CARBON DIOXIDE ADSORPTION AND DESORPTION ON O-RINGS AT HIGH PRESSURE EQUIPMENTS

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RESUMO: Estudamos a adsorção de dióxido de carbono em vários tipos de anéis de vedação de equipamentos de alta pressão utilizados na indústria de petróleo e gás. Um equipamento simples é utilizado para medir a dessorção de dióxido de carbono na temperatura constante. A difusividade e concentração de equilíbrio de dioxide de carbono são estimados a partir dos resultados experimentais. A metodologia experimental e o equipamento utilizado mostram se efetivos . As informações obtidas podem ser utilizadas na especificaçãoe escolha de anéis de vedação de equipamentos utilizados para processamento de fluidos com elevado teor de dióxido de carbono na alta pressão.

PALAVRAS-CHAVE: O-ring; dióxido de carbono; adsorção; dessorção; coeficiente de difusão.

ABSTRACT: We study the adsorption of carbon dioxide on various types of o-rings of high pressure equipments used in the oil and gas industry. A simple set-up is utilized to measure the desorption of carbon dioxide at constant temperature. The diffusivity and equilibrium adsorption concentration are estimated from the experimental results. The experimental set-up and methodology showed promising desorption results. The information obtained can be used in selecting and specifying o-rings for high pressure equipments processing gases or liquids with high carbon dioxide content.

KEYWORDS: O-ring; Carbon dioxide; Adsorption; Desorption; Diffusion coefficient.

1. INTRODUCTION.

Many oil reservoirs, especially in pre-salt regions are currently producing oil and gas with high amount of carbon dioxide (CO_2). The absorption and adsorption of CO_2 affect the performance of polymer seals like o-rings in production and testing equipment as well as in the pipelines. The reduction of pressure causes explosive decompression in o-rings and can cause severe damage in expensive equipments. It is necessary to investigate the effect of CO_2 on o-rings to ensure the safety of workers and avoid unnecessary costs.

The development, design and operation of the adsorption and desorption processes require the knowledge of equilibrium, which means the data on adsorption isotherms is in need. There are various models to predict the adsorption isotherm in literature. However these predictions are not usually reliable enough for process design (Markmann and Mersmann, 1998).

The different applications require basic adsorption data in a particular range of experimental conditions (temperature, pressure, gas composition). These data consist of adsorption isotherms, selectivity curves and heats of adsorption or kinetic data. One of these area that adsorption/desorption is important to be considered is the polymer o-ring used for sealing purposes. Polymers can adsorb different gases like CO_2, H_2S and methane. The presence (adsorption) of these gases inside the structure of the material affects the properties of the o-rings. In this work some initial experiments were performed on the adsorption of carbon dioxide and the diffusion coefficient of the o-ring was calculated.

A wide range of chemical processes includes sorption of the CO_2. Among such processes, polymerization, foaming, creation of polymer composites, impregnation and modification of polymers were mentioned in literature (Nikitin et al., 2003). Carbon dioxide became recently an area of increased attention by the investigators. Understanding of mechanisms determining CO2, sorption, solubility and the kinetic of diffusivity in polymers as well as their subsequent swelling in all these processes is therefore very important (Nikitin et al., 2003 and Sato et al. 2001). The mentioned authors performed series of swelling test on polystyrene and CO_2.

2. EXPERIMENTAL SETUP AND PROCEDURE

A simple setup was developed in house to carry out some preliminary adsorption/desorption tests. The experiments were focused on the effect of carbon dioxide on polymer o-rings.

A small tube was chosen as a sample container. One end of the tube was connected to the source of carbon dioxide with a pressure gauge and the other side was blocked. Laboratory temperature which is quite stable is the temperature of our preliminary experiments (Figure 1).

A "Viton" type o-ring with the hardness of "70 D" was chosen for the initial test. The o-ring is small size with the inner and outer diameter of 6.01 and 9.67 mm, respectively.

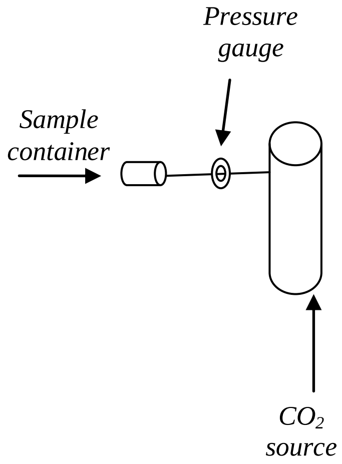

Figure 1: Schematic diagram of the in-house developed adsorption/desorption setup

The weight of the o-ring was measured using a balance with four digit precision before adsorption test, and then it was exposed to the carbon dioxide gas (at 500 psig and 22 ºC) for 5 hours to reach the equilibrium. After finishing the adsorption process, a quick de-pressurizing followed by transferring the sample to the balance was performed (in less than 50 s). The desorption process was monitored by recording the weight of the sample and consequently the amount of desorbed gas were measured. The test was performed on a complete o-ring and then on an o-ring cut into four pieces. Besides the weight, the surface areas of both samples were also calculated for better evaluation.

3. RESULTS AND DISCUSSION

To evaluate the process, the desorption curves are drawn to illustrate the changes in adsorbed gas in two different ways. Figure 2 shows the rate of desorption with gram of carbon dioxide per gram of initial sample against time and Figure 3 depicts the desorption rate with gram of carbon dioxide per unit area against time.

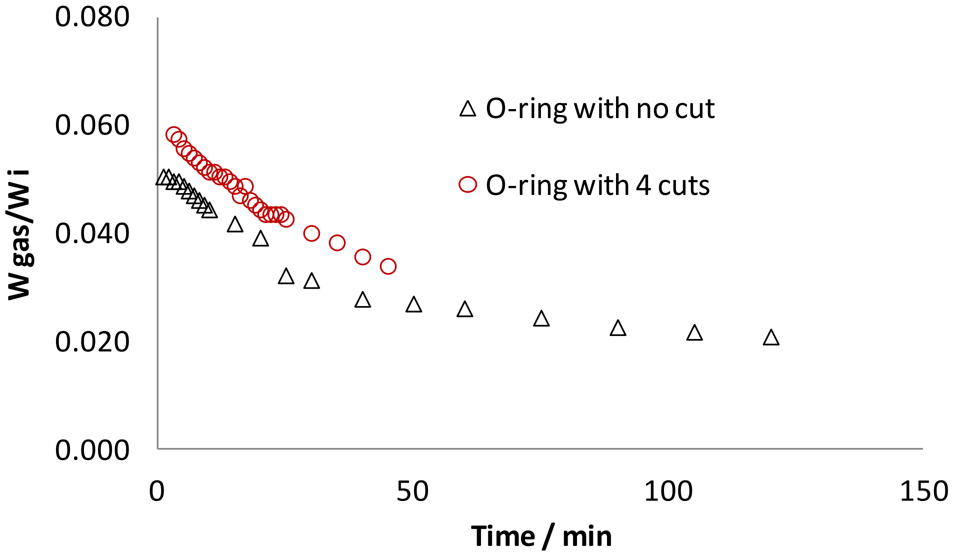

Figure2: The rate of carbon dioxide to initial weight of sample vs. time

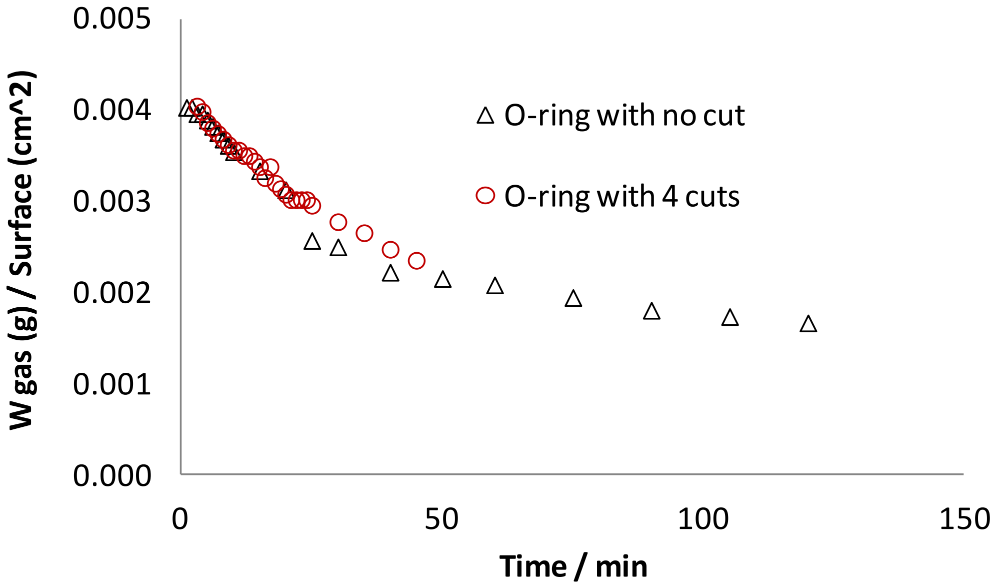

Figure 3: The rate of carbon dioxide to surface area of the sample vs. time

The equilibrium adsorption percentages, that are the values taken right after the decompression, were 5.05% and 5.84% for the "complete" and the "4-cut piece" o-rings, respectively (Figure 2). This excess amount of desorption is due to more available surface for the 4-cut piece o-ring. As it can be clearly seen in Figure 3, the equilibrium values of adsorption per unit area for both samples are very close and the trends were also the same.

For estimation of diffusion coefficient the following formulation is used (Crank and Park,. 1968):

$$\frac{M_t}{M_\infty} = 1 - \sum_{n=1}^{\infty} \frac{4}{a^2\alpha_n^2} \exp(-D\alpha_n^2 t). \qquad (1)$$

where, M_t is the mass of adsorbed gas at the time t, M_∞ is the saturation amount of CO2 (the initial equilibrium mass at the moment of decompression), and D is the diffusion coefficient, with radius "a" for cylindrical samples and "α_n" are the roots of equation $J_0(\alpha a)=0$ (hereJ_0 is Bessel function of 0-order). A diffusion coefficient of 2.02×10^{-8} m^2/s for carbon dioxide was calculated using the desorption data after two hours.

The developed setup showed promising results for adsorption/desorption tests. We are currently installing a precise gas dosing system to apply different pressures and temperature control system to generate more valuable and wide range of adsorption/desorption data.

4. CONCLUSIONS

Authors introduced a simple setup for adsorption and desorption measurements. A preliminary set of experiments on a Viton type o-rings and carbon dioxide gas were carried out confirming the applicability of their system. The tests were performed at 500 psig and 22 ºC. The diffusion coefficient for carbon dioxide in the o-ring was also calculated. The adsorption result was promising, so the laboratory will continue its work by preparing the setup for wide range of experimental data.

5. ACKNOWLEDGEMENTS

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