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M.O. OHIRKO, O.G. USHENKO, O.V. DUBOLAZOV, I.V. SOLTYS, Y.M. STRUK

INVESTIGATION OF THE INFLUENCE OF PACKAGING CARDBOARD SURFACE TOPOGRAPHY ON THE QUALITY OF PRINTED PRODUCTS

Yuriy Fedkovych Chernivtsi National University, 2 Kotsjubynskyi Str. Chernivtsi, Ukraine

Анотація. У статті досліджено вплив топографії поверхні різних типів пакувального картону на якість офсетних друкарських відбитків. таким, проаналізовано морфологічну структуру картонів із крейдованим (GD2) та некрейдованим (UD3) покриттям, їхню мікроструктуру, а також параметри шорсткості Ra, площі піків та впадин. У статті представлено також порівняльний аналіз морфологічних показників незадрукованих поверхонь картонів та їхніх друкарських відбитків. Запропоновано рекомендації щодо вибору пакувальних матеріалів для забезпечення оптимальної якості друку.

Ключові слова: картон, рельєф поверхні, шорсткість, офсетний друк, адгезія, морфологічна структура

Abstract. The article investigates the impact of surface topography of various types of packaging cardboard on the quality of offset printed impressions. It analyzes the morphological structure of coated (GD2) and uncoated (UD3) cardboard, their microstructure, as well as surface roughness parameters such as Ra, peak, and valley areas. The article also provides a comparative analysis of the morphological indicators of unprinted cardboard surfaces and their printed impressions. Recommendations are proposed for selecting packaging materials to ensure optimal print quality.

Key words: packaging cardboard, surface topography, roughness, offset printing, adhesion, morphological structure.

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INTRODUCTION

Modern requirements for packaging are constantly increasing due to the growing demand for high-quality printed impressions that ensure both aesthetic appeal and functional properties. Improving print quality not only helps to maintain the product's attractiveness for the end consumer but also fully preserves the product in proper condition, protecting it from external factors. An essential role in ensuring the quality of printed impressions is played by the correct selection of packaging material, as its physical properties can affect image transfer accuracy, ink distribution uniformity, and resistance to external influences [4].

Packaging cardboard is one of the most widely used materials in the printing industry. In printing production, two main types of cardboard are used — coated and uncoated. Coated cardboards have a special coating that provides a smooth surface and reduces roughness, allowing for high print quality, even when using a greater number of colors [6]. Uncoated cardboards have considerable surface roughness and unevenness, which can lead to uneven ink application and reduced print quality.

Conducting a comparative analysis of coated and uncoated cardboards, such as Umka Color GD-2 and DivoEco® UD-3, allows for identifying optimal parameters to ensure the highest print quality. Thus, studying the microstructure of the cardboard surface, including characteristics like roughness, porosity, and the areas of peaks and valleys, is key to understanding the impact of these parameters on ink adhesion and distribution uniformity. The method of this study involves a detailed analysis of how the surface topography of packaging cardboard affects the quality of offset printing, enabling recommendations to be made to ensure high-quality printed impressions.

OBJECTS OF THE STUDY

The objects of the study are the GD2 and UD3 packaging cardboards, which differ in coating type and structural properties. GD2 cardboard is a coated material with a triple coating layer that provides a uniform surface, reduced roughness, and optimal ink adhesion. This cardboard is made from a blend of recycled paper, pulp, and wood mass, which enhances its strength and improves overall printing properties.

UD3 cardboard is an uncoated material made from recycled paper with the addition of mechanical wood pulp. Its structure is characterized by high porosity and the absence of a coated layer, which leads to greater surface roughness and uneven ink distribution during printing. The high porosity of UD3 results in irregular ink formation, reducing sharpness and detail in the printed images [6].

The study of the morphological properties of these cardboards allows for the assessment of their ability to achieve uniform ink application and to set optimal parameters for use in packaging materials with high print quality requirements.

1. METHODS OF THE STUDY

1. Electron microscopy analysis

To study the microstructure of the packaging cardboard surface, a JEOL JSM-T220A scanning electron microscope was used. It enabled the acquisition of detailed microphotographs of the surface and cross-sections of each sample. This method is particularly useful for analyzing the internal structure of cardboard and assessing the uniformity of pigment coating fill. In the case of coated cardboards, such as GD2, microscopy revealed dense pore filling, which promotes better ink adhesion. In contrast, uncoated cardboard UD3 showed larger pores and irregularities, which can reduce print quality due to uneven ink distribution.

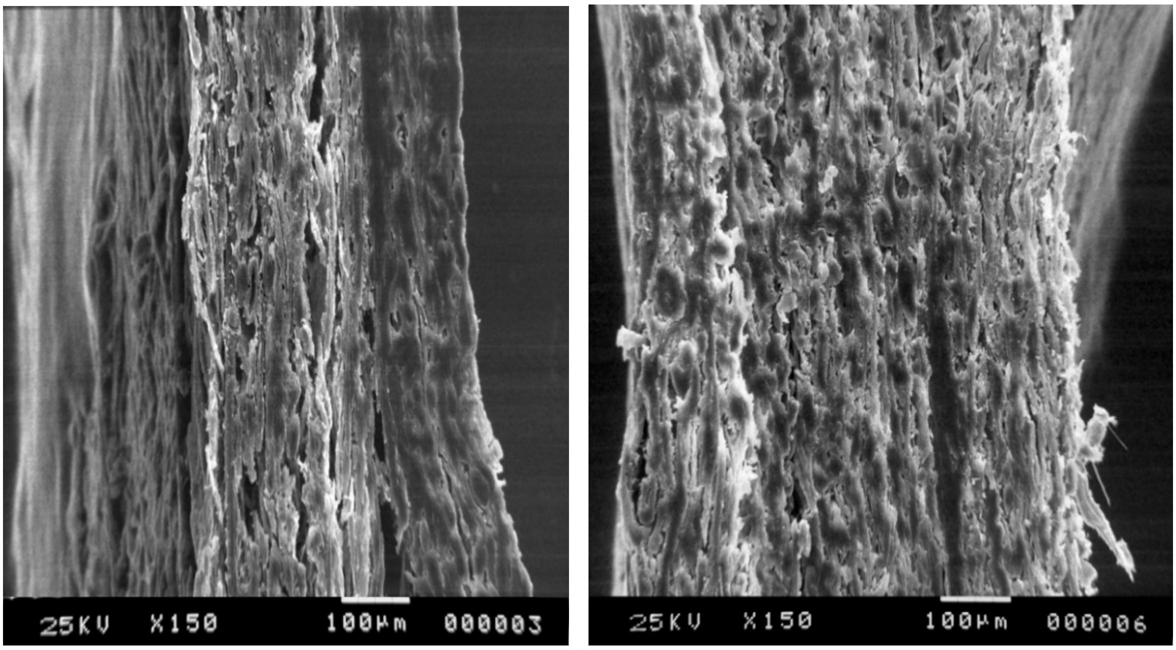

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Figure 1 – Microphotographs of cross-sections of the studied prints on cardboards:
a – UMKA COLOR GD2; b – DivoEco® UD3

Microscopic analysis of cross-sections of UMKA COLOR GD2 cardboard reveals the presence of pores filled with pigment filler particles of various shapes and sizes. The surface of the particles has a blurred, indistinct structure. The cardboard itself consists of tightly interwoven microfibrils and fibers of bleached sulfate and chemithermomechanical pulp. The voids within the microfibrous space are unevenly filled with filler, with large aggregates of particles clogging the pores and leaving small gaps from 0.2 to 1 μm, thereby reducing its porosity.

Electron microscopy analysis of the structure of DivoEco® UD3 cardboard, which lacks a coated layer and is made from recycled paper with the addition of mechanical wood pulp, revealed the presence of clearly visible oval pores on the fiber surfaces, measuring up to 6 μm. Twisted microfibrils are observed around the pores, along with through macro- and micropores, indicating the heterogeneity of its structure.

The analysis of morphological studies (Fig. 2) shows that for UD-3 cardboard, which lacks a coated layer and contains cellulose fibers, there is a high degree of surface irregularity, ranging from -5.48 to +6.24 μm, indicating an uneven distribution of surface structure elements. This is further confirmed by a roughness parameter of Ra = 1.416 μm. In contrast, GD-2 cardboard demonstrates a significantly lower amplitude of surface irregularities—from -2.98 to +2.02 μm—indicating a more uniform distribution of bleached cellulose fibers without large macro-irregularities. GD-2 cardboard has three layers of coating, resulting in a low roughness parameter of Ra = 0.514 μm, indicating a highly developed micro- and submicrostructure of the surface.

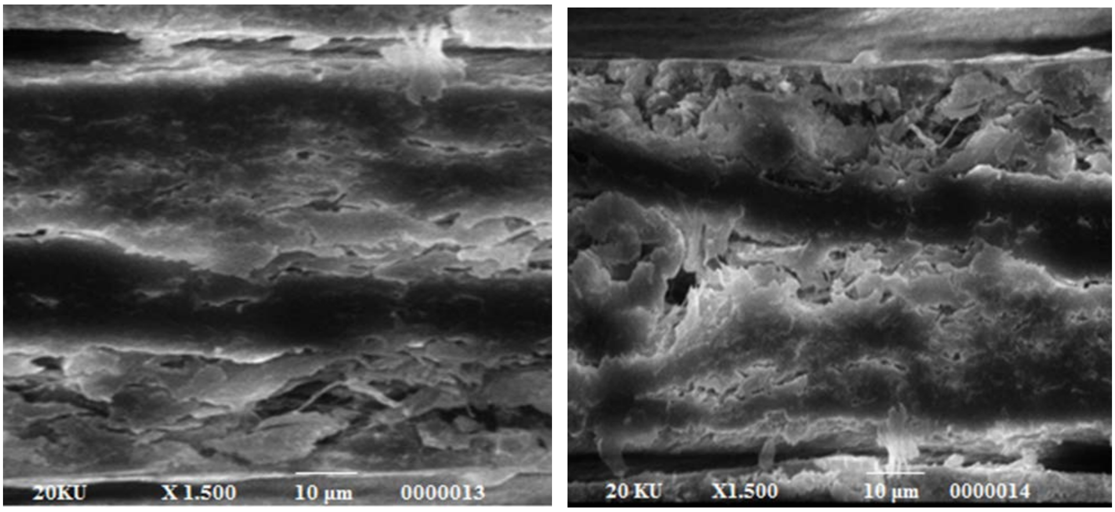

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Figure 2 – Microphotographs of the surface structure of cardboards before printing: a – GD2, b – UD3

2. ANALYSIS OF THE SURFACE MORPHOLOGICAL STRUCTURE AND ITS 3D MODELS

To better understand the distribution of ink on the cardboard surface, 3D models of the structure of printing impressions were created (Fig. 3). This allowed for the visualization of the micro-relief formed during ink application on different types of cardboard. The 3D models demonstrated differences in surface characteristics that affect the uniformity of the color layer.

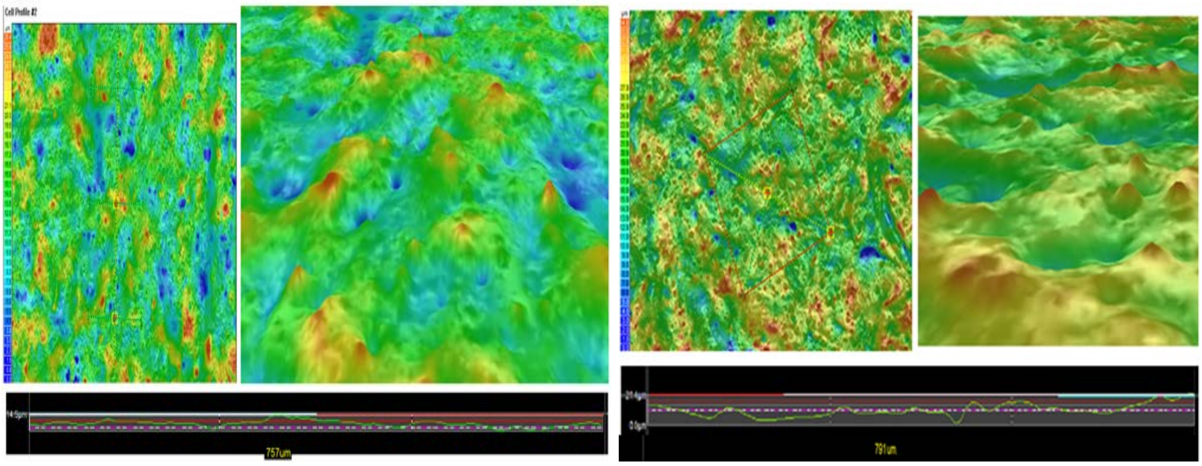

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Figure 3 – Microphotographs of the morphological structure of the surface of offset printing impressions and their 3D models on cardboards: a – GC2, b – UD3

In the case of GD2, the 3D model showed that the surface remains uniform with minimal variations, with surface irregularities ranging from -3.1 to +2.02 μm. This indicates a more even distribution of elements within the bleached cellulose fiber structure and the absence of large macro-irregularities, which ensures image sharpness. For the UD3 model, significant height variations on the surface were observed, ranging from -5.76 to +6.37 μm, contributing to uneven ink distribution, creating shadows and blurriness on the printing impression.

The measurement of roughness parameters was conducted to determine the arithmetic mean deviation of the surface profile (Ra), the average roughness depth (Rz), the surface peak area (Sp), and the valley area (Sv). These parameters are key to understanding the cardboard's capability for uniform ink application.

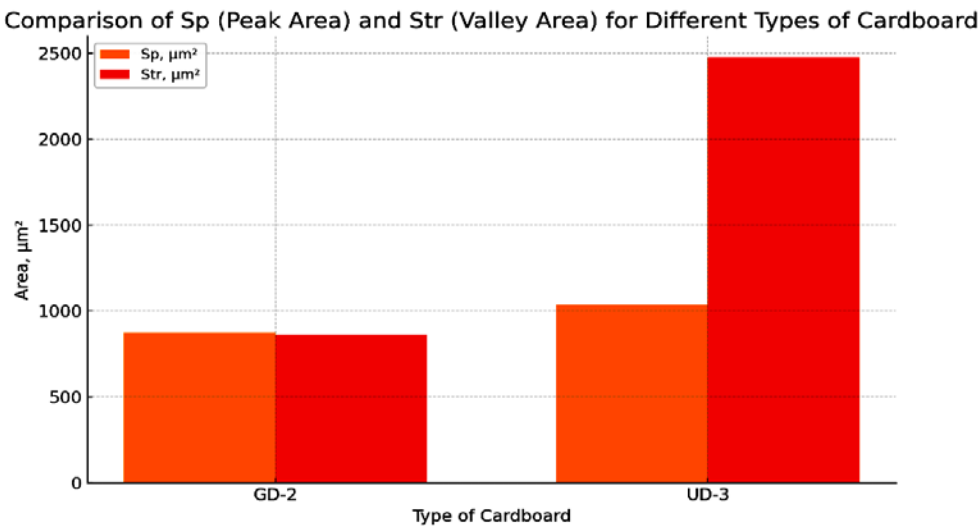

Figure 4 – Diagram of morphological indicators of the surfaces of the studied cardboards and their prints – peak area (Sp) and valley area (Sv).

The diagram compares the peak and valley areas for two types of cardboard — coated (GD-2) and uncoated (UD-3). UD-3 cardboard has a slightly larger peak area (1,034 μm²) compared to GD-2 (874 μm²), indicating a rougher surface. The valley area is also significantly larger for the uncoated UD-3 cardboard (2,475 μm²) compared to the coated GD-2 (860 μm²), indicating a high level of porosity and unevenness, which can affect the uniformity of ink distribution and overall print quality.

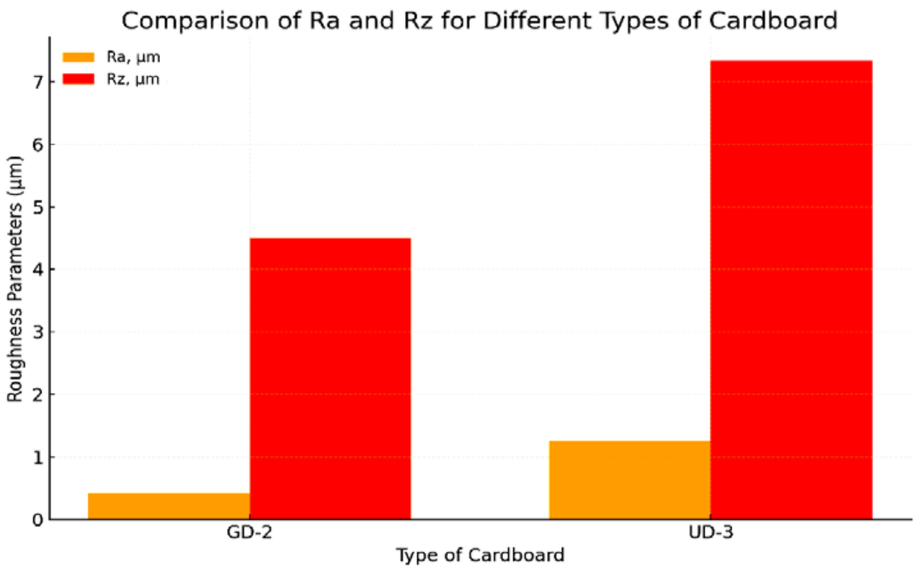

Figure 5 – Comparison of roughness parameters Ra and Rz for different types of cardboard (GD-2 and UD-3)

The data analysis (Fig. 5) demonstrates a significant difference in roughness between the coated GD-2 cardboard and the uncoated UD-3. For GD-2, the Ra value is 0.426 µm, indicating a smooth surface that provides better ink adhesion and coating uniformity. The uncoated UD-3 cardboard has a much higher Ra value of 1.26 µm, indicating substantial surface roughness, which can cause image blurring and less accurate transfer of fine details. The Rz parameter also shows differences between the cardboards: it is 4.5 µm for GD-2 and 7.34 µm for UD-3, further highlighting the rougher texture of the latter.

Thus, the conducted studies confirm that the presence of a coated layer significantly impacts the microgeometry of the surface. This layer alters the roughness parameters and the peak and valley areas on the cardboard. The roughness parameter Ra decreases threefold from uncoated cardboard to double-coated cardboard.

Densitometric analysis of the samples was conducted to determine the optical density of ink on each sample after printing. Colorimetric analysis allows for the assessment of color coverage uniformity and its distribution on the prints. The results showed that the coated GD2 cardboard has a significantly higher optical density (1.52) than the uncoated UD3 cardboard, for which this value is less than 0.77. This confirms better ink adhesion and distribution on the smooth and even surface of the coated cardboard [1,6].

CONCLUSIONS

1. The results of the study confirm that the surface topography of cardboard is a determining factor influencing the quality of printing impressions. Reducing surface roughness improves ink adhesion, contributing to clear and high-quality prints. Optimization of topographic characteristics can be achieved by selecting materials with suitable properties, enabling a high level of print quality.
2. The presence of a coated layer significantly affects the microgeometric characteristics of cardboard, particularly the roughness parameter Ra, which contributes to uniform ink application on the print surface and enhances overall image quality.
3. For the coated GD2 cardboard, the Ra value after ink application is 0.415 µm, indicating coating stability and uniform ink layer distribution, which enhances image sharpness and detail.
4. UD3 cardboard, which lacks a coated layer, is characterized by higher roughness and an uneven surface, leading to image blurring and uneven ink application, thus reducing print quality.
5. Coated cardboards demonstrate better characteristics for offset printing, providing high optical density and uniform ink application, making them optimal for packaging materials with high print quality requirements.
6. It is recommended to use coated cardboards with low surface roughness for the production of high-quality packaging. This will ensure better print quality, reduce ink consumption, and enhance the overall attractiveness of the product.

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OHIRKO MYKHAYLO – PhD, Assistant professor of Optics and Publishing Department, Yuriy Fedkovich Chernivtsi National University, Chernivtsi, Ukraine, **e-mail: m.ohirko@chnu.edu.ua**

USHENKO OLEXANDER - DSc.,Professor of Optics and Publishing Department, Yuriy Fedkovich Chernivtsi National University, Chernivtsi, Ukraine**, e-mail:** ***o.ushenko@chnu.edu.ua***

DUBOLAZOV OLEXANDER – DSc., Professor of Optics and Publishing Department, Yuriy Fedkovich Chernivtsi National University, Chernivtsi, Ukraine, ***e-mail: a.dubolazov@chnu.edu.ua***

SOLTYS IRYNA – PhD, Associate professor of Optics and Publishing Department, Yuriy Fedkovich Chernivtsi National University, Chernivtsi, Ukraine, **e-mail:** ***i.soltys@chnu.edu.ua***

STRUK YAROSLAV – PhD, Associate professor of Information Technology Department , Yuriy Fedkovich Chernivtsi National University, Chernivtsi, Ukraine, **e-mail:** ***y.struk@chnu.edu.ua***

М.О. ОГІРКО, О.Г. УШЕНКО, О.В. ДУБОЛАЗОВ, І.В. СОЛТІС, Я.М. СТРУК

ДОСЛІДЖЕННЯ ВПЛИВУ ТОПОГРАФІЇ ПОВЕРХНІ ПАКУВАЛЬНОГО КАРТОНУ НА ЯКІСТЬ ДРУКОВАНИХ ПРОДУКТІВ

Чернівецький національний університет ім. Ю. Федьковича, Україна