

Relationship in between compression of the rollers and contact area width and the clamp force

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In an offset printing machine the rollers (ink unit) and the cylinders (printing unit) are in contact in a lot of places. The contact surfaces comprise a metal surface and a rubber surface. As appears from findings based on the professional literature and experience of people working in printing houses the issue of contact between ink rollers and printing cylinders in an offset printing machine is of great importance. It has impact on the quality of printouts (generation of printouts errors), consumption of energy, time of making the printing machine ready for operation, wear of the machine's components and related consumables like ink, dampening solution, paper, ink rollers, plate.

During the theoretical studies, the equations were derived to show how the rollers compression depends on the contact area width and clamping force. The equations involve Young's modulus and Poisson's ratio of rollers' materials. The difference between these equations and the so far existing equations has resulted from changing the place of applying the clamping force and involving Poisson's ratio. The paper includes the comparison of the aforesaid new equations and those known from the literature. Moreover, the relationship in between the contact area width and the compression of metal roller and rubber-covered roller was subject to experimental attempts aimed at verification of the equation presented. In order to measure the rollers compression a clock sensor was used, and for measurement of the contact area width – a device called Roller Nip Control. The results of these measurements are presented in this paper and are compared with the results obtained from the equation derived in the course of theoretical studies using the analytical method.

Keywords and phrases: contact problem, offset, blanket cylinder, rubber blanket

Background

The most important elements in an offset printing machine are rollers and cylinders. A printing unit (fig. 1), which transfers image to the print substrate, is composed of an ink unit, a dampening unit and three cylinders, namely: a plate, a blanket and an impression. Ink rollers in the ink unit transfer ink from ink fountain onto the plate cylinder. The relatively big number of rollers in combination with the axially oscillating motion of some of the rollers aims at correcting the ink pulp to make it even in terms of ink film thickness. Dampening rollers transfer a dampening solution from the dampening fountain onto the plate cylinder. Some of these rollers bring about the axially oscillating motion. In the ink unit and in the dampening unit there is a contact between the soft and the hard surfaces of the rollers. Such a contact in the ink unit takes usually place between steel rollers coated with copper, ebonite or nylon and rollers which have an in-built steel shank coated with a thick layer of synthetic rubber or another artificial material.

In the dampening unit there is a contact provided between rollers made of brass or steel coated with chrome film or ceramic material and synthetic rubber rollers which are sometimes coated with a fabric or a special paper [1].

On the plate cylinder there is fixed a printing plate with

printing and non-printing points. Because of oleophilic properties of the printing points they absorb ink from the ink unit. At the same time, the dampening solution is absorbed by the non-printing points which have hydrophilic and oleophobic properties. Subsequently, the image is

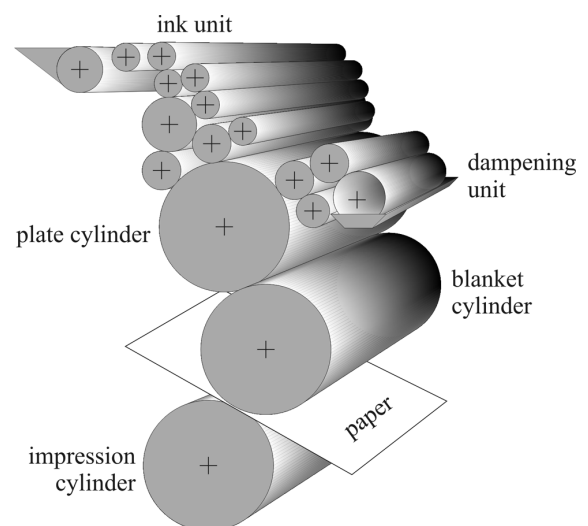


Fig. 1. The printing unit

transferred onto the blanket cylinder provided with the fixed blanket and then the image is transferred onto the print substrate which is pressed by the impression cylinder. There are two types of blankets: compressible and incompressible (hardly ever used). The blankets are made of rubber layer and fabric layers, where the compressible blanket has an additional compressible layer with air microbubbles [1,2].

Printing technologies use differentiation between rollers and cylinders in the printing unit of the offset machine. The rollers have smaller diameters (and they may differ in size) and the circumference of the rollers is closed. In turn, cylinders are bigger in radius. The diameters of all the three cylinders must be of the same size or the size of diameter of the impression cylinder can be two times bigger than the diameter of the plate or the blanket cylinders. The cylinders' circumference is not closed, because they are provided with an axial recess (the cylinder gap), where the plate is fixed (in the plate cylinder) or the blanket is fixed (in the blanket cylinder) or a sheet of paper is held by grippers during the printing process (in the impression cylinder). Additionally, the plate cylinder and the blanket cylinder have on their ends the bearer rings made of hardened steel. The bearers have a closed circumference. Most of the machines are in contact while printing.

It is very important to ensure appropriately set contact between the cylinders and the rollers (fig. 2), because it has influence on printout errors, increase of energy consumption and faster wear of the machine's components (e.g.: bearings, bearer rings). The printout errors like slurring, banding and too big tone value increase make quality of printouts worse. Consequently, the elimination of such errors brings about increasing the wear of consumables like

paper, ink, dampening solution. To obtain the printout of good quality (without errors in question) involves the need to spend more time to make the printing machine ready for operation which, in turn, involves bigger energy consumption. The faster wear of the machine's components can as well result in generating printouts errors, for example because of too high vibration occurring in the machine. This is another consequence, in addition to an increase in the cost of early wear of machine's components, such as ink rollers or plate [3].

Materials and methods

In frame of theoretical considerations an equation for compression of two rollers (fig. 3) was developed. First, a non-linear contact condition was derived for two mutually contacting bodies, which after rejecting very small non-linear elements became a linear contact condition [4]:

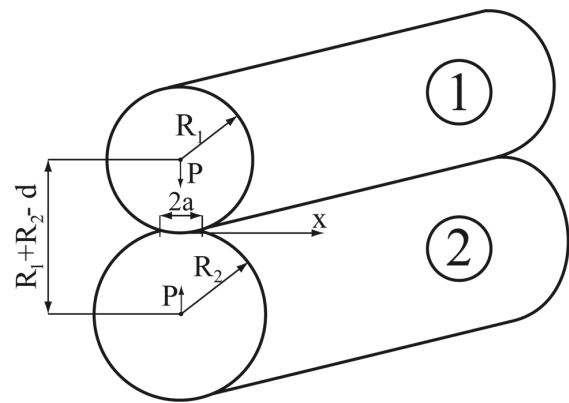


Fig 3 Contact of two rollers [5]

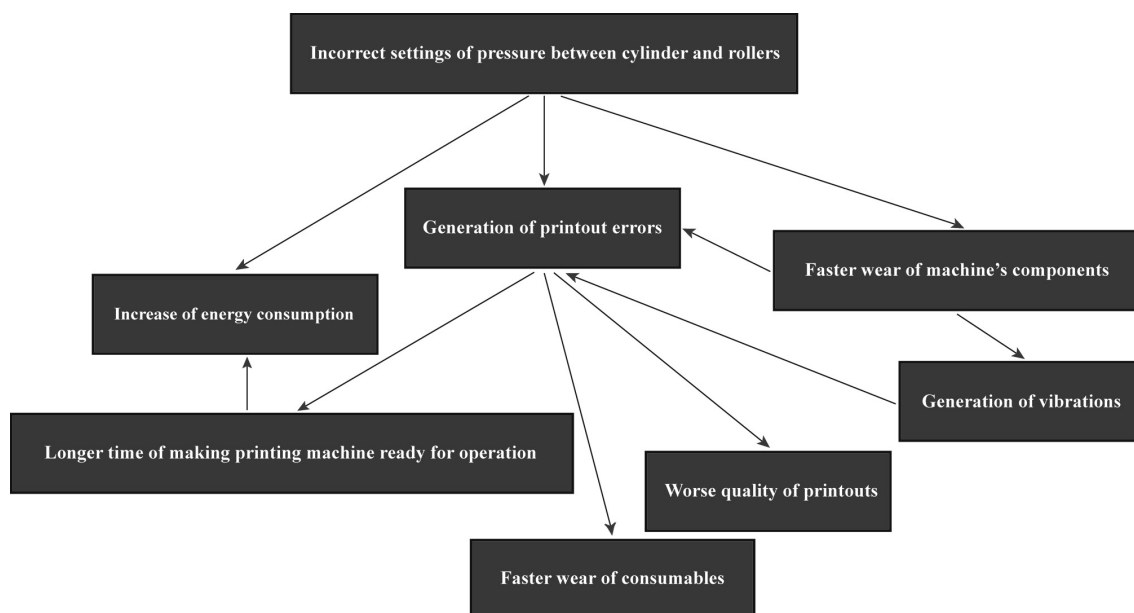


Fig. 2. Consequences of incorrect settings of stress between rollers and cylinders

$$u_{\zeta}^2 + u_{\zeta}^1 = d_1 + d_2 - f_1(x) - f_2(x), \quad x \in \langle -a, a \rangle \quad (1)$$

where

u_{ζ}^2, u_{ζ}^1 – normal displacement to the contact area,
 d_1, d_2 – displacement like in case of rigid bodies,
 $d = d_1 + d_2$ – total deformation (compression) of bodies
 1 and 2,

$f_1(x), f_2(x)$ – the function of surfaces' shapes.

Then, the issue was divided into two issues, namely for
 lower body no. 2 and for upper body no. 1. In the first case,
 the upper body 1 was replaced by pressure of unknown
 value $p(x)$, and in the second case – the lower body 2 was
 replaced by pressure of unknown value $p(x)$ but opposite
 in direction. The following assumptions were made:

- Assumption on no friction force;
- The assumptions of Hertz: radii of the printing cylinder
 are much bigger than the linear dimension of the contact
 area, and the surface of the cylinders is smooth.
 Therefore, each of the cylinders was assumed to be an
 elastic half-space;
- The bodies in question are homogeneous and isotropic;
 There is a plane strain.

The final equation for compression of two rollers de-
 pending on the contact area width and the compression
 force is as follows [6]:

$$d = \frac{P}{\pi} \left[\eta_1 \ln \left(e^{m_1} \frac{4R_1^2}{a^2} \right) + \eta_2 \ln \left(e^{m_2} \frac{4R_2^2}{a^2} \right) \right] \quad (2)$$

where

$$m_l = -\frac{\nu_l}{1-\nu_l} + \frac{1}{1-\nu_l} \frac{a^2}{4R_l^2}, \quad l = 1, 2,$$

a – half of the contact zone width,

R_1, R_2 – radius accordingly of the upper roller and the lower
 roller

P – vertical clamp force (compressing force) placed into the
 centre of the cylinders,

$$P = \int_{-a}^a p(s) ds = \int_{-a}^a \left(p_{\max} \sqrt{1 - \frac{x^2}{a^2}} \right) dx = \int_{-a}^a \left(\frac{aE_0}{2R_0} \sqrt{1 - \frac{x^2}{a^2}} \right) dx = \frac{\pi a^2 E_0}{4R_0}$$

$$p_{\max} = \frac{aE_0}{2R_0}, \quad p(x), \quad - \text{contact pressure [4],}$$

$$\frac{1}{R_0} = \frac{1}{R_1} + \frac{1}{R_2}, \quad \frac{1}{E_0} = \frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}$$

$$\eta_l = \frac{1-\nu_l^2}{E_l} \quad \text{for } l = 1, 2,$$

ν_1, ν_2 – Poisson's ratio accordingly of the upper and the
 lower rollers,

E_1, E_2 – Young's modulus accordingly of the upper and the
 lower rollers.

Experimental research for measurement of compression
 between the rollers and the contact area width was per-
 formed. A special test facility (fig. 4) was built in the ink
 unit of the Romayor offset printing machine. The rubber
 roller (with hardness of Sh) had radius of 29,5 mm, and
 the steel one had radius of 20 mm. The contact area width
 was measured with the Roller Nip Control device, and
 compression of the rollers was measured with a dial indi-
 cator. The rubber roller was repeatedly compressed to the
 static steel roller. The indicator used to measure the contact
 area width was 0,39 mm thick. First, the contact area width
 was set approximately to 0 mm – the number shown by
 the Roller Nip Control device was 2 mm. It was then as-
 sumed that the initial compression is equal to the thickness
 of the indicator, i.e. 0,39 mm, and for the contact area
 width – 2 mm. According to the instruction applicable to
 the Roller Nip Control device, a difference between the
 contact area width measured by the device and the one
 measured using the traditional method involving reflection
 of the ink stripe of the ink roller on the clean roller is not
 the same for all contact area widths (the relationship is not
 linear). Unfortunately, no relationship was provided in de-
 tail. By that reason we could not subtract from all values

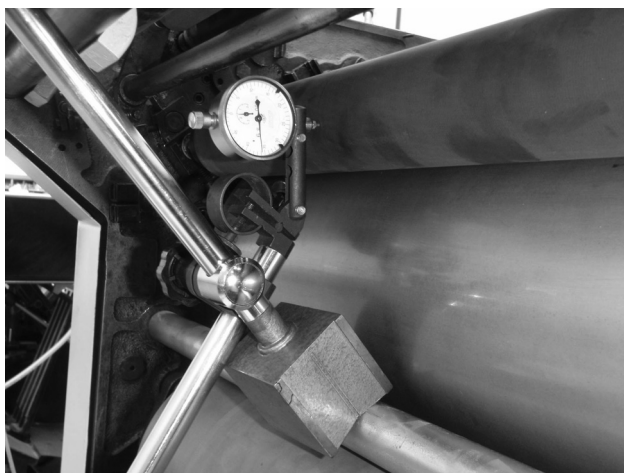


Fig. 4 The test facility for measuring the contact area width and compression of the rollers

shown by Roller Nip Control the initial contact area width shown by the device, i.e. 2 mm. During the research the air temperature in the room run within C.

Results

From literature [5] the formula is known which is derived using the engineering method consisting in the relationship between the compression d and the contact area width $2a$:

$$d = \frac{(2a)^2}{8} \left(\frac{1}{R_1} + \frac{1}{R_2 + b_{cz}} \right) \tag{3}$$

where b_{cz} – thickness of the Roller Nip Control indicator which was used for the experimental research.

After using the formula for relationship between the maximum contact pressure p_{max} and the half of the contact area width the equation (3) is as follows:

$$d = \frac{2p_{max}^2 R_0}{E_0^2} \tag{4}$$

If one of the rollers is steel-made it can be assumed that $E_2 = \infty$. Then, the equation (4) is as follows:

$$d = \frac{2p_{max}^2 R_0 (1 - \nu_1^2)}{E_1^2} \tag{5}$$

To compare these equations against the derived equation (2) we assumed that the contact takes place between the rubber roller (body 1) and the steel roller (body 2) and then $E_2 = \infty$. The entire contact area width $2a$ was taken into account. The relationship between the compression d and the contact area width $2a$ is as follows:

$$d = \frac{(2a)^2}{8} \left(\frac{1}{R_1} + \frac{1}{R_2 + b_{cz}} \right) \left(\ln \frac{4R_1}{2a} - \frac{1}{2} \frac{\nu_1}{1 - \nu_1} + \frac{1}{1 - \nu_1} \frac{(2a)^2}{32R_1^2} \right) \tag{6}$$

In turn, the relationship between the compression d and the maximum contact pressure p_{max} is as follow:

$$d = 2p_{max}^2 \left(\frac{1 - \nu_1^2}{E_1} \right)^2 \frac{R_1 R_2}{R_2 + R_1} \left(\ln \left(\frac{E_1}{(1 - \nu_1^2)} \frac{R_1 + R_2}{R_2} \frac{1}{p_{max}} \right) - \frac{1}{2} \frac{\nu_1}{1 - \nu_1} \right) \tag{7}$$

Figure 5 shows the relationship between the compression d and the contact area width $2a$. Dashed curve shows the relationship known from literature, (3) and continuous curve – the relationship derived in the work (6). Radius of the rubber roller was assumed as 29,5 mm and radius of the steel roller is 20 mm – taking into account to the size of the rollers used in the experimental research. Poisson’s ratio equal $\nu_1 = 0,49$ was assumed. The divergence between results from the work (6) and those from literature (3) is quite big.

Two measurement methods were used to determine the compression and the contact area width. The first of the methods consisted in rotating screws with the same angle for compressing the rubber roller to the steel roller, and in putting the Roller Nip Control indicator to the centre of

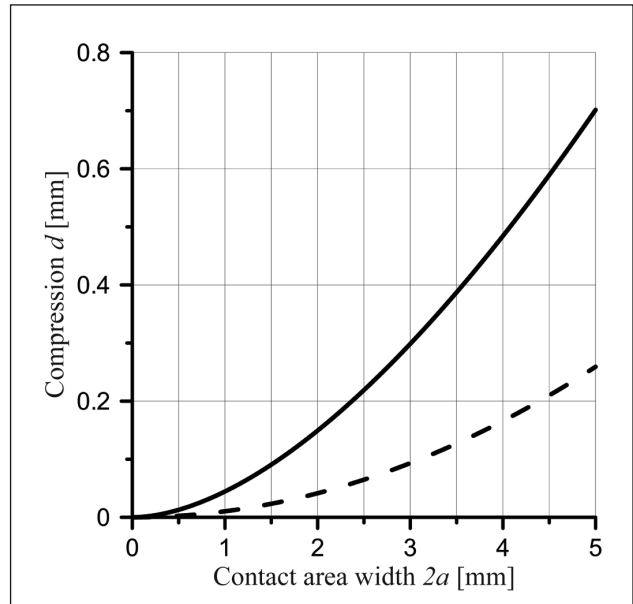


Fig. 5 Relationship between the compression d of the cylinders’ axes and the contact area width $2a$; Continuous curve – equation (6); Dashed curve – equation (3)

the roller (curve (a) fig. 6) and to the ends of the roller (curve (b) fig. 6), where the indicator for measurement of compression is placed in the centre of rollers. Curve (c) (fig. 6) shows results of measurements when the indicator for measurement of the contact area width are placed on the side of the machine’s driving unit. The other of the methods consisted in keeping the Roller Nip Control device between the rollers without removing it, and then the rubber roller was compressed to the steel roller to a distance so as to make the contact area width shown by the device change at every 0,5 mm (curve (d) fig. 6).

Graphs show that results of measurements are different depending on the method used. It seems that the best method is the one without removing the indicator for measurement of the contact area width from the rollers.

The results presented by way of curves (a) and (b) confirm that pressure on the centre of rollers is smaller than that at the ends of rollers [7, 8], but only in case of bigger contact area width. This problem is observed for compression of 0,69 mm, which makes the contact area width equal 4,5 mm in the centre of rollers, and 5 mm at the ends of rollers. Producers of offset printing machines recommend that the contact area width between ink rollers should run within 3,0-4,5 mm.

Figure 7 shows relationship between the compression d and the maximum contact pressure between rollers. In this case the radius of rubber rollers is 29,5 mm and radius of steel rollers equals 20 mm – taking into account the size of rollers used during the experimental research. There were assumed Poisson’s ratio $\nu_1 = 0,49$ and Young’s modulus $E_1 = 4,9$ MPa.

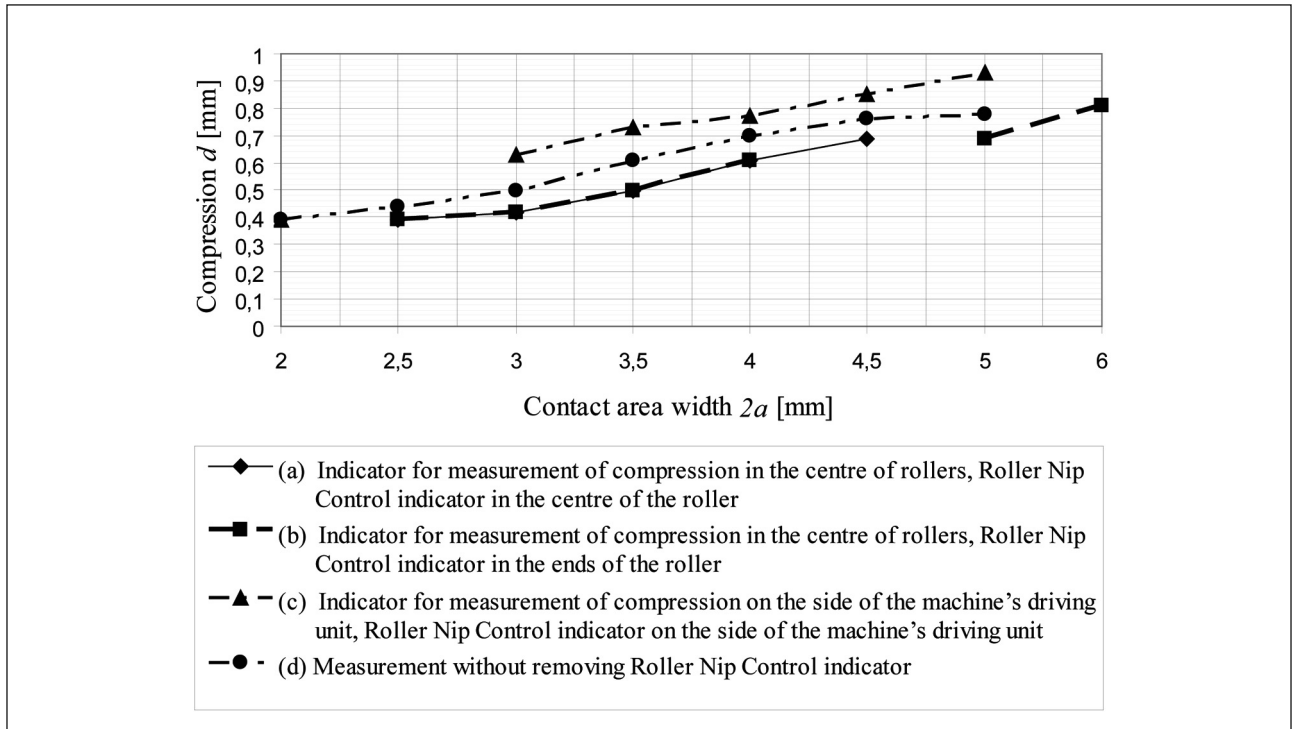


Fig. 6. Results of experimental research for the relationship compression d and the contact area width $2a$

The Young’s modulus was derived taking into account the rubber hardness of ink roller used during the experimental research. If Young’s modulus is changed for example to 2 MPa or to 10 MPa, the graphs of relationship between the compression of rollers’ axes and the maximum contact pressure will be like in the graph 8.

Figure 9 shows relationship between the compression

of cylinders’ axes d and the maximum contact pressure P_{max} for different kinds of blankets. This graph is elaborated on the basic data placed in the book [1]. Unfortunately, the book does not specify the source of the data. The graphs demonstrate that with the same contact pressure, the compressible blanket shows bigger compression than the incompressible one. This is because the compressible blanket includes a compressible layer. According to the data in

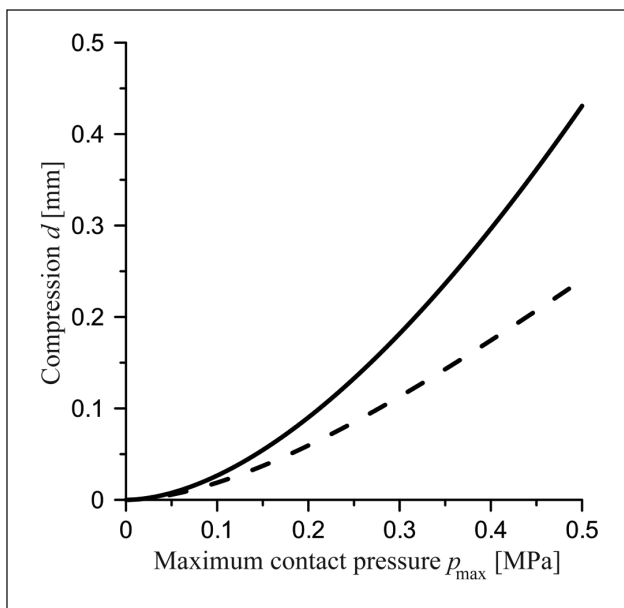


Fig. 7 Dependence of the compression of cylinders’ axes d on the maximum contact pressure p_{max} ; Continuous line – equation (7); Dashed line – equation (5)

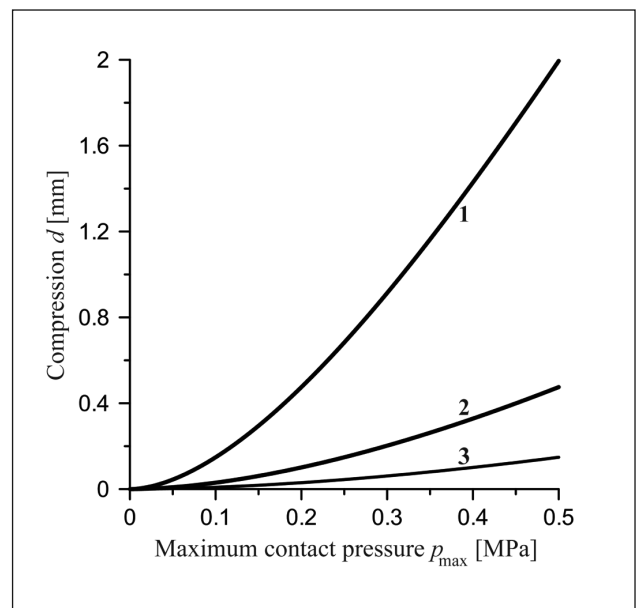


Fig. 8 Relationship between the compression of cylinders’ axes d and the maximum contact pressure p_{max} for different values of Young’s modulus; Curve 1 – $E=2$ MPa, 2 – $E=5$ MPa, 3 – $E=10$ MPa

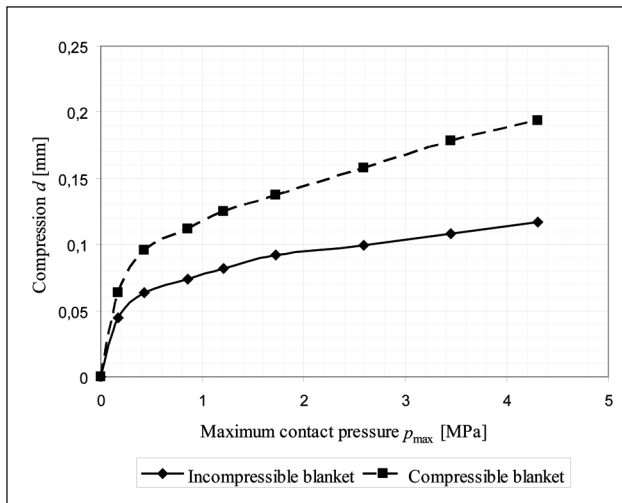


Fig. 9 Relationship between the compression of cylinders' axes d and the maximum contact pressure p_{max} for different kinds of blankets

question, if pressure is bigger, the difference in compression of rollers is bigger, too. It seems that with the compression layer being completely compressed, the corresponding curves should become parallel, because in this moment the rubber layer in the compressible blanket starts to compress.

Conclusion

Big divergences are observed between the relationship computed in the work and that found in literature, as regards compression of two rollers and maximum contact pressure between them (as shown in the graphs). The same is as regards relationship between compression and contact area width. The equations computed in the work are closer to

results of the experiment than those known earlier from literature. Experimental research shows that different methods give different results. There is a problem with measurement accuracy of the contact area width by the Roller Nip Control device. Therefore, in the future it is planned to build more accurate test facility for measuring contact area width. It is considered to compare relationship between contact area width measured by this device and the one measured using the traditional method consisting in reflecting an ink stripe from roller with ink on a clean roller.

References

- [1] Dejidat L. P., Jr., Desree T. M., *Technologia offsetowego drukowania arkusowego*, COBRPP, Warszawa 2007
- [2] Kipphan H., *Handbook of Print Media*, Springer-Verlag, Berlin Heidelberg 2001
- [3] Destree T. M., *Trudności w arkusowym drukowaniu offsetowym*, COBRPP, Warsaw 2007
- [4] Johnson K. I., *Contact mechanics*, Cambridge University Press, Cambridge 1985
- [5] Jurkiewicz A., Pyryev Y., 2011, *Analiza nacisków pomiędzy wałkami w arkusowej offsetowej maszynie drukującej*, *Opakowanie* 3/2011, str. 75-79, 2011
- [6] Jurkiewicz A., Pyryev Y., *Analysis of stress problem between two rollers or two cylinders in sheet-fed offset printing machine*, *Acta Mechanica et Automatica* 5(4), str. 58-61, 2011
- [7] Čechman Ja.I., Senkus' V.T., Didyč V.P., Bosak V.O., *Drukars'ke ustatkuvannja. Pidručnyk*, Ukrayins'ka akademija drukarstva, L'viv 2005
- [8] Ciupalski S., *Maszyny offsetowe zwojowe*, Oficyna Wydawnicza politechniki Warszawskiej, Warszawa 2000

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