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ACOUSTIC CHARACTERISTICS OF NEW MATERIALS WITH COMBINED FEATURES

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A new direction in noise reduction ways - development of materials with combined features is examined with the aim of their application in multi-layered sound-insulating structures. They are sound-absorption, sound-insulation and vibro-absorption.

This direction started with the late eighties. Experimental patterns of materials "Fornem" were obtained, which are unwoven material of ATM-15 type soaked with thermoreactive binding. The patterns of new materials with improved combined features, obtained in present, are made on the basis of unwoven material of supermodule fiber (SVM is made as analog to Kevlar, USA). A comparison between the acoustic characteristics of new material patterns and the material of "Fornem" type was carried out.

In the late eighties experimental patterns of material "Fornem", which are unwoven material of ATM-15 type soaked with thermoreactive binding were obtained. According to the soak composition, either sound-absorption or vibro-absorption or sound-insulation features were predominant in different experimental patterns.

Table 1 presents structural characteristics (volumical mass (ρ), thickness (h), surface mass (m), porosity (P)), middle in the range of 100 - 1000 Hz vibro-absorption characteristics (loss coefficient (η), Young module (E), loss module ($\eta \delta E$) and sound-absorption coefficient (α) at a distance of 1/4 wave from the rigid wall of separate patterns of material "Fornem", used in the tests of multi-layered sound-insulation structures.

Table 1

Name	ρ , kg/m ³	h, mm	M, kg/ m ²	P, %	η	E, N/m ²	$\eta \delta E$, N/m ²	α
Fornem 3	313	4.8	1.5	78	0,05	1,6 δ 10 ⁸	5,0 δ 10 ⁷	0.99
Fornem 8	1083	2,4	2.6	48	0,37	7 δ 10 ⁸	2,6 δ 10 ⁸	0.83
Fornem 17	1550	0.8	1.24	38	0,26	2.3 δ 10 ⁹	6 δ 10 ⁸	0.6

All the three patterns of material "Fornem" presented relate to vibro-absorption ones, since their loss coefficient is not lower than 0.05.

Table 2 presents measurement data for these patterns related to attenuation constant (β) which characterize their sound-insulation ability.

Table 2

Name	f, Hz	125	250	500	1000	2000
Fornem 3	β , 1/m	25	30	36	38	75
Fornem 8		60	80	129	258	450
Fornem 17		280	408	570	751	1062

Fig. 1 presents measurement data on attenuation constant normalized by volumical mass (β/ρ) of separate patterns of material "Fornem". Fornem 17 possesses the highest mass efficiency in the field of sound-insulation.

Fornem 3 is the best sound-absorber. Fig. 2 presents frequency characteristics of sound-absorption coefficient (α) at a distance of 100 mm from the rigid wall.

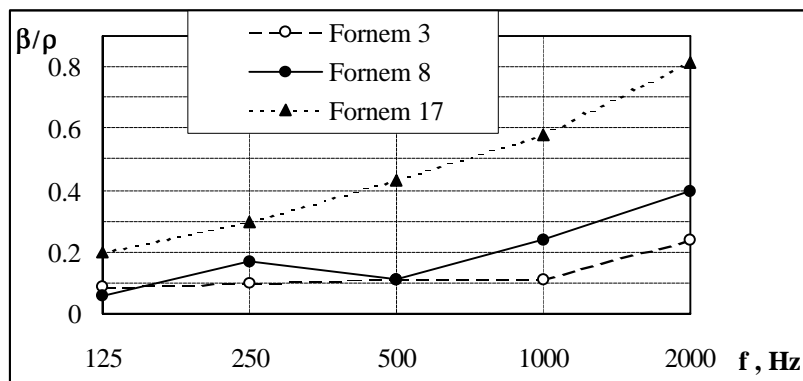


Fig. 1. The measurement data on attenuation constant normalized by volumical mass (β/ρ), for separate patterns of material "Fornem".

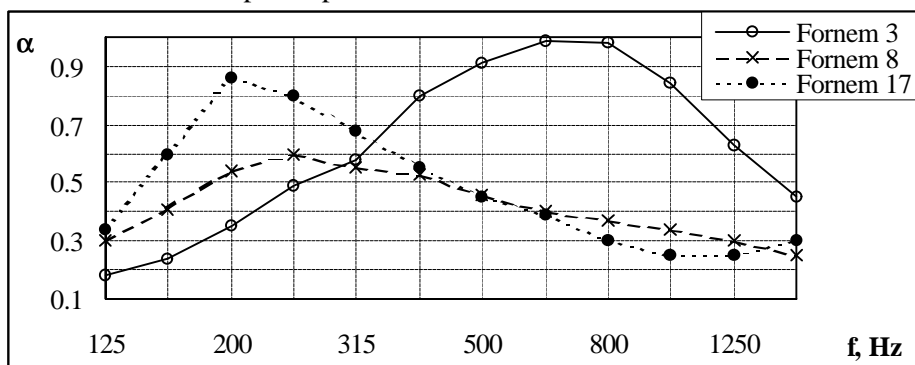


Fig. 2. The frequency characteristics of sound-absorption coefficient (α) in the case of placing the patterns of material "Fornem" at a distance of 100 mm from the rigid wall.

Thus, the materials were obtained which had not been previously used in sound-insulating structures. They possess simultaneously a complex of the acoustic features: sound-absorption, sound-insulation and vibro-absorption. These characteristics can be found to a certain degree in all three "Fornem" types considered above. However each of them possesses one, the most pronounced feature: Fornem 3 is the best sound-absorber, Fornem 8 is the best vibro-absorber, Fornem 17 is the best for sound-insulation. All these materials appeared good in experimental aircraft sound-insulating structures. Their application in multi-layered panels permitted obtaining essentially better sound-insulating (by 5 - 10 dB) and sound-absorbing characteristics at low frequencies (100 - 250 Hz) in comparison with the traditional double-walled board structure.

At present the research work with the materials which possess combined features is carried out on the basis of new unwoven materials and soaking.

The reference unwoven materials were the material of supermodule fiber (SVM, an analog to the foreign material of Kevlar type, USA) and the material presenting its mixture with Lavsan in proportion: SVM 75% + Lavsan 25%.

Description of structural and vibro-damping characteristics of different patterns with different soaking is given in table 13 under conditional numeration. Since loss coefficient (η), Young module (\hat{A}) of these materials slightly depend on frequency in the measurement range of 100 - 1000 Hz, their mean values are indicated in this range.

If the data from Table 13 are compared with the description of Fornem materials presented in Table 11, one can see that the new series patterns are analogical to Fornem 3 and, first of all, in porosity and volumical mass. The volumical mass of some new patterns is comparable with the volumical mass of Fornem 3 (300 kg/m³) and it is approximately in 1.5 times less than that in some others; the test pattern porosity either agrees with that of Fornem 3 or exceeds it.

Table 3

N in order	ρ , kg/m ³	h, mm	M, kg/m ²	P, %	η	E, N/m ²	$\eta \delta E$, N/m ²	α
1	140-158	2-2.2	0.31-0.32	87-89	0.148	$4.1 \delta 10^8$	$6.068 \delta 10^7$	0.99
2	106-134	2-2.2	0.27-0.28	90	0.162	$1 \delta 10^8$	$1.62 \delta 10^7$	0.83
3	228-316	3-15	0.95-3.42	73-81	0.198	$3.8 \delta 10^8$	$7.52 \delta 10^7$	0.6
4	118-169	3-15	0.51-1.78	86-89	0.132	$2.3 \delta 10^8$	$3.04 \delta 10^7$	
5	221-286	3-15	0.96-3.3	74-80	0.128	$5 \delta 10^8$	$6.4 \delta 10^7$	

It follows from Table 13 that all the new materials have a higher loss coefficient in comparison with that of Fornem 3 ($\eta \sim 0,05$); it exceeds 0.12 and material 13 has it about 0.2. Young module of most new materials is 1.5 - 2 times higher than that of Fornem 3.

If the values of mass efficiency (β/ρ) of the same materials are compared (see Fig. 3), Fornem 3 appears to be one of the least efficient materials and the best ones are the most light ones: SVM with soaking 12 at volumical mass 106.7 kg/m³ and the same material at volumical mass 128. 4 kg/m³. Note that the material soaking reduces its efficiency and the more is the mass increase due to soaking, the lower it is.

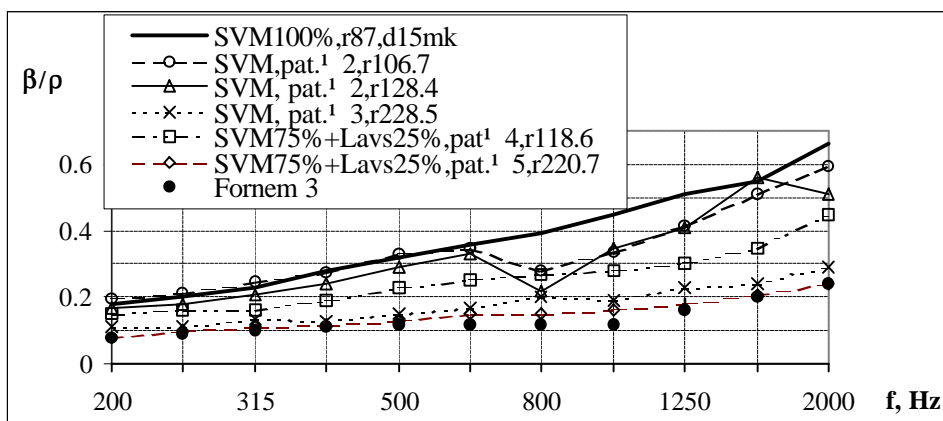


Fig. 3. Measurement data on attenuation constant normalized by volumical mass (β/ρ) for separate patterns of new materials: SVM and its mixture with Lavsan without and with soaking and Fornem 3.

For the best new materials (SVM with soaking) the data on sound-absorption coefficient in the case of placing the materials at a distance of 100 mm from the rigid wall are given in Fig. 4, in comparison with the characteristics of Fornem 3 (thickness 5 mm).

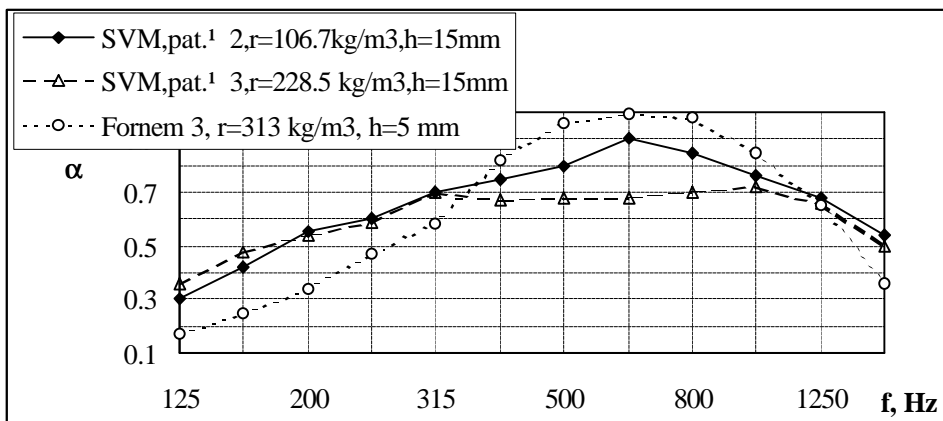


Fig. 4. Sound-absorption coefficient of material patterns SVM with soaking (12, 3), Fornem 3 in the case of placing them at a distance of 100 mm from the rigid wall.

The data show that the maximum absorption value of the new materials is somewhat less than that of Fornem 3 ($\alpha = 0,7 - 0,8$ and $\alpha \sim 1$, respectively). However at low frequencies ($f < 400$ Hz) the sound-absorption coefficient of the material on the basis of SVM is higher ($\alpha = 0,4 - 0,7$ instead of $0,2 - 0,6$ for Fornem 3). The most probable that this is connected with a large layer thickness.

The above characteristics of the materials with combined features investigated earlier ("Fornem") and new development on SVM basis permit making the following conclusion.

According to the mass increase due to soaking, the volumical mass of the test materials is $\sim 120 - 300$ kg/m³. The material porosity is within of 70 - 90%. The material patterns possess combined acoustic features. Young module of all the materials is of one order and within the limits of $(1 - 5) \cdot 10^8$ N/m²; their loss coefficient is from 0.12 to 0.19. The attenuation constant increases with frequency and is not less than 17 m⁻¹ at low frequencies and not higher than 45 m⁻¹ at the frequencies of about 1000 Hz for all the materials. The best mass efficiency is observed in the patterns with slight mass increase due to soaking (< 1.5 times in comparison with the reference one). Sound-absorption coefficient of the materials out of SVM with soaking in the case of placing the layer of 15 mm in thickness at a distance of 100 mm from the rigid wall varies from 0.3 to 0.8 in the frequency range of 125 - 1000 Hz.

One can observe some tendencies in the material behavior. The patterns with larger mass increase due to soaking and hence with a larger volumical mass have somewhat increased Young modules and a less attenuation constant (and a less mass efficiency). It is also to note that the materials made out of unwove cloth of SVM only have the attenuation constant a little larger than those made out of SVM and Lavsan.

Thus, the experimental patterns of materials made on the basis of unwove cloth out of SVM or its mixture with Lavsan, with soaking, which can be a fundamental for working out the materials with combined acoustic features for sound insulating aircraft structures, are obtained.