Chemical resistance of a surface of an offset cylinder of printing equipment

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Abstract. The mechanical properties and chemical stability of the rubber-fabric coating of the printing cylinder of offset printing equipment were studied according to the parameters: compression and recovery rates during cyclic deformation of the material in the printing contact strip before and after swelling in printing ink solvents and technological solutions.

1. Introduction
In the offset printing, ink on the substrate is transmitted through elastic polymer of the offset cylinder of offset printing equipment (web), which are subjected to cyclic "compression-recovery" deformations at a high speed. Thus, for example, in a Speedmaster XL 105 offset printing press, the rotation speed of the offset cylinder reaches 3000-18000 rpm, which corresponds to the time of periodic partial restoration of the thickness of the rubber-fabric coating after impulse compression of 0.2-0.4 s [1]. Cyclic deformations of a rubber blanket are combined with the destructive action of components of printing inks and liquid products of a periodic cleaning the surface of a offset cylinder.

In the printing industry, various solvents are widely used for cleaning parts and coatings of polymeric materials from solid components of paints [2, 3]. Many solvents are multicomponent mixtures developed by trial and error and cause swelling of polymeric materials [4]. To select and develop the optimal composition of solvents in the works [5, 6], mathematical models of cyclic deformations of rubber are used, considering the insignificant anisotropy of its mechanical properties, as well as models of the compression layer of an offset rubber blanket [7]. Special attention should be paid to the rubber compression model developed in [8], which offers several advantages over currently available models since it is able to describe with high accuracy the mechanical behavior of rubber to very small short-term deformations of compression and stretching of rubber [9], which occur when operating high-performance equipment for offset printing.

In the article [10], the theoretical foundations of an approach to the development of environmentally safe and easily recyclable (recoverable) means of cleaning offset rubber blanket with the simultaneous restoration of their operational qualities are laid. In [11–14], methods were proposed for increasing the chemical resistance of polymer coatings and materials used in equipment for offset printing by chemical modification of the rubber surface with gaseous fluorine.

The purpose of the work is by instrumental determination of the rate of deformation of the offset rubber blanket of the offset cylinder of printing equipment after exposure to individual components of liquid cleaning agents, for the subsequent development of recommendations for optimizing their composition, which ensures the restoration of the performance of the coating.
2. Subjects and methods
Offset rubber blanket (ORB) brand: Saphira Blankets 1.9 mm thick. Model fluids whose physicochemical properties and sorption are like solvents of printing inks and components of the technological solution used in the operation of offset printing machines: Propanol-2 (ChDA), n-Decan (Ch), Castrol Sintel RHS cutting fluid: mineral oil solution in Propanol-2.

To quantify the processes of compression and restoration of ORB, a unit was assembled, including a modernized TIB-1 thickness gauge and a video camera (figure 1). The compressive load on the samples of elastic materials (figure 2), corresponding to the pressure in the areas of the printed contact of machines for flexographic and offset printing up to 4 MPa, is provided by installing a weight of 1 kg on the lever. The restoration of the size of the samples in a free state after the termination of the pressure is performed by instantly raising the lever (6).

The technique of treating a ORB with liquids from the side of the printing layer (1) for a time commensurate with the time of printing or prophylactic cleaning of its surface with washing and restoring solutions [8–9] is described in [11].

![Figure 1. Installation diagram for video recording of web deformation.](image1)

**Figure 1.** Installation diagram for video recording of web deformation 1-thickness gauge with indicator; 2-rubber cloth; 3-load; 4-tripod; 5-video camera; 6-lever.

![Figure 2. The section of the offset rubber fabric.](image2)

**Figure 2.** The section of the offset rubber fabric 1 - the printed layer of rubber; 2 - a stabilizing layer of tissue; 3 - compression layer; 4 - fabric.

Now of installation of the weight, the elastic part of the deformation of the polymeric material ($\varepsilon_{el}$) is realized almost instantly, which increases somewhat due to the highly elastic ($\varepsilon_{val}$) and plastic ($\varepsilon_{pl}$) deformation. Compression time less than 0.01 s. While the material is outside the printed contact zone, up to 1.5 s, the “current” deformation of the material under study is reduced due to the reversible highly elastic ($\varepsilon_{val}$). The total deformation ($\varepsilon$), determined by the ratio of the change in the thickness of the material during video recording ($\Delta h$) to the thickness of the material taken as the initial (h) (before compression), is the sum of the strains of various sizes and physical nature:

$$\varepsilon = \varepsilon_{el} + \varepsilon_{val} + \varepsilon_{pl}.$$  

(1)

According to [8, 9], the relaxation processes of compression in rubbers can be described by analytical expressions of an exponential type (formula 2). Kinetic curves of semilogarithmic coordinates allow you to determine the characteristic values of relaxation time with a high degree of reliability according to an equation of the form:

$$\varepsilon = \varepsilon_0 \cdot \exp\left(-t / \tau\right)$$  

(2)

where: $\tau$ - strain relaxation time, which is determined by the structure of the material.
3. Results and discussion
The fast processes of repeated deformation of the ORB, which are implemented in the area of the printing contact of printing machines and are limited by the design of the printing shaft with a maximum value of relative compression of 20-25%, are investigated. Under the purpose of the work, the processes of compression and restoration of the size of the ORB after repeated deformation were compared using samples of the fabric before and after treatment with various liquids from the side of the printing layer.

Figures 2 and 3 show the cross-section and change in the thickness of the ORB obtained using equipment for slow-motion video filming of compression and recovery processes (figure 1).

![Graphs showing deformation and recovery](image-url)

**Figure 3.** Cyclic deformation of an offset rubber blanket (ORB) in a laboratory setup in inverse time coordinates in the air (a) and after treatment with n-decane (b). 1 – compression; 2 - restore.

The graphs of the compression and recovery deformation functions in time in inverse coordinates do not coincide and form a loop of mechanical hysteresis [15]. This means that the compression strain rate and the recovery strain rate are not equal. During web deformation, when tested in dry form in the air, the recovery rate of interest to us is greater than the compression rate. Upon deformation of the ORB after exposure to contact with n-decane, which is a model of solvents for paints based on mineral oils, the recovery rate is lower than the compression rate. In the initial recovery period, in the first 0.3 seconds, after the termination of the compression force, the recovery rate is especially low. This indicates a significant decrease in the rate of stress relaxation on the ORB under the action of n-decane. To quantify the rate of deformation of the ORB recovery during the test time interval corresponding to the period of rotation of the printing shaft less than 0.3 seconds, the recovery deformation (formula 1) and the deformation relaxation time (formula 2) were determined by testing a series of samples of the ORB treated in isopropyl alcohol, in n-decane and a liquid from a mixture of solvents for washing off printing inks.

Using Excel® software, the average recovery speed and relaxation time of the thickness recovery was determined from the results of measuring the thickness of polymeric materials and the graph of trend lines of the time dependence of the strain recovery of sample sizes after compression in the first 0.2-0.4 seconds (figures 4, 5) canvases (table 1). The table shows the values of sorption by a ORB of liquids, contact with which occurs during printing and maintenance of offset printing machines. The sorption of liquids is calculated relative to the unit mass of the ORB having a thickness of about 2 mm and a multilayer structure (figure 2).
Figure 4. The initial sections of the curve of the restoration of the thickness of the ORB in the coordinates of relative deformation after contact with n-decane (1) ($\varepsilon = -20.4t + 15.5, R^2 = 0.97$) and propanol-2 (2) ($\varepsilon = -13.9t + 13.5, R^2 = 0.99$).

Figure 5. The initial sections of the curve restoration of the thickness of the ORB in semilogarithmic coordinates after contact with n-decane (1) ($\ln(\Delta h / h_0) = -2.6t + 3.0, R^2 = 0.96$) and propanol-2 (2) ($\ln(\Delta h / h_0) = -1.6t + 2.7; R^2 = 1$).

Liquids in contact with the ORB during the test are sorbed mainly by the external rubber layer of the ORB, therefore their content in the rubber exceeds the value given in the table by an order of magnitude. The use of sorption values for assessing the chemical resistance of an ORB is not correct. The aggressiveness and negative impact on the performance properties of ORB should be evaluated by the values of the recovery rate of deformation and the time of deformation relaxation.

Table 1. Conditions and characteristics of deformation of the restoration of the thickness of the offset rubber blanket (ORB).

| Indicators                  | Propanol-2 (IPA) | n-Decane | Solvent mixture (Castrol RHS + IPA) | Air |
|-----------------------------|------------------|----------|------------------------------------|-----|
| Sorption, % of the mass.    | 2,2±0,1          | 2,4±0,1  | 0,7±0,1                            | -   |
| Recovery speed, ms$^{-1}$   | 140±0,14         | 200±0,12 | 715±0,22                           | 770±0,26 |
| Relaxation time, s          | 0,44±0,04        | 0,40±0,03| 0,17±0,02                          | 0,16±0,01 |

4. Conclusion
An experimental technique has been developed and quantitative parameters have been proposed for assessing the chemical resistance of an ORB by relaxation time and the average rate of cyclic deformations. The influence of solvents, printing inks and technological solutions used to clean the surface offset cylinders of press machines on the performance of ORB is determined.

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