Morphology and Structure of the Polypad® Sandwich Composite Material Used in a Machine Element

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The present article is the first in a series of three articles presenting results obtained by our team in a study on sandwich composite materials. The aim was to study the damping capacity of some sandwich structures used for a structural element of a machine tool that was reduced to scale (namely, a column), as well as all aspects of the material's recyclability. The first stage of the study involved the characterization of the Polypad® composite material by scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectrometry (EDX), Fourier transform infrared spectrometry (FTIR) and X-ray diffraction (XRD)

Keywords: composite, sandwich materials, characterization, recyclability, damping capacity

Today, three types of composite materials are being developed and are widely used in many kinds of engineering applications such as metal–matrix composites (MMC), polymer–matrix composites (PMC) and ceramic–matrix composites (CMC). The composite materials can be classiûed according to the reinforcement type into ûber-reinforced, structural, and particulate composites [1]. Among these types, the PMC composites dominate the market [2].

With higher strength, lower weight, corrosion resistance, durability, and speedy construction, the composite materials - in particular sandwich composite structures- are being used in a wide range of industrial applications such as automotive, aerospace and renewable energy [2, 3].

The widespread use of these materials stresses the need for evaluation in terms of mechanical performance and vibration damping. Moreover, current and future environmental legislation in various countries requires all engineering materials to be recovered and recycled at the end of life (EOL).

Under these circumstances, our research aimed to study the damping capacity of the Polypad composite material on one hand, and all aspects of this material's recyclability on the other hand. For this aim, the first stage of the study was to characterize the composite materials using a variety of available techniques, as described below.

Experimental part

Characterization of the Polypad® material

The investigated material was a composite material produced by Texmer Gmbh, Germany, under the trade name Polypad. It is available on the market in two thicknesses, 9 and 18 mm (fig. 1).

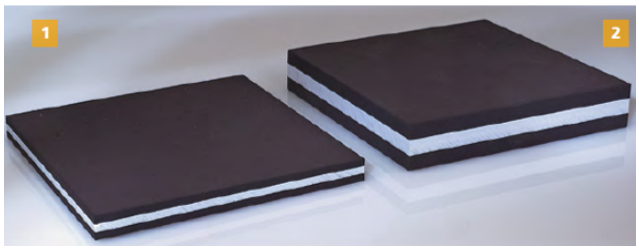

Fig. 1 The composite material Polypad (1-thickness 9mm; 2-thickness 18mm) [4]

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According to the manufacturer's recommendations, the Polypad composite material allows shock absorption and is used in industrial machines as a vibration damper due to of its antifriction properties that ensure stability of equipment placed upon it. It is also resistant to contact with oils and acids used in industry [4].

To characterize the Polypad composite material, the following techniques and methods were used [5-7]:

- scanning electron microscopy (SEM) coupled with energy dispersive X-ray (EDX) spectrometry;
- fourier transform infrared spectrometry (FTIR);
- X-ray diffraction (XRD).

SEM imaging was performed with a Philips XL 30 ESEM TMP apparatus equipped with an EDX spectrometer. The EDX analysis completed the structural analysis, allowing simple identification of the chemical elements present on the sample surface [8].

The SEM microscope (XL 30 ESEM TMP) was used with an electron beam at the accelerating voltage of 10 kV, which generated a current of 30 μA in the sample; the distance between the pole piece of the microscope and the sample was 10 to 13 mm.

The resulting images had a magnification factor of between 25x and 500x and provided information about the material's morphology and composition (using a secondary electron detector in water vapor, with vapor pressure between 0.9 and 5 torr in the sample chamber). Secondary electrons images were taken from the sample surface and the samples were investigated by positioning the beam over the two components of the composite material (the brown and white zones, respectively), as well as on the interface between them.

Two areas can be distinguished on the micrograph in figure 2: a brown (dark) area that appears to be rough and

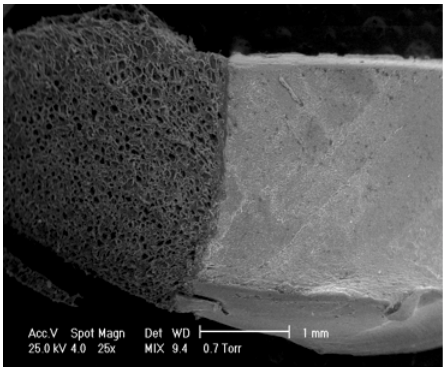

Fig. 2. SEM image: composite material Polypad assembly, 25x magnification

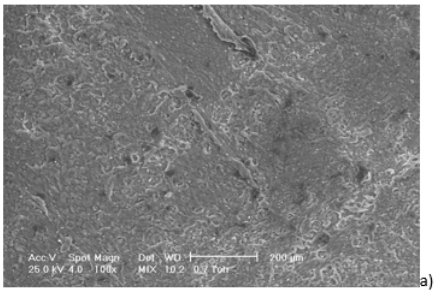

Fig. 3. SEM image:
a) the compact area and b) the porous area,
100x magnification

porous, with pores of different sizes, and a compact area in which the particles of the reinforcing elements are well incorporated in the polymer matrix.

By analyzing the surface morphology of the compact area, we can observe that Polypad is a composite material with a reinforced polymeric matrix with inorganic powders (fig. 3a). Similar conclusions can be drawn by analyzing the surface morphology of the porous area, (fig. 3b). Given the low porosity and the small pore size (20–60μm), we

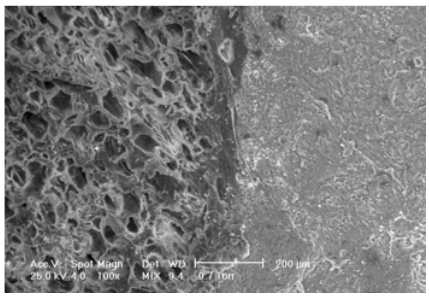

Fig. 4. SEM image:
the hybrid zone,
100x magnification

also checked the manufacturer's statement that the material does not absorb water, oil, and other chemicals.

Next, the interface between the two zones was investigated and the presence of an adhesive could be observed. Because of the small dimensions, it was difficult to determine its exact nature, but a hybrid zone could be identified (fig. 4), in which the adhesive has penetrated the porous area; this hybrid zone confers increased stability to the composite material.

From the EDX analysis on the main factors identified in the composition (O, C, Cl) and their proportion, we consider that the polymeric matrix is a polyvinyl chloride (PVC) (fig. 5). We have also identified a number of chemical elements from the composition of the inorganic powders used to reinforce the polymeric matrix (Ca, Ti, Si) for the compact area and, respectively, for the porous area (Na, Si, Ca, Fe).

XRD measurements were performed with a Philips 1050/70 diffractometer, with crystal graphite, Kα radiation (wavelength 1.541A), a voltage of 40 kV, and a current of 30 mA. The presence of an amorphous halo with only a few crystalline peaks only proves that we have a composite material with a polymeric matrix containing reinforcing elements of inorganic powders (fig. 6). Although it was

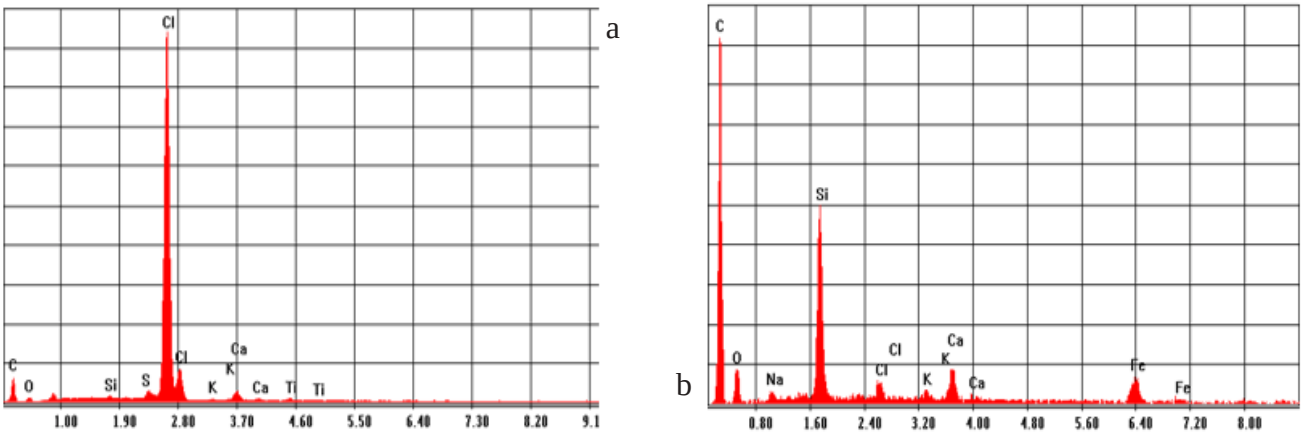

Fig. 5. EDX spectrum for the compact area a) and porous area b)

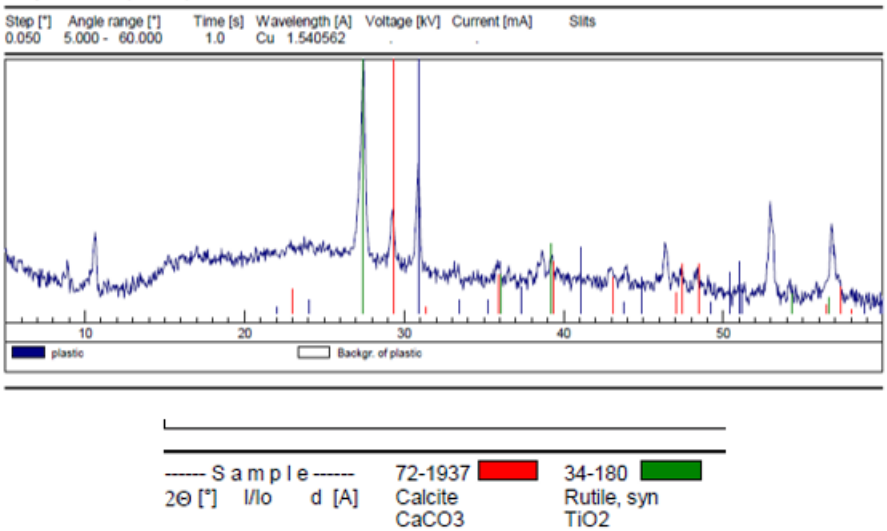

Fig. 6. The results of XRD measurements

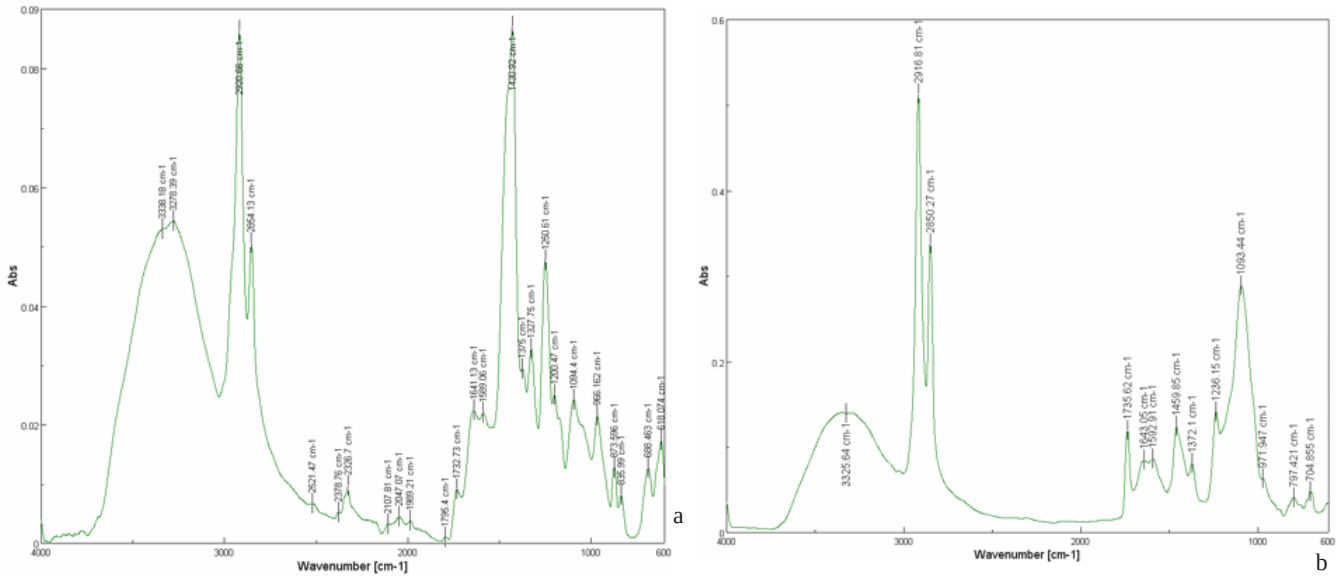

Fig. 7. FTIR spectrum for the sample taken from the porous area a) and the compact area b) of the composite material

difficult to estimate their exact nature because of their reaction with the polymeric matrix, the software (and the existing database) helped us to identify at least two of these potential materials, namely rutile (TiO_2) and calcite ($CaCO_3$).

As we had to analyze a composite material with a polymer matrix reinforced with inorganic powders, the analysis required additional characterization using FTIR. We used a JASCO FTIR spectrometer 6200 with an attenuated total reflectance (ATR) reflection system (MK II Golden Gate), with the spectral range between 4000 and 600 cm^{-1}. Spectra were recorded using the resolution of 4 cm^{-1} and an accumulation of 160 spectra in the wavelength range of 4000–600 cm^{-1}.

The previous experimental measurements have led us to the assumption that the polymer matrix of our composite material was of the PVC type. The IR spectra (fig. 7) show the presence of an ester additive together with the PVC.

For the sample taken from the porous area, the bands characteristic to PVC were recorded at 2916.81 and 2850.27 cm^{-1} (because of the elongation vibrations of the C–H bond of the groups methylene $–CH_2-$ and methine –CH-), between 600 –715 cm^{-1} (attributed to the elongation vibrations of the CCl bond).

At 1736.62 cm^{-1} we have the band attributed the elongation vibration of C=O bond from the ester grouping and at 1592.91 cm^{-1} the band attributed to the benzene nucleus present in the plasticizer structure.

For the sample taken from the compact area, the IR spectrum contains the PVC characteristic bands at 2920.66 and 2854.13 cm^{-1} (ν(C–H)), at 1430.92 cm^{-1} (δ(C–H)), between 600–715 cm^{-1} (ν(C–Cl)), together with plasticizer-specific bands ((1732.73 cm^{-1} ν(C=O); 1589.06 cm^{-1} benzene nucleus).

Conclusions

After correlating the experimental results obtained with SEM, XRD, EDX, and FTIR spectroscopy, we could say that both components of the material are composite materials with a polymeric matrix that is a type of PVC. The difference between the two areas in the material was not only the color (the material has two identical brown zones on the extremities, and a white zone in the middle), but also morphological (a compact area for the white zone and a porous area for the brown zone). SEM examination revealed the compact morphology of the white zone and the vaporous morphology of the brown zone (with small pores of 20–60 μm). SEM analysis of the area between the two zones also revealed the presence of a fine film of adhesive. Because of the very small size it was difficult to determine the type and nature of this adhesive, but we identified a hybrid zone where it has penetrated the porous area. We cannot comment this adhesive because it seems to be a manufacturing secret.

In addition, the experimental study has shown that the two parts of the composite were different in terms of composition of the reinforcing elements. The porous area contained reinforcing elements and inorganic powders such as silicate salts, calcium carbonate, and pigment (of iron oxide type) and the compact area also contains silicate salts, calcium carbonate, and titanium oxide as reinforcing elements. It can be said that the iron oxide gives the brown color of the porous area and the titanium oxide confers higher rigidity and strength to the compact area.

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