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# Influence of the Polymer Plate Thickness on the Plate Distortion Factor in Flexography

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**Abstract:** Flexographic printing plate is used for the transfer of image onto a printing substrate. The surface of printing plate is stretched lengthwise when the plate is mounted on plate cylinder. As a result, the print length on the impression is always longer than the actual length of the plate. Prepress must compensate for this difference in length. The result of wrong plate distortion is different print length in flexography compared to the processes that follow printing. The aim of this paper is to research the influence of repeat length in printing and polymer plate thickness on the factor distortion. The distortion factor values were calculated using the derived formulas. Regardless of the repeat length in printing, the value of the thickness factor for a particular printing plate is constant. However, the values of the distortion factor decrease with the increasing thickness of the polymer plate and the decreasing of the total plate cylinder circumference.

**Keywords:** factor distortion; flexography; polymer plate; print diameter; repeat length

## 1 INTRODUCTION

Flexographic printing has an advantage over other printing techniques, which can use a wider range of inks [1], and due to elastic printing plates, it is good for printing on various absorbent and non-absorbent printing substrates such as plastic foils and films, cardboard and paper, and other materials used in the production of packaging [2]. The quality of reproduction in flexographic printing is conditioned by a combination of different parameters related to the platemaking technology and type of polymer plates [3], specification of anilox rollers and pressure strength in printing [4] as well as characteristics of printing substrate [5]. The lightest pressure or "kiss impression" is ideal for printing [6]. Kiss impression is a clean print image created while applying the lowest value of pressure possible with the plate against the paper [7]. The gap value or the nip engagement between the plate and impression cylinder for lightest printing pressure is 3 thousand of an inch or 75 microns (0,0762 mm) [8]. It is not very often easy to print with the lightest pressure, primarily due to the characteristics of the printing substrate's surface, the uneven height of the printing elements or the type of work that is being printed. On the other hand, if the pressure is too high, the halftone dots will be more compressed leading to ink spreading and accumulation at the edges [9]. The entire process of flexography consists of a large number of influential parameters [10] that need to be standardized in accordance with the ISO 12647-6 standard [11].

Polymer plates are popular for products that do not require continuous printing on web materials, as plate gap appears at the joint of the plate when placed on the cylinder. Wrapping in elastic and relatively soft plate around the hard plate cylinder causes distortion in printing [12]. If this deformation is not predicted or calculated exactly, or if it is not applied to the original image, then the image in print will stretch and distort along the circumference of the cylinder, i.e. in the direction of the web movement. The text and images will appear elongated on the print. The elements printed in such manner will be misregistered with the other stages of the production process following the printing. It can also happen that the plate cannot be completely mounted on the plate cylinder at all because it is too long.

To prevent this, such distortion needs to be anticipated and taken into account when doing the graphic preparation. The image on the polymer plate will not be in good ratio until it is placed on the plate cylinder. The process of calculating the distortion factor of a flexographic printing plate requires specific knowledge and data on the repeat length in print, basic circumference or number of plate cylinder gear teeth, plate thickness and sticky back thickness.

It is also important to know the technical characteristics of the printing press, and particularly the cylinder specification. The outer diameter of the plate cylinder includes the diameter of the cylinder, the thickness of the mounting tape and the polymer plate. The relationship between the plate and impression cylinder in combination with the printing substrate will determine if the printing is done in correct position. Otherwise, unless the surface of the plate is synchronous with the printing substrate, slurring occurs during the printing process [13]. Most parameters are determined by the configuration of the printing press, and the only parameter that needs to be controlled is the outside diameter of the plate cylinder, also called the print diameter.

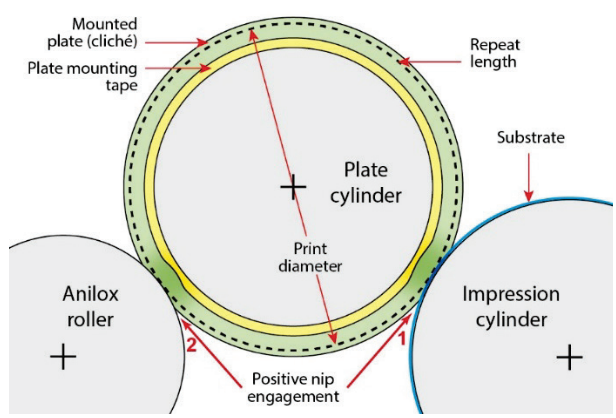


**Figure 1** Positive engagement between the printing plate and the printing substrate

Although flexographic printing is called "kiss printing", minimal compression must exist in printing in order for impression to occur (Fig. 1). Therefore, there is an interaction between the circumference of the outer surface of the plate towards the circumference of the anilox roller and the printing substrate. If this compression is too high (nip engagement > 150 μm), the surface of the plate will be outside the print diameter, so a slurring effect will occur at the places of contact between the plate and the printing substrate due to faster circumferential speed of the plate surface [14]. Otherwise, if the compression is too low (nip engagement < 20 μm) slurring also occurs due to lower circumferential speed of the plate surface [15].

Faulty printing process settings will affect the appearance of slurring, the accuracy of the repeat length, the print register in the direction of the web, the adjustment with the finishing stages (hot-stamping, die-cutting, screen-printing, numbering, printing of variable data), ink accumulation and tone value increase [16]. The inconsistency of the repeat length with the processes that follow after printing causes an error in the register between individual phases of operation. Print misregistration is constantly repeated and is visible within the printing format.

## 2 POLYMER PLATE DISTORTION

Nowadays, most polymeric plates are made of solid polymer, in sheeted form [17]. Single-layer photopolymer plates intended for CtP (Computer to Plate) production processes are mainly used [18]. The plate consists of LAMS (Laser Ablative Mask System) layer for laser processing, a photopolymer layer and a polyester backing that forms the basis of the printing plate and is dimensionally stable [19]. The polymer plate is placed on the plate cylinder using double-sided adhesive mounting tape.

The finished polymer plate transfers an identical but inverted copy of the image onto the printing substrate. However, if taken into account that the plate is wrapped around the plate cylinder, this image will not have the same length (Fig. 2).

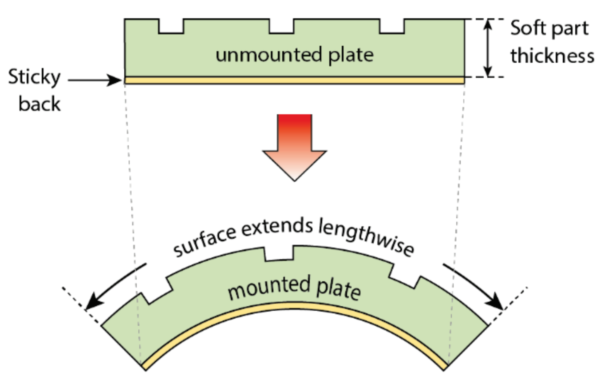


**Figure 2** Distortion of the polymer plate when mounted on the plate cylinder

When mounted on the cylinder, the soft parts of the plate are extended in the direction of wrapping and an elongated image is obtained in the printing process. This effect is called distortion [20] and is shown in Fig. 3. The difference between the image on the polymer plate and the impression is predictable. It depends on the diameter of the plate cylinder and the thickness of the polymer plate. The amount of distortion, or distortion factor, is defined in percentages. The correct distortion factor is applied in packaging prepress on imposition file, only for horizontal size of document, which represents the circumference of the plate cylinder. Therefore, the finished polymer plate is shorter in relation to the original image size. However, the print will be done in the real ratio. In this way, the elongation of the impression is already compensated when making the polymer plate.


**Figure 3** Display of "distortion effect" on the impression

The compensation of extending the polymer plates is usually done in prepress, before or during the screening phase. During the process of screening, scaling or distortion factor is applied. Therefore, any change in the polymer thickness, due to possible change in the printing press, requires re-screening. However, there are software solutions that allow the application of a distortion factor to a 1-bit data file created after screening, without affecting the middle tones. For plate making, this means that there is no need to create a new data file. Screening corrections are made to the existing one. The mounting tape is not a factor affecting the distortion of the polymer plate since it is used to place the polymer plate on a steel cylinder.

In order to calculate the distortion factor, it is necessary to know all the variables that affect the distortion of the image, i.e. the elongation of the impression, and these are the repeat length, print diameter and the thickness of the polymer plate and its backing [21].

Packaging converters typically have sets of plate cylinders for only ten most common repeat lengths. It is not uncommon for a customer to request a repeat length that is not available to them. There are three options in such cases: hope that the customer will accept a different repeat length, buy cylinders and gears for the required repeat length, or refuse a particular printing job. Very often, the customer simply cannot accept any compromise due to the precise packaging specifications.

Print diameter is the diameter of the plate cylinder together with the thickness of the polymer plate and the thickness of the adhesive mounting tape. The thickness of the adhesive mounting tape for narrow flexographic printing presses can be 0,25; 0,38 or 0,51 mm, depending on the configuration of the plate cylinder. It is through the interaction of plate cylinder rim (which is defined by the print diameter) and the impression cylinder, and by applying a light "kiss" pressure in the printing process that the ink is transferred to the printing substrate.

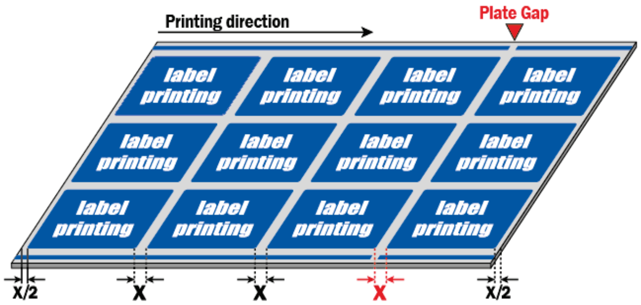


**Figure 4** Placement of multiple labels by plate cylinder circumference and adjustment to the repeat length

The total thickness of the polymer plate consists of a soft polymer part and a hard polyester part. The hard polymer plate part is also called polyester adhesive or sticky back or mylar [22]. Polymer plates are usually available in thicknesses of 0,76 - 6,35 mm. The chosen plate thickness depends on the configuration of the printing press, the roll width, the print length, and the type of graphic product. The thickness of the polymer plate backing is usually 0,178 or 0,127 mm, and should not be thicker than half of the total plate thickness. Thin polymer plates, 0,76 - 3,94 mm thick, are reserved for narrow flexographic printing presses with the web width of up to 60 cm.

The K-factor (the name is derived from the word thic**K**), also known as the thickness factor, is directly related to the thickness of the soft polymer plate part. For a certain plate thickness and that of its backing, the K-factor is constant (e,g. for plate thickness of 1,7 mm and polyester backing thickness of 0,127 mm). Therefore, it is also called a distortion constant or a Plate Thickness Constant.

## 3 THEORETICAL APPROACH TO DETERMINING DISTORTION FACTOR

The aim of this paper is to theoretically determine the distortion factor depending on the repeat length and base thickness of the polymer plate in five most common thicknesses of polymer plates in narrow flexographic printing presses: 1,14; 1,70; 2,54; 2,84 and 3,94 mm. Two basic thicknesses of polyester backing used in the production of polymer plates in form of sheets are defined: 0,127 mm (0,005") and 0,178 mm (0,007"). Furthermore, five most common plate cylinder circumferences used in printing on narrow flexographic printing presses were selected: 127; 190,5; 254; 317,5 and 381 mm. These are actually repetitive lengths of printouts on web of paper, which are formed by one turn of the plate cylinder. By combining the selected values of the mentioned variables, the values of the distortion factor values in percentages are obtained, which can be in turn applied in scaling methods during graphic preparation.

The procedure of calculating the distortion factor can be represented by two strategies accompanied by the display of geometric models on the basis of which these formulas were created. The first strategy is based on the diameter values of the plate cylinder and the polymer plate thickness, while the second is based on the thickness of the soft polymer plate part. Both procedures will be explained in detail and presented using mathematical formulas.

### 3.1 Method 1: Calculation of distortion factor based on cylinder diameter and plate thickness

The applicability of this strategy is related to the fact that the total thickness of the polymer plate consists of a hard polyester backing and a soft polymer. By mounting or placing the polymer plate on the plate cylinder, the soft part of the polymer plate is stretched, which does not include the hard polyester backing. The soft part of the polymer plate participates 2 times in the total print diameter, both times at the ends of the diameter length. This makes the basis for obtaining the formula used for calculating the distortion factor. All the necessary elements for deriving the formula are shown in Fig. 5.

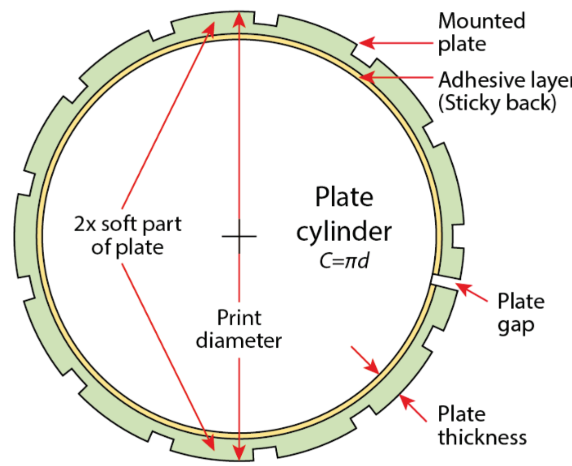


**Figure 5** Cross section of a flexographic plate cylinder showing the variables involved in distortion

The distortion factor is the ratio of the print diameter reduced by double thickness of the "soft" polymer plate part (without the hard back thickness) and the total print diameter, and can be presented using the following formula:

$$distortion\ factor = \frac{print\ diameter - 2\times\ soft\ thickness}{print\ diameter} \quad (1)$$

Print diameter can be obtained using the formula for circle circumference $C = \pi d$ as follows:

$$print\ diameter = \frac{C}{\pi} \quad (2)$$

The thickness (*THK*) of the soft polymer plate part is obtained based on the total thickness of the polymer plate and the thickness of the polyester backing:

$$soft\ THK = total\ plate\ THK - \ sticky\ back\ THK \quad (3)$$

For example, for printing process in which a plate cylinder with a repeat length of 381 mm and a polymer plate of 1,7 mm thickness with 0,127 mm thick backing are used, the calculation of the distortion factor based on formulas (1), (2) and (3) is as following:

$$print\ diameter = \frac{381}{\pi} = 121{,}276\ mm$$

$$soft\ THK = 1{,}7 - 0{,}127 = 1{,}573\ mm$$

$$distortion\ factor = \frac{121{,}276 - 2\times 1{,}573}{121{,}276} = 0{,}9741 = 97{,}41\ \%$$

### 3.2 Method 2: Calculation of distortion factor using plate thickness factor

Plate thickness factor or K-factor is a constant that is related to the thickness of the polymer plate, more precisely to the thickness of the soft polymer plate part.

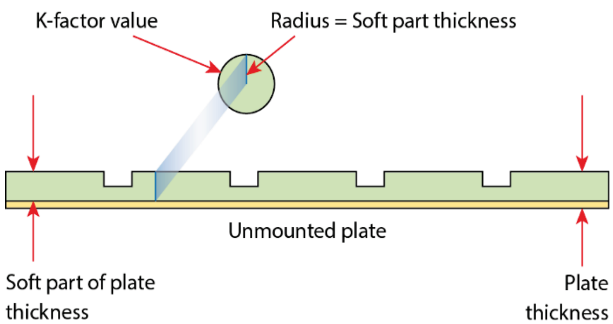


**Figure 6** Schematic display of the polymer plate thickness factor derivation

This is actually the value of the circle circumference $C = 2\pi r$ where the value of the thickness of the soft polymer plate part is used for radius (Fig. 6). Accordingly, the K-factor is calculated using the formula:

$$K\_factor = 2\pi(total\ plate\ THK - sticky\ back\ THK) \quad (4)$$

The repeat length is usually specified for each work printed. If the repeat length is unknown, it can be determined by measuring on the printed web. It can also be calculated based on the formula for circle circumference $C = 2\pi r$, where $r$ it shows the total print radius including the radius of the plate cylinder and the thickness of the polymer plate together with the polyester backing:

$$printing\ repeat = 2\pi(cylinder\ radius - total\ plate\ THK) \quad (5)$$

The distortion factor is the ratio of the repeat length in print minus the K-factor and total repeat length. Accordingly, the final formula for calculating the distortion factor based on plate thickness and repeat length factors in print is:

$$distortion\ factor = \frac{printing\ repeat - K\_factor}{printing\ repeat} \quad \text{or} \quad (6)$$

$$distortion\ factor = 1 - \frac{K\_factor}{printing\ repeat} \quad (7)$$

Calculation of distortion factor according to the data from the given example of printing process based on formulas (4), (5) and (6) is as following:

$$K\_factor = 2 \times 3{,}14 \times (1{,}7 - 0{,}127) = 9{,}883$$

$$distortion\ factor = \frac{381 - 9{,}888}{381} = 0{,}9741 = 97{,}41\%$$

It can be seen that both methods of distortion factor calculation had a completely identical result, which proves the credibility of the presented procedures.

## 4 RESULTS AND DISCUSSION

The final formulas (1) and (6) from both described methods were used for the calculation with the aim of determining the distortion factor for five most common thicknesses of polymer printing plates in narrow web flexo printing presses. The calculation also used five values of the total plate cylinder circumference (or print repeat length) according to the number of gear teeth, in a step consisting of 20 teeth (Tab. 1).

**Table 1** Circumferences of the plate cylinder in relation to the number of gear teeth used for calculating the distortion factor

| Number of gear teeth | Total cylinder circumference (mm) |
|---|---|
| 40 | 127 |
| 60 | 190,5 |
| 80 | 254 |
| 100 | 317,5 |
| 120 | 381 |

The results obtained by applying both formulas are completely identical, which confirms the credibility of the results and the applicability of the described methods. The results of calculating the distortion factor in percentages for the two thicknesses of the polyester backing are shown in Tab. 2 and Tab. 3.

**Table 2** The distortion factor (%) for all combinations of repeat length and plate thickness for 0,127 mm polyester backing

| Sticky back 0,127 mm | | Plate thickness (mm) | | | | |
|---|---|---|---|---|---|---|
| | | 1,14 | 1,70 | 2,54 | 2,84 | 3,94 |
| Repeat length (mm) | 127 | 94,99 | 92,21 | 88,06 | 86,55 | 81,14 |
| | 190,5 | 96,66 | 94,8 | 92,04 | 91,03 | 87,43 |
| | 254 | 97,49 | 96,1 | 94,03 | 93,27 | 90,57 |
| | 317,5 | 97,99 | 96,88 | 95,22 | 94,62 | 92,46 |
| | 381 | 98,33 | 97,4 | 96,02 | 95,52 | 93,71 |

**Table 3** The distortion factor (%) for all combinations of repeat length and plate thickness for 0,178 mm polyester backing

| Sticky back 0,178 mm | | Plate thickness (mm) | | | | |
|---|---|---|---|---|---|---|
| | | 1,14 | 1,70 | 2,54 | 2,84 | 3,94 |
| Repeat length (mm) | 127 | 95,22 | 92,47 | 88,31 | 86,83 | 81,39 |
| | 190,5 | 96,82 | 94,98 | 92,21 | 91,22 | 87,59 |
| | 254 | 97,61 | 96,24 | 94,16 | 93,42 | 90,69 |
| | 317,5 | 98,09 | 96,99 | 95,33 | 94,73 | 92,56 |
| | 381 | 98,41 | 97,49 | 96,1 | 95,61 | 93,79 |

Results of the calculation show that the values of the distortion factor increase with the increasing thickness of the polymer plate and decrease of the total plate cylinder circumference. The lower the percentage value of the distortion factor, the larger the print elongation compensation. In addition, the compensation is larger with a thinner polyester backing, which is understandable because the thickness of the soft part is greater in the same total thickness of the polymer plate.

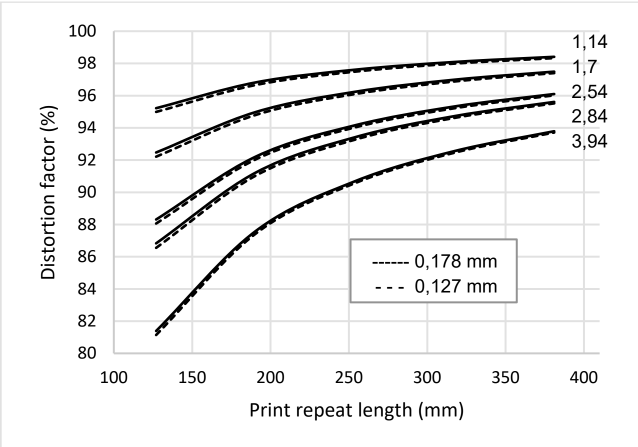


**Figure 7** Dependence of distortion factor on repeat length for two polyester backing thicknesses

The difference between the results of distortion factor measurements for the two thicknesses of the polyester backing is an identical value for individual circumferences of the plate cylinder, regardless of the polymer plate thickness (Fig. 7). So, the difference is the greatest for 127 mm repeat length and it amounts to 0,25. By increasing the repeat length, the difference between the values for the two thicknesses of the polyester backing decreases, and at 381 mm it amounts to 0,08. However, this difference is not negligible because any deviation from the correct distortion factor value will not give good results in printing and will create problems in the working phases that follow printing; it will also create problems in application of such graphic product to the primary packaging product.

The thickness factor of polymer plate or K-factor increases as the plate thickness increases and as the thickness of the polyester backing decreases (Tab. 4). Since the K-factor is directly related to the thickness of the soft part in the polymer plate, its change is completely logical.

**Table 4** K-factor for all combinations of plate thickness and polyester backing thickness

| K-factor | | Plate thickness (mm) | | | | |
|---|---|---|---|---|---|---|
| | | 1,14 | 1,70 | 2,54 | 2,84 | 3,94 |
| Sticky back (mm) | 0,127 | 6,3649 | 9,8986 | 15,1672 | 17,083 | 23,9481 |
| | 0,178 | 6,0669 | 9,563 | 14,8409 | 16,7258 | 23,6373 |

The repeat length in printing has no effect on the change of K-factor because it is a constant for an individual type of polymer plate, and as such is used for calculating the distortion factor. The change of K-factor in relation to the thickness of the polymer plate is linear and can be shown in form of a straight line, which can be seen in Fig. 8.

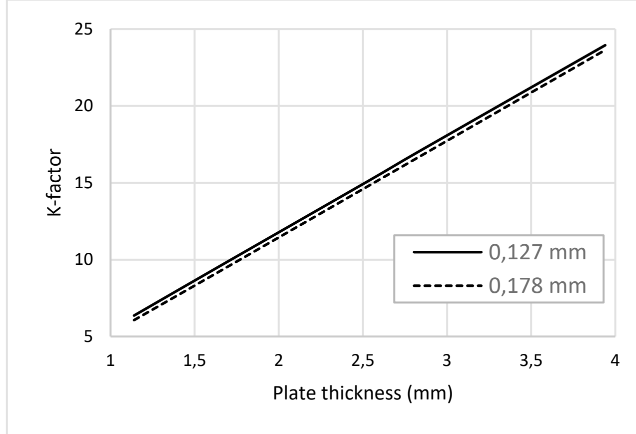


**Figure 8** Dependence of K-factor on the change in the polymer plate thickness

## 5 CONCLUSION

This research was conducted to analyze the change in distortion factors depending on the variables that affect image distortion in printing process. When wrapping the polymer plate around the plate cylinder, the soft part of the polymer plate is stretched. This affects the elongation of the impression. This lengthening of the impression must be compensated in order to obtain the actual product size in print. The compensation procedure is performed during graphic preparation using distortion factor. The distortion factor is directly dependent on the total circumference of the plate cylinder and its print diameter as well as the thickness of the soft polymer plate part.

The calculation of the impression elongation compensation is shown using two formulas. Each formula is based on a different approach. They are both explained in detail based on the geometric models presented. Both formulas primarily take into account the thickness of the soft polymer plate part. The obtained results are identical, which confirms the applicability of the described methods.

Five most common thicknesses of polymer plates and five most common sizes of the plate cylinder in narrow flexographic printing presses were used to calculate the distortion factor. Results show that the value of the distortion factor decreases with the increasing thickness of the polymer plate and the decreasing of the total plate cylinder circumference. In addition, the largest change in the distortion factor was recorded at a polymer plate thickness of 3,94 mm (12,5%) and a plate cylinder circumference of 127 mm (13,8%). The difference between the values of the distortion factor for the two polyester backing thicknesses (0,127 and 0,178 mm), at the same polymer plate thickness, does not change regardless of the plate cylinder circumference. Therefore, this difference is constant; for polymer plate thickness of 1,14 mm it amounts to 0,25, and for thickness of 3,94 mm it amounts to 0,08. Further on, regardless of the repeat length in print, the value of the thickness factor for a particular printing plate is always constant.

It can be concluded that any deviation from the correct values of the distortion factor, for a particular combination of plate cylinder circumference and polymer plate thickness, will affect the repeat length in printing and thus cause problems in printing or in the work phases following printing.

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