

THE RIGIDITY OF THE CALENDER WITH TWENTY CYLINDERS

DANIELA FLORESCU, IULIAN FLORESCU

University of Bacău, Romania

Abstract: The rigidity of the cage is one of the main criteria, which defines the quality. In fact, it decides in what way the variations of the technological conditions can affect the product. The rigidity of the cage is defined by the relations between the changes made in the force of laminate and the elastic distortions that correspond to the cage.

Keywords: calendar, calendar's rigidity,

1. INTRODUCTION

To give a more precise interpretation we have introduced the concepts: absolute/total rigidity and relative rigidity. The former indicates the average between the no/void point and the working point of the elasticity curve of the cage (K_A), the latter indicates the average value of the rigidity close to the working point (K_R).

The calculation of the laminate rigidity has to take into account the flexibility of its constitutive elements that are being distorted during the exchange; what the cage gives away equals the sum of the elastic distortions of the constitutive elements.

The theoretical calculation of the elastic distortions was confined, under such circumstances, to the computers depending on programs taking into account the flattening and the crush of the cylinders, the elastic distortions of the support axes and their landings, those of the ascent and finally the yielding and the global rigidity. The following paragraphs offer a summary description of these kinds of programs; figure 1 shows the calculation of rigidity.

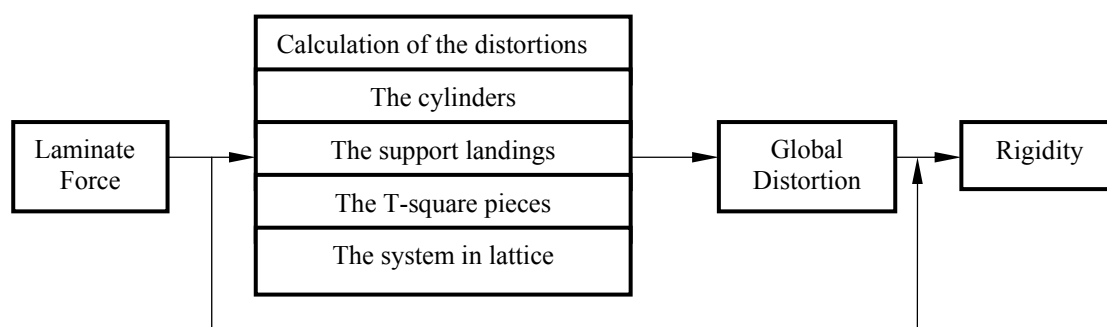


Figure 1. The rigidity calculation scheme

2. THE CALCULATION OF THE INFLICTED DISTORTIONS UPON THE CYLINDERS

The flattening and the crush of the cylinders exert an important influence upon the yielding of the cage [1] and [2], and consequently, for the global rigidity of the cage with twenty cylinders was used Föpple formula defining the approach of the two cylinders pushed one against the other:

$$\Delta w = \frac{2(1-\nu^2)}{\pi E} \cdot p \left[\frac{2}{3} + l_n \frac{\pi}{4} \cdot \frac{E(D_1 + D_2)}{4(1-\nu^2)p} \right] \quad (1)$$

with:

$$p = \frac{F_i}{4}$$

F_i - component of the force of the laminate, (kN);

E - Module of elasticity in traction;

D_1 - diameter of the cylinder;

ν - Poisson constant;

l - Length of the contact between the cylinders (mm).

Figure 2 shows the organization and indicates the numbering of the cylinders in the pyramid, but also the decomposing of the force of the laminate. It emphasizes upon the fact that we had to study seven distortions all in all when entering in contact with the cylinders. The advanced formula does not allow however to calculate the contact between the intermediary cylinders 3 and 6 and the landings of the support axes, because in the case of the latter it does not refer to full cylinder and the elasticity problem of the cylinders 3 and 6 in contact with the support landings is reduced to the calculation of the elasticity pushed against a plane.

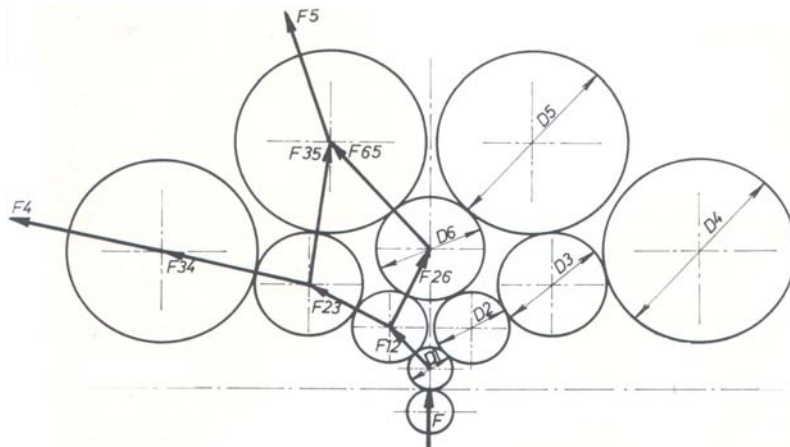


Figure 2. The decomposing of the forces in the pyramid of the cylinders

According to [3] we have:

$$\Delta w = \frac{(1-\nu^2)}{\pi E} \cdot p \left[\frac{2}{3} + l_n \frac{\pi}{4} \cdot \frac{ED}{(1-\nu^2)p} \right] \quad (2)$$

3. THE CALCULATION OF THE ELASTIC DISTORTION OF THE SUPPORT AXIS AND ITS LANDINGS

The elastic distortion of the landing decomposes in that of the bearings and that of the exterior ring. The distribution of the charges between the cylindrical coils of the landing was submitted to as number of theoretical

and experimental studies [2], based on a hypothesis according to which the exterior and interior rings of the landing are rigid in flexion. If, however, the landing is used as a support pebble, there is no supporting effect of the landing's alesage for the exterior ring and we have thus to admit that it suffers an elastic distortion.

For an elastic exterior ring, the calculation of the distortion of the bearing is more complicated. Indeed, the bearings undergo a supplementary distortion because of that of the exterior ring and therefore it is necessary to calculate the distortion of the landing taking into account the forces exerted by the bearings. The calculation of the distortions of the exterior ring – such as the three-time hyper static system –made use of the iterative method [2].

For the calculation of the landing, it is used a program which explores the distortion and the functioning solicitations of the rigidity in flexion of the exterior ring, of the interior rolling movement, of the number of cylindrical coils and of the number of their lines.

The results of these calculations were applied to the calculation of the distortions of the support axis. The distortion of the support axis guidance was based on the distortion of the T-square piece. For symmetry reasons, the calculation was based on a half of the T-square piece, filled with 49 elements. The reaction of the landings of the support axis was used as charge; this reaction was calculated as a hyper static beam resting upon seven supports.

4. THE CALCULATION OF THE ELASTIC DISTORTION OF THE FRAME

The frame of the cage with twenty cylinders was considered as a perfectly symmetrical body. The system – a three-dimensional type in lattice was thus suggested for 1/8 of the frame body. Figure 3 is showing that is made of 72 bars and 43 knots.

The bars 6 – 8 –10 –12 –14 and 26 –28 –30 –32 –34 were situated in the planes of results F_4 and F_5 of the decomposition of the forces in the cylinders' pyramid (figure 3).

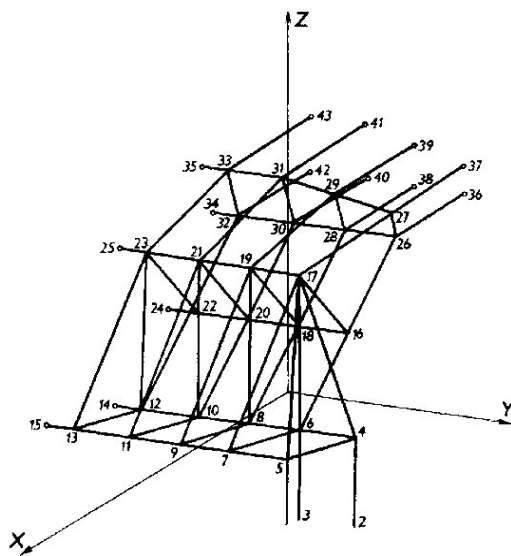


Figure 3. The three-dimensional system in lattice used in simulation

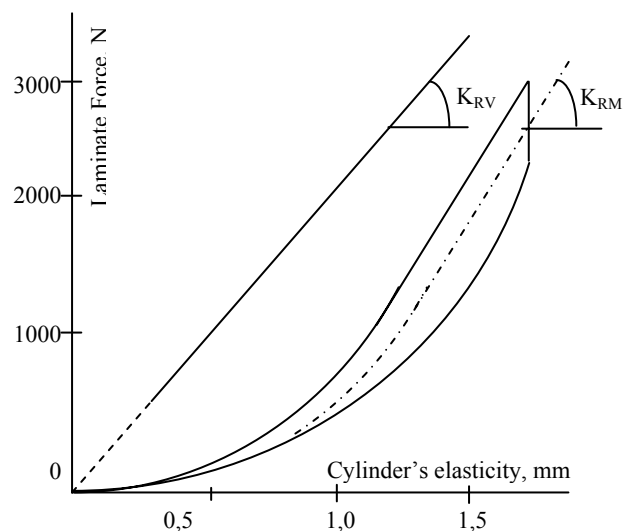


Figure 4. The elasticity curve

We have already mentioned that the support axis was calculated as a hyper static beam resting upon seven supports and suffering, in the interior, permanent and continuous charges.

The reactions, thus defined, were taken, for calculating the frame, as charges asking for a three-dimensional system in lattice.

The comparison of calculation results with the measures on the model allowed saying in what way the three-dimensional system in lattice succeeded in replacing effectively the frame of the cage.

The calculation is not however capable of interpreting the concentration of efforts made around the metal entrance. Briefly, the calculation by means of the system in lattice has produced satisfactory results.

5. THE CALCULATION OF THE TOTAL DISTORTION AND OF THE LAMINATE RIGIDITY

The calculations according to the described programs reached some results used in the next stage as database of the program that was elaborated for vectorial addition of the distortions and for the calculation of the absolute rigidity of the cage. The scheme for the respective calculations is represented in figure 1.

The iterative calculation of the laminate force successively modified because of 500 kN allowed to establish the values of the global distortion and of the rigidity. The result of the cage is in figure 4. For the laminate forces between 3000 and 3500 kN we have obtained $K_{AV}=2459\text{kN/mm}$ and $K_{RV}=2631\text{kN/mm}$ whereas for the interval from 2000 up to 2400kN we have $K_{RV}=2640\text{kN/mm}$. The first values represent the limits of the calculated rigidities; the others correspond to the charges of the cage during the second pass and they are compared further on with the results of the measurements.

The program of the global distortions calculation has allowed to establish, by means of the iteration together with the successive introduction of the partial distortions of the entrance, also the contributions of the laminate sub-ensembles to the total of the elastic distortions. The flattening of the cylinders and the elastic distortions of the landings represent 60%, the elasticity of the frame 31% and that of the landings guiding the support axes 35 of the sum.

The contribution of the frame is generally indicated by a value inferior to that of the described calculation; thus, the study [3] claims that the difference is due to the unequal evaluations of the role that the frame plays in the laminate global distortions.

Anyway, the frame distortions revealed by the calculation are clearly inferior to those of the cylinders pyramid. The frame is distorted vertically, according to the calculation made for example for the laminate force of 2000 kN, by 0.853 mm. This means that the vertical distortion of the frame represents almost only 1% of the global distortion.

Even if the frame suffers only slight distortions, its role in the sum of distortions is far more obvious under the influence of the vectorial composition of the partial distortions. Consequently, the pyramid of cylinders “expands” under the effect of the frame distortion that, although small, underlines a relatively important course of the working cylinders. It is this that makes the difference, a twenty cylinder differs from a duo or a quarto that does not suffer from „multiplication” inflicted upon the frame.

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