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STUDY OF OPTIMAL CONDITIONS FOR THE PRODUCTION OF PAPER BARRIER PACKAGING BY THE FLEXOGRAPHIC PRINTING METHOD

Tetyana Telegina[1], Svitlana Havenko[1], Marta Labetska[1]
[1]Lviv Polytechnic National University,
Institute of Printing Art and Media Technologies

Abstract

Increasing environmental pollution from plastic packaging, especially multi-layer films that are difficult to recycle, necessitates the search for effective ecological alternatives. Simultaneously, modern packaging requirements include enhanced barrier properties to meet global logistics needs and long-term product storage. A promising solution is the creation of paper packaging with functional coatings, particularly barrier coatings and heat seal varnishes. The study aimed to determine the optimal technological conditions for creating such packaging using flexographic printing.

The research was conducted on an Optima 2 flexographic printing press manufactured by Soma Engineering, using an additional IPU (Intelligent Printing Unit) section. Two types of paper with grammage of 70 g/m² and 80 g/m² from different suppliers were tested. A water-based heat seal varnish based on copolymer dispersion and a barrier primer were used to provide the paper with barrier and heat-sealing properties. The study included experiments with various combinations of functional varnishes, printing speeds (100-300 m/min), types of ink pumps, and forms of anilox roller cells. Parameters such as dry residue content, oil resistance, and heat-sealing strength at different temperature regimes and sealing conditions were evaluated.

It was determined that the best results are achieved with the combined application of barrier varnish followed by heat seal varnish at a speed of 100 m/min. Measurements showed that paper with lower grammage (70 g/m²) and lower smoothness can accept more varnish during printing (2.8 g/m² vs 2.3 g/m² for barrier varnish and 5.9 g/m² vs 5.4 g/m² for heat seal varnish). The barrier varnish provided excellent oil resistance (5 points after 1 hour of exposure), which remained high (3 points) even after 24 hours of exposure. Heat sealing studies showed that optimal sealing is achieved at temperatures of 130–210 °C with a clamp width of 25 mm and a clamping time of 0.5 seconds.

It was established that using an anilox roller cell produced with GTT technology and a peristaltic pump significantly reduces foam formation and improves varnish transfer in the printing unit's ink system. It was determined that the quality of paper packaging sealing is significantly affected by the clamp width and sealing time, with an increase in both factors improving adhesion strength. The practical result of the research is the developed technology for creating environmentally friendly paper packaging with enhanced barrier properties against moisture and fats, which can also be effectively heat sealed. This approach allows for the replacement of multi-layer plastic packaging materials with ecological paper alternatives without losing functional properties.

Keywords: *barrier coating, flexographic printing, paper packaging, varnish.*

Introduction

The situation with environmental pollution by plastic packaging (especially multilayer films, which are difficult to recycle) requires the search for effective ecological solutions. At the same time, the fast pace of life, global logistics, and large warehouse residues require an increase in the barrier properties of packaging. One way to solve this problem is to create packaging from paper with the application of various functional varnishes. Paper is one of the oldest types of packaging material. Currently, paper and cardboard are the most common packaging materials, occupying the third place in the food packaging market (Netramai et al., 2016).

As varnishes, various barrier coatings are usually used, ensuring the tightness of the packaging – cold seal and heat seal. In most cases, the image is applied to this type of packaging using flexographic printing, which has proven itself best in small and medium runs. Flexographic printing is also used for heat seal application (Chiu et al., 2012). As for cold seal, sometimes flexographic printing does not allow to achieve a certain grammage of this coating, and therefore, in this case, rotogravure is a more effective method (Ilhan et al., 2021).

In (Aghamohammadi, 2023), the author shows that four main factors can influence the process of producing cardboard packaging using functional varnishes, namely: the chemical composition of the varnish, the amount of varnish applied to the cardboard, the weight and thickness of the reference cardboard, and the parameters of the welding equipment. In addition, the author argues that the heat sealability of varnishes depends not only on their chemical composition, but also on the increase in the number of varnish layers during flexographic printing, which can improve the water resistance and heat sealability of products. The work shows that the choice of cardboard of the correct thickness and mass can positively affect the processability of the material during the production process. It should be noted that the author of the article does not fully disclose in his work the aspects of the factors influencing the amount of applied coating (primarily referring to the factors of the varnish application process) and does not take into account the influence of the paper structure on the heat-sealing properties in the paper-varnish system.

Methodology and equipment

This work investigated the technological conditions for creating paper packaging using barrier varnish and heat seal coating. Both functional varnishes were applied using flexographic printing on an Optima 2 flexographic press manufactured by Soma Engineering.

The coating was applied using the IPU (Intelligent Printing Unit) section, which is an additional option for a printing press with a central printing cylinder and consists of a small central printing cylinder and one or two flexographic printing sections (these can be either flexographic or rotogravure sections, as determined by the production tasks). This option in a printing press is typically used to apply various functional varnishes, including primers, finishing varnishes (matte, glossy, tactile (paper touch)), heat seal varnish and cold seal adhesive.

During the tests, a 4-color image was printed on one side of the paper simultaneously on the main printing sections of the press and functional varnishes were applied on the back side on the additional IPU section.

Two types of paper were taken from different suppliers with a grammage of 70 g/m^2 and 80 g/m^2. It should be noted that the 70 g/m^2 paper had less smoothness and more porosity. For application to paper materials for the manufacture of packaging, the studies used a water-based heat seal adhesive intended for direct contact with food products. This adhesive is fully recyclable. The coating, based on a copolymer dispersion and a stable vegetable wax emulsion, provides specific barrier properties. In particular, excellent grease resistance (OGR) combined with providing a certain level of water vapor transmission rate (MVTR), low values of water absorption capacity of paper Cobb and coefficient of friction of packaging (CoF). The ability to heat seal this adhesive occurs even at low temperatures (75–80°C) (Mostyka et al., n.d.).

It should be noted that the level of adhesion strength is related to the stability of the paper itself, since in all cases we have fiber breakage (Hishinuma, 2009). In addition, to reduce the porosity of the paper, it was decided to apply an additional layer of the so-called primer, which not only smoothes out the paper's irregularities, but also performs an additional barrier function. This primer has the following characteristics: some resistance to oil and grease; some water resistance depending on the substrate and printing technology (it is often applied in two passes to cover all paper defects).

Since both varnishes (heat seal and primer) are water-based, as noted in the technical specification, better drying will be achieved if the airflow is increased and the drying temperature is reduced.

The following material and equipment parameters were selected for applying the first and second layers of varnish:

- Printing plate specification:
  - Printing plate type – digital.
  - Design type – solid plate.
  - Printing plate manufacturer – XSYS.
  - Printing plate thickness – 1.14 mm.
- Anilox roller specifications:
  - Anilox cell shape: 1st step – hexagonal; 2nd step (to increase ink transfer and reduce foam formation in the ink container) – GTT.
  - Cell volume – 25 cm^3/m^2 (2 IPU section) and 18 cm^3/m^2 (1 IPU section).
- Mounting tape specification: medium hardness (manufacturer 3M, series 1020).

Presentation of research results

As a result of several tests with changing combinations of two types of varnish, changing the printing speed, the amount of dry residue was monitored and the barrier properties of the resulting layers were determined (Table 1, 2). Also, Table 3 shows the results of the study of the quality of heat sealing. During the tests, it was decided to change the type of ink pump and the type of anilox cell in order to improve the conditions for applying varnishes.

As can be seen from the results of the conducted research optimal conditions for creating paper barrier packaging are achieved through the combined application of functional coating layers – first applying the barrier coating, followed by heat seal coating at a speed of 100 m/min, which provides the best dry residue mass (5,9 g/m^2).

Table 1. Test results with changing combinations of functional varnishes

No.	Mass of dry residue, g/m^2	Type of varnish on section 1, cell volume 18 cm^3/m^2	Type of varnish on section 2, cell volume 25 cm^3/m^2	Printing speed, m/min
1	2,6	Heat seal	X	100
2	5,9	Heat seal	Heat seal	100
3	4,9	Heat seal	Heat seal	200
4	5,9	Barrier varnish	Heat seal	100

Table 2. Results of applying functional varnishes at different speeds

No.	Substrate type	Coating	Printing speed	Mass of dry residue, g/m^2	Grease resistance (olive oil)		
					1 hour	4 hour	24 hour
1	Paper 70 g/m^2	without coating			0	0	0
2	Paper 80 g/m^2	without coating			0	0	0
3	Paper 70 g/m^2	Barrier varnish	100 m/min	2,8 g/m^2	5	4	3
4	Paper 80 g/m^2	Barrier varnish	100 m/min	2,3 g/m^2	3	2	2
5	Paper 70 g/m^2	heat seal	300 m/min	5,9 g/m^2	1	1	1
6	Paper 80 g/m^2	heat seal	300 m/min	5,4 g/m^2	1	1	1

0 – no grease resistance, 5 – excellent grease resistance

Table 3. Dependence of fiber strength on welding conditions

Sample type	Welding conditions	Tensile strength of fibers at different temperatures							
		70º	90º	110º	130º	150º	170º	190º	210º
70 g/m² paper with heat seal layer applied at a speed of 300 m/min	Welding equipment clamp width 25 mm, pressure time 0,5 s	0	1	3	4	5	5	5	5
	Welding equipment clamp width 5 mm, pressure time 0,2 s, cooling time 0,5 s	0	0	0	2	3	3	2	2
	Welding equipment clamp width 25 mm, pressure time 0,5 s, cooling time 0,3 s	0	2	3	3	3	2	0	0

0 – no welding (fiber breakage), 5 – maximum welding (complete fiber breakage)

The research demonstrated that paper with lower basis weight (70 g/m²) and smoothness can accept more coating during printing and shows better oil resistance (5 points in the first hour) compared to 80 g/m² paper. Using anilox rollers with a channel structure (GTT) and a peristaltic pump significantly reduces foam formation and improves coating transfer. Regarding heat sealing, the best results are achieved using clamps with a width of 25 mm and a clamping time of 0,5 seconds at temperatures above 150 °C, which ensures maximum bond strength (5 points out of 5).

Conclusions

During the tests, it was found that to apply the maximum amount of adhesive, ensure weldability and create the best barrier properties, the optimal solution would be to apply a layer of barrier varnish followed by application of heat-sealing varnish at a speed of 100 m/min. It was noted that the choice of an anilox roller cell manufactured using GTT technology and the use of a peristaltic pump reduces foaming and increases varnish transfer in the ink system of the printing press. It has been noted that paper with a lower grammage and smoothness is able to accept a greater amount of varnish during the printing process. It has been determined that the sealing quality is affected by the width of the clamp and the time of sealing the package, increasing both factors improves the adhesion strength.

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