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PROBLEMS SPECIFIC TO MATERIALS OF CAGES USED FOR BEARINGS FROM AERONAUTICS INDUSTRY

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Abstract: *The reliability and durability are two of the most important quality characteristics of the bearings. Another important role in the proper running of the bearing belongs to the cage, more specific to the materials used to fabricate it. Generally, to make the cages of high speed bearings are used plastic materials based on phenolic resins delivered as tubes.*
Keywords: *cages of bearings, stratitex tubes (textolite), phenol formaldehyde resin.*

1. INTRODUCTION

The materials used for textolite (stratitex) cages require some features: -when closing the mold, burrs are not allowed to remain, as they would have consequences in the process of treatability, -the textile layers of insertion must be equidistant and uniform, -the technological treatability must be as good as possible, to allow continuous splinters (not powdery splinters), -the digression from circularity must belong to a lower field of tolerance, -the dimensional variation must be as low as possible in time.

2. THEORETICAL AND EXPERIMENTAL ASPECTS

The products studied experimentally are fabricated from phenol formaldehyde resin with textile canvas insertion, both those of stratitex type and also the products of two foreign companies. After tests, the mechanical and pysico-chemical characteristics of the products have been found out.

2.1. The compression test- mainly, the problem is that of creating a homogeneous tension in samples. The test is executed applying an increasing axial force to some cylindrical samples of 25±0,3(mm) length, with the sides at 90º towards the axis, with an interior and exterior diameter of 0,01(mm) precision; also, the variations of the samples' length have been measured, the test being carried on until the breakdown of the sample. (Fig. 1)

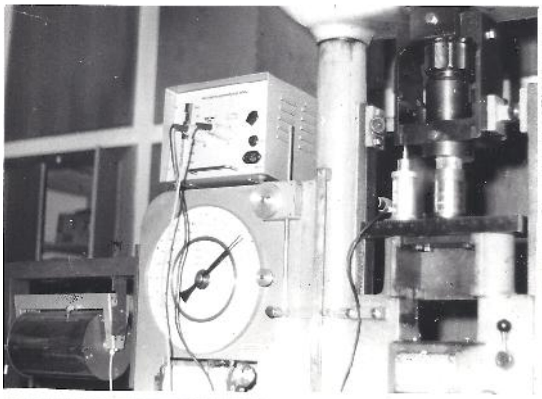


Figure 1

2.2. The bending test- a simple strain diagram is chosen (Fig.1), a cylindrical sample of 5 (mm) thickness, with parallel sides at 90º towards the axis, inserted in an adapted traction yoke. The test is fixed between the pressure plates of the testing equipment

and loads with constant speed are applied, the load being measured with precision of 1N on the tested sample.
The evaluation of the maximum bending moment requires the increase of indetermination (a quarter of a ring is isolated and the sectional pressures are applied at the ends). The determination of the normal tensions σ from the dangerous section (2) is made by applying Winkler's relation:

$$\sigma = \frac{M_i}{A \cdot e} \cdot \frac{y_i}{R_i} \qquad (1)$$

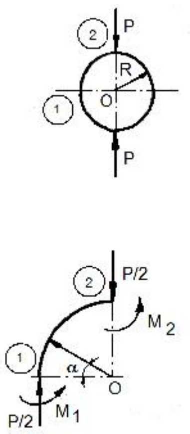


Figure 2

The bending strength σ_i(MPa) is given by the relation (2):

$$\sigma_i = \frac{3P(D+d)^2}{\pi L d (D-d)^2} \qquad (2)$$

where P represents the load applied on a broken sample in (N), D represents the exterior diameter of the sample in (mm), d- the interior diameter of the sample in (mm), L-the thickness of the sample in (mm).

2.3. The test for determining the hardness using Brinell method- through impregnation with a P force of a steel ball with the prescribed diameter D, perpendicular on the surface of the tested piece, where:
S = the surface of the spherical cap:

$$S = \pi D \frac{D - \sqrt{D^2 - d^2}}{2} \qquad (3)$$

$$HB = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)} \qquad (4)$$

The values of the Brinell hardness obtained with ball penetrators of different diameters or with different loads are not compatible among them. The comparison is possible only if the geometrical similitude of the traces produced is respected.

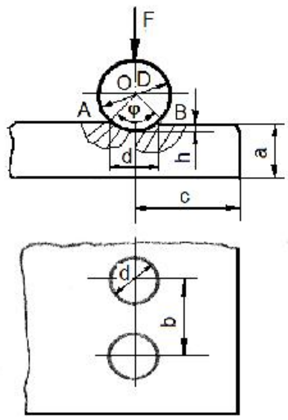


Figure 3

From Fig. 3 can be observed that the similitude is satisfied if the angle φ is identical at the hardness traces applied to the material. Thus, the HB hardness becomes:

$$HB = \frac{2P}{D^2\left(1 - \sqrt{1 - \sin^2 \frac{\varphi}{2}}\right)} \qquad (5)$$

Respecting the similitude condition (φ=ct.) results, in order to obtain the constant hardness, the condition that the relation P/D^2 is constant, where $k=P/D^2$ is named strain degree and is chosen when determining the hardness depending on the material nature and the thickness of the test. The minimum thickness must be 8 times the depth of the trace, in order to avoid the influence of the support on the test. The applied speed of the load is 0,8-1(mm/s).
2.4. The materials' density- is determined through the pionometer method through water immersion at 20ºC temperature.
2.5. The content of volatile substances-to determine the humidity of the tests, cylindrical samples have been used, which, after weighing, with a precision of 0,01(g), have been introduced into the drying oven at a temperature of 105ºC and 130ºC, according to standardized temperatures. In two hours time, they are cooled in dessicator and are weighed with precision. The determination is repeated until the final mass of the sample is constant at two repeated weighing. The humidity is calculated:

$$U = \frac{M_i - M_f}{M_f} \cdot 100\% \quad (6)$$

where M_i is the initial mass of the test, in (g), and M_f is the final mass of the test in (g).
At 105ºC temperature, the tests have not reached the constant mass, not even after 30 hours of staying in the drying oven. For this reason, the conditioning temperature has been increased up to 130ºC, the limit value of using the cages for bearings. The determination has been made after two hours of thermostatic conditions. Rings of 5-20 (mm) width and different diameters have been used for experiments.
2.6. The acetone strength-the determination has been executed on three samples cut perpendicularly on the axis of the tube, with the length of 50±1(mm). The sample is weighed with a precision of 0.001(g), is immersed into a glass containing acetone, the glass is covered and maintained for two hours at a temperature of 20±2ºC. After the conditioning time is over, the sample is taken out of acetone and is set on a watch glass for about 15-20(min) until the evaporation of the acetone. The gravimetric variation after conditioning is given by the relation:

$$G = \frac{G_f - G_i}{G_i} \cdot 100\% \quad (7)$$

where G_i is the initial weight of the sample in (g), and G_f is the final weight of the sample in (g).
2.7. The contraction in paraffin oil- the determination is executed on samples cut perpendicularly on the axis of the tube, with a 50±1(mm) length. The exterior diameter of the sample is measured, with a precision of 0.01 (mm) and is immersed in a glass containing paraffin oil at a temperature of 120±2ºC. The glass with the sample is introduced into the drying oven at a temperature of 120±2ºC, for five hours. After cooling, the exterior diameter is measured in the same points of the initial measurement. The contraction after conditioning in paraffin oil is given by the relation:

$$D = \frac{D_i - D_f}{D_f} \cdot 100\% \quad (8)$$

where D_i is the initial diameter in (mm), and D_f –the final diameter in (mm).

Table 1: The physical, chemical and mechanical characteristics of the studied materials

The characteristic	Stratitex CS 50-87	S Experimental values	Japanese - J	R.F.G	Duramid	Wood polymer
Density at 20 °C ·g/cm^3	-	1,2490	1,3749	-	1,886	-
The content of volatile substance, %		ϕ35 ϕ45 ϕ115	ϕ 45			
30 h at 105°C	-	4,95 2,82 2,93	3,77	-	0,614	-
2h at 130°C	-	0,36 0,24 0,34	0,40	-	0,036	-
Total 105; 130°C	-	5,31 3,06 3,27	4,17	-	0,65	-
The strength at acetone, ΔG %		ϕ 35 ϕ112				
After 1 h drying	- 0,3	-0,03 + 0,06	+ 0,0764	+ 0,182	-	-
After 72 h drying	-	-0,38 +0,01	-0,1280	+ 0,369	-	-
The contraction in paraffin oil, Δϕ ext., %	-0,15	-0,2 - 0,4	-	-	-	-
The bending strength, MPa	≥ 80	67,8 81,4 83,5 86,2	177,5 184,9	162,0 218,3 197, 211,3	Very large Elastic deformation	152,3 spruce 122,2 lime
The compression strength, daN/mm^2	≥ 8 ≥ 7	12,80 12,60	18,92 18,11	16,67 15,92 16,56 15,70	- - - -	- - - -
The elasticity modulus, E, MPa	-	$1,3 \cdot 10^4$	$2,68 \cdot 10^4$	$1,56 \cdot 10^4$ radial $2,94 \cdot 10^4$	$3,59 \cdot 10^4$	-

				axial		
Brinell hardness, daN/mm^2	-	13,0 – 20,0	8,48	17,9 – 18,9	14,40 – elastic probe	-

In Tab. 1 are presented the values obtained experimentally for the dimensions measured and processed.

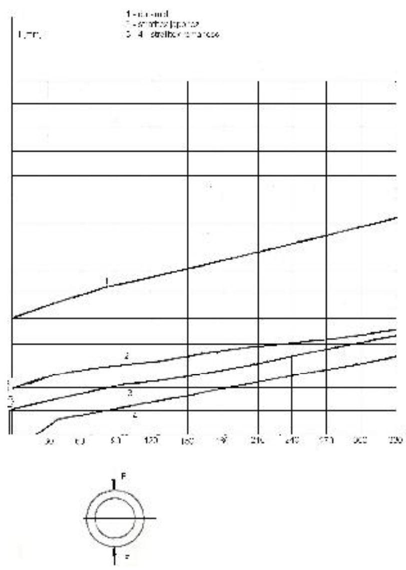


Figure 4

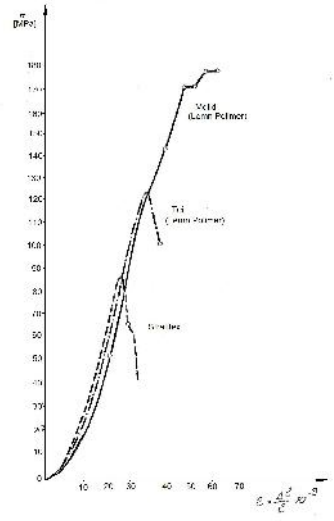
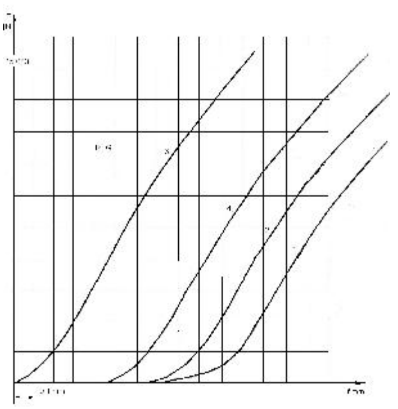
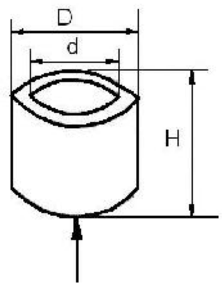


Figure 5





Compression test
Whitespirt p_{1rup} = 15500 N
Hydraulic oil p_{2rup} = 14800 N
Oil p_{3rup} = 15400 N
Acetone p_{4rup} = 14600
D = 45 mm; d = 29 mm; H = 25 mm

Figure 6

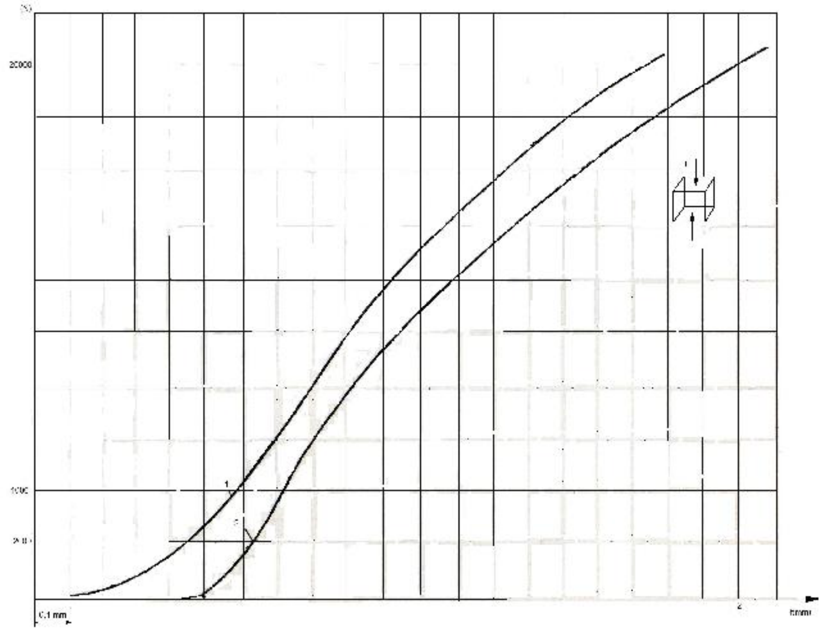


Figure 7

1. Romanian stratitex: $A_s = 1{,}31\ cm^2$, H = 10,7 mm, F = 20000, $\sigma = 15{,}2625$ MPa
2. Japanese stratitex: $A_s = 0{,}955\ cm^2$, H = 15,52 mm, F = 2000, $\sigma = 20{,}944$ MPa.

The curves obtained experimentally at mechanical tests are presented in Figure 4 – Figure 7.

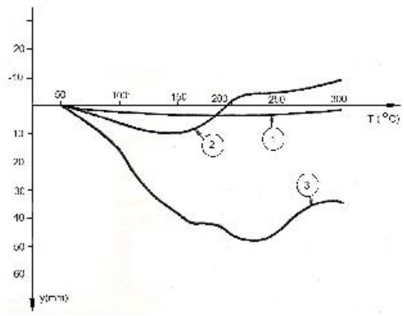
Figure 8

Figure 9

The fractographies obtained at electronic microscope for the stratitex tests and Japanese textolite are presented in Figure 8 and Figure 9.

Table 2: Coefficients of medium dilatation at various temperatures

Temperature domain, °C	The dilatation coefficients, α		
	Japanese product	Stratitex	Stratitex
20 - 100	$6{,}25 \cdot 10^{-6}$	$8{,}50 \cdot 10^{-6}$	$14{,}40 \cdot 10^{-6}$
20 – 150	$6{,}61 \cdot 10^{-6}$	$8{,}61 \cdot 10^{-6}$	$18{,}60 \cdot 10^{-6}$
20 – 200	$6{,}27 \cdot 10^{-6}$	$5{,}39 \cdot 10^{-6}$	$17{,}20 \cdot 10^{-6}$
20 - 250	$6{,}21 \cdot 10^{-6}$	$5{,}78 \cdot 10^{-6}$	$14{,}10 \cdot 10^{-6}$
20 - 300	$6{,}50 \cdot 10^{-6}$	$4{,}86 \cdot 10^{-6}$	$11{,}50 \cdot 10^{-6}$



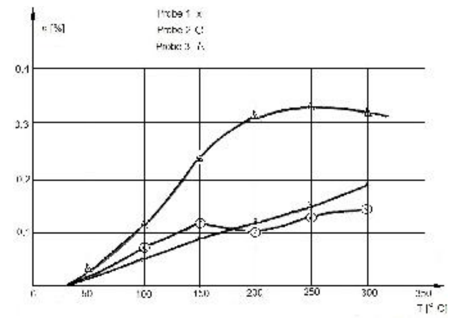


Figure 10 **Figure 11**

The experimental dilatometrical curves are presented in Fig. 9 and Fig. 10, and in Tab. 2 are presented the values of the dilatation coefficients for the tests used at various temperatures.

3. CONCLUSIONS

The tests allow us to draw the following conclusions:

- It is noticed that the stratitex product is not stable, taking into consideration the chemical composition, because it presents a relatively high content of volatile substances between 3-5,3%, without reaching the constant mass during determination process. Similarly, the acetone strength and the contraction in paraffin oil exceed the standardized values (Table 1), also the values for the imported products.
- Mechanical strength for conditioning tubes in whitespirt (1), hydraulic oil (2), consistant grease (3) and acetone (4), according the values from Table 1 are about 2.5 times lower at stratitex as opposed to imported products. Compared to the standardized values, the compression strength is adequate, and the bending strength is lower than necessary for the conditioned products in whitespirt
- The elasticity of the stratitex product is about two times lower than that of the imported products
- The hardness of the stratitex tubes is higher than that of the Japanese and comparable with that of the German product
- The dilatation coefficients at temperatures of 20-150ºC are higher with about 30-200% at stratitex as opposed to the Japanese product. To be noticed that in the case of the Japanese product, the dilatation coefficients are maintained constant in a high temperature range (20-300ºC), while in the case of the stratitex, at temperatures from 200 to 300ºC, the dilatation coefficients decrease with about 40% (Table 2).

As consequence, the following must be imposed: the necessity of establishing experimentally the parameters of the pressure regime, of the characteristics proper to the syphon used, of the influence of impregnation degree with phenolic resin of the canvas on the proprieties of the stratified product. To sum up, the stratitex product does not correspond entirely to the conditions provided by the standards, and compared to the imported products presents lower mechanical and physic-chemical proprieties (on the one hand, differences are due to the nature of the materials used to fabricate stratitex tubes, phenol formaldehyde resin and the fabric made from 70% cotton and 30% substitutes, and, on the other hand, due to the fabrication technology)

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