THE EFFECT OF PH AND TEMPERATURE ON CORROSION RESISTANCE OF TIO_2 COATED AISI 316L STEEL

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Abstract:-

A thin film of titania (TiO_2) was deposited onto AISI 316L steel using physical vapour deposition (PVD). Coating thickness was measured using Elecometer instrument and it was (150µm).Corrosion resistance to (H_2SO_4,HCl, H_3PO_4, and HF) acids with (2&4) pH, and to (NaOH, KOH,$Ca(OH)_2$, and NH_4OH) basis with (10,12) pH, of coated specimen was measured at temperatures ranges from (25-190) C^o by weight loss method. It has been found that TiO_2 coating largely enhance corrosion resistance of steel alloy especially at high temperatures.

Keywords:-Thin coatings; ceramic thin films; PVD coating; TiO_2 Thin films.

تأثير الأس الهيدروجيني (الـ PH) ودرجة الحرارة على مقاومة التآكل للفولاذ نوع AISI316L المطلي بالـ TiO_2

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الخلاصة:-

طبقة رقيقة من التيتانيا (TiO_2) تم ترسيبها على سطح سبيكة الفولاذ نوع AISI 316L باستخدام طريقة الترسيب بالتبخر الفيزيائي (PVD). سمك الطبقة تم قياسه باستخدام الاليكوميتر وكان (١٥٠ مايكرون). مقاومة التأكل لكل من حوامض (الكبريتيك، الهيدروكلوريك، الفسفوريك، والهيدروفلوريك) تم قياسها عند رقم هيدروجيني مقداره (٢,٤)، باستخدام طريقة الفقدان بالوزن كما تم قياسها للقواعد (هيدروكسيد الصوديوم، هيدروكسيد البوتاسيوم، هيدروكسيد الكالسيوم، والامونيوم) عند رقم هيدروجيني مقداره (١٠,١٢)، وكانت درجات الحرارة في الاختبارات (من ٢٥ الى ١٩٠) درجة مئوية. وقد وجد بأن طلاء التيتانيا حسن وبشكل كبير من مقاومة التأكل لسبيكة الفولاذ وخاصة في درجات الحرارة العالية.

كلمات البحث:- الاغشية الرقيقة ، أغشية السيراميك الرقيقة ، الطلاء بالترسيب الفيزيائي ، أغشية التيتانيا الرقيقة

Introduction:-

Corrosion is defined as destructive chemical or electrochemical reaction between the metal and its environment, which results in the formation of oxide or some other compounds. Corrosion begins at

the surface and then spreads in the interior of the metal. It depends on the temperature, mechanical stress, erosion and concentration of the reactants. Most metals get corroded due to chemical attack by other materials, water or environment [1-5]. Alloy steels are not particularly corrosion resistance, yet corrosion resistance of stainless steel is however better than many other alloys especially austenitic steel [6]. Ceramic coating materials are normally relatively noble, but there are many factors influencing the corrosion resistance of the coating-substrate system [7-9]. The most effective method preventing the harmful effect of the corrosion attack on the parts is adding a protective barrier between the part and corrosive environment. PVD-ceramic coatings have been widely used as thin protective layers. Especially the excellent properties of thin films of TiO_2 such as high hardness, good wear and corrosion resistance, high electrical conductivity, chemical stability and good adhesion have led to many useful applications Ceramic coating materials are normally relatively noble[10-14]. This research tends to study the effect of (150μm) TiO_2 thin film on corrosion resistance of 316L alloy steel.

Experimental Part:-

1- Specimen Preparation:- TiO_2 coatings were deposited onto mechanically polished (surface roughness Ra 0.05 μm) steel (AISI 316L) substrates by cathodic arc method using device type (YAKMUR. Japan). Substrate composition is as follows: C 0.03%, Cr 18.0%, Mn 2.0%, P 0.o45%, S 0.030%, Si 1.0%, Ni 14% and Fe balance. The cylindrical samples with dimensions of (2cm) diameter and (1 cm) height were used for corrosion tests. The substrates were ultrasonically cleaned before coating deposition to enhance adhesion of TiO_2 coating.

2- Thickness and Microstructure:- Coating thickness was measured by an Elecometer type (SH.F.U., U.S.A) instrument. This is achieved by putting specimen between the two contact points of the instrument push a small button to release the pointer which comes to rest indicating the thickness of the coating. Microstructure was determined by light microscope testing using a microscope type (Nikon, m 73346, Japan).

3- Corrosion Testing:- A set of tests for acid and alkali resistance for coated 316L steel were accrued. Special attention was given to temperature, and pH. The used solutions are (H_2SO_4, HCl, H_3PO_4, $C_6H_8O_7$) acids with (2&4) PH values, and (NaOH,) base with (10&12) PH value. Tests were accrued at fixed time of 9 hours with temperature ranges from (25,50, 75, 100, 125, 150,175,and 190) C^0. These tests are according to the ASTMC703. In every case the corrosion rate was determined by weight loss and calculated using equations below[15]:-

$$C.R = \Delta w/A.t \text{ (mdd)} \ldots\ldots\ldots\ldots\ldots \quad (1)$$

(mdd) milligram . decimeter^2. day

Where Δw is weight loss in (mg),A is area of the specimen in (dcm²), t time in day. In mill per year corrosion rate is calculated from the equation below[16-20]:-

$$C.R = 1.44.mdd/S.G \text{ (mpy)} \ldots\ldots\ldots\ldots \quad (2)$$

Where; S.G is the specific gravity, (mpy) mill. per year

Results and Discussion:-

Figure (1) shows steel specimen before and after coating. Grain boundaries are the most candidate areas for corrosion in every alloy, TiO_2 coating cover all the specimen evenly and completely isolated steel from its environment, and as we know corrosion resistance of ceramic material is much better than metals, this fact will ensure us that corrosion resistance will decrease in both acidic and basic solutions.
Figures (2,and 3) illustrates corrosion resistance of coated alloy at different acidic solutions at temperatures ranges from 25 up to 190 with pH values 2,and 4 respectively . We may notice that there is no corrosion at temperatures up to 75^oC, and even at high temperatures corrosion rate was too small with values lower than 3.5 mpy this is a better rate than uncoated specimen. As can be seen from figures (5) &(6).

Using of enamel as a protecting surface against the action of alkali solutions is wide spread, especially in washing machines where high concentration of alkali is usual. All the enamels in this study have not been affected by an alkali solution of NaOH with pH values of 10, and 12 at room temperature. Figures (4,and 5) which illustrates corrosion rate of coated alloy at different basis may told us that at room temperature for all types of enamel there is no weight loss in any of the test solutions .Weight loss in most of cases starts when temperature exceeds $100C^o$, and increases with temperature increase, At pH10 there is no weight loss, but corrosion rate increases with pH value.

Conclusions :

We conclude that Tio_2 coating decrease corrosion rate of 316L steel especially at temperature range (25-75) ^oC.

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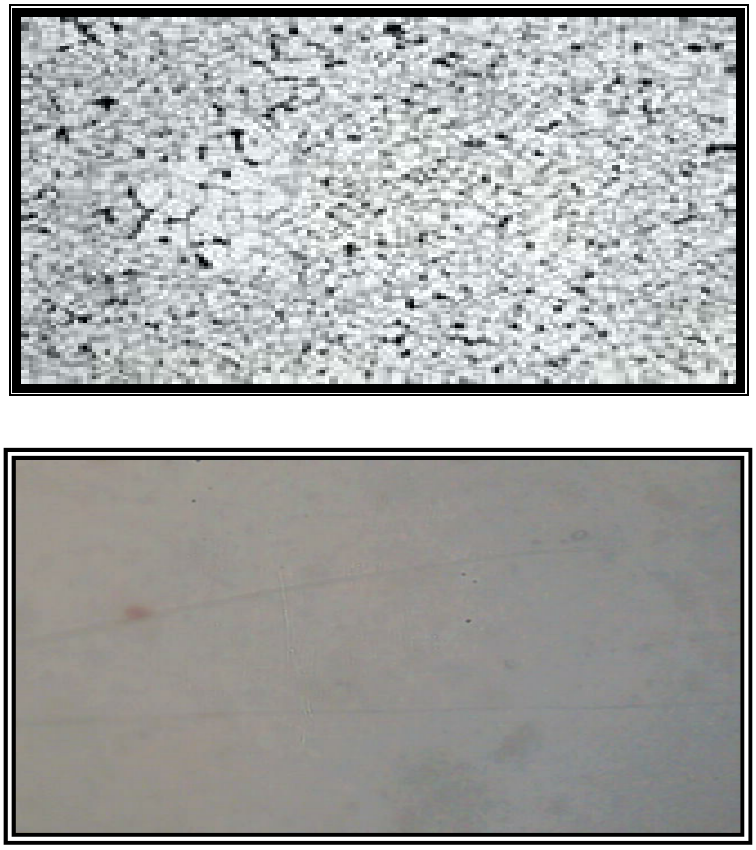

Figure (1) At the top AISI 316L before coating. At the bottom AISI with TiO_2 coating

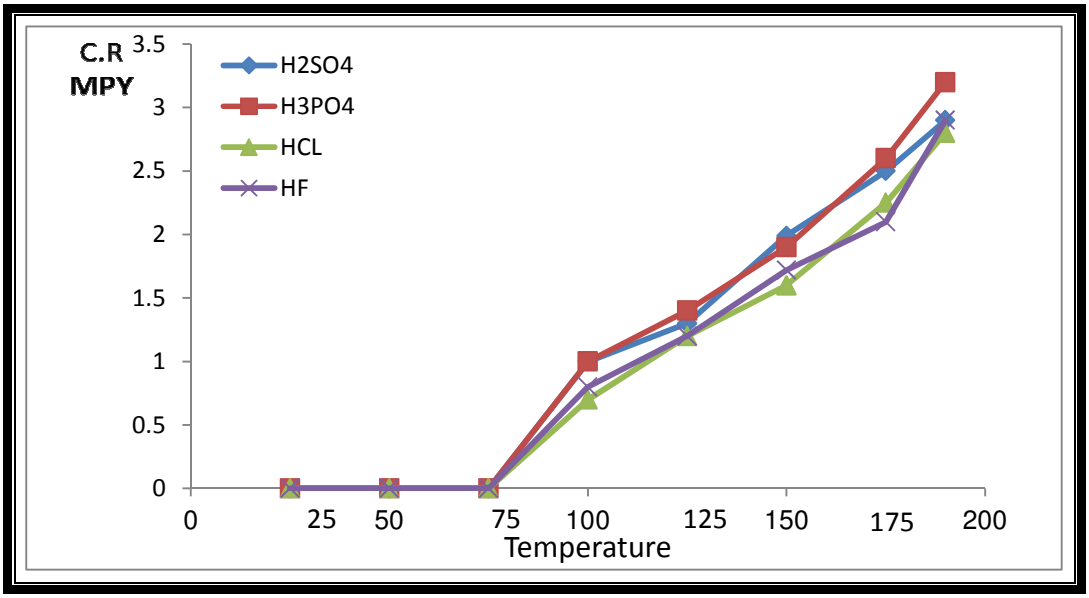

Figure (2) corrosion resistance of coated AISI316L at different acids with pH value 2

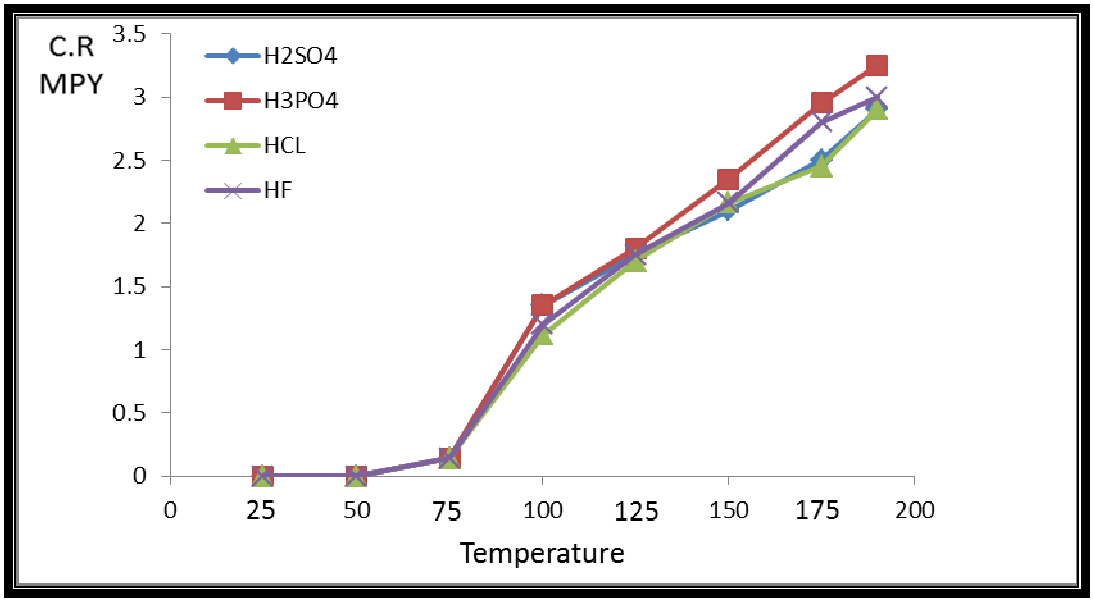

Figure (3) corrosion resistance of coated AISI316L at different acids with pH value 4

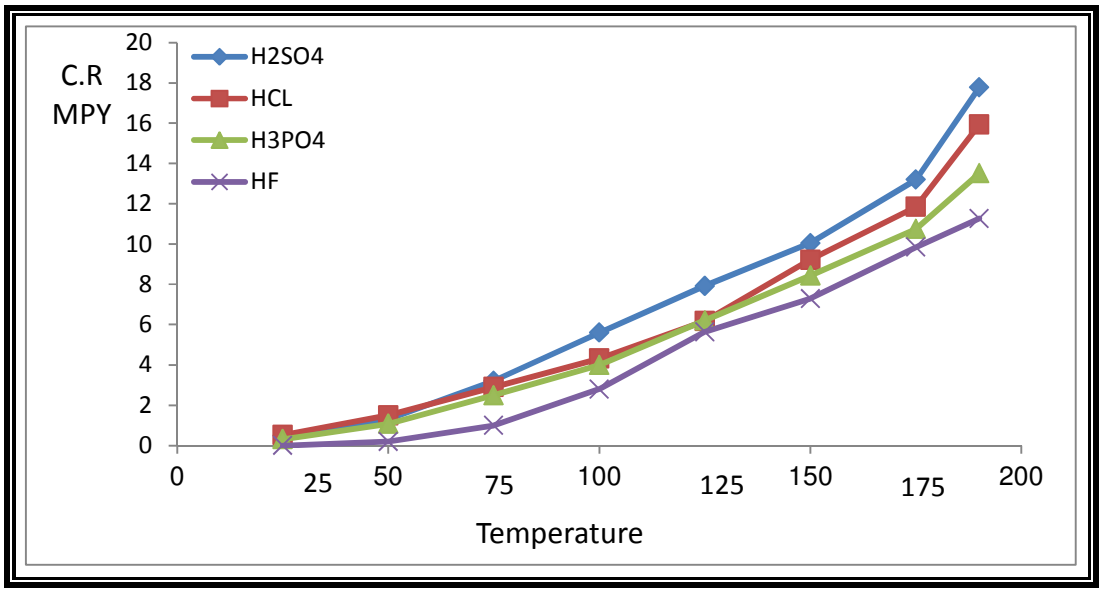

Figure (4) corrosion rate of uncoated AISI316L at different acids

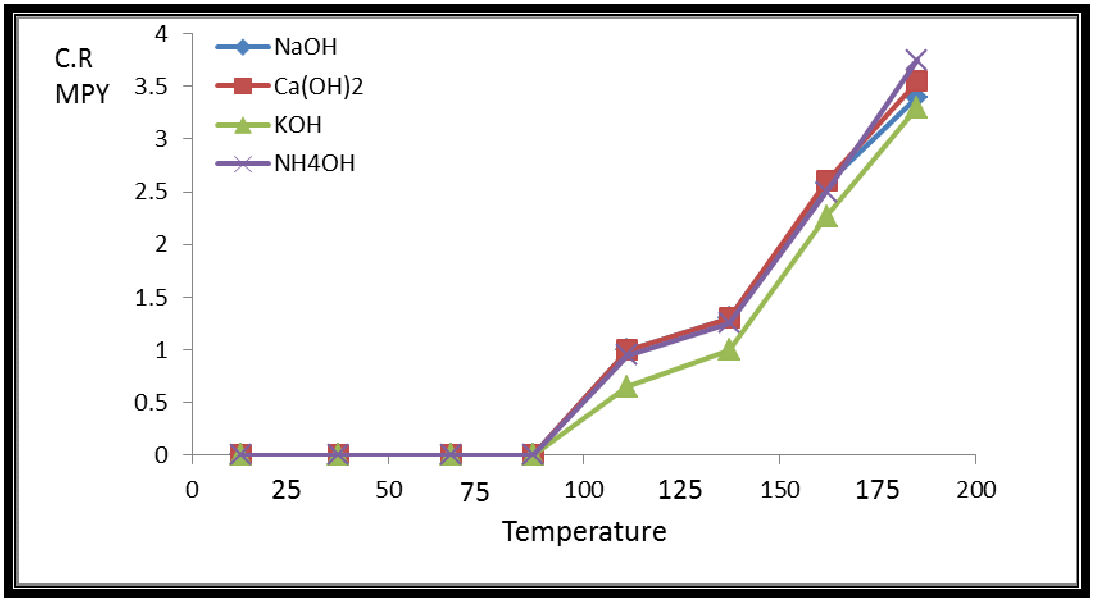

Figure (5) corrosion resistance of coated AISI316L at different basis with pH(10)

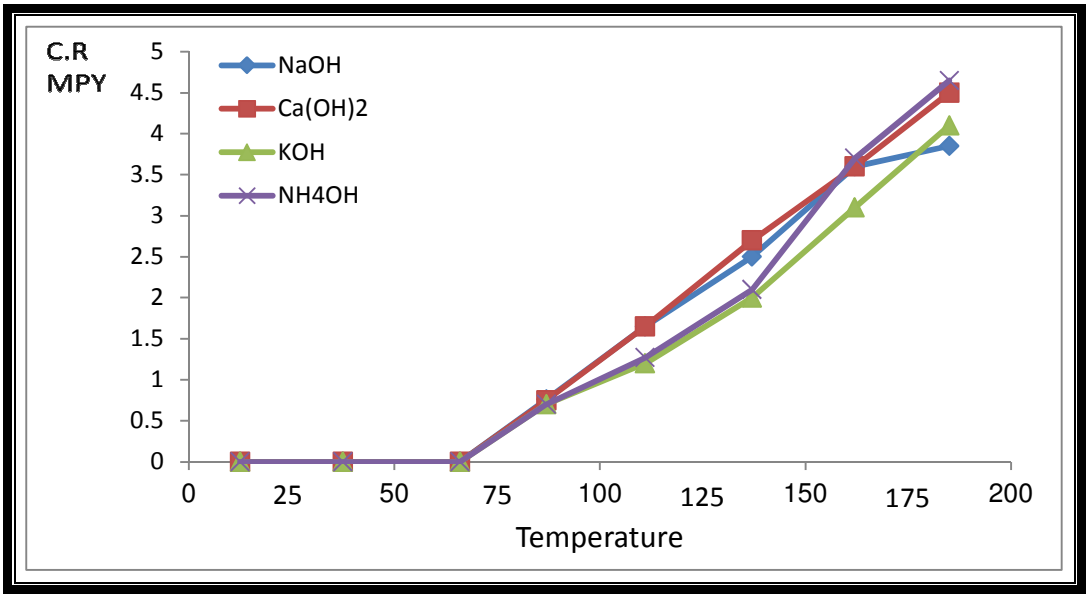

Figure (6) corrosion resistance of coated AISI316L at different basis with pH(12)

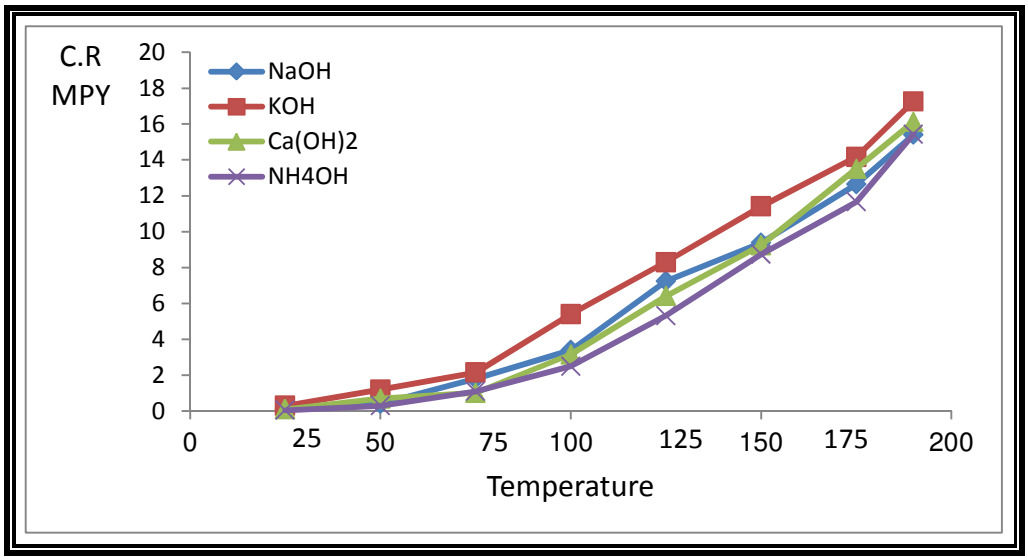

Figure (7) corrosion rate of un coated AISI316L at different acids