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RESEARCH PRINTING DEFECTS OF FLEXIBLE PACKAGING

The article presents the results of studies of defects in the production of flexible packages by gravure printing. An analysis of trends in the development and use of gravure printing technologies was performed: ensuring the quality of printing, new materials — inks and films. Based on the analysis of the most common printing defects, the causes of their occurrence were established and solutions were proposed to eliminate these problems.

Keywords: gravure printing; flexible packaging; quality assessment; defects of gravure printing.

Introduction

Currently, flexible packaging is in great demand, which is constantly growing and makes some areas of life easier [1, 2]. It solves and simplifies many tasks: preserving the product from the influence of external factors, increasing the shelf life of the product, acting as product advertising (attracting attention), performing packaging functions (convenience of transportation), etc. [3–5].

Since flexible packaging acts as advertising (bright labels should encourage the purchase of goods), great attention is paid to the quality of manufacturing of these packaging [6, 7]. Therefore, ensuring high-quality printing is an urgent issue. For this purpose, it is worth analyzing the trends in the development of gravure printing technologies, the types of defects that occur most often, the causes of their occurrence and ways to eliminate them.

Methods

In order to establish trends in the development and use of gravure printing technologies, a patent search was conducted with a retrospective of 10 years (2010–2021), since new materials and modernized equipment appeared during this period, as well as an increase in the production of flexible packaging and its use in the world. The purpose of the patent search was the need to find new inventions in the researched area, as well as to create a classification of existing printing inks and films for the production of flexible packaging.

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When performing the work, a thematic search is used, which is a search for inventions on a certain topic, namely, the quality of production of flexible packaging and a search for inventions noted for objects of similar purpose. The patent search was carried out in the following position: setting the subject of the search, determining the search area and setting the depth and country search.

The search was carried out in the database of international patents, where more than 100 countries are represented. Patents under different IPC classes including B32B27, B41F9/00, B42D25, B41F13, B41F31, B65D75, C09B67, C09D11 were analyzed.

Results

Initially, the search was conducted only by the search object, 41 patents were found with a mention of the manufacturing quality of flexible packaging. The data was sorted by the specified period. So, during this period, 23 patents satisfying the search object were found with this wording (fig. 1). Zoning by country of origin of patents was also carried out. Thus, the main share falls on China (more than 50 %) and Japan (20 %). The general percentage ratio is shown in fig. 1.

The most recent patents were devoted to packaging materials: 'Flexible packaging material with oxygen adsorption function based on natural gallic acid, method of preparation of packaging material and application to packaging material', 'Flexible packaging containing cholesteric liquid crystal layer', 'Polyethylene laminates for use in flexible packaging materials'.

In addition, a patent search was conducted for the main materials for printing flexible packaging, namely inks and films. The search was conducted for the same years as the previous one, with the key term 'universal inks for flexible packaging and gravure printing'. This query found 584 international patents that satisfy the search, including Solvent-Based Lamination Gravure Inks, Printing Products and Laminates, Lamination Gravure Ink, Object Printing and Laminates. According to the received data, a graph of the dynamics of patenting by year in different countries for gravure printing inks was created (fig. 2). It is worth noting that the main number of patents is registered in the USA, Japan and China.

Similarly, a patent search was conducted for various types of printing films. The search was conducted for the years from 2010 to 2021

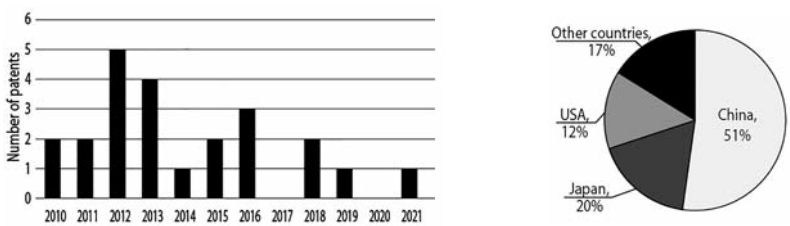

Fig. 1. Dynamics of patent registration regarding the quality of production of flexible packaging by year and country

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ISSN 2077-7264. Технологія і техніка друкарства. 2023. № 1(79)

based on the database of international patents, on the request 'Polymer flexible films for rotogravure printing and lamination for the production of flexible packaging'. According to the search results, 1283 patents were found, including: 'Printing laminate based on polyester film, method of production and application', 'Environmentally clean multilayer barrier film and method of its production', etc. [8]. According to the received data, a graph of the dynamics of patenting by year in different countries for gravure printing inks was created (fig. 3). It is worth noting that the number of patents and their distribution is similar to the values of patenting dynamics for gravure printing inks. The main number of patents is registered in the USA, Japan and China. But the total number of patents devoted to new polymeric materials for printing is more than twice as large as the number of patents for gravure printing inks.

From the obtained data, it can be concluded that this area has many unexplored points, and therefore it has a development perspective and space for various researches.

So, for example, the number of patents for materials (films and inks) from 2010 to 2019 is steadily increasing, which indicates a constant increase and development of new materials. During 2019–2021, the growth stopped a little, but this trend was most likely caused by external factors, as well as the fact that patents registered in these years may appear in the open access 1–2 years later.

The purpose of this study is to systematize the printing defects of flexible packaging, the causes of their occurrence, and the search for ways to eliminate them.

Discussion

The occurrence of defects, as well as the quality of products, is influenced by three main factors: manufacturing, technological, raw material. Another human factor can also influence the occurrence of defects [9].

As a defect caused by the human factor, the most common is the use of the wrong series of ink, abuse of solvents, failure to carry out timely washing and cleaning of form cylinders and squeegees, failure to comply with approved technological regimes (drying temperature, pressure, speed, amount of glue application, etc.) [10]. According to the results of the printing of flexible packages, the types of defects caused by the production fac-

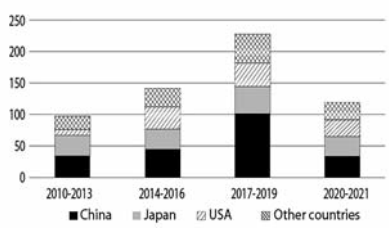

Fig. 2. Dynamics of patent registration for flexible packaging ink

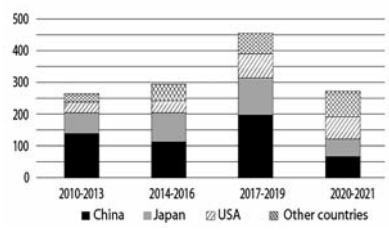

Fig. 3. Dynamics of patent registration for flexible packaging film

tor can include: insufficient tension of the canvas, insufficient alignment, insufficient drying of the ink. As a raw' material shortage, the most common are: sagging of the canvas, non-fixation of ink, non-printing of a shallow raster, low intensity of ink, insufficient activation of the material. Examples of defects that are quite common in the production of flexible packaging are summarized in fig. 4.

According to the results of the analysis of the wastes, no-good of print circulation, the main reasons for its occurrence were analyzed and the primary reason were identified. The generalized result is presented in the table 1.

According to the identified types of defects, possible ways to eliminate each of these types of defects are proposed.

Therefore, to eliminate the defect of non-printing of a shallow raster, it is necessary to wash the printing cylinders on ultrasonic cleaners in an alkaline solution using a copper brush before each order. Technological modes for washing should be 87 % power and washing time 15 minutes. In addition, in

Table 1

The main causes of printing defects

Defects	The main cause of occurrence
No small raster printing	Drying of ink in the cells of the printing roller, inhomogeneity of the film surface
Different tone (in one edition)	Diluting the ink, reducing or increasing the viscosity of the ink, adding the original ink, adjusting the color during printing
Non-combination of design elements	Misalignment of forms on the machine, failure in the operation of the alignment system during automatic roll gluing
Not gluing laminates	A small layer of glue application, low pressure of the pressure rollers on the laminator, low web tension
Layering of laminates	A small percentage of glue application, failure to observe the balance of glue components
Insufficient film activation	Violations in the technological modes of film production, long storage time of the film
Stains and splashes	Work without ductor shafts, incorrect location of ink pumps
Drying of the ink (non-uniform application of the ink layer)	High viscosity of the ink, clogging of the cells of the printing roller
Sticking together of ink-layers	Non-observance of technological regimes (speed, tension, sedimentation of products), abuse of solvents and retarders, storage of residual solvents in layers of products, tightening of rolls during winding, insufficient temperature of dryers
'Stairs'	Technical wear and tear of the printing shaft, squeegee knife pressure too high
Stripes	Getting foreign particles and ink clots under the squeegee
Tinting	Squeegee knife pressure too high, low roughness of the shaft
No printing/poor printing of design elements	Fill the cells of the printing shaft

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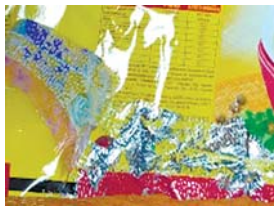
No small raster printing

Different tone
(in one edition)

Non-combination
of design elements

Non-gluing laminates



Layering of laminates

Insufficient film
activation

Stains and splashes

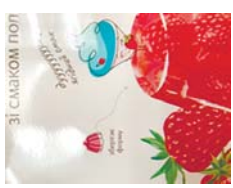
Drying of the ink (non-
uniform application
of the ink layer)

Sticking together
of ink-layers

‘Stairs’

Stripes

Tinting



No printing/poor
printing of design
elements

Fig. 4. Types of defects of flexible packaging

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order to minimize the non-printing of the raster during the print run, after the shafts have passed 50,000 linear meters, the shafts should be washed on the machine (washing at high speed without stopping the machine). To reduce the number of non-prints, you should also check the film for topological structure before printing the print run (the more the film has an uneven, wavy structure, the greater the probability of non-printing of a shallow raster).

In order to eliminate the defect of different tones, there are technological recommendations for constantly checking the viscosity of inks, both by the autoviscosity system and manually, in order to constantly maintain the inks in working condition. Viscosity can be from 13 to 15 m^2/s, depending on the type, color of ink and its application. Also, in order to minimize the formation of different tones, after each removal of the roll, it is necessary to make a cut of the canvas, where to check both the delta of the deviation of the main colors using a spectrophotometer (it should be no more than 3 units), and visually see the identity of the colors.

Non-combination of design elements can be eliminated using the settings of the machine's automatic alignment system, as well as manually (using a joystick on each machine) by the operator. In order to minimize this kind of defect, it is necessary to constantly monitor the alignment marks (crosses, traffic lights) on each cut of the canvas and on the machine monitors by printers. You should also try to make even gluing between the rolls (glue adhesive tape evenly in the middle). When the machine receives a signal about misalignment, prompt measures must be taken to eliminate this type of defect. It also depends on the qualifications of the staff. In addition, misalignment can be caused by an error in the manufacture of shafts, in which case the order must be removed from the print run, and the printing forms are sent for processing or finishing. Deviation from alignment can be 0.5 mm for inks and 1 mm for selective varnishing.

In order to eliminate such a non-gluing laminates, the percentage of glue application should be increased (70–90 %), the pressure during winding and on the carding shaft, as well as the tension of the fabric on the winding of the roll should be increased. For products where non-gluing of the laminate may occur, the recommended printing parameters are listed in table 2.

Layering of laminates can be eliminated by increasing the application of glue (4–4.5 g/m^2) on the laminations and changing the technological parameters (namely, minimizing the temperature of the glue and the transfer shafts, reducing the gap between the shafts for dosing the concentrated glue solution). An example of the parameters necessary to prevent delamination is given in table 3. The delamination of laminates can also be affected by: the quality of the materials and their rheological parameters (film structure, sliding parameters, its purpose, etc.), the percentage of ink application (from 100 to 400 %), the thickness of the ink application (more than 0.5 g/m^2).

Insufficient activation of the film may cause removal of the ink layer from the print (lack of adhesive resistance). To increase the activation of the film during printing (before

ISSN 2077-7264. Технологія і техніка друкарства. 2023. № 1(79)

Table 2

Lamination parameters to prevent non-gluing formation

Tension parameters		Pressure parameters		Temperature conditions	
Parameter	Value	Parameter	Value	Parameter	Value
Unwinding	80 H	Laminating shaft	3 bar	The base of the glue	40° C
On the winding	200 H	Silicone shaft	4 bar	Approver	35° C
Tension relaxation	30 %	Pressure shaft (on the winding)	2 bar	Transmission shaft	45° C
Interval	1 мм	Pressure shaft (unwinding)	0 bar	Laminating shaft	50° C
Application of glue	85 %			Intershaft gap	40° C
Glue consumption	3 г/м^2				

inks are applied), the film is passed through an activator that activates the unactivated film, or increases the activation of the activated film, thereby allowing the ink to attach to the activator.

The maximum power of the activator is 4.5 kW. Only corona-activated film (polypropylene film) can be activated. Polyethylene teraphtolate (PET) cannot be activated because it also has chemical activation, which loses its properties when passing through the coronar. Special markers and inks must be used to check the activation of the film. So, for polypropylene films, the activation must be at least 38 Din, and for polyethylene teraphtolate 42 Din.

Stains and splashes can be eliminated by installing ductor shafts and shallow ink troughs during printing, but then such a negative phenomenon as poor pantone application, drying and streaking may appear. It is also necessary to change the position of the ink pump (immerse it more in the ink), because in the wrong position the pump can spray ink, which, falling on the film, will form splashes, spots and dilutions of ink.

Table 3

Lamination parameters to prevent delamination

Tension parameters		Pressure parameters		Temperature conditions	
Parameter	Value	Parameter	Value	Parameter	Value
Unwinding	0 H	Laminating shaft	3 bar	The base of the glue	35° C
On the winding	220 H	Silicone shaft	4 bar	Approver	30° C
Tension relaxation	30 %	Pressure shaft (on the winding)	2 bar	Transmission shaft	40° C
Interval	0,1 мм	Pressure shaft (unwinding)	0 bar	Laminating shaft	50° C
Application of glue	100 %			Intershaft gap	35° C
Glue consumption	4 г/м^2				

ISSN 2077-7264. Технологія і техніка друкарства. 2023. № 1(79)

Drying of the ink can be caused by its high viscosity, high concentration of pigment and the peculiarity of the ink. To prevent this, you should keep the viscosity of the ink no higher than 15 m^2/s, and add the ethoxy-propanol drying retarder (this is an alcohol group that has a volatility of 33 s, which is much higher than the usual thinner — ethyl acetate, where the volatility is 3 s).

Nevertheless, when adding a retarder, it is necessary to change some technological modes of speed reduction (not more than 180 m/min), additional drying (turning on additional dryers and increasing their temperature to 65–70° C), so that there are no residual solvents in the layers of the semi-finished product. In addition, when adding a retarder, it is necessary to increase the amount of the original ink by 10–20 % and reduce the amount of binder (up to 10 %), as the color may lose its intensity.

Sticking together of products' ink-layer is caused by the presence of residual solvents in the layers of the semi-finished product, which, together with the tension during winding, can cause the film to stick together and a partial transfer of the ink layer to the backside of the film (waxing). The same problem can appear with insufficient activation of the film, and then the ink simply does not stick and under pressure can break through to the backside of the film. To prevent this, all established technological processes should be followed (drying the product for at least 12 hours) to evaporate residual solvents. When printing, do not set a high speed (up to 250 m/min), give the minimum possible tension when winding (1.2–2 H), turn on additional dryers, set the temperature to at least 60° C, etc. Technological parameters of printing to prevent sticking together of products are presented in the table 4.

'Stairs' occur when the printing shaft wears out, if it has already passed the warranty run (for white and metallized ink it is 500,000 linear meters, for other triad inks and pantones — 700,000 linear meters). In addition, steps can occur when the squeegee is over-pressed (increase in pressure on the squeegee bed should not exceed 3 MPa). To eliminate this phenomenon, it is necessary to control the wear of the shafts and rework them after a certain period of use. Also, if steps appear during printing, the pressure on the squeegee should be reduced by approximately 1 MPa.

Squeegee slippage occurs during printing when foreign particles (dust, ink clots that have dried, etc.) fall between the squeegee and the printing cylinder. To eliminate this defect, squeegee knives should be periodically cleaned with special wooden sticks with a pointed end, thus removing dirt in the area of contact between the squeegee and the printing cylinder. Also, to prevent long-term contact between the squeegee and dirt on problematic colors, where cross-overs are common, you should use harder squeegees (lamella thickness 0.2).

Tinting can occur due to overpressure of the squeegee knives, in which case the pressure on them should be released. Tinting can also occur due to low roughness of the shaft. This causes insufficient contact between the squeegee and the printing cylinder. As a result, due to the high slippage of the printing roller, the squeegee cannot com-

ISSN 2077-7264. Технологія і техніка друкарства. 2023. № 1(79)

pletely remove the ink layer from the blank areas. Residues of ink on the printing cylinder transfer to the film and form translucent spots and stripes of a different color on it. To eliminate this defect, it is necessary to change the angle of the squeegee during printing and choose the most optimal option (which will provide greater contact and resistance). During the production of printing forms, the required level of roughness should be ensured.

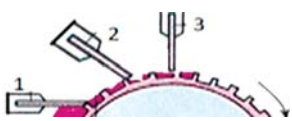
Failure to print design elements can be caused by clogged printing cells of the shaft. To eliminate the defect, as well as in the case of non-printing of a shallow raster, before printing, the printing rollers should be washed at the stage of ultrasound treatment, and during printing on the machine using a copper brush. In the case of minor non-printing, the printing roller can be washed at high speed, in the case of a significant one, the machine should be stopped and the roller washed thoroughly.

Conclusions

A study of the modern state of technologies for the production of flexible packages by gravure printing was carried out. The analysis of patent information over the past ten years has revealed the constant

Table 4

Technological parameters of printing to prevent sticking together of products

№	Control parameters	1	2	3	4	5	6	7	8
1	Ink color	P102	P219	P268	P2273	K	C	M	Y
2	Ink viscosity, m^2/s	14	14	13	13	13	13	13	13,5
3	Dryer temperature, °C	70	70	55	55	55	55	55	55
4	Silicone shaft pressure, MPa	3/75	3/75	3/75	3/75	3/75	3/75	3/75	3/85
5	The distance from the squeegee to the silicone, cm	4	4	4	4	4	4	4	4
6	Squeegee angle / squeegee brand	2 M-Flex II 							
7	Presence of duct shaft, yes/no	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	Duct shaft pressure, MPa	3	3	3	3	3	3	3	3
9	Squeegee pressure/ oscillation speed, MPa/unit	1	1	1	1	1	1	1	1
10	The solvent is ethyl acetate	100	100	100	100	100	100	100	100
11	Tension of the film web, MPa	On the winding				Unwinding			
		1,2				3			

ISSN 2077-7264. Технологія і техніка друкарства. 2023. № 1(79)

development of technologies for ensuring the quality of printing, new materials — inks and films. The most common printing defects of flexible packages have been determined. According to the results of the analysis of the wastes, no-good of print circulation, the main reasons for its occurrence were analyzed and the primary reason were identified. According to the identified types of defects, possible ways to eliminate each of these types of defects are proposed.

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В статті представлено результати досліджень дефектів виготовлення гнучких паковань глибоким способом друку. Виконано аналіз тенденцій з розвитку та використання технологій глибокого друку: забезпечення якості друку, нових матеріалів — фарб та плівок. На основі проведеного аналізу найпоширеніших дефектів друку встановлено причини їх виникнення та запропоновано шляхи вирішення для усунення даних проблем.

Ключові слова: глибокий спосіб друку; гнучке паковання; оцінка якості; дефекти глибокого друку.

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