SWELLING OF ELASTOMERIC SEALS

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Abstract. *An important factor to be considered in the study of the friction in a tribological pair (seal-rod) is the change in volume that the seal is submitted, that constitutes the Swelling. This variation tends to change the physical properties of the material of the seal. In the swelling phenomena there is a non-linear correlation with the leakage of a sealing system. The measurement of the change in volume of seal is obtained by standard procedures that limit to employ samples with predefined geometries that restrict their direct application in seals, because their geometries differ from pattern samples. This paper treats of a comparative study among the procedure adopted by the Brazilian standard NBR 11407 and a new approach developed for the measurement of volumetric variation of seals. This method is based on the production of samples with similar geometries to an elastomeric seal belonging to a sealing system (Stuffing Box) witch compose a pumping unit of petroleum. The study presents a modeling of the phenomenon and a relationship between the experimental results obtained by means of the two cited methods and the applicability of the new method applied to Polyurethane (PU) and NBR rubber samples.*

Keywords*: Tribology, seal, swelling, elastomer, leakage*

1. INTRODUCTION

The selection of seals is generally an imprecise and many times delayed, because involve numerous criteria. Some characteristics that a seal should have are obvious, how to keep the fluid for which was designated. The seal should also be compatible with the fluid in order to guarantee its physical integrity. Dynamical seal materials must be wear resistant to guarantee a long life cycle. Other desirable characteristics are their extrusion resistance under high temperature and pressure conditions, high stability and resistance to change in volume and deformation. The cost is another relevant feature during the seal selection.

Unfortunately, in a design point-of-view, some of the characteristics conflict between itself. The loading applied on the dynamics seal are a good example of that. High normal loads between the seal and dynamic counterface results on an efficient sealing, nevertheless increase the friction of the system, accelerating the wear rate. Low normal loads extend the life cycle of the seal and can imply on high leakage rate for low pressure level (ERIKS, 2002).

The prediction of how much an elastomer swells in contact with a given solvent is important in many industrial processes (NIELSEN, 2005). An important factor to be considered in the study of friction between the seal and the rod of positive displacement pumps is the change in volume of the seal. After the contact of the seal with some liquid or gaseous fluid, can have an increment or decrease of the volume, and this variation is almost always accompanied of a change in the hardness (ERIKS, 2002). In some static applications the volume increase of the seal is desired, however for dynamic applications, a swell of up to 15-20% is an upper limit. Higher swell values cause premature wear by friction increase. Already the volume reduction is caused by the fluid, which extracts some plastificants of the polymeric chain. The contraction of the seal is more critical than the expansion, since that will not be with an efficient compression and the emptying will occur more easily. More than 3 or 4% of contraction it can be sufficiently critical in dynamic applications. (ERIKS, 2002).

Starting from that, this study intends to compare change in the volume of specimens with rectangular and ring-shaped geometry verifying the best option for the study of swelling of elastomeric seals.

2. MATERIALS AND TECHNIQUES

In this paper two elastomers (Polyurethane and Nitrilic rubber - NBR) was studied (both quite porous ones). The NBR is largely used in seals for petroleum extraction by jack pumps. The PU elastomer is also used in this type of application, in low scale, and was adopted as a comparative material for presenting a good abrasion resistance but with change of volume questionable.

The adopted technique to swelling measurement was based on Brazilian standard NBR-11407, that quantify the alterations of physical properties, for effect of immersion in liquids in the vulcanized elastomers. This technique uses specimens with linear geometry (solid rectangular) only and was added for this study also ring-shaped specimens, with distinct initial volume of the standard, (Figure 1), in order to verify the viability of immerge the seal directly into the standard liquid. The standard immersion fluid adopted was toluene and the immersion time was 24-hours.

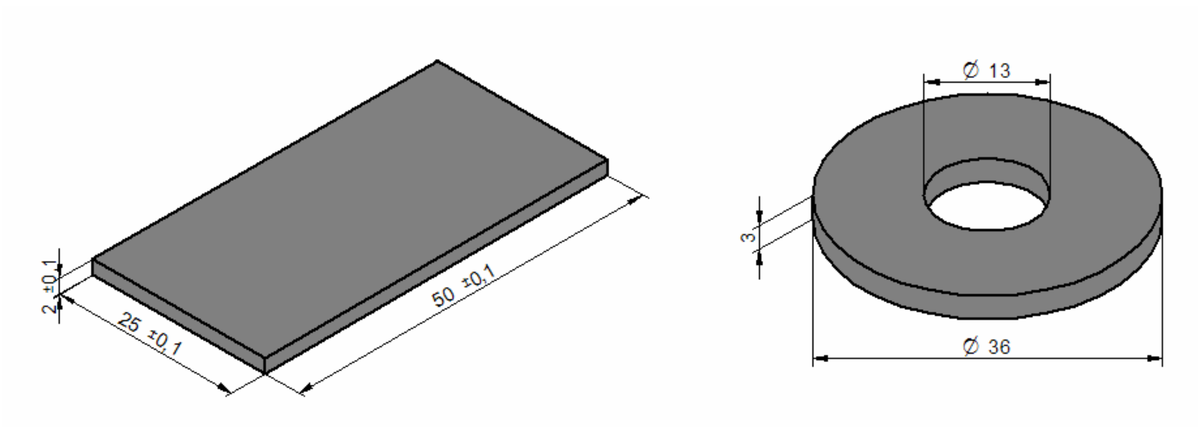

Figure1. Specimens morphology (dimensions in mm)

3. EXPERIMENTAL PROCEDURE

For each material, six specimens was confectioned, being three with solid rectangular shaped and three with solid ring shaped, which had been placed in a borosilicate glass bottle with 100ml of toluene (Figure 2).

Figure 2. Submerged specimens in toluene

The immersion period time was 24-hours to environmental temperature and atmospheric pressure. The dimensional variation was measured with a caliper rule and micrometer (Figure 3), both with 0,01 mm of resolution. To make calculations of the dimensional alteration, the equations (1) and (2) were used. Three measurements were made for each dimension of the specimen and the mean was considered.

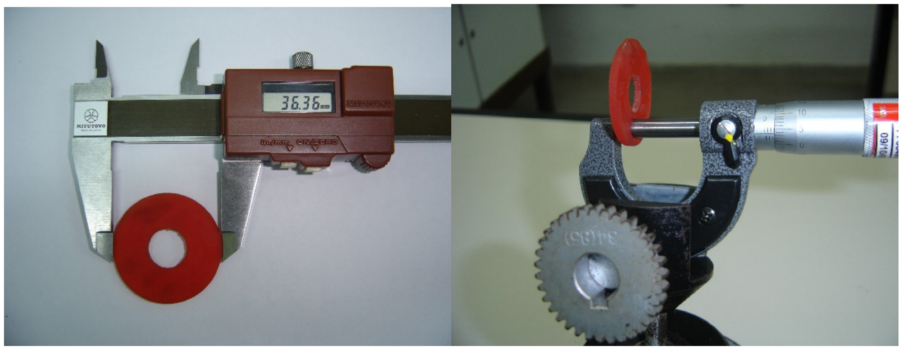

Figure 3. Measurement proceeding

$$\Delta L_{\%} = \frac{L - L_0}{L_0} \cdot 100 \qquad (1)$$

ΔL= change in length, %
L_0= initial length of specimen, mm and
L= length of specimen after immersion, mm.

The next step was the calculation of the percentage change in width, *ΔW*, and thickness, *ΔT*, accordingly. Then the change in volume of specimen was calculated.

$$\Delta D_{\%} = \frac{D - D_0}{D_0} \cdot 100 \qquad (2)$$

ΔD= change in external diameter, %
D_0= initial external diameter of specimen, mm and
D=external diameter of specimen after immersion, mm.

Calculate the percent change in internal diameter *Δd*, and thickness, *ΔT*, accordingly. Then the change in volume of specimen was calculated.

4. RESULTS AND DISCUSSIONS

To measure the change of volume in an elastomer caused for its swelling, after the immersion in fluid, is something complicated, therefore some variable can influence in the final result of experiment, and thus contribute to increase the error of measurement. It is necessary to have attention with: a) The type of elastomer; b) The solvent type, oil or fuel for immersion; c) The time of immersion and the measurement time; d) The geometry of samples that is objective of study of this article.

Depending of porosity and/or its composition, the elastomer can have an independent swelling of other parameters, for example its geometry. This fact occurred in the tests carried out with manufacture NBR samples and that will be presented.

The type of fluid used for immersion can to cause, depending of immersion time, some chemical change in the samples. A common example of this is the loss of plasticizing agent of the sample caused for a chemical reaction, which can to cause the reduction of volume of sample instead of the swelling. The incompatibility and the chemical degradation also can occur and are complex processes.

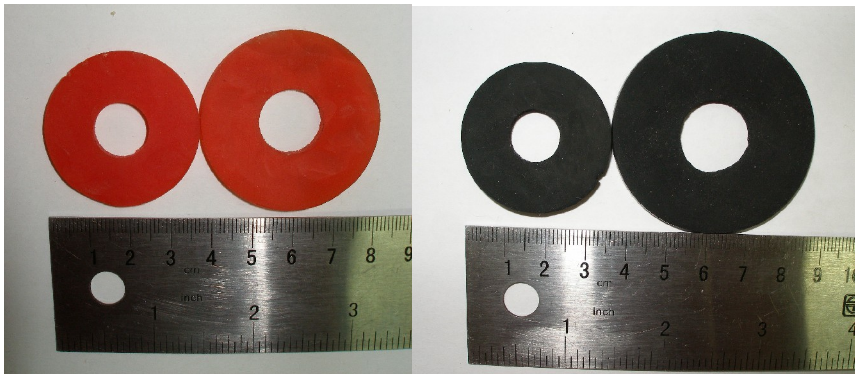

Figure 4. Ring-Shaped specimens before and after immersion (PU and NBR)

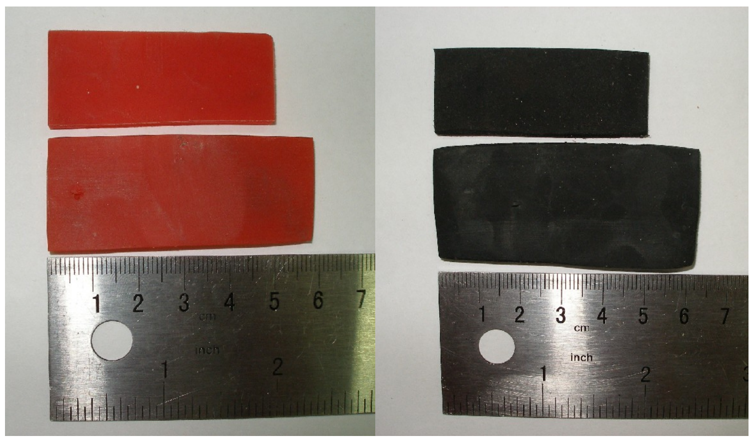

Figure 5. Rectangular specimens before and after immersion (PU and NBR)

The immersion time is a very important factor for the swelling of samples, which will be established by the elastomer type, the fluid of immersion and other conditions as temperature and pressure, therefore, when the experiments were carried out verified that there is influence of this parameters on necessary time to complete swelling of sample. After some tests conclude that for this experiment 24h was enough for the complete swelling of samples. As well as the immersion time, it is important to establish the time for measures in order to minimize the error caused for volatilization of immersion fluid. For these tests the measure carried out 10 seconds after to remove of samples of immersion fluid (GOPAKUMAR, 2005).

After 24 hours of immersion in toluene a considerable dimensional variation of all of the specimens was verified (Figure 4 and 5)

Then the calculations were made relative to dimensional alterations and consequently the change in the volume (%) was calculated (Figure 6).

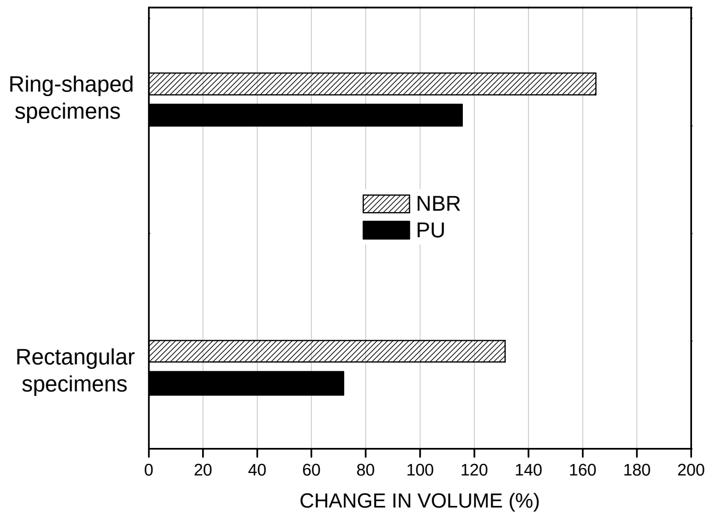

Figure 6. Results of the change in the volume

Visually the samples seems to have same change in the volume (Figures 4 and 5), however the calculations prove the different dimensional changes. This phenomenon occurs due greatest variation occurred mainly in the thickness of samples.

The figures 7 and 8 relate the volumetric differences (ΔV%) between the two geometries for a same material before and after of the immersion, respectively. It is observed that the differences among the volumes after the immersion is considerably smaller than before the immersion, in other words, there is an influence of the geometry of the specimens in tests of fluid absorption. The specimen with ring-shaped geometry presented a larger dimensional variation.

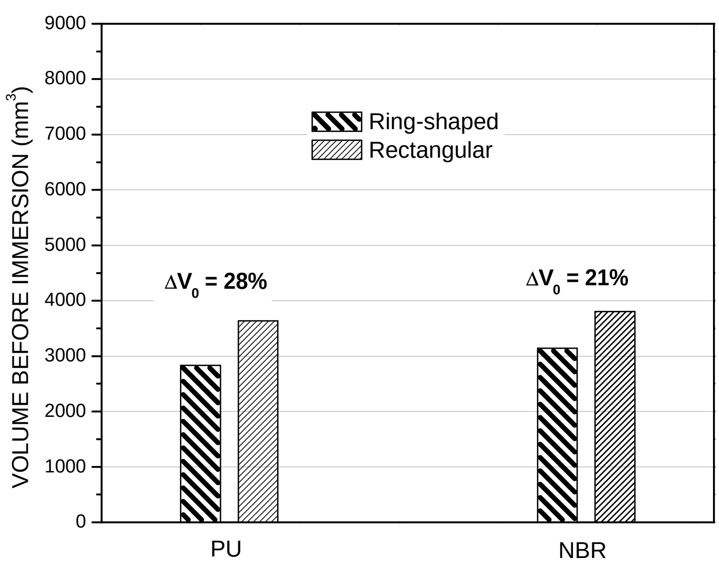

Figure 7. Volumetric differences before the immersion

The figure 7 presents the difference, of the initial volumes, enters the specimens with rectangular and ring-shaped geometry, while the figure 8 shows the influence of the geometry of the specimen in the result of immersion in fluid.

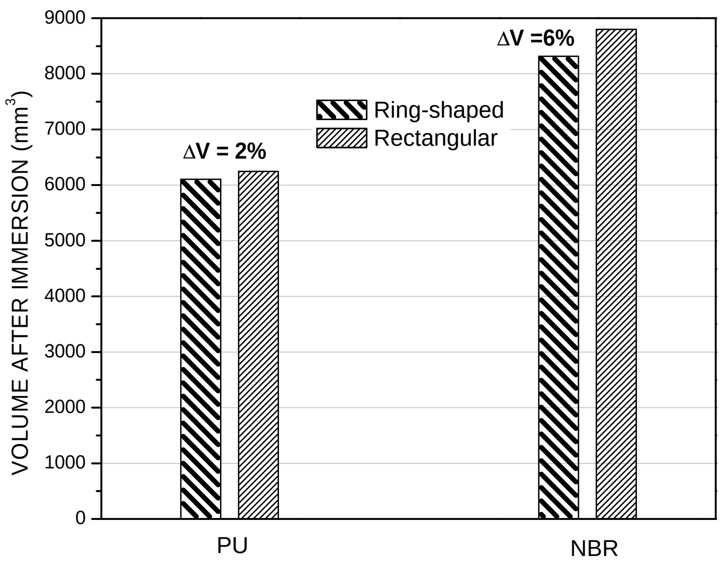

Figure 8. Volumetric difference after the immersion

The Figure 9 showed that the ring-shaped specimen made of PU increased its volume 25% more than the rectangular specimen. For the specimens made of NBR, this difference was around 3% more than ring-shaped specimen.

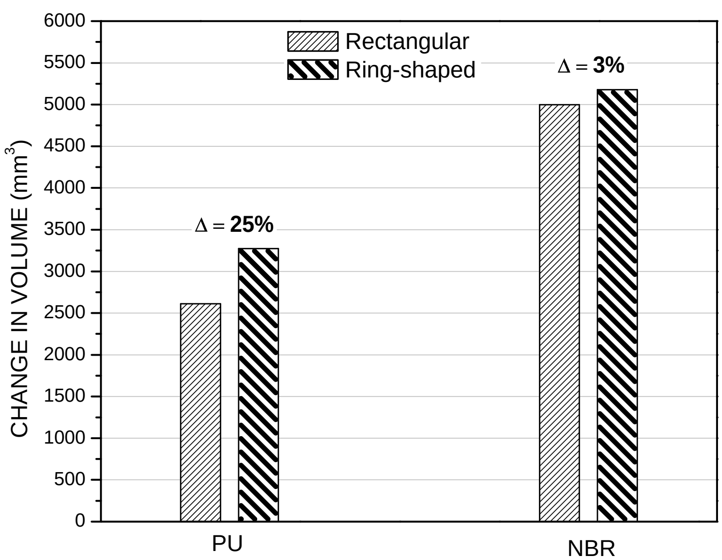

Figure 9. Change in volume (mm^3)

5. CONCLUSIONS

The tests showed or suggested that, for the conditions presented in this article:

1. The method for quantification of the swelling using rectangular geometry specimens as prescribed in the Brazilian standard, it doesn't act to real change in the volume of an elastomeric seal, due to the variation of the volume in ring-shaped specimens to be considerably larger than in the rectangular specimens.

2. For some elastomers (for example PU), the measurement of the swelling in seals with ring geometry, it becomes more representative being adopted specimens with approximate geometry of the seal.

6. ACKNOWLEDGEMENTS

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8. RESPONSIBILITY NOTICE

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