EXPERIMENTAL DETERMINATION OF CALENDER ROLLS DEFLECTION USING DIAL GAUGES

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Abstract: This paper presents several experimental models with different configurations for the measurement of the calender rolls deflections, under an adequate internal pressure correlated with a uniform distributed load, using dial gauges.

Keywords: calendar, roll deflection, dial gauge

1. DESCRIPTION OF THE MEASURING CHAIN BY USING DIAL GAUGES

The measuring chain for determination of the calender rolls deflections contained seven dial gauges. Six dial gauges were placed on the upper generatrix of the roll, and one was placed on the lower side of the roll. Each dial gauge was fixed on a rigid magnetic support, which guaranteed a good stability and functionality.

The upper dial gauges were distributed along the roll at equal distances from each other. The dial gauges had a measuring accuracy of 1 micrometer.

After all dial gauges were set to zero, the testing procedure was started using pressure. The experimental setup is presented in Figure 1.

2. A METHOD FOR MEASURING DEFLECTIONS BY USING DIAL GAUGES

The schematic for this case is shown in Figure 2. Taking into consideration that the transversal section of the calender roll will not deform (will not become oval), we supposed that the deflection from the upper side of the generatrix of the roll is equal with the lower deflection.

$$\frac{L}{2} = R_c \cdot \sin\alpha; \tag{1}$$

$$\frac{L^2}{4} = R_c^2 \cdot \sin^2\alpha$$

$$R - f_0 = R_c \cdot \cos\alpha. \qquad (R - f_0)^2 = R_c^2 \cdot \cos^2\alpha \tag{2}$$

Adding Eqns. (1) and (2), we obtain:

$$\frac{L^2}{4}+(R_c-f_0)^2=R_c^2 \rightarrow R_c=\frac{L^2+4f_0^2}{8f_0} \tag{3}$$

where:

$f_0 = f_7$.

L – the length of the calender roll, in mm.

For a specific force F_c it resulted a deflection f, measured by the dial gauge C7, and in the same way for the other six deflections measured by the upper dial gauges C1, ... C6.

The correlation of the deflections was made as is presented in Figure 3.

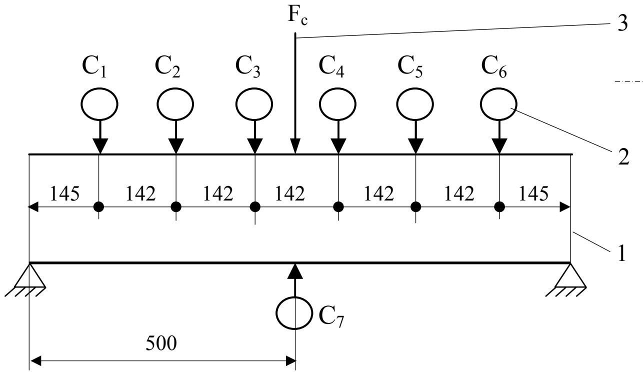

Fig. 1. *Experimental setup:*
1 – calender roll; 2 – dial gauge;
3 – concentrated force.

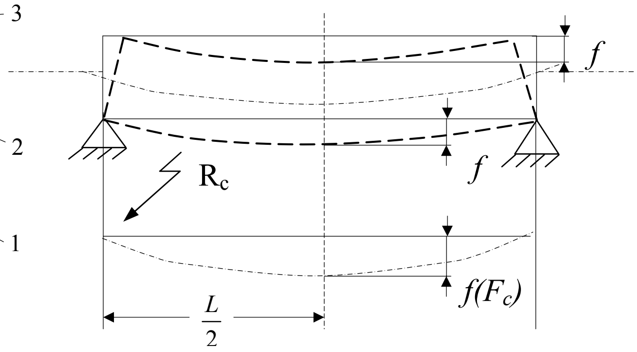

Fig. 2. *Schematic for measuring the deflections using dial gauges.*

$$\sin\theta_1=\frac{d}{R_c};\ \cos\theta_1=\sqrt{1-\frac{d^2}{R_c^2}};$$

$$\sin\theta_2=\frac{d}{R_c-f_0};\ \cos\theta_2=\sqrt{1-\frac{d^2}{(R_c-f_0)^2}}.$$

$$\theta=\theta_2-\theta_1 \tag{4}$$

We know that

$$\cos\theta=\cos(\theta_2-\theta_1)=\cos\theta_2\cos\theta_1+\sin\theta_2\sin\theta_1$$

and it results

$$\cos\theta=\sqrt{\left(1-\frac{d^2}{R_c^2}\right)\left(1-\frac{d^2}{(R_c-f_0)^2}\right)}+\frac{d^2}{R_c\cdot(R_c-f_0)} \tag{5}$$

If we apply the general form of Pythagoras' theorem in the ABC triangle, it results:

$$AB=\sqrt{OB^2+OA^2-2OB\cdot OA\cdot\cos\theta}$$

$$f_3 \approx f_4 = AB$$

$$f_3 = \sqrt{(R_c - f_0)^2 + R_c^2 - 2R_c \cdot (R_c - f_0) \cdot \cos\theta} \tag{6}$$

where cosθ is determined using Eqn. (5).

The other deflections are determined modifying the distance *d* with *2d*, *3d*, ... or with the distances measured from the dial gauge to the middle of the calender roll.

3. EXPERIMENTAL PROCEDURE

In these tests it was investigated mainly the rigidity of the calender rolls, their characteristic deflections under loads, uniformly distributed along the generatrix, and under a specific internal pressure, respectively. This situation is intended to cancel the deflection caused by the external load.

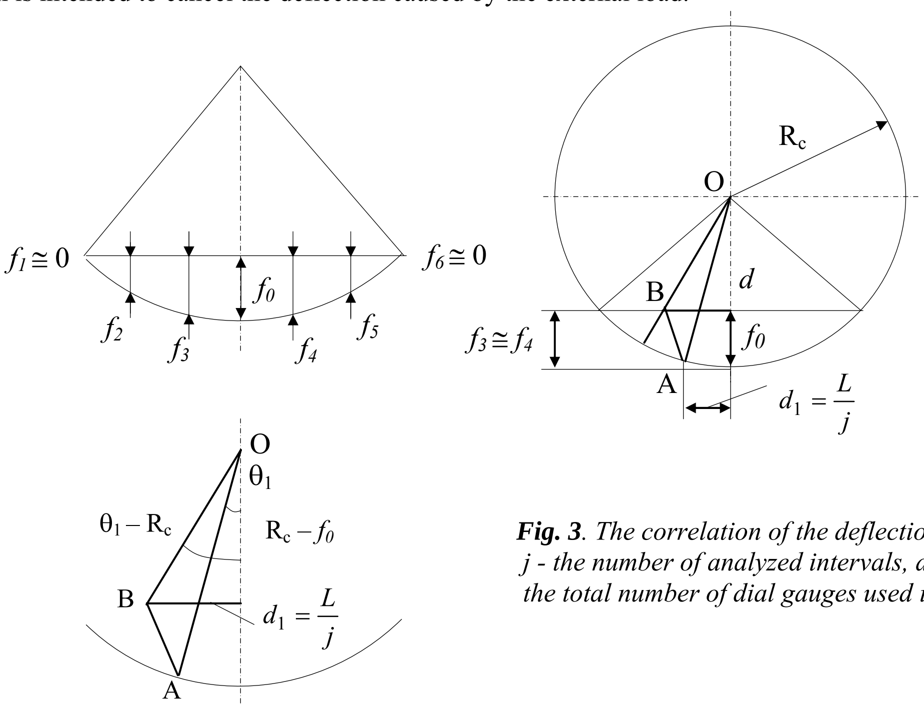

Fig. 3. *The correlation of the deflections; j - the number of analyzed intervals, dependent on the total number of dial gauges used in the system.*

It is very important to know if the calender roll will work properly in real working conditions. In practice, if the camber is manufactured in a wrong way, this leads to an accelerated process of compression of the paper web, a premature wear of some areas from the surface of the roll, concurrently, in an implicit mode, with the decrease of the medium pressure on the roll and the perturbation of the pressure uniformity on the surface. In the worst case, a penetration of the roll casing is possible to occur; in such situation, the calender roll will be seriously damaged and the paper machine will be stopped immediately.

When studying the behaviour of the calender rolls the main aspect is to determine with accuracy the configuration of the internal surface of the roll, which can assure an optimal camber. This is the reason, without any exceptions, for that all industrial roll producers are investigating various design models of rolls on special testing stands.

It is important to mention that this kind of research represents an absolute novelty in Romania and, except some data published in the scientific literature, there is no any other research done in this field.

The first step was to establish the configuration and the geometric characteristics of the rolls. Analyzing the available data we decided that, at this stage of the research, the goal is to test the calender roll under internal and external pressures and to see how the roll with predetermined shapes of the internal surfaces resists under extreme loads. In the same time, it was checked the evolution of the deflections and the deformations obtained on the external surface using dial gauges. We make a remark, without reference data it is almost impossible to make the equalization of a certain number of cycling tests, mainly because between the real working conditions and the testing conditions of the rolls are considerable differences of loading on some components.

The testing stand was built especially for the calender rolls used in paper machines, with a maximum length of 1000 mm and a maximum diameter of 750 mm. These parameters are required by the available testing rolls performances. The testing stand can be easily adapted to analyze, also, the behavior of the rolls used in rubber or plastic industry.

On the testing stand can be reproduced the critical working conditions of the rolls used in the burnishing calender (smoothing) of the paper used for newspapers on the Machine no. 11 at "Letea" S.A. Company, in Bacau. Thus, the rolls are working in the most unfavorable conditions of pressure and/or temperature, these conditions producing deformation of the components, premature wear and poor quality of the paper web.

For the first type of tests four rolls were installed on the testing stand. After that the testing program was started. At the end of the tests it was established which internal surface configuration behaved better to the testing conditions. For the second type of tests it was necessary to use, in the same time, the measuring technique of the roll deflections, deflections that should cancel the deflection produced by the roll load.

The testing equipment incorporated also several electronic devices used for data acquisition.

4. RESULTS AND DISCUSSION

For each model (rolls with internal cylindrical, ellipsoidal, double cylinder-truncated conical or double truncated conical surfaces) were obtained the results presented in Table 1 and in Figure 4.

Table 1.

Internal pressure 0.5 MPa

Cycle no.	Experiment no.	C1	C2	C3	C4	C5	C6	
I	1	0.025	0.05	0.08	0.1	0.1	0.015	
	2	0.02	0.055	0.085	0.08	0.09	0.02	
	3	0.017	0.07	0.1	0.15	0.1	0.03	
	4	0.015	0.035	0.075	0.08	0.1	0.05	
	5	0.017	0.04	0.065	0.135	0.1	0.05	
II	1	0.02	0.045	0.065	0.045	0.03	0.01	
	2	0.03	0.045	0.09	0.055	0.05	0.018	
	3	0.055	0.06	0.06	0.06	0.05	0.018	
	4	0.03	0.042	0.045	0.055	0.03	0.01	
	5	0.025	0.045	0.04	0.04	0.05	0.018	
III	1	0.025	0.045	0.044	0.045	0.03	0.01	
	2	0.03	0.042	0.048	0.055	0.05	0.018	
	3	0.025	0.06	0.06	0.065	0.05	0.018	
	4	0.035	0.065	0.065	0.07	0.05	0.018	
	5	0.035	0.065	0.065	0.07	0.05	0.018	
Medium value		0.02636	0.04993	0.06586	0.07393	0.06286	0.02164	0.0501

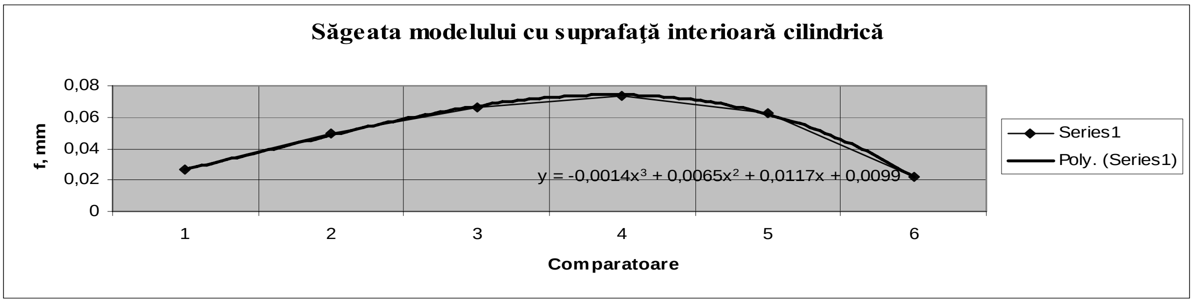

Fig. 4. The deflections of the roll with internal cylindrical surface under an internal pressure of 0.5 MPa.

At the end, we drew up tables and graphs with the variations of deflection for each value of the testing pressure and for each model. The results obtained in the case of the roll with internal cylindrical surface, for different internal pressures, are presented in Table 2.

Table 2.

Internal Pressure, MPa	C1	C2	C3	C4	C5	C6
0.5 Series 1	0.0266	0.05026	0.066	0.074	0.0633	0.02
1.0 Series 2	0.094	0.14015	0.27	0.28625	0.2177	0.1
2.5 Series 3	0.4678	0.674	0.897	0.9308	0.702	0.45
4.0 Series 4	0.699	1.0508	1.315	1.322	1.131	0.603
7.0 Series 5	0.7733	1.4601	1.7333	1.8505	1.612	0.7036

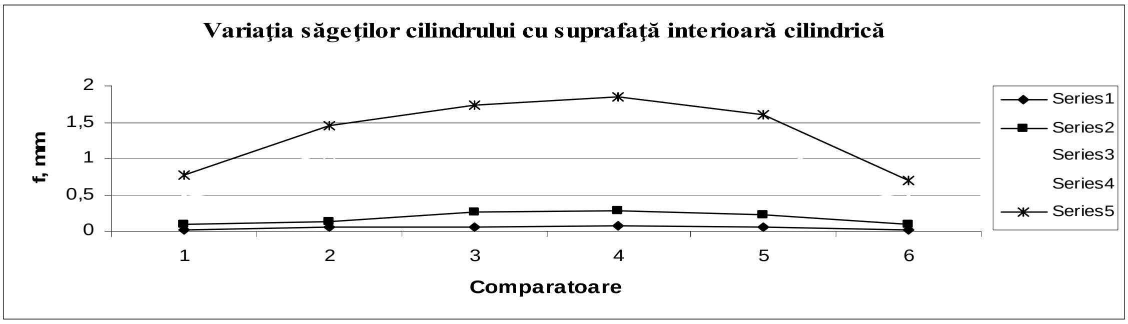

Fig. 5. The deflections of the roll with internal cylindrical surface under different internal pressures.

The results obtained for the same internal pressure for each tested model were recorded. In Table 3 and in Figure 6 are presented the results in the case of an internal pressure of 7.0 MPa.

Table 3.

Model	C1	C2	C3	C4	C5	C6
I – internal cylindrical surface	0.77333	1.46013	1.73333	1.85053	1.6122	0.70367
II – internal ellipsoidal surface	0.695	0.869	1.31375	1.335	0.8125	0.71125
III – internal double cylindro-truncated conical surface	0.69933	1.01027	1.25087	1.2482	1.1414	0.72287
IV – internal double truncated surface	0.69933	0.91936	1.13967	1.13187	0.98787	0.70393

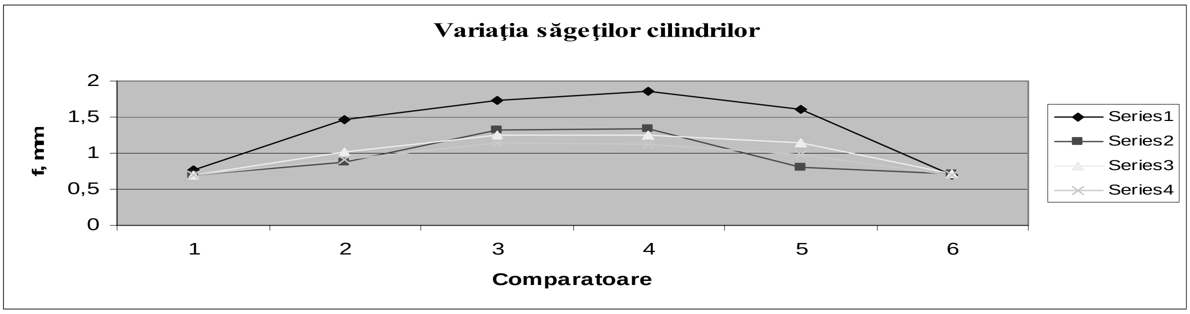

Fig. 6. The deflections of the rolls under an internal pressure of 7.0 MPa.

5. CONCLUSIONS

Analyzing the results we concluded that the roll with internal double truncated conical surface satisfy very well the testing conditions and for each internal pressure tested the deflection has the smallest maximum value.

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