Desalination 409 (2017) 183–188

Contents lists available at ScienceDirect

Desalination

journal homepage: www.elsevier.com/locate/desal

Enhancement of corrosion resistance in thermal desalination plants by diamond like carbon coating

Hamid Reza Golsefatan [a,*], Mojtaba Fazeli [a], Abdollah Rashidi Mehrabadi [a], Hamid Ghomi [b]

[a] Faculty of Civil, Water & Environmental Engineering, Shahid Beheshti University, East Vafadar Blvd., Tehran, PO Box: 16765-1719, Iran
[b] Laser and Plasma Research Institute, Shahid Beheshti University, Evin, 1983963113 Tehran, Iran

ARTICLE INFO

Article history:
Received 31 October 2016
Received in revised form 3 January 2017
Accepted 18 January 2017
Available online 3 February 2017

Keywords:
DLC
Thermal desalination
Corrosion
Cyclic Polarization
Cathodic vacuum arc

ABSTRACT

The development of thermal desalination units is a suitable solution to tackle global water scarcity, especially for areas that have cheap energy. Stainless steel due to special properties, such as the durability and minimum maintenance requirement is a good choice for desalination plants. However, corrosion is the major problem with this material. Nevertheless, by selecting a thick enough and suitable cover, the corrosion resistance of the material greatly increases. To achieve this goal a thin layer of diamond like carbon (DLC) was deposited on the stainless steel 316 by Cathodic vacuum arc method and Raman spectroscopy was used in order to evaluate the quality of DLC layer. Subsequently electrochemical behavior of coated and uncoated substrates were studied and compared by using cyclic polarization test. It is found that current density and uniform corrosion rates of coated samples are far less than the uncoated sample even in different concentrations of sodium chloride solution and the DLC coating can increase uniform corrosion resistance.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Living standards are fortunately improved over time but this has increased the rate of consumption and has imposed water stress along with other issues such as population growth, drought and climate change for most countries especially the countries with low water resources. So far several solutions are provided to deal with the issue of water stress. But due to the access of many countries to the sea, a good solution to deal with this problem is the desalination of sea water [1–4]. Predictions show that this approach will play an important role to deal with the global water shortage in the future [5].

Nowadays, a large proportion of water production in desalination plants is performed by membrane and thermal techniques (there is also a combination of both). Although membrane methods have made considerable progress in recent years and have obtained a greater proportion of production, the thermal methods because of high produced water quality, simple performance, no need for special pre-treatment, being suitable for high salinity water and the possibility of the production at high capacities are still the first choice for desalination especially where cheap energy is also available [6,7].

A major advantage of thermal desalination systems is the possibility of using low grade heat energy which is a kind of energy that cannot be used efficiently by the conventional methods [8]. This energy is usually wasted and it is the by-product of the processes and helps global warming. Suitable use of this energy leads to solve some of the water shortage problem without increasing the global warming [9].

On the other hand, thermal desalination systems work in difficult conditions which corrosion is their common problem. In these units (and generally in different industries), stainless steel is widely used because of significant properties such as corrosion resistance, relatively affordable cost and ease of use [9,10]. The corrosion resistance of this material is due to the formation of a passive film of Cr_2O_3 on the surface that has a low penetration rate against oxygen and metal ions and thus has a high corrosion resistance [11]. The main cause of failure of the steel passive film and its corrosion is the chloride ion that is the most common material in the marine environment [12].

World Corrosion Organization estimates that the cost of corrosion in each country is about 3% of the GDP[1] of the country [13]. Accordingly in Iran > 12 billion dollars is imposed on the industry as the costs resulting from corrosion. These figures reveal the need to deal with the issue of corrosion, especially in highly corrosive environments.

The following solutions are proposed to overcome the problem:

1.1. The use of corrosion resistant materials

Corrosion resistant materials are expensive and increase the cost of the initial investment. For example, the titanium resistance to corrosion

* Corresponding author.
E-mail addresses: h_golsefatan@sbu.ac.ir (H.R. Golsefatan), m_fazeli@sbu.ac.ir (M. Fazeli), a_rashidi@sbu.ac.ir (A.R. Mehrabadi), h-gmdashty@sbu.ac.ir (H. Ghomi).

[1] Gross domestic product

http://dx.doi.org/10.1016/j.desal.2017.01.027
0011-9164/© 2017 Elsevier B.V. All rights reserved.

is higher than the conventional metals but its cost has reduced its application in the desalination industry [14].

1.2. Increasing surface resistance or coating using resistant materials

In this regard many studies are conducted by researchers and different techniques are proposed to modify the surface and improve steel behavior against corrosion [15]. Surface chemical modification, use of lasers to change the surface properties or changing the surface phase such that the new phase has higher corrosion resistance to the mass are methods presented in many studies and can increase the lifetime of the parts [16,17]. But with regard to working conditions of the desalination units, more research is needed and these methods are not yet completed.

Another method is the use of polymer coating that is not popular due to low thermal conductivity and the possibility of ductility. Polymers in comparison with conventional metallic materials have advantage such as simple implementation, low density, low cost, low tendency to scaling and excellent resistance to corrosion and chemicals. But their thermal expansion is ten times greater than the metals and their thermal conductivity is ten times less than the metals and these properties have limited their application in thermal systems. However, in the case that the thermal performance is not the main function of the system or the wall's thermal performance has no impact on the thermal duty of the system, polymer materials can be useful [18,19].

1.3. The use of anti-corrosion chemicals

It is possible to reduce corrosion of metals using corrosion inhibitor chemicals. These materials are widely used in various industries such as oil, gas, chemicals and water. But most of these materials have their own toxicity and may cause new pollution to the environment [20].

Nowadays most of desalination units use the combination of the first and third method. In this way, the stainless steel or copper alloys that are relatively resistant to corrosion and corrosion resistant chemicals are used to reduce the level of corrosion. But despite these measures, corrosion still exists and is still a major problem in these units so that the wastewater of these units is polluted with harmful metals and contaminates the recipient waters. Moreover the corrosion inhibitor chemicals that finally appear in the wastewaters cause more environmental pollution [21,22]. This issue is a major problem in areas such as the Persian Gulf with various desalination systems and can cause problems to the environment.

On the other hand, by increasing the top brine temperature, it is possible to increase system efficiency and reduce costs. One consequence of this increase in temperature is increased tendency to corrosion [23] and to deal with corrosion it is necessary to use more resistant materials (higher cost). Accordingly the effect of material selection on cost optimization of thermal desalination systems is the subject of many studies [24].

A proposal to solve the corrosion problem and reduce environmental pollution is the use of a neutral resistant coating that has high resistance to corrosion. Moreover it should have thermal conductivity and appropriate strength.

Diamond-like carbon with high chemical resistance, high thermal conductivity and properties such as high hardness and low friction coefficient [25,26] can be a good choice in this regard. DLC properties are given in Table 1 (to show the special properties of this material, steel and diamond specifications are also provided for comparison). Due to these properties, this material has an increasing use in various industries, such as automotive, drilling, medicine, etc. [27–29]. Therefore it is expected to be a good barrier against oxygen and chloride ion diffusion into substrate. (Fig. 1)

Table 1
DLC, diamond and steel specification.

Material	Diamond	DLC	Steel
Property			
(g/cm^3) density	0.1 ± 3.4	1.8–2.8	7.59
(μm) thickness	1–1000	0.1–5	–
(W/m·K) conductivity	>1300	400–1000	16
(Kg/mm^2) hardness	5000–10,000	2000–9000	220
Friction factor	0.05–0.15	0.01–0.2	0.16–0.74

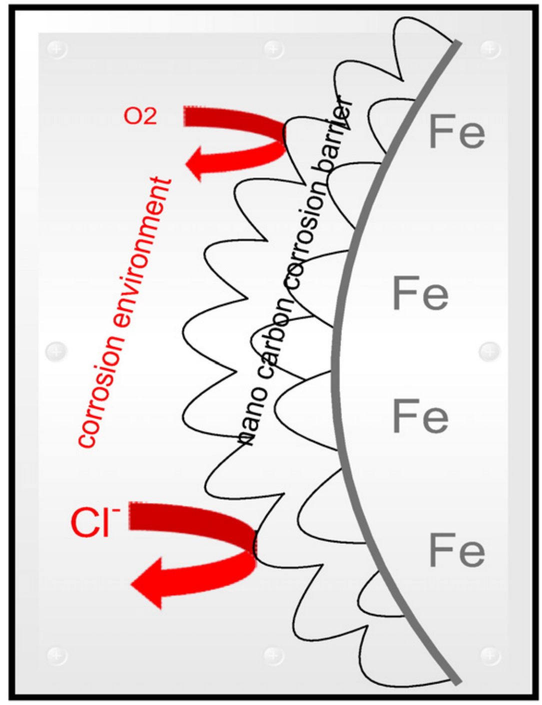

Fig. 1. Low penetration rate versus oxygen and chloride ion.

Due to high conductivity of the DLC compared with steel (about 50 times greater), depositing a film of a few microns thickness has a very little impact on the overall thermal resistance (overall thermal resistance of the coating and substrate) while in case of ensuring the corrosion reduction, it is possible to apply thinner film in the design and manufacturing process and just rely on the thickness required to have satisfying strength.

$$l_t = l_m + CA \tag{1}$$

l_t: total design thickness.
l_m: thickness required for mechanical strength.
CA: total corrosion allowance.

$$CA = CR \times t \times SF \tag{2}$$

CR: anticipated uniform corrosion rate.
t: expected project life.
SF: safety factor.

Carbon with three chemical states sp^1, sp^2 and sp^3 is one of the interesting elements in nature. Carbon can be crystalline or amorphous. Graphite with the chemical structure of sp^2 and diamond with the chemical structure of sp^3 have crystalline structure. DLC is amorphous and has a high percentage of sp^3 structure [30].

Amorphous and hard carbon film was first designed by Aisenberg and Chabot using ion beam assisted deposition and used the term DLC [31]. Today there are several methods for producing a film with this structure [32]. Each of these methods has its own advantages and disadvantages. But one of the conventional and widely used methods in the production of these films is using cathodic vacuum arc.

Download English Version:

https://daneshyari.com/en/article/4987879

Download Persian Version:

https://daneshyari.com/article/4987879

Daneshyari.com