Optimization of the quantity of two-component primary lacquer to be applied to the gravure printing technology

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Abstract

In addition to the realization of high-quality prints, gravure printing technology offers broad-ranging options for the development of such engraving parameters for the printing block that are suitable for reducing the prime costs of the finished product. One group of the base materials in food packaging is constituted by metallized laminated films whose surface printing is recommended to be performed with the use of appropriate primary lacquers. The quantity of primary lacquer applied in the course of gravure printing is primarily determined by the characteristics of the screen structure of the gravure cylinder, and the volume of the applied lacquer is also influenced by the properties of the lacquer and the speed of the gravure printing machine.

For our studies, we examined and compared eight different screen structures with the screen structure that was specified and used in practice. When determining the parameters of the printing cylinder, the primary goal was to develop a screen structure that could be used to reduce the quantity of the applied primary lacquer in comparison with the original standard design. In the samples made with test printing, the authors studied the quantity of the applied lacquer and abrasion resistance of the applied lacquer and cover white ink with reliance on microscopic images.

Keywords: primary lacquer, metallized film, gravure printing

1. Introduction

Gravure printing is a high-speed printing process based on rotary (roll-to-roll) technology. It is used in three essential market areas: publication, packaging and specialty printing. Gravure printing is a simple printing technology featuring outstanding quality and high consistency even in large print runs. While for many years publication printing struggles with the changes of the market structure caused by the internet, the production of packaging materials produced with gravure printing flourishes. This growth is all the more surprising as only a few years ago gravure printed packaging manufacturing was stagnant and flexography seemed to be more flexible and cost-effective. Taking a look at the proportion of different printing technologies used for producing flexible packaging materials it is obvious that gravure printing is in an excellent position. Gravure and flexo printing have identical market share in this important segment in Europe and gravure printing is clearly a leading process in the dynamically growing packaging market of the emerging countries in Asia *(Heintze, 2003) (Silver, 2011)*.

The attractiveness of the external packaging of the products has become a fundamental expectation for the majority of consumers. The basic demand of customers in relation to packaging is similarly the proper consideration of the needs of the target consumers, high-standard and aesthetic appearance that is suitable for generating profit. One way to achieve this effect when manufacturing flexible packaging materials is printing on metallized film which immediately arouses the interest of customers with its "bright" appearance (Figure 1). Printing business operating gravure printing technologies can serve the broadest possible circle of customers with this solution. The basis of metallized films is a polymer film coated with a thin layer of metal, usually aluminium. The reflective silver surface of metallized films is similar to the surface of aluminium foils. The coating also reduces the light, water and oxygen permeability of the foil. The properties of metallized films, including higher toughness, weldability and lower density, are combined with lower costs compared to the cost of aluminium foils *(Application Insight, online) (Plastic Packaging, 2010)*.

Figure 1: Metallized film

Suitable inks should be selected for printing metallized films and it is recommended to subject the machine to renewing corona treatment in order to increase the surface tension of the metallized layer and to achieve consistent ink adhesion. Besides corona treatment appropriate ink adhesion can be facilitated by pre-printing with primary lacquer. When using metallized films pre-printed with primary lacquer it is recommended to print opaque white ink on the surface as an undercoating before printing process colours and spot colours *(Breiholdt, online).*

Due to the crisis and the accelerated world of business every company in mass production makes efforts to prepare and sell its products at the smallest possible material consumption, as cost-efficiently as possible and in the best possible quality in order that market position and sales volume is not lost. In addition to the realization of high-quality prints, gravure printing technology offers broad-ranging options for the development of such engraving parameters for the printing cylinder that are suitable for reducing the prime costs of the finished product *(Kapur, 2003; Chiawei, 2010)*.

The volume of primary lacquer applied by gravure printing is principally determined by the screen structure characteristics of the cylinder (Figure 2).

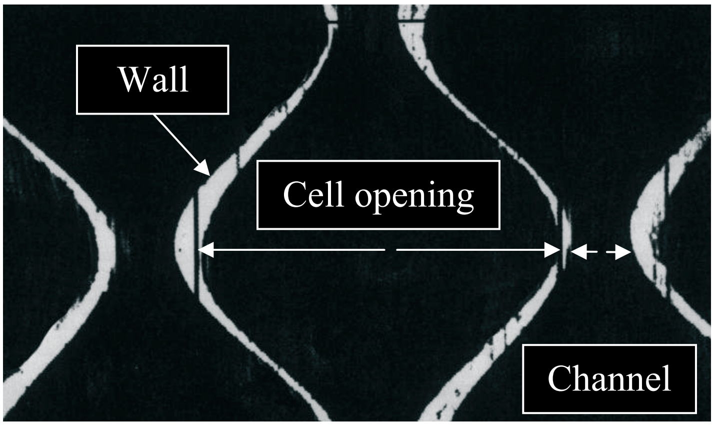

Figure 2: Characteristics of the cell

The volume of the lacquer applied is also influenced by the properties of the lacquer and the speed of the gravure printing press.

Electromechanical engraving is a standard method for producing gravure cylinders. Simplicity, stability and good reproducibility are among its advantages as well as the semi-autotipical (variables of depth and area) manufacturing method. Diamond stylus is used to cut cells in the copper layer to produce the desired image. The image of the printing elements of the gravure cylinder is influenced by the ink, the print media and obviously by the printing press itself. The geometry of the diamond stylus, screen ruling and screen angle also have an effect on the quality of the print. These parameters influence the transfer behaviour of the cylinder. The following parameters determine the volume of the cell: stylus angle, angle of the screen compression, cell wall, channel and screen ruling *(Wessendorf, 2003) (GST, 2010)*.

The stylus does not control cell opening, however, it does effect depth and, therefore, volume. A change to the screen ruling, angle, wall, or channel will change the cell opening. Main parameters influencing ink transfer: the ink, the print media as well as the relationship between cell size and dot size. The choice of cell and screen ruling depends on the ink applied and the print media influences the choice of cell characteristics. Metals or plastic films lift the ink from the cell differently than calendared paper orheavy cardboard. The Moiré pattern can be avoided by the proper selection of line screen and stylus *(Brethour, 2001)* (*Clist at al, 2005)*.

2. Methods

The aim of this research was the examination of the screen parameters of the printing cylinder and the optimization of the quantity of primary lacquer applied during the gravure printing process. A cylinder surface structure necessary for test printing optimization was designed. To perform the test printing, a gravure cylinder surface structure required for the optimization of test printing was developed. On the surface of the cylinder, nine bands of identical width were engraved with varied screen properties. In between the engraved 125 mm bands, 5 mm wide unprinted areas can be seen to easily distinguish the bands from each other. The examination and evaluation of the different structures took place by changing the speed of the printing press and the viscosity of the primary lacquer. The properties of the screen structures on the cylinder were determined by the contact angle between the diamond stylus and the gravure cylinder, the screen ruling and the screen shape *(Bohan at al., 2001) (GST, 2010) (Beißwenger, online)*. On the surface of the test cylinder, grid types featuring the following parameters were established (from left to right on *Figure 3*): Band 1: 120^0/70/0; Band 2: 130^0/70/0; Band 3: 130^0/70/4; Band 4: 120^0/80/0; Band 5: 130^0/80/0; Band 6: 130^0/80/4; Band 7: 120^0/90/0; Band 8: 130^0/90/0; Band 9: 130^0/90/4.

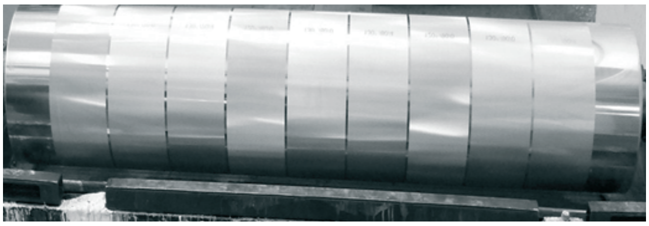

Figure 3: Lacquer gravure cylinder with nine bands

Band 1 and the surface structure of 120^0/70/0 was the standard (etalon) (*Figure 4)*.

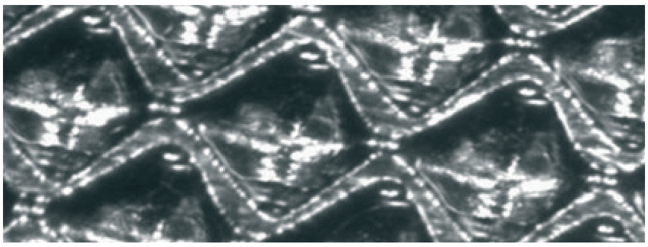

Figure 4: Surface structure 120^0/70/0

The gravure printing form was produced by cylinder engraving equipment type Hell Gravure System Gmbh K405. The diamond engraving stylus engraved the printing elements of the cylinder with a frequency of 8000 Hz. The total time taken for completely engraving the printing form cylinder was 10 hours.

Test printing was performed on OPP metallised film (manufacturer: Tagleef), thickness: 25 µm. Its structure is illustrated on *Figure 5*.

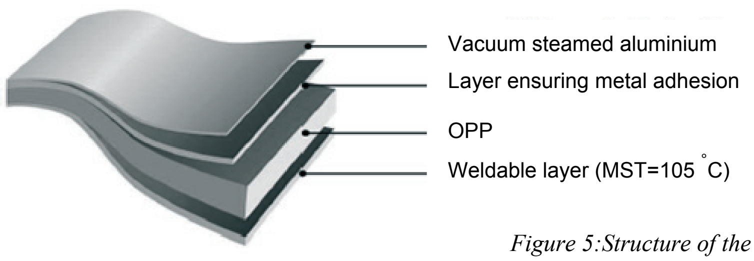

Figure 5:Structure of the metallised film print media examined

Printing was carried out by Cerutti 940 type 10-colour gravure printing press. After unrolling the surface of the print media was renewed in the corona equipment. The gravure press had warm air drying system. In the printing unit the circumference of the cylinders was 380-920 mm which at the same time indicates the minimum and maximum dimension of printed packaging materials. The maximum printable width of the print media is 1320 mm equal to the width of the impression cylinder. To facilitate the proper printability of smalller screen dots of the printing form an Eltex unit was mounted into the printing units. This system ensures that the smallest (2-3 %) screen cells are completely emptied which is triggered by the electric field through the impression (pressure) cylinder.

Printing was performed under normal operating conditions. During the tests the production speed of the printing press and the viscosity (outflow rate) of the primary lacquer were changed as follows:

- 160 m/min printing press speed and 15 s lacquer viscosity,
- 210 m/min and 12 s lacquer viscosity.

The characteristics of the materials used in the tests:
Primary lacquer: Siegwerk 10-600151-4 GA 2K 10
Harter: Siegwer 10-6000015-1 H
Dry matter content of the two-component primary lacquer system: 21%
Opaque white ink: Siegwerk NC-48.1 type nitrocellulose acrylic-based ink
Solvent: ethyl acetate

The wet quantities of the applied primary lacquer were measured and compared for the different screen types of the cylinder. Furthermore, we examined the abrasion resistance of the prints produced with the combined use of primary lacquer and nitrocellulose acrylic-based opaque white ink.

3. Results and discussion

During test printing the primary lacquer layer was first applied to the surface of the metallized foil with the cylinder with bands. Following the application of the primary lacquer sample sheets were taken off from the printing press to carry out further measurements and tests. After printing the primary lacquer layer the opaque white tone surface was directly printed. The engraving structure of opaque white was used in accordance with the practice used previously. The cylinder surface was not modified. The viscosity of the opaque white ink was 12 s. The viscosity of the primary lacquer and the opaque white ink was checked with a standardised measuring cup Ford at regular intervals during the period of test printing.

3.1 Applied quantity of wet primary lacquer

Knowing the parameters (dry matter content) of the primary lacquer the quantity of the wet lacquer applied was determined by weighing the sample sheets on a FZ-300I type digital balance. The evaluation considered the quantity of wet primary lacquer application recommended in the specification of the lacquer manufacturer (2–2.3 g/sq m). In case of 160 m/min printing press speed and 15 s lacquer viscosity, structures 120^0/80/0, 130^0/90/0 and 130^0/70/4 resulted the application determined in the specification (*Table 1*).

Table 1: Applied quantity of wet primary lacquer at 160 m/min machine speed and 15 s viscosity in case of different structures

Screen structure	Applied quantity of wet primary lacquer, g/sq m
120^0/70/0	5.23
120^0/80/0	**2.23**
120^0/90/0	4.14
130^0/70/0	2.85
130^0/80/0	2.85
130^0/90/0	**2.23**
130^0/70/4	**2.04**
130^0/80/4	0.95
130^0/90/4	1.57

In the case of 210 m/min printing speed and 12 s viscosity, the most favourable application was found for the 130^0/70/0 and 130^0/80/0 (*Table 2*).

Table 2: Applied quantity of wet primary lacquer at 210 m/min machine speed and 12 s viscosity in case of different structures

Screen structure	Applied quantity of wet primary lacquer, g/sq m
120^0/70/0	3.80
120^0/80/0	0.47
120^0/90/0	1.28
130^0/70/0	**2.04**
130^0/80/0	**1.90**
130^0/90/0	2.85
130^0/70/4	1.76
130^0/80/4	1.09
130^0/90/4	1.28

Out of the 18 lacquer samples 5 samples were satisfactory when evaluating the wet application quantity. These were examined under microscope to view the structures. With the help of the images taken with the microscope we examined and compared the spread and coverage of the structures. The tests were carried out using Carl Zeiss-Jenatech type microscope and the images taken of the samples were recorded using a special program: Scope Photo. It can be stated that on the image taken with the microscope of screen type $120^{0/}$80/0 the metallized effect of the raw material prevails and the contours of the engraved cells become distinct. The sample is more covered in case of screen 130^0/90/0 and the contours of the cells are paler. The metallized effect of the raw material was also insignificant unlike in case of screen type 120^0/80/0. It was characteristic of screen 130^0/70/4 that the contours of the cells were distinct and the metallized effect of the raw material was more considerable than in case of the previously examined two screen types. In case of screen type 130^0/70/0 the contours were pale and the metallized effect was not significant either. It can be stated that in case of screen type 130^0/80/0 the contours of the cells were pale and the raw material has no significant metallized effect. These microscopic studies confirmed our earlier examination results (*Table 3*).

Table 3: Summary of the applied quantity of the wet primary lacquer and the visual results of the microscopic examination

Screen structure	Printing speed m/min	Primary lacquer outflow rate, s	Applied primary lacquer, g/sq m	Microscopic results
120^0/80/0	160	15	2.23	Very good
130^0/90/0	160	15	2.23	Appropriate
130^0/70/4	160	15	2.04	Very good
130^0/70/0	210	12	2.04	Appropriate
130^0/80/0	210	12	1.90	Appropriate

As a summary it can be stated that out of 5 samples, all samples examined were satisfactory at the visual microscopic examination. We could ensure with 2 screen structures that by applying the appropriate quantity of primary lacquer the coverage and spread values were appropriate.

3.2 Abrasion resistant

From the mechanical tests of packaging materials one of the most important tests is the abrasion resistance test. Inappropriate abrasion resistance of printed plastic foils may lead to numerous problems. The purpose of the abrasion resistance test is primarily the examination of smearing of prints and the abrasion resistance examination of the opaque white ink layer applied on the primary lacquer surface in various layer thicknesses. It is an important aspect that the coverage properties of the opaque white ink layer, printed on the primary lacquer layer with irregular bands, are appropriate. The tests were carried out on Prüfbau Quartant equipment. During the test the stamp pressed the sample piece against the 250 g/sq m 50 x 110 mm cardboard fastened to the surface of the support with 620 g weight. 50 cycles were specified as the cycle of abrasion resistance reproducing the typical stress of metallized films. One cycle meant one back and forth movement during which the pressure stamp rotated with 22.5°, according to the toothing of the tool. After rubbing the sample sheets printed with primary lacquer and opaque white layer the scratches and alterations generated on the surface of the rubbed sheets were evaluated with a Carl Zeiss Jenatech microscope at 20x magnification. *Table 4* illustrates the results of the abrasion resistance tests and visual microscopic examinations of the sample pieces.

Table 4: Summary of the abrasion resistance results of the tested screen types

Screen structure	Printing speed, m/min	Primary lacquer outflow rate, s	Applied primary lacquer, g/sq m	Abrasion resistance
120^0/80/0	**160**	**15**	**2.23**	Appropriate
130^0/90/0	160	15	2.23	Non appropriate
130^0/70/4	160	15	2.04	Non appropriate
130^0/70/0	**210**	**12**	**2.04**	Appropriate
130^0/80/0	210	12	1.90	Non appropriate

Samples having screen structures 120^0/80/0 (15 s; 120 m/min) and 130^0/70/0 (12 s; 210 m/min) were satisfactory on the abrasion resistance tests. Based on the technological parameters of printing (viscosity 12 min, speed 210 m/min) from the tested structures cylinder structure 130^0/70/0 was optimal.

4. Conclusions

We studied 8 different screen structures during the test and compared them with a screen structure already used and specified in practice thus we considered structure 120^0/70/0 as the etalon. The primary goal when determining the parameters of the engraved cells was to develop a screen structure that would help reduce the quantity of the primary lacquer applied compared to the original standard structure. We have changed the contact angle between the diamond stylus and the cells, the screen ruling and the screen compression. Different structures were examined by increasing the speed of the printing press and reducing the viscosity value of the primary lacquer.

Based on the qualitative examination of the wet primary lacquer applied five out of nine screen structures arranged on the surface of the printing form cylinder complied with the primary lacquer application quantity recommended by the specification. Based on the technological parameters of printing (viscosity 12 min, speed 210 m/min) and on microscopic examinations and abrasion tests from the tested structures cylinder structure the optimal cylinder structure (130^0/70/0) is characterised by a smaller angle diamond stylus and identical screen ruling and compression, compared to the etalon. Printing was performed at a higher speed and lower viscosity. The optimal cylinder structure results in considerable savings in the primary lacquer quantity and is a cost-effective solution.

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