THE OPTIMAL ANALYSIS OF THE CYLINDER PACKING IN THE OFFSET PRESS

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ABSTRACT

In this paper the problem for logically selecting cylinder packing in an offset press is discussed. Firstly, after analyzing the "πD Experiment" and the "Contact Rolling Experiment", the authors point out the difference between these experiments and the practical printing process. Then, based on the analysis of "sliding" between the contacting areas of cylinders, with minimum sliding as the objective, an analysis was made for the diameters of the plate-cylinder and the blanket-cylinder. The calculated result shows that, for best performance, the thickness of packing should result in the diameter of blanket-cylinder being a little larger than the diameter of plate-cylinder, and the ratio of compression of packing, for these two cylinders is $3/5\lambda$ to $2/5\lambda$ respectively, where λ is the total compression.

1. General Description

Determining the diameter of cylinders logically is one of the important problems in offset press research. In the early 1930's, Sites discovered that while the rubber blanket cylinder is rolling under pressure, the rubber on its surface will be stretched. He assumed that during printing the radius of the contacting surface is decreased due to compression of the rubber cylinder, but because the volume of rubber remains constant, a protrusion will be produced at the edge of the contacting area, thus increasing the rotating radius. To keep the surface velocity of these two cylinders equal to each other, the diameter of the rubber cylinder should be a little less. This is

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called the "Different Diameter Method". In 1960, R. D. Willer experimented with equal diameter cylinders in rolling contact for studying the difference of velocity between these two cylinders. He pointed out that the thickness of rubber gives an additional effect to velocity differences.

Takewuche, Poschke, Temple and Kuehu also have done research on cylinder deformation and velocity differences.

Generally, two fundamental methods are used for packing selection. They are "Different Diameters Method" and "Equal Diameters Method". Both are based on the same point of view that during printing, the "sliding" between two cylinders in the contact area must be kept minimum. This minimizes dot deformation. The diameter determination in both methods are analyzed following two aspects:

(1) The variation of volume or "rotating radius" of the rubber after being compressed, and

(2) The velocity difference and "sliding" in the contact area.

The "Different Diameters Method" is based on the " D Experiment" and the "Contact Rolling Experiment", so we must investigate these two experiments and compare the results with practice.

2. The Velocity Difference In Contact Area Between Two Cylinders and "Sliding"

The following analysis is based on the assumption that there is no tangential deformation of the rubber. In fact, "velocity difference" involves the tangential velocity of rubber, and "sliding" involves the tangential deformation of rubber. Consequently, we analyzed the velocity difference and sliding between the two cylinders.

In Fig. 1, let Rp and R_b denote the radius of the plate cylinder and of the blanket cylinder, respectively. Point Kp on the plate-cylinder coincides with point K_b on the blanket cylinder. Point K_b moves along arc AK_pB, with its absolute velocity directed along its tangential direction.

V_k can be replaced by its components V_{k1} and V_{k2}

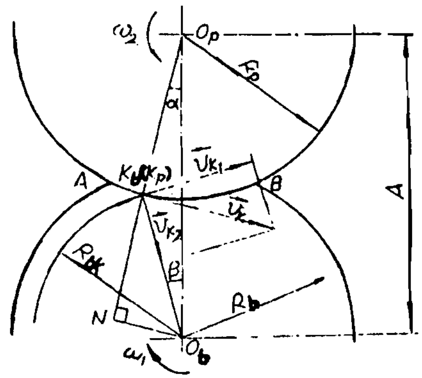


Fig. 1

and

$$V_K = \frac{V_{K_1}}{\cos(\alpha + \beta)} \tag{1}$$

where
$$V_{K_1} = \omega_1 R_{ik}, \quad R_{ik} = \sqrt{R_p^2 + A^2 - 2AR_p\cos\alpha}$$

Substituting into (1), we have

$$V_K = \frac{R_p^2 + A^2 - 2AR_p\cos\alpha}{A\cos\alpha - R_p}\,\omega_1 \tag{2}$$

representing the velocity of any point on the surface of plate-cylinder being equal to each other. Since $V_p = R_p\omega_2$ and while printing $w_1 = w_2 = w$, the velocity difference between points K_b and K_p is given by

$$V_r = V_K - V_P = \left(\frac{A^2 - R_p^2}{A\cos\alpha - R_p} - 3R_p\right)\omega \tag{3}$$

The relative slide ΔS can be calculated as follows:

$$d(\Delta S) = V_r dt = V_r \frac{dt}{d\alpha} \cdot d\alpha = \frac{V_r}{\omega} d\alpha$$

$$\Delta S = \int_{\alpha_A}^{\alpha} V_r dt = \int_{\alpha_A}^{\alpha}\left(\frac{A^2 - R_p^2}{A\cos\alpha - R_p} - 3R_p\right) d\alpha - F(\alpha) - F(\alpha_A) \tag{4}$$

where αA is the angle corresponding to the beginning point A of contact area

$$F(\alpha) = \sqrt{A^2 - R_p^2} \ \ln \left| \frac{\sqrt{A^2 - R_p^2}\, tg\frac{\alpha}{2} + A - R_p}{\sqrt{A^2 - R_p^2}\, tg\frac{\alpha}{2} - A + R_p} \right| - 3R_p\alpha$$

Thus, the amount of sliding ΔS can be calculated from Equation (4).

The maximum value of ΔS may be reached at point B or within the contact area.

Let
$$\frac{d}{d\alpha}(\Delta S) = \frac{A^2 - R_p^2}{A\cos\alpha - R_p} - 3R_p = 0$$

then we have

$$\alpha_{1,2} = \pm \arccos\left(\frac{A^2 + 2R_b^2}{3R_pA}\right) \tag{5}$$

and generally $\left(\frac{A^2+2R_p^2}{3R_pA}\right) \neq 1$ then $\alpha_{1,2} \neq 0$

$$\frac{d^2}{d\alpha}(\Delta S) = \frac{(R_p^2 - A^2)A\sin\alpha}{(A\cos\alpha - R_p)^2} \neq 0$$

So, within the contact area, when $\alpha = \alpha_{1,2}$, ΔS has its extreme value, and $|\Delta S|$ becomes maximum.

For example, on a J2108 type offset press, the center distance between cylinders A=300mm, compression is λ=0.15mm.

One can plot the curves of velocity difference and sliding, then find the maximum sliding, as follows:

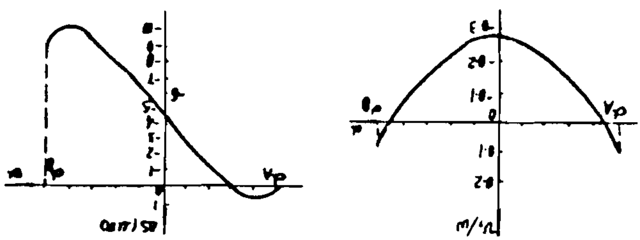
(1) Assume the radius of plate-cylinder R_p=150.15mm and radius of blanket-cylinder R_b=150mm. From Fig. 1 the angle corresponding to point B of the contact area is

$$\cos\alpha_B = \frac{A^2 - R_p^2 - R_b^2}{2AR_p} \qquad (6)$$

and α_B=1.81°. From Equation (5), one can find $\alpha_{1,2}$ = 1.478°, and substitute into Equation (4), to find that when

$$\alpha = \alpha_1 \quad , \quad \Delta S = 0.422\,\mu m$$
$$\alpha = \alpha_2 \quad , \quad \Delta S = -9.9\,\mu m$$

The curves of velocity difference and relative sliding can be plotted and are shown in Fig. 2 (a) and (b) respectively, in which the abscissas are scaled in equal portions at 1/10 width of the contact area.

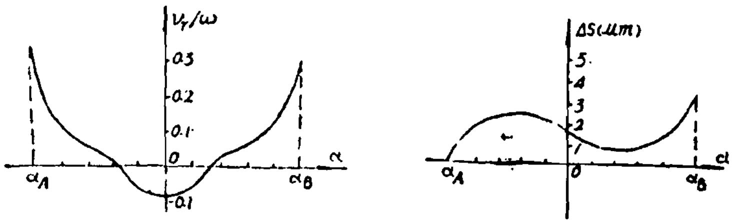


(a) Fig. 2 (b)

(2) Assume R_p = 150.05mm and R_b = 150.10mm, then one finds α_B = 1.818° and $\alpha_{1,2}$ = 0.854°. From Equation (4), we have

$$\alpha = \alpha_1 \quad , \quad \Delta S = 2.6\,\mu m$$
$$\alpha = \alpha_2 \quad , \quad \Delta S = 0.651\,\mu m$$

The curves of velocity difference and relative sliding in this case are shown in Fig. 3 (a) and (b), respectively.



(a) (b)

Fig. 3

From Fig. 2 and Fig. 3, we can see that

(a) The velocity differences V_r are distributed symmetrically and differ both in magnitude and direction within all of the contact area.

(b) The relative sliding, ΔS, differs considerably with different packing methods.

3. The "πD Experiment"

The "πD experiment" is also called the "True Rolling Method" that was carried out by Sites in the 1930's. It deals with the theory of friction.

In Fig. 4, a rubber roller is put on a rigid plane. Force P is applied and distributing force p'(x) is produced and its resultant may be denoted by Q.

$$Q = \int_{2a} p(x)dx, \qquad P = Q$$

When a horizontal force F acts on the center of this roller a tangential friction force will be produced in the

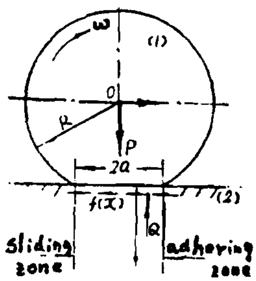


Fig. 4

contact area that balances force F until the roller starts to rotate. At this time, assuming the resultant of friction f(x) is $F' = \int_{2a} f(x)\,dx$, $F=F'$. Force Q acts at the forward part of the contact area, where there exists an adhering zone and a sliding zone. Then

in the adhering zone $\quad f(x) < \mu p(x)$

and in the sliding zone $\quad f(x) = \mu p(x)$

where μ is the sliding friction coefficient.

Obviously, under the action of f(x), the surface of the rubber in the contact area will be stretched tangentially, but at the zone closed to force Q, where adhesion occurs, there is no sliding. The resultant F' can be expressed as:

$$F' = \int_{2a} f(x)\,dx = \frac{4p^{3/2}}{3\pi^{3/2}}\,\varepsilon\sqrt{\frac{1}{R}\left(\frac{1-\gamma_1^2}{E_1} + \frac{1-\gamma_2^2}{E_2}\right)}$$

where ε is the specific energy of elastic hysteresis about two materials, γ_1 and γ_2 are Poison ratios and E_1 and E_2 are moduli of elasticity.

The "πD experiment" was carried out under static condition; the stretching of the rubber surface is caused by a tangential force of f(x) and occurs in the same direction.

Comparing with the condition in printing processes, the deformation of dots and of rubber packing are caused by velocity differences and sliding. As we have calculated (Fig. 2, Fig. 3), the velocity difference changes both in magnitude and direction. Thus the surface of rubber deforms in various directions.

4. The "Contact Rolling Experiment"

The "Contact Rolling Experiment" was carried out by R. D. Willer in 1960. Two equal diameter rollers (rigid roller I, rubber blanket B) (Fig. 5) contact each other under pressure. One roller was driven by outside means and it frictionally drove the second one. It was discovered that rotating speeds of these two rollers were different. The higher rate of speed on a driven roller is shown in Fig. 6. The rubber roller is always slower, independent of whether it is driver or driven. The value of "a" refers to packing material hardness and thickness.

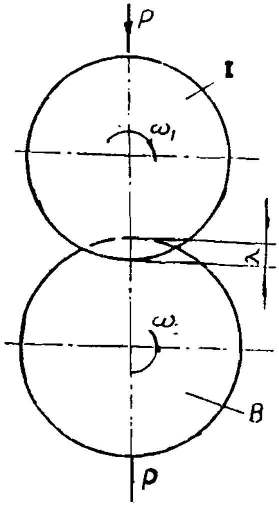


Fig. 5

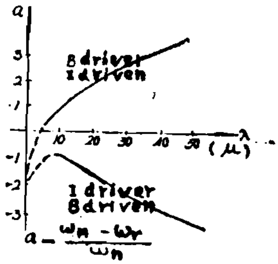


Fig. 6

Willer proposed that during printing, the surface of the rubber cylinder is stretched, increasing the rolling diameter. He suggested that the diameter of the rubber cylinder should be less than that of the plate-cylinder.

Based on this suggestion, some formulae for determining diameters of cylinder have been proposed.

Diameter of rubber cylinders $$D_B = A + \lambda - \frac{a\lambda(A+\lambda)}{2+a\lambda}$$

Diameter of plate cylinders $$D_p = A + \lambda + \frac{a\lambda(A+\lambda)}{2+a\lambda}$$

where A is the center distance between two cylinders, and λ is the compression.

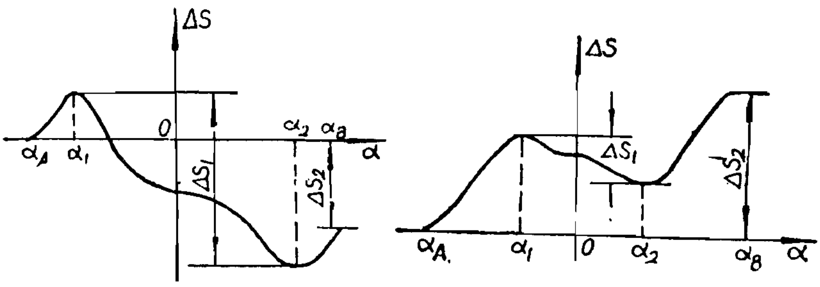
In Willer's experiment, the velocity difference between the two rollers is mainly caused by the fact that the second roller is driven by the first one. Under the action of a tangential drawing force, deformation exists in the surface of the rubber roller. This induces the velocity difference and its magnitude is affected by the magnitude of the drawing force.

But in an offset press, both cylinders are driven by a gear transmission and have the same rotating speed. No tangential drawing force, no tangential stretching of rubber packing takes place. Thus, the velocity differences as described in Willer's experiment do not exist.

5. The Optimization Of Diameters Of Plate-Cylinder And Rubber Blanket-Cylinder

As we have stated above, in practical printing processes, the deformations of dots and of rubber are caused by the velocity difference and the relative sliding existing on surfaces of the cylinders. And, different packing methods will affect the velocity difference considerably.

With "minimum sliding" as the objective, we tried to find the optimal diameters of cylinders. We selected a pair of gears of 300mm pitch diameter as the driver of the cylinders, and the center distance between cylinders is also 300mm.



(a) (b)

Fig. 8

Let δ denote the compression, then after packing,

radius of plate cylinder $R_p=150+\delta$

radius of rubber-cylinder $R_b=150+(\lambda-\delta)$

And since δ is the only variable, this is a one dimensional problem.

In Section 2, we have shown there are two types of velocity difference curves due to two different packing methods. After entering the contact area, the maximum sliding distances between two corresponding points on the two cylinders are shown in Fig. 8(a) and Fig. 8(b) respectively. Thus, the objective function is

$$\min_{(0 \leq \sigma \leq \lambda)} \left\{ \max \left(\left| \Delta S_1 (\delta) \right| , \left| \Delta S_1 (\delta) \right| \right) \right\}$$

where

$$\Delta S_1(\delta) = \int_{\alpha_1}^{\alpha_2} \left[\frac{A^2-(R+\delta)^2}{A\cos\alpha-(R+\delta)} - 3(R+\delta) \right] d\alpha$$

$$\Delta S_2(\delta) = \int_{\alpha_A}^{\alpha_B} \left[\frac{A^2-(R+\delta)^2}{A\cos\alpha-(R+\delta)} - 3(R+\delta) \right] d\alpha$$

From equations (5) and (6), we have

$$\left. \begin{aligned} \alpha_{1,2} &= \pm \arccos\left(\frac{A^2+2(R+\delta)^2}{3A(R+\delta)} \right) \\ \alpha_{A,B} &= \pm \arccos\left(\frac{A^2+(R+\delta)^2-(R+\lambda-\delta)^2}{2A(R+\delta)} \right) \end{aligned} \right\} \quad (7)$$

Analysis indicates that $|\Delta S_1(\delta)|$ and $|\Delta S_2(\delta)|$ are continuous functions.

We used an exhaustive searching method with a step size of $\lambda/20$ and calculated compression ratios at various total compressions. Table 1 gives the results.

Table 1 (mm)

Compression	0.050	0.075	0.100	0.125	0.150	0.175	0.200	0.225	0.250
Distribution to plate-cylinder	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090	0.100
Distribution to Blanket-cylinder	0.030	0.045	0.060	0.075	0.090	0.105	0.120	0.135	0.150

From Table 1, we can see the actual distribution ratio of compression between two cylinders $\delta : (\lambda-\delta)$ remains unchanged, equal to $2\lambda/5:3\lambda/5$. That is, after packing, the radius of the rubber cylinder should be /5 larger than the radius of the plate-cylinder.

6. References

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