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Acoustic performances of nickel-based materials

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ABSTRACT

This paper deals with an investigation on a multilayer panel suitable for noise insulation and absorption joined with electromagnetic and thermal insulation properties. Two nickel-based materials were studied: sinterized nickel (SN) and green nickel-copper (GNC); they are characterized by high acoustic insulation and electromagnetic shield properties. SN and GNC layers were coupled to low density polyethylene foam layers (LDP) in order to improve thermal and acoustic abatement performances. Acoustic absorption and transmission loss were measured for different configurations based on the investigated materials. Measurements were carried out by impedance tube method. Results show that the best performing panel is the one constituted by SN and LDP layers.

1 INTRODUCTION

An innovative panel which gathers acoustic, thermal and electromagnetic insulation properties was studied. Morphologic and granulometric analyses on metallic dusts allowed to individuate two nickel-based materials characterized by high acoustic and electromagnetic insulation properties: sinterized nickel (SN) and green nickel-copper (GNC). A single layer of the proposed materials (SN thickness = 0.5 mm; GNC thickness = 1.2 mm) was coupled to two low density polyethylene foam layers (thickness = 30 mm), a closed cell material able to improve acoustic absorption and thermal insulation properties. Thermal and electromagnetic properties of the proposed multilayer panels were verified by a measurement campaign. Impedance tube methods were used to evaluate acoustic performances. Results showed that the best panel is the one constituted by SN and two LDP layers in terms of acoustic insulation and electromagnetic properties (acoustic absorption and thermal properties are very close to GNC+LDP panel). In particular, transmission loss due to the individuated panel is higher than 30 dB for frequencies higher than 1900 Hz and higher than 15dB in the [100, 1900] Hz range.

2 THE PROPOSED MATERIALS

New materials were proposed in order to obtain high acoustic, thermal and electromagnetic insulation. A preliminary study individuated metallic materials which may guarantee good acoustic and electromagnetic insulation. These materials were coupled to closed cell plastic materials in order to improve acoustic absorption and thermal insulation. Metallic material fabrication procedures were analysed. A lot of kinds of metallic dusts were characterized on a morphologic and granulometric point of view. The analysis allowed to individuate the optimum percentage of organic binders; this is needed to obtain wetting and viscosity properties suitable for an optimum leakage. Two kinds of metallic dusts were individuated and studied: nickel and a

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mixture of nickel and copper. Morphologic analyses by a scanning electron microscope were reported in figures 1 and 2.

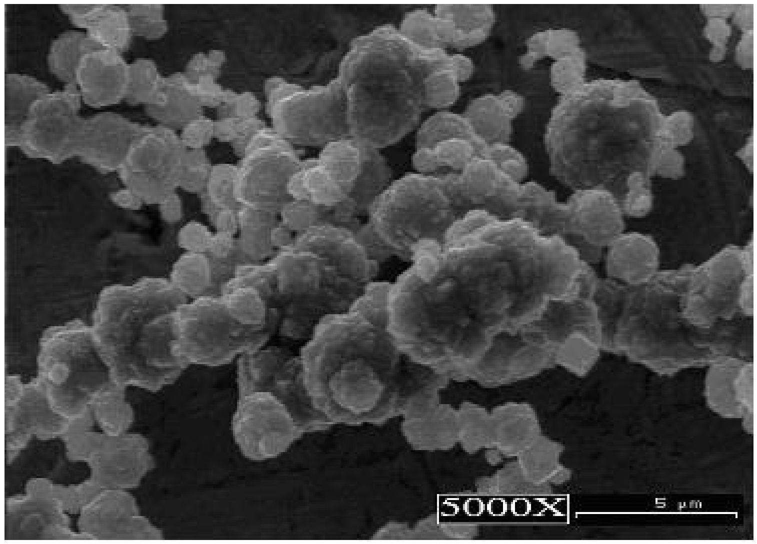

Figure 1: Nickel morphologic analysis by scanning electronic microscope (5000 X)

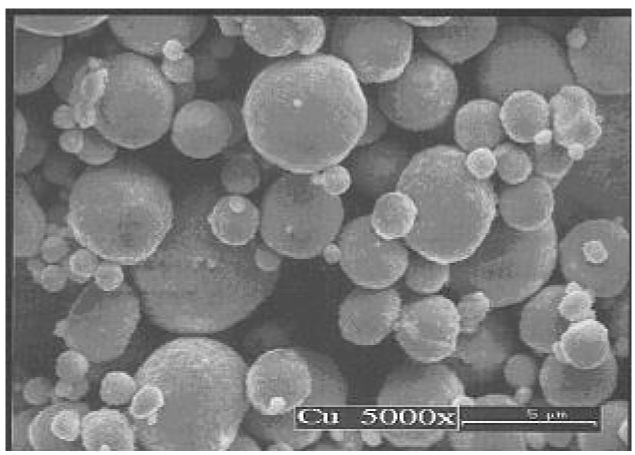

Figure 2: Copper morphologic analysis by scanning electronic microscope (5000 X)

Granulometric analyses showed metallic dust dimension distribution in terms of granulometric D_{10}, D_{50}, D_{90} and mode (see Table 1).

Table 1: granulometric test results

Metallic dust	**D_{10} (μm)**	**D_{50} (μm)**	**D_{90} (μm)**	**Mode (μm)**
Nickel	4.53	26.23	82.55	37.80
Copper	1.25	6.30	22.40	7.05

Laboratory tests were carried out to determine the metallic dust compatibility with plastic materials used as organic binder for tape casting moulding in thin layers. The best organic binder is polyisobutylene: it is characterized by high extensibility properties, also when loaded with mineral materials. Besides, polyisobutylene is an electric insulation material (resistivity is 10^{15}

Ω cm, ε_r = 2.2, tanδ= 0.004); thus, it was needed to heavily load it with metallic conductive dusts. Table 2 shows the results obtained by the leakage tests on the proposed materials.

Table 2: leakage test results

Material	Mass Percentage of mineral load (%)	Leakage
Nickel	68%	Good
Nickel/Copper (50/50)	50%	Optimum

At last, two kinds of metallic layers were realized:

- a green tape (nickel-copper, GNC), which is obtained by leakage and drying processes. GNC single layer is 1.2 mm thick;
- a nickel tape (SN, see Figure 3), constituted only by mineral component, which is obtained by leakage, drying, dewaxing and sinterization processes on vacuum kiln (maximum temperature = 1080 °C). SN single layer is 0.5 mm thick.

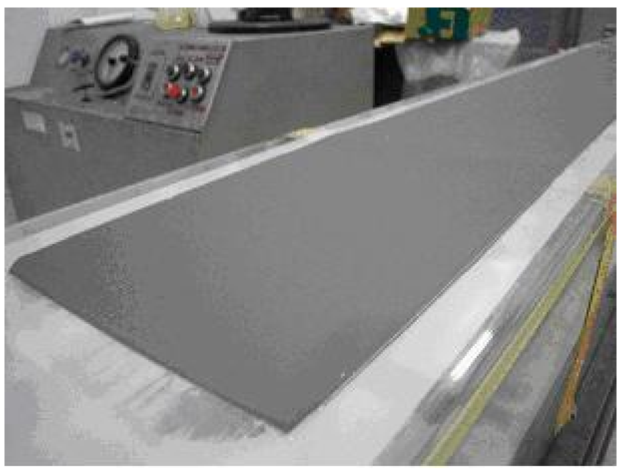

Figure 3: nickel tape after drying process

The metallic layers were coupled to low density polyethylene foam (LDP), which is a closed cells material with theoretically good acoustic and thermal insulation properties. Coupling is obtained by epossidic resins. Thus, the obtained multilayer panels are characterized also by optimum wet resistance, good water absorption resistance, no gas toxicity when fired, autoextinguibility.

3 ELECTROMAGNETIC AND THERMAL PROPERTIES

3.1 Electromagnetic Shielding Measurements

Metallic layers were tested in terms of electromagnetic shield efficiency into an anechoic room. Test equipment was constituted by:

- an horizontal polarized antenna as electromagnetic source able to generate an electromagnetic field at variable frequency and intensity;
- an isotropic probe as receiver; it is placed at a 3 m distance from the antenna. It is used to measure the transmitted electromagnetic field intensity.

Tested materials insulation properties are optima; as an example, test results relative to 2.4 GHz electromagnetic field (wireless nets) are reported in Table 3 for three field intensity: -20dBm, -10dBm and -4dBm [1].

Table 3: electromagnetic shield measurement results (2.4 GHz frequency)

Tested material	***Transmitted Power (f=2.4 GHz)***		
	- 20dBm	***-10 dBm***	***-4dBm***
	Measured Field [V/m]		
No material	2.52	7.97	11.90
SN	LOW	LOW	LOW
GNC	0.27	1.74	2.62

LOW values in Table 3 are referred to a field intensity lower than 0.2 V/m. SN is characterized by electromagnetic shield properties better than GNC. LDP is a plastic material which has not electromagnetic insulation properties.

3.2 Thermal Insulation Measurements

Thermal conductivity of the proposed materials was measured according to ISO 8301 [2]; the following 0.0036 m^2 squared area panels were tested:

1) LDP (thickness 60 mm);
2) a multilayer panel constituted by LDP (thickness 30 mm) + SN (thickness 0,5 mm) + LDP (thickness 30 mm);
3) a multilayer panel constituted by LDP (thickness 30 mm) + GNC (thickness 1,2 mm) + LDP (thickness 30 mm).

Tested elements are reported in Figure 4.

Figure 4: components for thermal conductivity measurements

Table 4 reports thermal conductivity of the tested panels. Results shows the proposed multilayer panels have high thermal insulation properties. The panel constituted by two LDP layers and a SN layer is the best one in terms of thermal insulation.

Table 4: thermal conductivity of the proposed multilayer panels

Tested panels	**Thermal Conductivity (W/m·K)**
LDP	0.071
LDP + SN + LDP	0.063
LDP + GNC + LDP	0.067

4 ACOUSTIC MEASUREMENTS METHODOLOGY

Acoustic absorption and insulation properties of the proposed materials were tested by impedance tube techniques. Measurements were carried out on the following panels:

1) LDP (thickness 30 mm);
2) LDP (thickness 60 mm);
3) a multilayer panel constituted by LDP (thickness 30 mm) + SN (thickness 0,5 mm) + LDP (thickness 30 mm);
4) a multilayer panel constituted by LDP (thickness 30 mm) + GNC (thickness 1,2 mm) + LDP (thickness 30 mm).

Measurements were carried out on two diameters cylindrical shape samples: 100 mm and 29 mm, which are respectively related for [100, 1600] Hz and [1600, 6400] frequency ranges. Some tested materials are reported in Figure 5. Figure 6 shows some measurement phases.

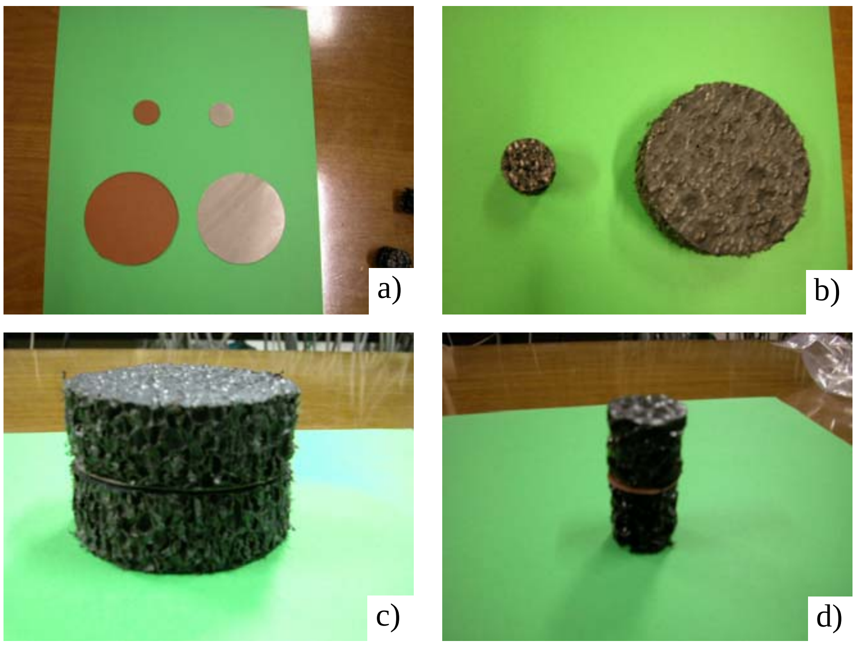

Figure 5: (a) SN and GNC samples (diameters 29 mm and 100 mm); b) LDP samples (thickness 30 mm, diameters 29 mm and 100 mm); c) multilayer panel constituted by LDP (thickness 30 mm) + SN (thickness 0,5 mm) + LDP (thickness 30 mm), 100 mm diameter; d) multilayer panel constituted by LDP (thickness 30 mm) + GNC (thickness 1,2 mm) + LDP (thickness 30 mm), 29 mm diameter

Figure 6: some measurement phases

Measurements were led on ten samples for each panel typology. Test equipment is constituted by:

- Brüel & Kjær PULSE data acquisition system (model 3560-B-030);
- Brüel & Kjær Impedance tube model 4206;
- Brüel & Kjær amplifier model 7206;
- Brüel & Kjær ¼” microphones model 4187;
- Brüel & Kjær preamplifiers model 2670;
- Brüel & Kjær pistonophone model 4228.

Acoustic absorption measurements were carried out according to ISO 10534-2 [3]. Acoustic insulation measurements were led by a methodology based on the same assumptions of ISO 10534-2, a four microphone transfer function method which is able to determine the Transmission Loss (TL) [4]. TL is determined by a two-load method: two successive acquisitions are made for each sample by modifying the characteristics of a tube extremity: for instance, a reflective and an absorbing material are installed on a tube terminal for the two acquisitions. Channels phase displacement errors are avoided by a calibration procedure. Signal to noise ratio is kept over 10 dB for each measurement session.

5 ACOUSTIC MEASUREMENT RESULTS

The absorption measurement results are reported in Figure 7.

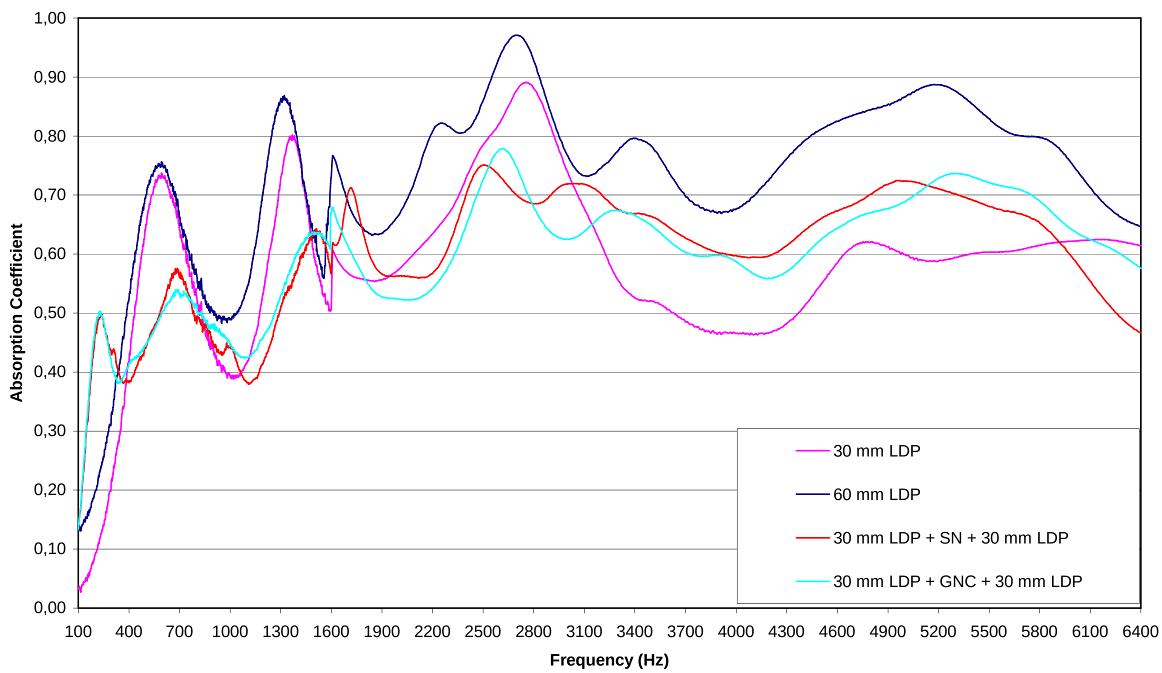

Figure 7: acoustic absorption measurement results (average values)

The best results are obtained for 60 mm LDP, especially for high frequencies. Metallic layers introduce a minimum worsening in the absorption properties: absorption peaks in the [300, 3000] Hz range are reduced with respect to 30 mm and 60 mm LDP samples. However, SN and GNC micro-porosity contributes to:

- increase absorption properties with respect to 30 mm LDP for frequencies higher than 3000 Hz;
- increase absorption properties with respect to LDP ones for frequencies lower than 300 Hz (absorption coefficient higher up to 0.3).

The difference between SN and GNC effect is negligible.

TL measurement results are reported in Figure 8.

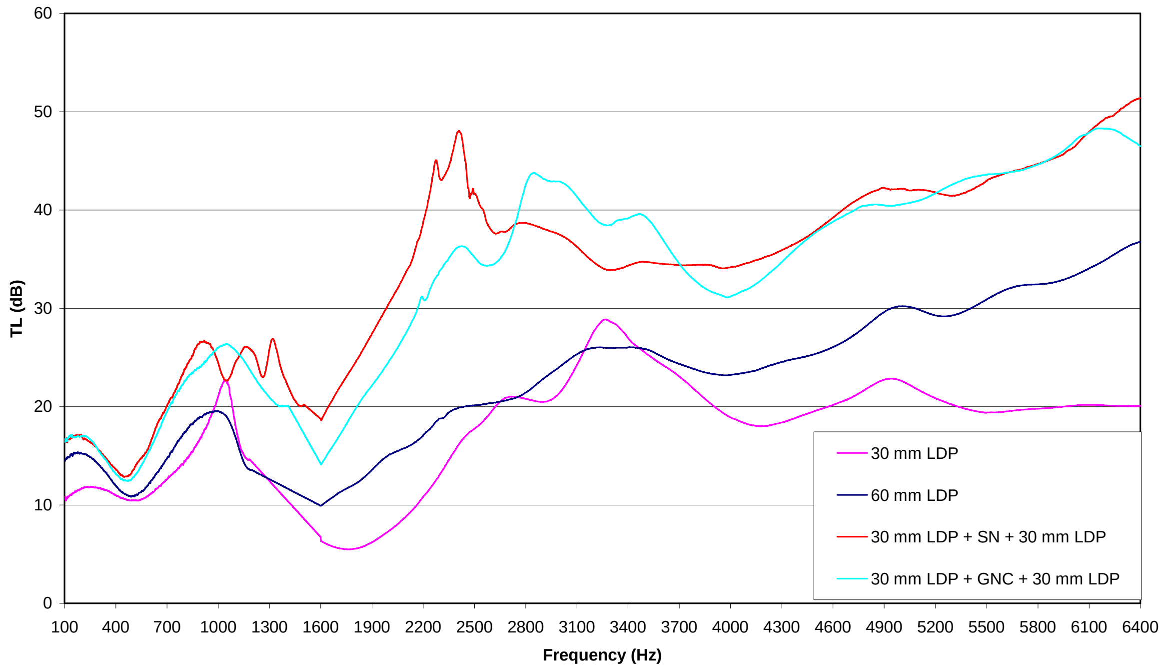

Figure 8: TL measurement results (average values)

SN and GNC layers introduce an about 15 dB increase in TL values related to 60 mm LDP samples. Besides, results show that:

- SN and GNC performances are close each other for frequencies lower than 1100 Hz;
- although SN single layer is characterized by a smaller thickness than GNC single layer one, SN-based panel is characterized by an acoustic insulation higher than GNC one for [1100, 2500] Hz range (average 5 dB with peaks of 10dB);
- SN and GNC performances are close for [2500, 2700] Hz frequency range;
- GNC performances are higher than SN ones for [2700, 3700] Hz frequency range (up to 5dB);
- SN performances are higher than GNC ones for [3700, 4400] Hz frequency range (up to 3dB);
- SN and GNC performances are close for frequencies higher than 4400 Hz.

6 CONCLUSIONS

Two multilayer panels characterized by high acoustic, thermal and electromagnetic insulation properties were studied. Panels are constituted by:

1) a sinterized nickel (SN) layer coupled to two LDP (low density polyethylene) layers;
2) a green nickel-copper (GNC) layer coupled to two LDP (low density polyethylene) layers.

High thermal and electromagnetic insulation properties were measured for each proposed panel. Acoustic measurements showed that LDP contributes to have acoustic absorption coefficient in the [0.4-0.75] range for frequencies higher than 150 Hz. Besides, metallic layers are characterized by a micrometric porosity; thus, their insertion between two 30 mm LDP layers induces an absorption coefficient increase for frequencies lower than 300 Hz and higher than 3000 Hz with respect to a simple LDP layer. SN panel performances are similar to GNC ones. Transmission loss (TL) was also measured. Results showed that the multilayer panel constituted by LDP and SN is characterized by:

- TL higher than 30 dB for frequencies higher than 1900 Hz;
- TL higher than 15dB in the [100, 1900] Hz range.

The multilayer panel constituted by LDP and GNC is characterized by:

- TL higher than 30 dB for frequencies higher than 2200 Hz;
- TL higher than 15dB in the [100, 2200] Hz range.

Measurement results and the smaller thickness of a SN single layer induce to prefer SN as the best acoustic insulation material. Thus, the proposed multilayer panel constituted by LDP and SN may be a good solution as acoustic, electromagnetic and thermal insulation material for building applications.

7 REFERENCES

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