate for the MMT45 cabin:

- Total surface area $S = \sum S_i = S_1 + S_2 + S_3 = 10.2m^2$
- Equivalent absorption area without phonic treatment

$$A_0 = \sum \alpha_i S_i = \alpha_1 S_1 + \alpha_2 (S_2 + S_3) = 0.626m^2$$

- Average sound absorption coefficient without phonic treatment

$$\alpha_{med} = \frac{\sum \alpha_i S_i}{\sum S_i} = \frac{0.626}{10.2} = 0.061$$

- Phonic absorption constant of the cabin without phonic treatment (Figure 3)

$$R_{\alpha} = \frac{\alpha_{med}}{1-\alpha_{med}} \sum_{i=1}^{n} S_i = \frac{0.626}{1-0.626} 10.2 = 17.1 m^2$$

Table 3. Sound level measurements

Situation	L_{Aeq}	$L_{AF\max}$	$L_{AF\min}$
Without acoustic treatment	45.7	61.8	38.6
With acoustic treatment	46.6	74.9	25.0

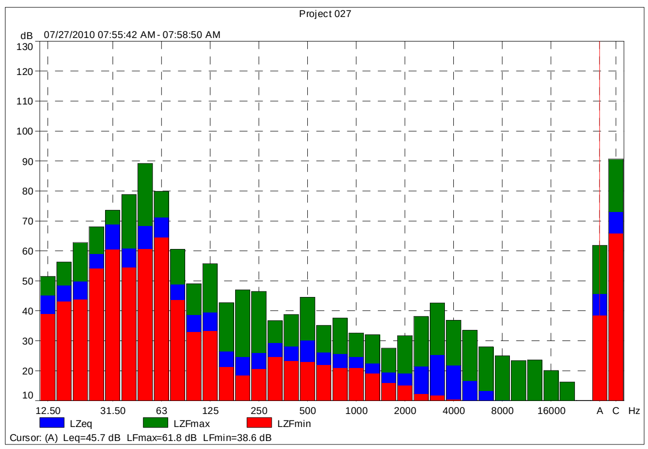

Figure 4. Noise spectrum on the driving position (without acoustic treatment)

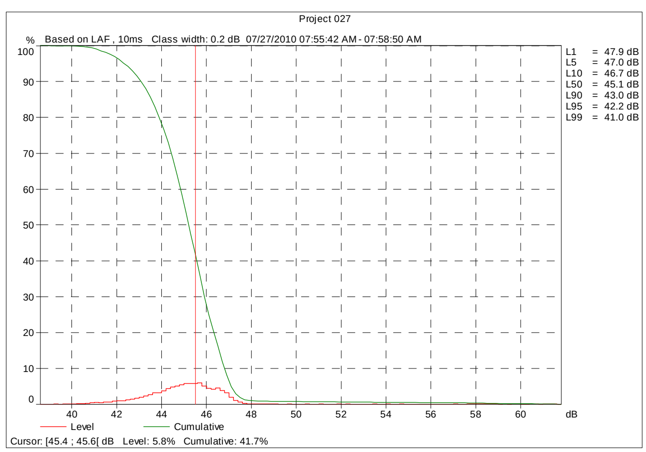

Figure 5. Percentage statistics of the L_{AF} on the driving position (without acoustic treatment)

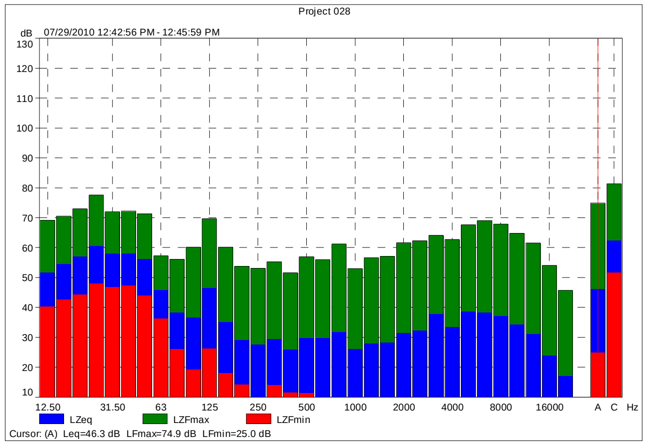

Figure 6. Noise spectrum on the driving position (without acoustic treatment)

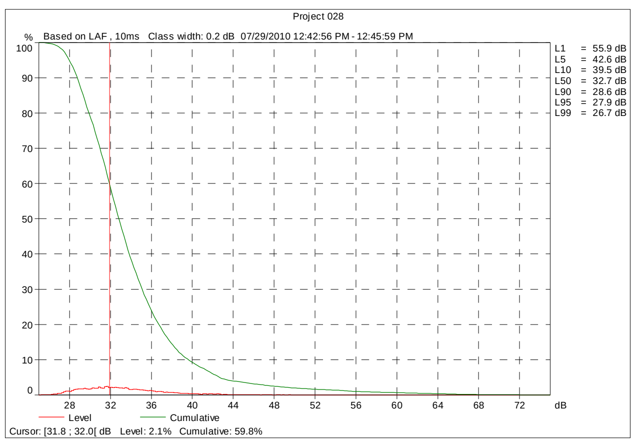

Figure 7. Percentage statistics of the L_{AF} on the driving position (without acoustic treatment)

Table 3 presents the measured acoustic noise level when use a acoustic treatment with a particular type of material. Noise spectrum on the driver position and percentage statistics of L_{AF} parameters when using or not of acoustic treatment we see in Figure 4-7.

5. Conclusion

The results are not as expected, and therefore is necessary a leading up calculation by which we can obtain a low noise to the driver's ears.

After each acoustic treatment, modeled by the acoustic method will choose optimal treatment. The acoustic treatment will be put into practice and finally will make acoustic measurements inside of the cabin (see Fig. 3-7).

In the future, the authors aim to carry out complex finite element analysis that will be taken into account composite materials absorption effect of the inner walls of the cabin. A great influence has operating mode of the equipment.

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