A Study On The Moisture Permeability And Corrosion Resistance Of Polyurethane Coating Used In The Gas Transmission Pipelines

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Abstract

Polyurethane (PU) coating shows properties such as low moisture diffusivity, corrosion resistance and high mechanical strength against stress impacts, as well as offers suitable flexibility according to the standards of EN-10290 and IGS-M-TP-020-1 of the National Iranian Gas Company is known as one of the methods of insulating gas transmission pipelines. In this study, the properties such as moisture permeability coefficient, hydrophobicity, and corrosion resistance are studied based on the mass transfer governing equations. In the experimental part, the impact of the thickness and the porosity of the coating, and also the type of environmental conditions in alkaline, and humid environments are investigated to evaluate the properties of PU coating. The aim of this study is focused on the construction of a reinforced PU coating against corrosion, low moisture permeability with minimum stress in the soil. In the modeling section, by considering specific and controlled boundary conditions on the coating, there will be the ability to calculate the permeability coefficient in steady-state conditions. The results indicated that the moisture permeability is a nonlinear function of the coating thickness. It's expected that the resulting coating will have a longer lifetime for use in humid environments. In addition, using it will significantly reduce the side costs and economic losses related to the repair or replacement of the transmission pipelines.

Keywords : *Polyurethane coating, permeability coefficient, corrosion resistance, moisture diffusivity, mass transfer equation*

Introduction

PU coating is known as one of the main methods of insulating gas transmission pipelines and fittings according to the IGS-M-TP-020-2 standard of the Gas Company of Iran [1]. PU coating has gained usually used due to it's adaptability and changeability, and suitable physical properties. The use of PU coating is a perfect choice for corrosion control and protection of gas transmission pipelines, and compared to old coatings and systems, they are more economical in terms of quality, efficiency, and cost benefits [2]. PU was first patented in 1935 by German chemist Otto Bayer and his colleagues through the reaction of an isocyanate and polyol reactants [3,4]. Today, various PU are produced, with different uses according to their type and shape. PU coating is also used to protect gas pipelines against corrosion [3]. One of the most important fields of chemical properties is corrosion resistance. Corrosion occurs due to the return of the metal to its previous state through an oxidation reaction. The main cause of failure of pipelines is corrosion [5]. To prevent the corrosion of metals, an effective and practical method is to use inhibitors [6]. An inhibitor is a substance that reduces or prevents the destruction of a metal when it is added in a low concentration to a corrosive environment. In addition, high efficiency, increased lifetime, corrosion resistance in acidic and alkaline environments, high wear and mechanical resistance, strong adhesion, immediate application and, drying, etc., all prove the effectiveness of PU coating in various industries. The gelling time of the PU coating in the process at 25 ℃ is about 2.5 min, while its surface drying time is 10-15 min. Along with other advantages of PU coating, this coating performs poorly in terms of mechanical strength and impact resistance. To improve the chemical properties, extensive studies and research have been done. Over the past years, efforts have always been made to improve its properties, fix defects and increase its use by working on PU coating [6]. The goal of this study is to focus on the defects of the current coating and to design a reinforced PU coating against corrosion, and low moisture permeability with minimum stress in the soil [1,2]. The permeability coefficient of governing equations on the mass transfer of moisture through the PU thickness is studied numerically in the steady state condition. and environmental conditions were studied on the permeability coefficients of PU film. The impact of coating thickness and polymer structure on the permeability coefficient and corrosion resistance of the PU film are investigated as, well as the mass transfer equations. In the experimental part, the impact of the thickness and the porosity of the coating, and also the type of environmental conditions in alkaline and humid environments, are investigated to evaluate the properties of resulting PU coating.

Governing equations

To investigate the effect of different thicknesses on the penetration coefficient of PU coating, we use the model developed by Tsay and McHugh (TM), which became known as the TM model in 1990 as a general and accurate method. In the following, we will introduce the equations. The available model is as follows:

$$\frac{\partial \varphi_{2p}}{\partial t} = \frac{\partial}{\partial z}\left(D_b \frac{\partial \varphi_{1b}}{\partial z}\right) \quad (1)$$

$$\frac{\partial \varphi_{1p}}{\partial t} = \frac{\partial}{\partial z}\left(D_{11} \frac{\partial \varphi_{1p}}{\partial z} + \frac{V_1}{V_2} D_{12} \frac{\partial \varphi_{2p}}{\partial z}\right) \quad (2)$$

$$\frac{\partial \varphi_{2p}}{\partial t} = \frac{\partial}{\partial z}\left(D_{21} \frac{\partial \varphi_{2p}}{\partial z} + \frac{V_2}{V_1} D_{22} \frac{\partial \varphi_{1p}}{\partial z}\right) \quad (3)$$

The boundary conditions for solving the mass transfer equations are as follows:

$$\varphi_{1p}(z, t=0) = \varphi_{1p0} \quad for\ 0 \le z \le l \quad (4)$$

$$\varphi_{2p}(z, t=0) = \varphi_{2p0} \quad for\ 0 \le z \le l \quad (5)$$

$$\varphi_{1b}(z, t=0) = \varphi_{1b0} \quad for\ 0 \le z \le l \quad (6)$$

$$\frac{\partial \varphi_{1p}}{\partial z} = 0 \quad at \quad z = 0 \quad (7)$$

$$\frac{\partial \varphi_{2p}}{\partial z} = 0 \quad at \quad z = 0 \quad (8)$$

$$\varphi_{1b} = \varphi_{1b0} \quad at \quad z \to \infty \quad (9)$$

Results and Discussion

Figure 1 shows the SEM images of PU coatings. It can be seen the existence of cavity-shaped structures and film porosity on the surface of the polymer structure. The presence of fibrous structures with apparent voids is visible on the surface of the PU coating.

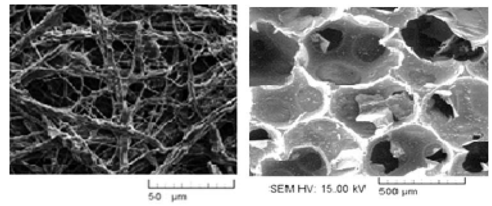

Figure 2 sh… …sorption by covers immersed in … …ting. According to the figure, th… …mm is higher than other thickne… …howed that during 48 h, the perf… …f the percentage of mass change

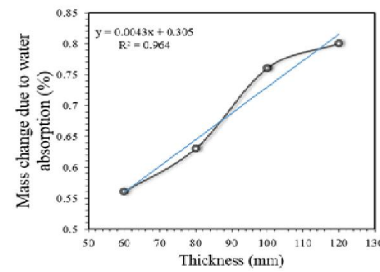

Figure 2. The results of mass change percentage due to water absorption by coating with thicknesses of 60, 80, 100, 120 mm

Figure 3 shows the contact angle results of the PU coating after placing water droplets on the film surface. The results showed that the angle of the water droplets on the surface of the coating is in the range of 40 to 50o, which shows that the film has good hydrophobic properties. In addition, the sphericity of water droplets on the surfaces of the samples indicates the increase in hydrophobicity. The creation of hydrophobic properties leads to an increase in the mechanical and structural durability of the coating in wet environments, so it is expected that the life of the coating will increase significantly.

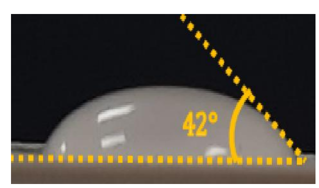

Figure 3. The results of Contact angle of the PU coating

Conclusions

This study proposed to construct of a hydrophobic coating resistant to moisture absorption, which led to a longer lifetime of the coating for use in different environments, incredibly humid climates. The impact of the thickness and the porosity of the coating, and also the type of environmental conditions in alkaline and humid environments, are experimentally investigated to evaluate the properties of PU coating. In the modeling section, by considering specific and controlled boundary conditions on the coating, there will be the ability to calculate the permeability coefficient in steady-state conditions. The results of this study indicated that moisture permeability is a nonlinear function of the coating thickness. It's expected that the resulting coating will have a longer lifetime for use in humid environments. In addition, using it will significantly reduce the side costs and economic losses related to the repair or replacement of the transmission pipelines.

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