Study of external impacts on composite materials

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Abstract. This article proposes a method for studying external impacts on the components of a composite material and on the material as a whole. The method is based on the analysis of digital micrographs of composite samples’ cross-section at the edge. Results of the analysis show the changes in the parameters of the composite’s different sections and of the composite material as a whole, caused by various types of external impacts.

1. Introduction

The demand for new composite materials is growing very rapidly, however, studying the properties of materials does not always keep pace with the development of the materials. The advantage of such materials in the printing is their workability, especially in the offset printing in large editions.

It is known that the properties of a composite material (CM) depend on the properties of its components and on the nature of their mutual influence at the phase boundary that means the material acquires new properties that individual components do not possess [1]. An assessment of the mutual influence and the mutual impacts of the CM components is of the practical interest, and can become a reference to develop composites of certain application fields and to control their properties.

Previously, a method for studying the physical and chemical and elastic properties of the offset blankets (OB) was proposed, which was based on the analysis of digital micrographs of the face sections of the samples and was called the “optical method” [2]. OB is a layered composite material [3], including layers of various properties and purposes (rubber ink-transferring layer, porous compressible layer, twisted cotton fabric layers, rubber fiber layers). The study of the OB properties as well as the properties of the filled rubbers, which can be considered as CMs with a dispersed reinforcing component, shows the prospects of using the optical method to study the effect of the components on the CM performance.

CM components can interact with solvents in different ways. In addition, the less swelling CM components restrain the swelling of nearby layers. In this case, the swelling ratio of the upper matrix layer is greater than that of the deeper layers and will correspond to its actual interaction with the solvent.

Dividing the CM layers of the digital micrographs into separate areas and evaluating the results of external impacts on these areas made it possible to reveal the mutual impact of the CM components and to obtain a reliable assessment of the CM properties.

The procedure of processing the digital photographs of the face sections of the OB samples, as well as of dividing of the blanket layers into areas and determining the swelling ratio of each of them, is described in detail in [4].
2. Results and discussion

Figure 1 shows the values of the swelling ratio over an hour ($H_{sw}$) of four areas of the ink-transferring layer (IT) located at different depths from the blanket surface. The $\varphi$ values on the y-axis correspond to the depth of division lines of the selected IT layer areas (vertical lines), expressed in fractions of the distances of division lines from the sample surface from the total IT layer thickness. Thus, $\varphi = 0$ value corresponds to the surface, $\varphi = 1$ does to the total IT layer thickness. The OB fabric layer restrains swelling of the border IT layer areas, and its swelling effect decreases as it approaches the blanket surface (red line). The swelling ratio of the blanket surface is approximately 5 times greater than one of the area at the phase boundary. The described method for assessing the effect of solvents on individual sections along the depth of the OB can be used to study the interaction of the surface of the CM matrix with liquids.

The procedure of determining the swelling ratio from the micrograph areas of the face sections of CM samples allows to evaluate the effect of the CM structure on the swelling of inhomogeneities, for example, dispersed fillers, fibres, etc.

Generally speaking, a filled rubber can be considered as a CM with the dispersed phase distributed in the rubber matrix. Figure 2 shows the size changing of the entire sample of filled rubber based on the NR as well as its selected areas after 30 minutes of swelling in kerosene. The lower boundary of the first area passes through the middle of a filler particle of 70 $\mu$m in size. As noted above, the procedure for determining the swelling ratio of the entire sample and each of the areas is described in detail in [4]. The swelling ratio of the areas adjacent to the filler particle ($H_1$ and $H_2$) is less than the swelling ratio of the entire sample ($H_3 = 39 \%$). With an increase in the areas under consideration in the total thickness of the sample, the effect of the filler on the swelling ratio decreases.

Composite materials may show various types of deformations under mechanical impacts. In this case, CM layers having various mechanical properties contribute to the integral parameters of the material.

The OB in the rotary apparatus undergoes cyclic compression strains in the printing zone. Different layers of this CM undergo strains of various rates. According to the procedure given in [5], compression strains of the blanket and its individual layers were determined. Highlighted in figure 3, the area of working deformations corresponds to the nip pressure.
Figure 2. Micrographs of the face section of the 1 mm thick filled NR rubber sample before (a) and after swelling in kerosene for 30 minutes (b).

Figure 3. Contribution of the strains of the inner layers to the total strain of the Atlas Web OB sample.

The contribution of the strains of the OB inner layers to its total strain is calculated from the values of the layerwise relative strains, and the relative strain of the entire blanket. The partial strain percent of an individual layer \( c_i \) in the total strain is:
where \( \varepsilon_i \) – relative strain of \( i \)-th layer, \( \% \); 
\[
\sum_{i=1}^{n} \varepsilon_i = \text{the sum of the relative strains of all } n \text{ layers, } \% .
\]

In the field of working deformations, the compressible and ink-transferring layer make the largest contribution to changing the blanket dimensions. The polymeric layer is slightly deformed. Under significant pressure on the blanket, the lower frame fabric layer begins to deform. Thus, based on the assessment of the contribution of the properties of individual layers of CM to its integral properties, it is possible design a composite with the required properties.

The analysis of digital micrographs obtained after the frame-by-frame breakdown of the video files makes it possible to study the kinetics of various processes, for example, relaxation \[6\] or capillary fluid flow processes in the porous composite media.

Figure 4 shows a fragment of a device modelling the technology for the production of Cyrel Fast, flexographic printing plates developed by DuPont \[7\]. Between the pressure plate and the model of the printing form, fibrous-porous material and coloured paraffin simulating a thermoplastic photopolymer are located.

A frame-by-frame breakdown of a video file obtained using a microscope with a video camera and subsequent processing of the micrographs made it possible to trace the kinetics of melting and the absorption of paraffin into the fibrous-porous material.

Figure 4. Simulation of the absorption of the thermoplastic photopolymer melt by a nonwoven fabric: a – initial system state before paraffin melting; b – the system state after complete melting and the absorption of paraffin into the fibrous-porous material.

3. Conclusion

The method of digital micrograph analysis of the face sections of the CM samples is recommended as an objective method for studying the external impacts on this class of heterogeneous structure materials both in stationary and in dynamic conditions. This method allows to identify the differentiated effect of the individual components on the material properties; the dividing the components into separate areas allows to identify interaction of the components and their interference at the phase boundary.

The technology for creating modern composite materials should be focused on reducing the development time and effective use of new material. The method proposed will contribute to solving these problems.
References

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