532. The investigation on the impact of the contact rings of cylinders and on transversal vibrations of blanket and plate cylinders in offset printing press

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Abstract. Transversal relative vibrations of blanket and plate cylinders in web offset printing press worsen the quality of prints. In the paper, the impact of contact rings upon the quality of prints is discussed upon.

Keywords: printing, offset, printing press, transversal vibrations, investigation.

Introduction

Web offset printing presses are widely used. The principal part of such a press is the printing equipment. At present, the most frequently used printing equipment consists of two plate cylinders 1, 4 and two blanket cylinders 2, 3 with a paper tape moving between them (see Fig. 1 and Fig. 2). Its precizity, high speed and other properties predetermine the quality of the prints as well as the productivity, economic exploiting and durability of the press. It is known that transversal relative vibrations of blanket and plate cylinders of the printing equipment restrict technological properties of the printing press. Changes of pressure between blanket cylinders as well as between blanket and plate cylinders worsen the quality of the prints, too. Usually, changes of pressure between cylinders occur because of relative vibrations between the cylinders that appear during operation of the press and static bends of the cylinders that appear on their pressing against each other via the blanket. In the first case, the pressure pulsation causes uneven transfer of ink onto the paper [1].

It was shown in earlier works that transversal vibrations between the cylinders can be considerably reduced if their dynamic characteristics and dynamic parameters are identical [2, 3]. However, it is difficult to produce a printing equipment with cylinders having absolutely identical dynamic characteristics. The important problem is an impact of changes of dynamic parameters of the cylinders upon the intensity of relative vibrations of the printing equipment.

The object of the paper is the investigation of the impact of using contact rings in web offset printing equipment upon the quality of prints produced by it. In the paper, the results of exploiting the printing equipment with and without the contact rings are compared. Two cases are analyzed: when all cylinders of the equipment are solid or all of them are pipe-type hollow ones, hereinafter referred to as cylinders of „identical“ parameters; and when blanket cylinders are solid and plate cylinders are hollow ones, hereinafter referred to as cylinders of „different“ parameters.

The object of the investigation and the methods of calculation

In Fig. 1, the scheme of the dynamic model of the printing equipment without contact rings is shown. In Fig. 2, the scheme of the general dynamic model of the printing equipment with contact rings is shown. In the first case, the equipment consists of four cylinders pressed against their working surfaces via the blanket along their generatrices (blanket is a thin elastic rubberized fabric that covers the blanket cylinders), as shown in Fig. 1. In the second case, the equipment consists of four cylinders pressed against their working surfaces via the contact rings and the blanket, as shown in Fig. 2. The layout of the cylinders shown in the Fig. 1 and 2 is the most frequent in web offset printing presses.

In the dynamic model, cylinders are disintegrated into finite elements. Rolling bearings are approximated by elastic mass-free elements with damping, errors of bearing – by kinematic excitation.

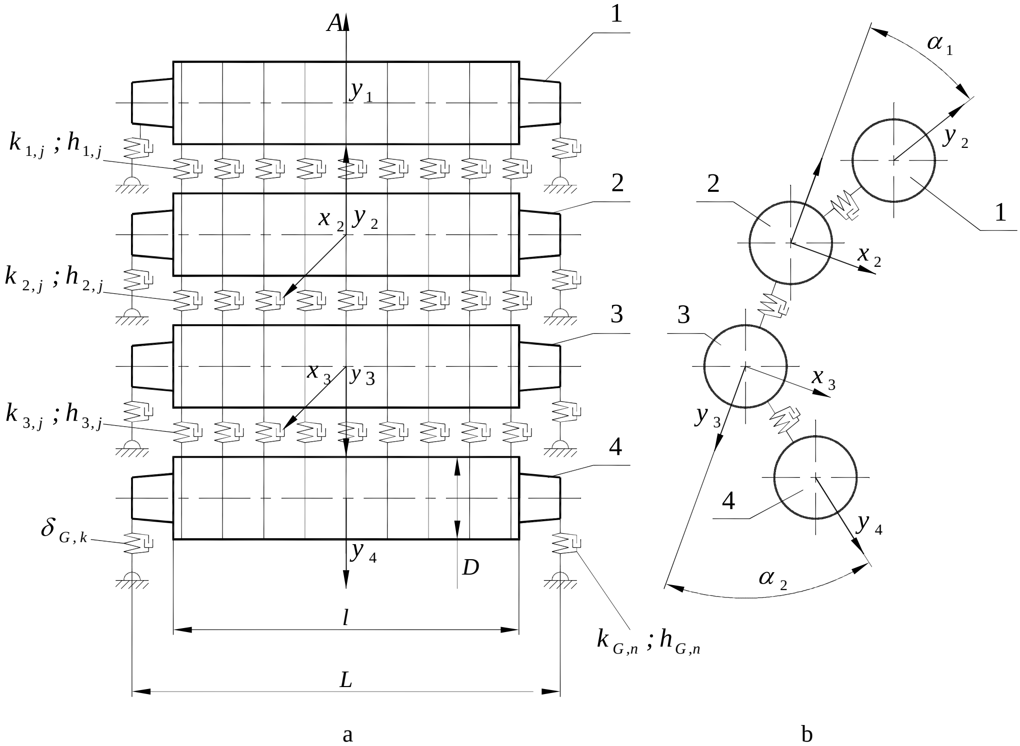


Fig. 1. The scheme of the general dynamic model of the printing equipment without contact rings.
a – the evolvent of the cylinders; b – the rear image; the blanket and plate cylinders disintegrated to finite elements, elastic elements with damping on their ends that simulate assemblies of bearings and the ones that simulate the blanket and connect the finite elements of different cylinders are shown; $y_1 \div y_4$, x_2, x_3 – the generalized coordinates that describe the elastic rectlinear shifts of the middle lines of the cylinders that also show the directions chosen for investigation of vibrations of such cylinders; $\delta_{G,k}$ - elements that simulate errors of the bearings; k, h – the coefficients of stiffness and resistivity of elastic members

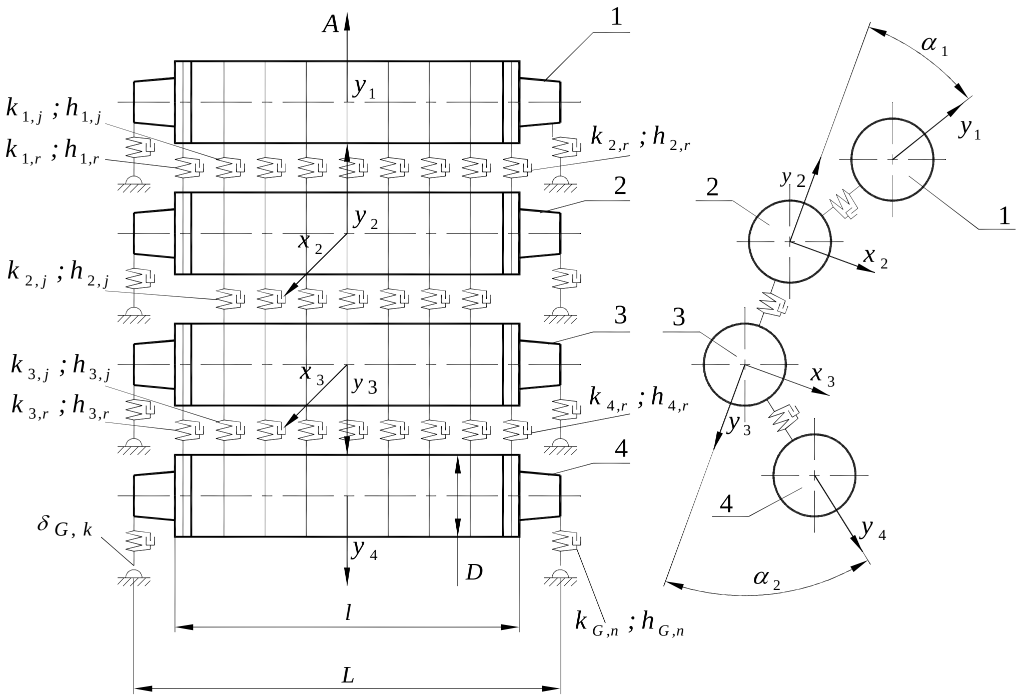
The blanket is approximated by discrete mass-free elastic elements with damping [2, 3]. The dynamic model of the system under discussion is complicated, it has multiple degrees of freedom. Direct using of it for formation of the equations of the vibrations is not purposeful. For this purpose, the *computer-aided* formation of the mathematical model is used. The proposed method of formation of the mathematical model is based on an artificial decomposition of the system into less complicated subsystems, formation of equations of vibrations for such systems and subsequent uniting of the said equation into the common system of equations that describes vibrations of the total system [4].

In the first phase, the following equation is found for each subsystem:

$$[A]_k\left\{\ddot{q}\right\}_k + [B]_k\left\{\dot{q}\right\}_k + [C]_k\{q\}_k = 0, \qquad (1)$$

where $[A]_k, [B]_k, [C]_k$ - the matrices of inertia, damping and stiffness of the *k*-th subsystem; $\{q\}_k$ - the vector of its generalized coordinates (the components of the vector are the principal and auxiliary generalized coordinates that define the location of the *k*-th subsystem).

In the second phase, taking into account the external exciting forces that affect the subsystems, an auxiliary system of equations of vibrations is formed:



a) b)

Fig. 2. The scheme of the general dynamic model of the printing equipment with contact rings.
a - the evolvent of the cylinders, b - the rear image; the blanket and plate cylinders disintegrated to finite elements, elastic elements with damping on their ends that simulate units of bearings and the ones that simulate the blanket and connect the finite elements of different cylinders are shown; $y_1 \div y_4$, x_2, x_3 – the generalized coordinates that describe the elastic rectlinear shifts of the middle lines of the cylinders that also show the directions chosen for investigation of vibrations of such cylinders; $\delta_{G,k}$ - elements that simulate errors of the bearings; *k*, *h* – the coefficients of stiffness and resistivity of elastic members

$$[A]_0\left\{\ddot{q}\right\}_0 + [B]_0\left\{\dot{q}\right\}_0 + [C]_0\{q\}_0 = \{F_B(t)\}_0; \qquad (2)$$

where the matrix $[A]_0$ is formed of the submatrices $[A]_k$ situated on its diagonal and the matrices $[B]_0$, $[C]_0$ are formed of submatrices $[B]_k$ or $[C]_k$ situated in an analogous way; $\{q\}_0$ - the vector that's components are the principal and auxiliary generalized coordinates included in all equations (1); $\{F_B(t)\}_0$ - the vector that‘s non-zero components are formed of errors of bearings or the elements of kinematic excitation of vibrations of the cylinders through the body of the printing equipment.

In the third phase, when the auxiliary system of equations for the vibrations (2) and the equations of links are known, the principal system of equations (without the auxiliary coordinates) that describes vibration of the whole system is found:

$$[A]\left\{\ddot{q}\right\}+[B]\left\{\dot{q}\right\}+[C]\{q\}=\{F_B(t)\}; \qquad (3)$$

where $\{q\}$ - the vector of the principal generalized coordinates that defines the position of the whole system (here the number of coordinates equals to the number n of the degrees of freedom of the system); $[A],[B],[C]$ - the square matrices of inertia, friction and stiffness of the n-th degree system; $\{F_B(t)\}$ - the vector of generalized forces obtained from the vector $\{F_B(t)\}_0$ after elimination of the zero components that conform to the auxiliary coordinates.

The equations describing vibrations of the printing equipment were formed using the methods provided in works [2, 3, 4] and the set of programmes DINCHAR. The forced harmonic vibrations of the cylinders are discussed upon. The intensity of the vibrations was discussed upon in course of examining the amplitute-frequency responses of the system that are obtained on kinematic exciting of the system under discussion by the errors of bearings of cylinders and in the vertical direction by the body of the press. It is shown in the works [2, 3] that the maximum intensity of forced transversal harmonic vibrations of cylinders is achieved in their middle lines, so the relative vibrations of the middle points of the cylinders when they are pressed against each other via contact rings are discussed upon herein and this case is compared to the case of the equipment where the cylinders are pressed against each other without contact rings along their working surfaces.

The results of the investigation

The vibrations are examined using the obtained amplitute-frequency responses – their examples are provided in Fig. 3. In the example: the distance between the bearings L=1,36 m; length of the working surface l =1,004 m; the external diameters of the cylinders D=0,2 m; the diameters of holes d_k=0,17 m; the length of the holes l_k=0,95 m; $k_{B,n}=1{,}7\cdot10^6$ N/m; $h_{B,n}$=49022 N·s/m; $k_{1,j}=k_{3,j}=6{,}91\cdot10^6\div1{,}39\cdot10^7$ N/m; $k_{2,j}=6{,}91\cdot10^6\div1{,}209\cdot10^7$ N/m; $h_{1,j}=h_{3,j}=9{,}79\cdot10^2\div1{,}963\cdot10^3$ N·s/m; $h_{2,j}=9{,}21\cdot10^2\div1{,}818\cdot10^3$ N·s/m (the values of $k_{i,j}$ and $h_{i,j}$ are smaller in the middle part of cylinders); $\alpha_1=30^\circ$, $\alpha_2=50^\circ$.

Forced transversal vibrations of the cylinders are excited in the kinematic way by the errors of bearings of cylinders or the vibrations of the stand of the printing equipment in the vertical direction. The intensity of the transversal vibrations of the centers of the cylinders was examined. In all cases, the amplitudes of kinematic harmonic excitation equaled to 1 μm. The amplitudes of transversal vibrations of the cylinders are expressed in micrometers. The following results were obtained for frequencies up to 500 Hz.

It was found that on changing the parameters of the printing equipment, i.e. using cylinders with „identical“ or „different“ dynamic parameters, as well as taking into account whether the cylinders were pressed against each other via the contact rings and blanket or via the blanket along their working surfaces, a narrow zone of resonances of transversal relative vibrations is formed. The zone with the expressed resonance peak that conformed to the vibrations of the maximum intensity is situated in the range of 170 – 210 Hz. The zone is well identified in all cases.

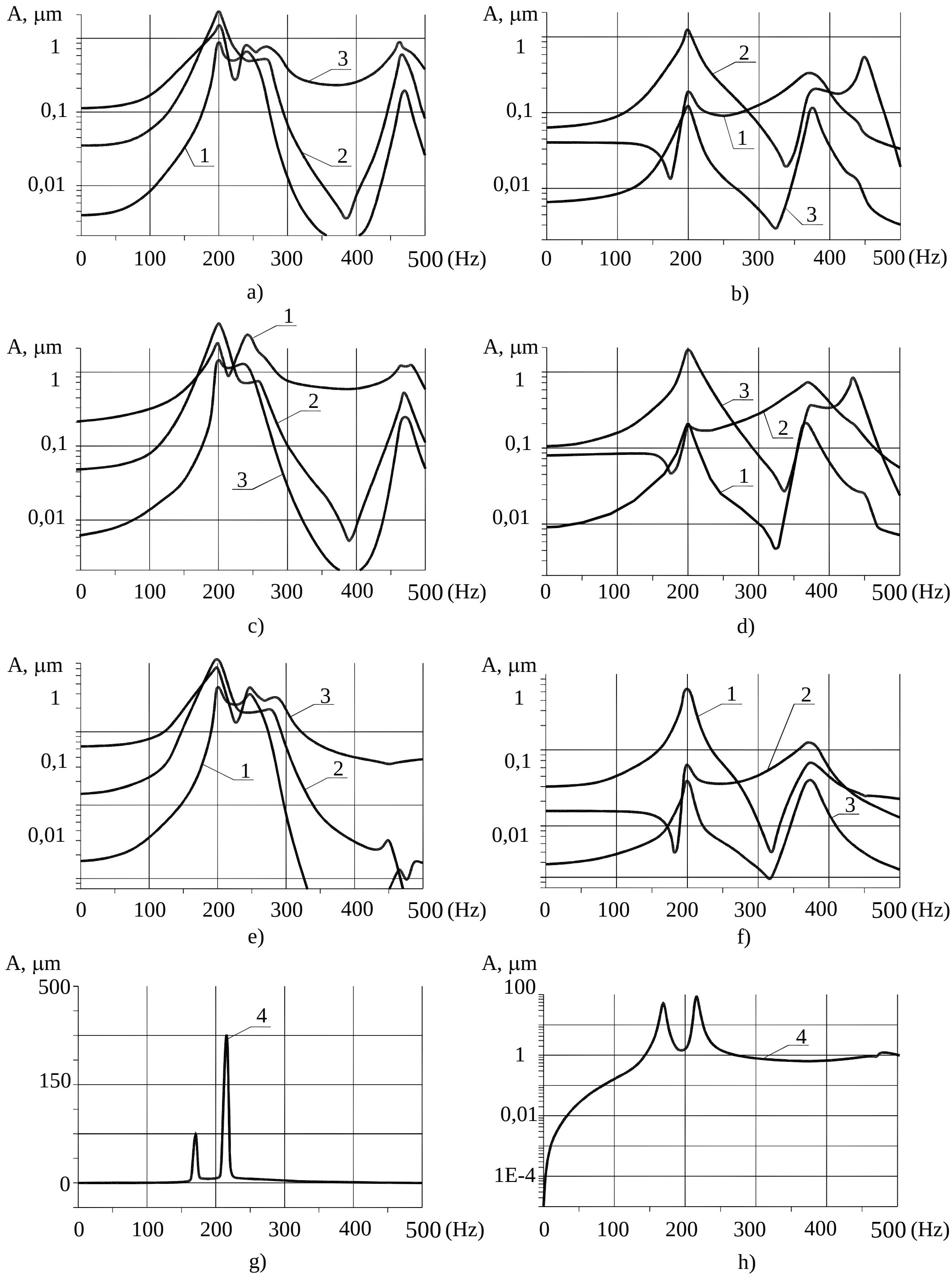


Fig. 3. The amplitude-frequency responses of transversal relative vibrations of cylinders in the printing equipment (a, c, e, g – the equipment without contact rings; b, d, f, h – the equipment with contact rings); 1 - vibrations between the upper blanket and plate cylinders; 2 – between blanket cylinders; 3 – between

the lower blanket and plate cylinders; 4 – tangential vibrations between blanket cylinders. a, b – vibrations excited in kinematic way by errors of one bearing of the upper plate cylinder; c, d – vibrations excited in kinematic way by errors of one bearing of the lower plate cylinder; e, f - vibrations excited in kinematic way by both bearings of the lower plate cylinder with identical errors; g, h – kinematic excitation in the vertical direction via the stand of the press. The values of the amplitudes of kinematic excitation equal to 1/μm. a, b, c, d, e, f – cylinders with „identical“ parameters; g, h – cylinders with „different“ parameters

On exciting the relative vibrations via the left bearing of one of blanket cylinders of web offset printing equipment, it was found that the intensity of the vibrations between the blanket cylinders reduces inconsiderably, if contact rings are used; in certain moments, it increases inconsiderably. However, if contact rings are used, the intensity of the vibrations between the blanket and plate cylinders reduced from 20 to 50% and in certain cases – even by 100%.

It was found that if relative vibrations are excited from both bearings of one cylinder of the web printing press with the identical errors, the intensity of the vibrations between the blanket cylinders reduces by about 10 – 15%, when contact rings are used. The intensity of vibrations between plate and blanket cylinders is reduced from 40 to 65%, if contact rings are used.

If the system is excited in the vertical direction via the stand of the press and contact rings are used, no changes of the intensity of vibrations between the blanket cylinders occur. The intensity of vibrations between plate cylinders reduces about 40%. However, the intensity of tangential vibrations fell down close to zero, when the cylinders had „identical“ parameters and contact rings were used. However, no changes of the intensity of tangential vibrations took place when the parameters of the cylinders were „different“, irrespectively of using the contact rings.

Conclusions

After the assessment of the results obtained, it may be concluded that in most cases contact rings reduce transversal vibrations. Such reduction improves the quality of the prints, increases the productivity and the service life of web printing machines.

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