EXPERIMENTAL STUDY ON LOADING - UNLOADING RUBBER SPHERES DEFORMATION

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Abstract: *The paper presents an experimental study regarding loading-unloading contact deformations between rubber spheres. The experimental test rig and the testing methodology were described. Three cases were investigated: spheres compressed between hemispherical supports, spheres compressed between flat supports and spheres compressed between a hemispherical support and a flat one. The results reveal that the loading is done according to similar curves, for similar experiments but with different deformations, while the discharge takes place on different deformation curves.*

Keywords: *friction, rubber, deformation.*

I. Introduction

In mechanics, more and more non-metallic materials from the category of natural and synthetic rubbers are used due to their special properties, respectively:

- high elasticity and deformability, being able to elongate exceeding the ratio from single to double;
- property stability;
- chemical stability and lack of reactivity with common environmental factors (atmospheric humidity, pollution, etc.) but also with many otherworking substances, such as hydraulic and tribological oils.

In addition to these properties, these materials have both a nonlinear mechanical characteristic (there is no direct proportionality between force and deformation), as well as the hysteresis property. The presence of the hysteresis phenomenon is due to the internal chemical structure, the linear but contorted shape of the molecules, which, during the deformation under the effect of stress undergoes a process of friction with neighboring molecules different at loading and unloading.

Many rubber parts have curved surfaces and are subjected to stresses through concentrated contacts which in the absence of load are reduced to a point or a line. The study of these pieces is not yet fully clarified precisely due to the particularities mentioned above, namely the nonlinear elastic behavior of the material and the presence of hysteresis. For this purpose, the present paper aims at an experimental study of the contact between rubber spheres, at loading and unloading, in order to highlight the force / deformation correlation as well as the presence and magnitude of the hysteresis phenomenon. Similar studies have been presented by: *1*. Johnson K.L. [85], *2*. Tatara Y., *3*. [93], Diaconescu E. [03] [09], *4*. Adams M.J. et al., [04]; *5*.Tung, K.L. [04].

II. Test rig

For the purpose of the compression experiments of the rubber spheres, a test rig shown in figure 1 was designed.

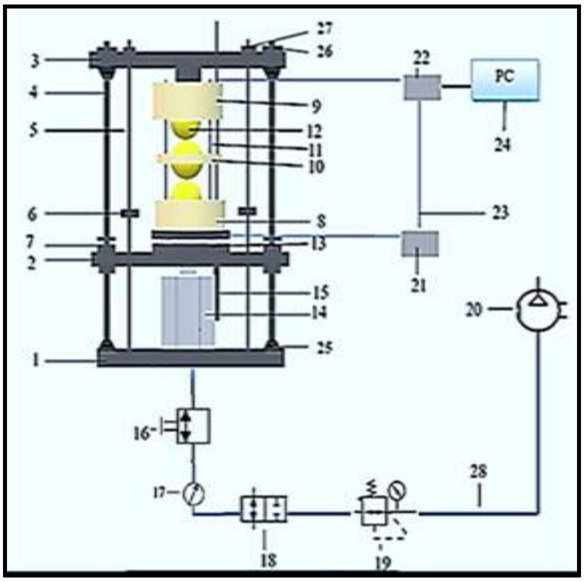

Figure 1. *Experimental stand for the study of compressive deformations of rubber spheres.*

This test rig consists of a frame of two rigid plates, lower and upper 1 and 3 interconnected by two parallel columns 4, on which slides a third plate 2.

Figure 2. *Ball support and guidance device.*

Between the upper plate and the sliding plate is mounted the set of test balls, which, in order to be positioned with the centers in the same normal direction at the parallel surfaces of the plates are mounted in a special device (figure 2), whose mode of operation is somewhat similar to the stand, in the sense that each sphere is held in the correct position by means of a mechanical element, all the elements of the assembly being positioned relatively by means of mini-columns 5.

The test rig is operated by means of a pneumatic cylinder 14, from a source of pressurized air 20. This solution was chosen to allow loading at very low speed, correlated with the air flow allowed into the cylinder. The discharge of the system is done by releasing air from the cylinder, the spheres (12) pushing the plates by the elastic force generated by deformation, as well as by gravitational forces.

The frictional forces between the columns and the sliding plate are neglected because these bushings are ball linear bushings, so with very low value friction, being rolling friction.

The measuring system attached to the test rig consists of a displacement transducer (15), which measures the change in distance between the movable plate (2) and the upper plate (3), from which the deformation of the spheres can be determined.

Under the system for maintaining the relative axial position of the spheres, a force transducer (13) is placed on the movable plate (2), which initially measures the weight of the whole system for maintaining the relative axial position of the spheres with the spheres and, during the experiment, to this weight is added the axial force applied to the system.

These parameters are transmitted to a data acquisition system (22), connected to a computer (24) which allows the storage and processing of the acquired data.

III. Experiment

The experiment involves the following steps:

1. With the pneumatic cylinder in the unloaded state and the piston in the lower position, the axial force transducer (13) is placed above the movable plate.

2. The spher support and relative positioning device shall be located on the force transducer. This device has two constructive variants for supporting the positioning of the lower and upper spheres respectively:

- with the positioning of the ball in a hemispherical cavity modeled from modeling plaster, so that it has exactly the shape of the sphere and is molded on it, and

-cylindrical shape with flat bottom, with the diameter of the cylindrical portion equal to the diameter of the sphere. In this case a concentrated contact of the sphere-plane type is formed at the bottom of the cavity which, due to the differences in mechanical properties between the rubber and the support material (polypropylene), can be assimilated with a contact between a sphere and a rigid plane.

The support and positioning device also allows testing with two or three spheres, in which case the third intermediate sphere is positioned by means of an additional ring made of the same material as the support supports of the bodies, with cylindrical bore of sphere diameter. , guided on the two guide bars. Possible variants of the guide device with mounted spheres that can be used for tests are shown in Figures 3,4, 5,6,7 and 8.

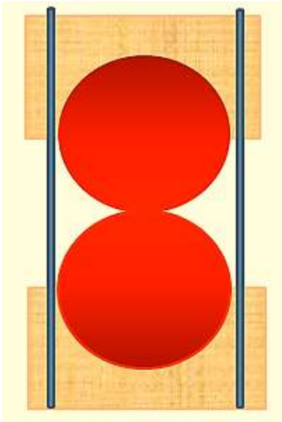

Figure 3. *Supporting and positioning device with two spheres supported in hemispherical supports.*

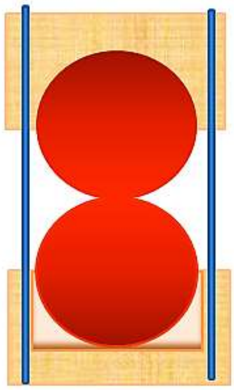

Figure 4. Supporting and positioning device with two spheres supported in a flat-bottomed support and a hemispherical support.

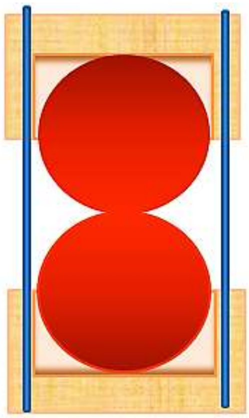

Figure 5. Supporting and positioning device with two spheres supported in flat bottom supports.

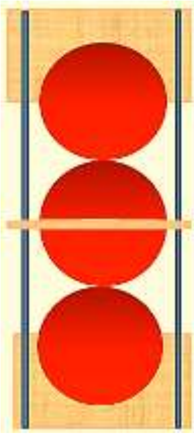

Figure 6. *Supporting and guiding device with two spheres and intermediate ball supported in hemispherical supports.*

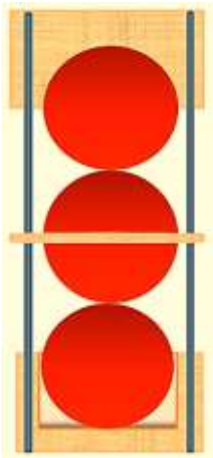

Figure 7. *Supporting and positioning device with two spheres and intermediate ball supported in a flat bottom support and a hemispherical support*.

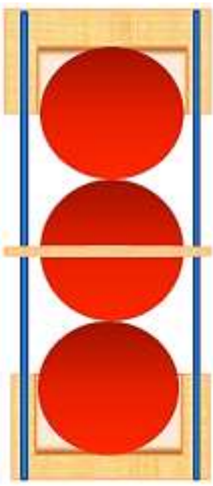

Figure 8. *Supporting and positioning device with two spheres and intermediate ball supported in flat bottom supports.*

In the case of placing the spheres in supports with hemispherical cavities, it is considered that due to the lack of play, large contact surface and rigidity of the support material, a low value pressure results during stress and consequently because the area is very large the deformation can be neglected.

3. Set transducers 13 and 15 to zero and connect the data acquisition system.

4. Start loading by opening the air intake valve in the very low speed cylinder.

5. When the degree of deformation has reached the desired value, the air intake is stopped and the exhaust valve is opened for such a slow evacuation, which can be assimilated with a quasi-static load.

Note: When placing the spherical support and relative positioning device on the force transducer between the device and the top plate there must be some distance otherwise it would not be possible to mount it.

At the beginning of the air supply, the piston moves, moving the movable plate that carries the system of holding and positioning the spheres, until it makes contact with the upper plate. Throughout this transport period, the force transducer records a constant value equal to the weight of the spheres cumulated with the weight of the positioning system. Subtracting this value from all the values recorded from the moment when the deformation of the spheres begins, the effective force applied to the set of spheres is obtained. Because the friction on the columns of the positioning and guidance system is much lower than the workforce is neglected.

IV. Experimental results

For a clearer representation of the experimental results, a system for symbolizing the experiments was established, which would show:

- the maximum deformation value;

- the type of sphere-support contacts;
- the number of spheres tested simultaneously;

Notations:

- **F** - deforming force [N];
- **Fmax**– maximum deforming force [N];
- **d** - total deformation of the spheres measured in the direction of the centers [mm];
- **d max** - the maximum deformation reached by the set of spheres measured in the direction of the centers [mm].

Symbol Structure:

2(3)bM(m)(gg,pg,pp)15(25)

2(3) - number of spheres in the test:

2 – two spheres (lower and upper);

3 – three collinear spheres (lower, upper and intermediate sphere).

b –sphere;

M(m) - spheres diametre: **M** - (56,1[mm]); **m** - (42,35 [mm]);

gg, pg, pp - type of contact between spheres and supports: sphere / support with flat bottom denoted **g** and sphere / support with spherical shape denoted **p**

15(25) – the maximum deformation reached by the set of spheres measured in the direction of the centers [mm].

Results:

For a better interpretation of the experimental results obtained, force / deformation diagrams were made. We present below some of the most conclusive results obtained for the two constructive variants presented above, using two spheres (with or without intermediate sphere), subjected to maximum deformations of different value.

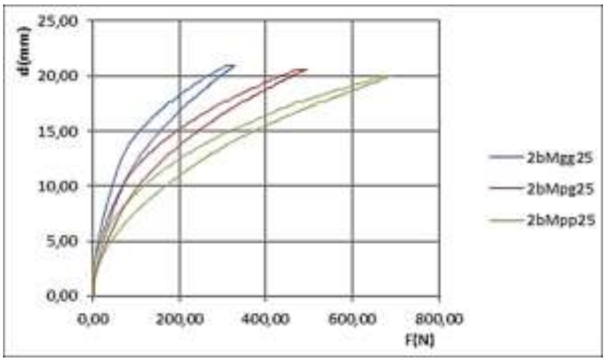

Figure 10. *Force / deformation values correlation 2bM25 (gg, pg, pp).*

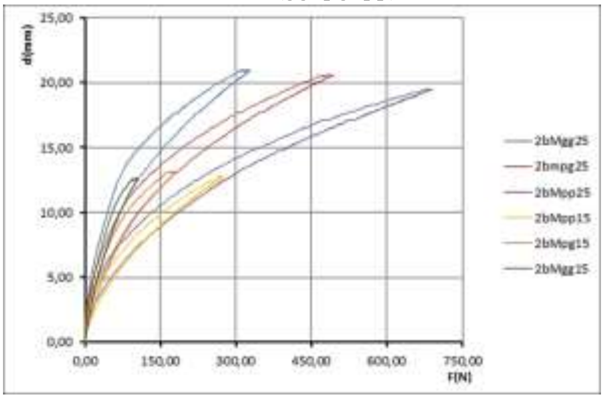

Figure 11. *Cumulative results for 2bM (g, pg, pp) 25-15 mm.*

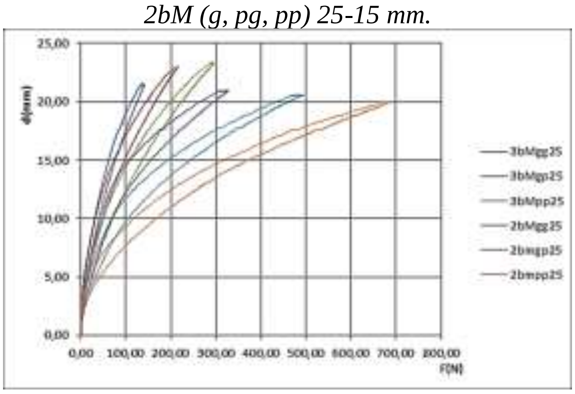

Figure 12. *Comparison of values 3bM9gg, pg, pp) 25 / 2bM (gg, pg, pp)*

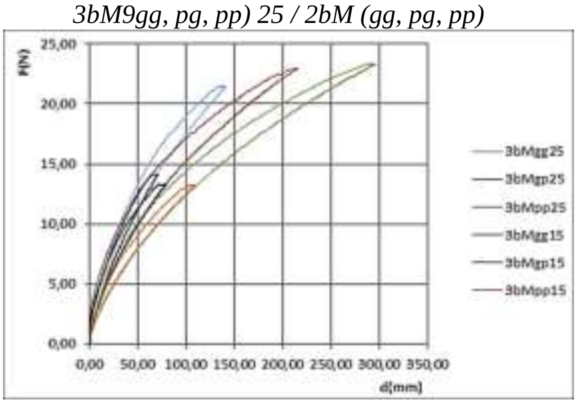

Figure 13. *Comparison of values 3bM25/15(gg,gp,pp)*

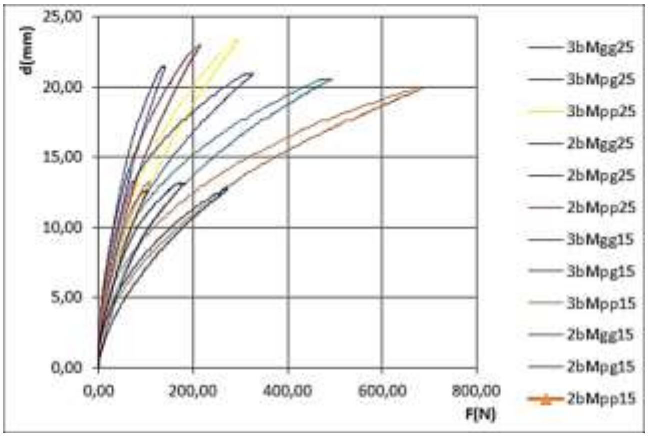

Figure 14 . *Comparison of values for 3bM(gg,gp,pp)25/15 with 2bM(gg,gp,pp)25/15.*

5. Conclusions

It is found that the rubber spheres tested in the experiment had a behavior of nonlinear deformation with the presence of the hysteresis curve;

The deformation curves are different in the three possible test cases (both supports are cylindrical cavities with flat bottom - gg, a cavity with flat bottom and a cavity with hemispherical bottom - pg, respectively both spherical cavities - pp);

It is observed that for the three experimental situations different deformation curves were highlighted.

It is observed that the loading is done according to similar curves, for similar experiments but with different deformations, while the discharge takes place on different deformation curves.

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