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Measurements of surface free energy as a tool to assess the effect of varnishing and printing of the paper substrates

Zuzanna Żołek-Tryznowska, Marta Więcek
Mechanics and Printing Institute, Faculty of Production Engineering, Warsaw University of Technology, Warsaw, Poland

Introduction

Nowadays, printing products might be finished in various ways. Varnishing process is one of the most popular finishing method which gives various effect, such as mate, glossy etc. However, the varnish layer applied on the paper is very thin, therefore it can be invisible to the naked human eye.

Paper is one of the most important carriers of the information (Car et al., 2018). Moreover, the history of human culture and civilization is directly connected with the history of paper. Nowadays, a large variety of paper are produced to suit to the customer requirements. Paper can be impregnated, coated, laminated, creped, molded etc. (Holik et al., 2013). One of the technique used to improve the paper and print resistance and its appearance is varnishing process (Majnarić et al., 2012). Various varnishes might be used, i.e. matt and gloss water based dispersive varnish, oil-base and UV varnish (Hudika et al., 2018). The typical varnish layers are applied with a thicknesses between about 0.5 and 6 µm depending on the specific printing method and the chemistry of the printing inks and varnishes (Mirschel et al., 2013). This roughly corresponds to coating weights from 0.6 to 7 g m^{-2}. Additionally, the composition of the varnish and the choice of a paper substrate used for printing may strongly influence the final coating properties.

Problem Description

The purpose of this analysis is estimation – which indirect methods might be used in order to evaluate whether the printing is enriched with transparent varnish layer or not. In the case of color layers of printing inks, the quality of the layer might be checked with reflectance densitometry or spectrophotometric techniques (Galić et al., 2015). However, this method are useless in the case of transparent layers. The goal was to assess the effect of varnished layer on the changes of the water contact values and surface free energy and its polar and dispersive components. Other methods, such as surface roughness, layer thickness and gloss measurement, were used in order to compare the influence of the printing and vanishing process on surface layer. The authors of this work, would like find answer, whether the measurements of the water contact angle are sufficient to evaluate the presence of varnish layer.

Methods

Six paper substrates were investigated: 1 – glossy, 73.5 µm thickness; 2 – uncoated, 100 µm thickness; 3 – uncoated, 136 µm thickness; 4 – uncoated, 70 µm thickness; 5 – coated, 140 µm thickness; 6 – coated, 143 µm thickness. The printing ink, color cyan and water-based dispersive varnish (SunChemicals) was used. The samples were laboratory printed and overvarnished and than the quality of the layer was assesed with various methods: ink layer thikness, surface roughness, gloss, contact angle, surface free energy determination.

Results

The schematic representation of the samples and samples photos are shown on Figure 1.
Table 1 shows the values of measured parameters: thickness of the layers, surface roughness, water contact angle and surface free energy and its total and polar component.
ANOVA results indicate statistically significant differences for thickness, surface roughness, water contact angle and surface free energy and its total and polar component.
Printing or varnishing increases the thickness of the samples. It is related with the application of ink or varnish layer on the paper substrate. However, the thickness of the layers formed on the paper, differs for each paper, what is related with the various absorbency of the papers. The varnish layer is in the range of 1.3 to 9.9 µm and the ink layer is in the range of 3.1 to 10 µm. In general the thickness of varnish layer is thinner than the ink layer.
The measured surface roughness of pure papers is much higher than overprinted or over varnished papers. It might be related with the proper cohesion forces in the ink or varnish layer. On the contrary, Gajadhur has observed the increase of surface roughness after printing or varnishing and at the same time, the varnish caused a much greater increase in the roughness surface than the ink coating (Gajadhur, 2018).
The gloss of ink or varnish dried ink layer of overcoated glossy or coated papers are much higher that the gloss of uncoated papers. The gloss of the top layer is strongly influence by the substrate properties which may be related with a very thin layers. Furthermore, the influence of the gloss of the coatings is related with lower surface roughness of the coating.
Based on the obtained results of water contact angle and the values of components of the surface free energy (SFE), influence of printing and varnishing on SFE maybe assessed. The values of water contact angles indicates that lowest wettability was determinate for papers prior printing or varnishing process. In general, the dried printing ink layer as a top layer exhibited higher values of water contact angles than varnished layer and simultaneously lower wettability. It might be related with the type of printing ink components. The values of water contact angles strongly affects the values of polar components of surface free energy. The values of polar components are very low and in the range of 0.26–12.24 $mJ \cdot m^{-2}$ for uncoated paper and coated paper, respectively. Simultaneously, the values of dispersive component are in the range of 31.38–44.08 $mJ \cdot m^{-2}$ for uncoated paper and coated paper, respectively. In general, the varnishing process increase the values of polar and dispersive component of surface free energy and, hence, the values of total surface free energy also increases. Furthermore, the values of total surface free energy of paper substrates are much lower than the values of dried varnish or ink layer.

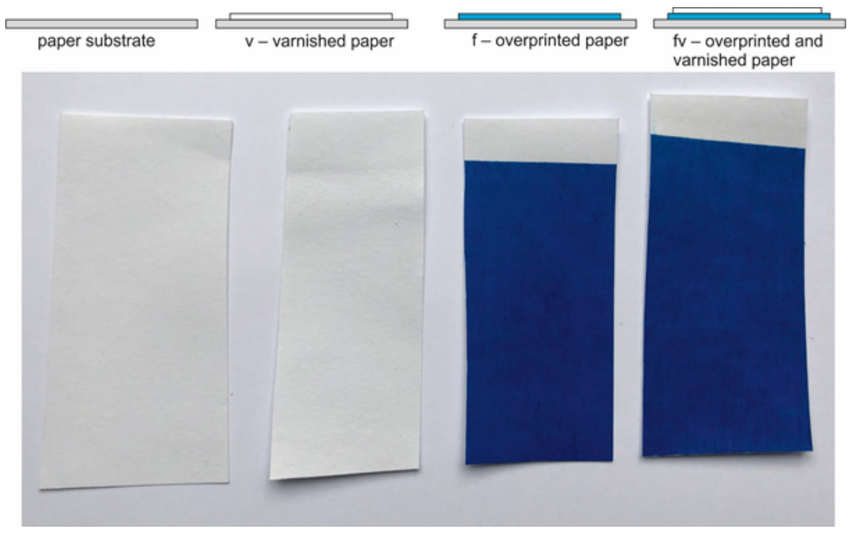

Figure 1

The samples of paper 3, overvarnished paper, over printed paper and both layer on the paper

Conclusion

The aim of this work was to analyze the surface properties of paper ink layer prior and after printing and varnishing process. The dried ink layer can be observed by human eye and the quality might be assessed by colorimetric method, whether the varnish is not observed by human eye or without reference samples.
Based on our results, we can conclude, that the printing or varnishing increases the thickness of the sample. Next, the varnishing process increases the gloss of the samples (depending on the varnish used; in this work, semi-gloss water based dispersive varnished was used). Finally, the printing or varnishing finishing of the paper substrate affects the dispersive and polar part of surface free energy. Finishing of the paper substrate increases the total value of surface free energy. Simultaneously, we have observed poorer wettability of the coatings layers, so the varnish layer protects the print layer.
The surface free energy measurements as well as the measurement of the water contact angle might be a useful tool in order to observe whether the varnishing was used in order to improve the coating. However, this measurement needs a reference sample without varnished layer.

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