THE COMPUTATION OF THE CALENDER ROLLS DEFLECTION USING THE STONE-GAEVSKI FORMULAE

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ABSTRACT

This paper presents new models for the change of the internal configuration of the paper calender rolls with extension to those for plastics and rubber, and the deflection calculation procedure using Stone-Gaevski formulae.

KEYWORDS: rolls deflection, stress, Stone-Gaevski formulae

1.New models suggested for the rolls deflection computation

1.1. Hypotheses used in the drawing up of the models

There have been conceived two computation models in which there are used plane elements for the stresses transmission, obtained by sectioning the rolls with longitudinal planes. There have been considered the following hypotheses:

- the load is constant, uniformly distributed along the calender rolls surface's for paper pressing (p_2 = 62 N/mm)
- the model undergoes a plane strain, due to the fact that the shearing strain of the plane element is actually impeded because of the rolls portions which have been removed and which have high stiffness
- the roll is supported at its ends; the length of the bearings and the bending moments due to the reactions with respect to the planes of the rolls ends are negligible
- the friction forces are negligible taking into account both their reduced values ant their influence on the other parameters. This hypothesis is confirmed by the experimental results
- the rolls dimensions are:
  - external cylindrical surface ∅ = 100 × 500 (mm × mm)
    - internal cylindrical surface ∅ = 40 × 50 (mm × mm)

1.2. The determination of the shape and dimensions of the computation models

The hypotheses used in conceiving new computation models of a calender roll elements stress lead to structures whose plane dimensions depend on the rolls geometry and on the paper tape width.

The roll under consideration has the following dimensions:

- external diameter D_2 = 100 mm
- minimum internal diameter D_1 = 50 mm
- total length L = 1 100 mm

For the following models we consider the possibility to obtain opposite rolls deflections by introducing a non aggressive work medium, under pressure, within the rolls

Further on we have in view to determine the deflections which appear in the calender rolls, when a uniformly distributed load, occurring during the rolling of the paper tape, acts upon them. In this respect, different internal shapes of the calender roll are considered.

Model I

We consider a calender roll whose internal surface has a cylindrical section along its entire length, (fig. 1).

The dimensions of model I are:

- external diameter D_2 = 100 mm;
- minimum internal diameter D_1 = 50 mm;
- total length L = 1000 mm;
- active length l = 500 mm.

Model II

A calender roll with an ellipsoidal internal section is considered. Fig. 2 shows the work diagram in the case.

The equation of the ellipsoid is:

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1 \qquad (1.1)$$

where a = b = R_1 stand for the ellipsoid small semi-diameters.

Because the calender rolls are thought to be thick-walled cylindrical bodies, they are characterized by the between the external and internal radius

$$\beta=\frac{R_2}{R_1}\geq 1{,}2 \Rightarrow R_1 \leq \frac{R_2}{\beta} \quad (1.2)$$

in which R_2 = 50 mm;

R_0 = radius necessary for the roll to operate, R_0 = 20 mm

c_1 = basic size, mm

$$c_1=\frac{L}{2}-h=\frac{1000}{2}-30=470\,\text{mm}.$$

$$R_1=\frac{R_2}{\beta}=\frac{50}{1{,}22}=41\,\text{mm}.$$

The ellipsoid equation in the roll longitudinal plane is:

$$\frac{y^2}{b^2}+\frac{z^2}{c^2}=1 \Rightarrow y=\pm a\cdot\sqrt{1-\frac{z^2}{c^2}} \quad (1.3)$$

Limiting conditions:

y = R_0 $\Rightarrow z=c_1$ (1.4)

Replacing we obtain:

$$c=\pm\frac{R_1c_1}{\sqrt{R_1^2-R_0^2}}$$

c = 538 mm (1.5)

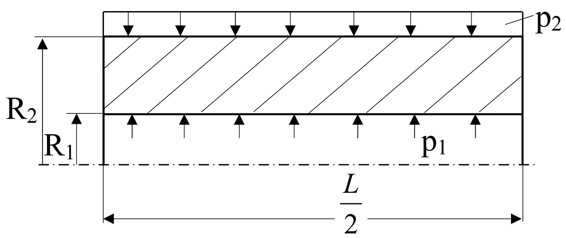

***Fig. 1.** Diagram of the constant internal section model shape roll*

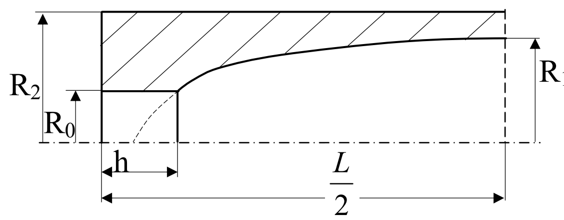

***Fig. 2.** Diagram of the ellipsoidal internal*

Model III

We consider the internal section in the shape of truncated cone, from the radius r, with current radius, to zero, on the length L.

Fig. 3. shows the diagram for the case under consideration.

The characteristic constructive dimensions are: =l = 500 mm;

$$\frac{r_i}{x}=\frac{r}{l}\Rightarrow r_i=\frac{r}{l}x$$

r = R = 20 mm, the external radius

R_2 = 50 mm.

Model IV

A calender roll with double truncated cone internal surface is considered. Fig. 4. shows the diagram for the roll under consideration.

The constructive dimensions of the model IV are:

- total length L= 1000 mm;
- computation length l = 500 mm.

distance from the center bearing median line to the paper tape margin, h = 30 mm

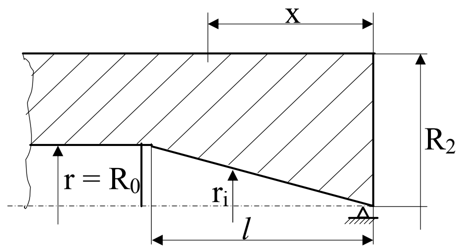

***Fig. 3.** The diagram of a calender roll with double cylindrical-truncated cone internal section*

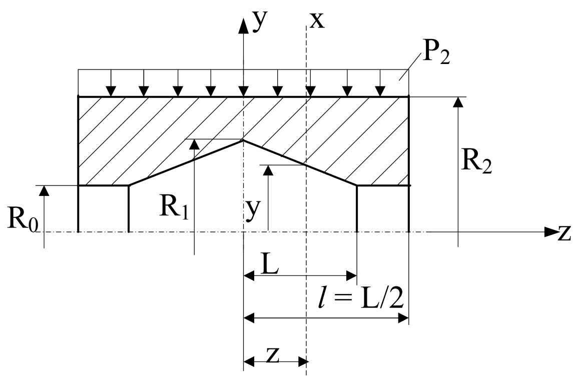

***Fig. 4.** The diagram of a calender roll with double truncated cone internal section*

2. Deflections computation

Stone's formula for calculating the maximum deflection of a roll is:

$$f_{\max} = \frac{5p_2L^4}{384EI_z} \cdot \left[1 + \frac{24}{5} \cdot \frac{h}{L} + 2 \cdot \left(\frac{D_2}{L} \right)^2 \right] \tag{2.1}$$

where:

p_2 – the external rolling pressure, N/mm
E – Young's modulus of the roll material
I_z – moment of inertia of the cylinder casing
D_2 – external diameter of the cylinder casing, mm
h – distance from the center bearing median line to the paper tape margin, mm

The first term in the square brackets introduces the bending produced by the uniformly distributed load, the second is due to the center bearing deflection, and the third stands for the curvature produced by the shearing forces. The magnitude of this last term is generally 5 %, but it can increase to 10 %.

Gaevski's formula for calculating the rolls total deflection is:

$$f_{\max} = \frac{5p_2L^4}{384EI_z} \cdot \left\{ \left[1 + \frac{24}{5} \cdot \frac{h}{L} + 2 \cdot \left(\frac{D_2}{L} \right)^2 \right] \right\} - \left\{ 8 \cdot \left[\frac{3}{5} + \frac{12}{5}\frac{h}{L} + \left(\frac{2R_2}{L} \right)^2 \right] \right\} \tag{2.2}$$

After doing the substations in the formulae (2.1) and (2.2) table 1 is drawn up for each case, and the deflections variation for the rolls under consideration is shown in Fig 5.

Table 1

Lenght L,mm	0	10	50	100	150	200	250	300	350	370	390	400	430	450	500
Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
I.a - Series I	1,278	1,275	1,264	1,219	1,145	1,044	0,918	0,768	0,597	0,52	0,448	0,41	0,291	0,118	0,01
I.b - Series 2	2,19	2,189	2,165	2,088	1,962	1,789	1,572	1,315	1,023	0,9	0,768	0,702	0,498	0,315	0,112
II - Series 3	1,44	1,439	1,423	1,373	1,29	1,176	1,034	0,865	0,673	0,59	0,505	0,461	0,327	0,215	0,111
III - Series 4	1,398	1,398	1,382	1,333	1,253	1,142	1,004	0,84	0,653	0,57	0,49	0,448	0,318	0,252	0,05
IV - Series 5	1,3	1,299	1,284	1,239	1,164	1,062	0,933	0,78	0,607	0,53	0,456	0,416	0,295	0,11	0,001

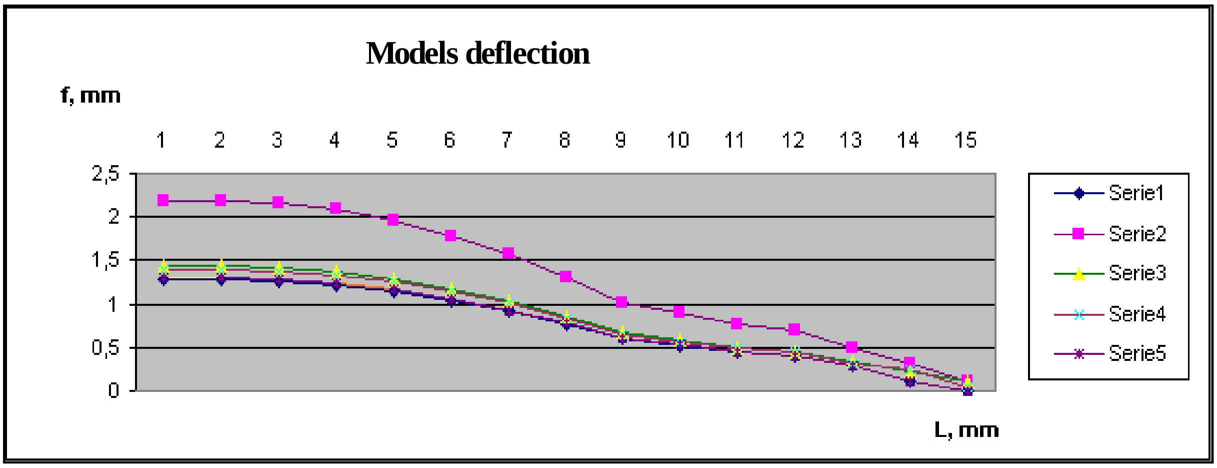

Fig. 5. *The variation chart of the calculating models*

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