

CORROSION RESISTANCE OF ALUMINUM ALLOY 2024 - T6 AT MULTI VARIABLE (TEMPERATURE AND VELOCITY) IN SEA WATER

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Abstract:

This work aimed to study the corrosion resistance of aluminum alloy 2024 - T6 at multi variable temperatures and velocities in seawater. 2024-T6 is widely used in aircraft structures, especially wing and fuselage structures under tension.

The specimens were manufactured by dimensions of 1.5 cm length x 1.5 cm width x 0.2 cm thickness, According to ASTM (G71-30). Corrosion test was implemented by using potentiostatic polarization measurements in seawater 3.5%NaCl at a temperature of 25°C, 50°C and 75°C , velocity 1, 2, 3 m/min . The potential of circuit was determined by open circuit depending on AL in electrochemical series after that the rate of cell's current is changed due to $100 \pm (m v)$.

From result which obtained by Tafel equation. It was found that the corrosion resistance of 2024 - T6 Al alloy, increases with increasing velocity and decreases with increasing of temperature.

Keywords: corrosion resistance, aluminum alloy, velocity, temperature, seawater.

مقاومة التآكل لسبيكة الألمنيوم 2024-T6 تحت تأثير تغير كل من (درجة الحرارة و
السرعة) في ماء البحر

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الخلاصة :

في هذا البحث تم دراسة تأثير مقاومة التآكل لسبيكة من الألمنيوم 2024-T6 تحت عدة متغيرات (درجة الحرارة و السرعة) في ماء البحر . وتستخدم هذه السبيكة في صناعة هياكل الطائرات وخاصة اجنحة الطائرات وكذلك خزانات الوقود التي تعمل عند درجات حرارة عالية. حيث تم تصنيع عينات اختبار بابعاد بطول 1.5 وعرض 1.5x1.5 وسمك 0.2)سم وفق المواصفة القياسية ASTM(G71-30). ان اختبار التآكل اجري بطريقة المجهاد الساكن حيث تم تحديد فرق الجهد للمعدن من دائرة مفتوحة (O.P.C) اعتمادا على موقع الألمنيوم في السلسلة الكهروكيميائية بعدها تم تغير التيار للخلية بعد زيادة في فرق الجهد $100 \pm$ ملي فولت . وقد تم ايجاد تيار التآكل بطريقة تافل ثم حساب معدل التآكل من معادلة تافل. وقد وجد من النتائج التي تم الحصول عليها ان مقاومة التآكل للسبيكة تزداد بزيادة السرعة للوسط وتقل بزيادة درجة الحرارة .

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Introduction:

Aluminum is actually a very active metal and it instantly reacts with oxygen to form aluminum oxide. This aluminum oxide layer is chemically bonded to the surface, and it seals the core of aluminum from any further reaction. This oxide film gives aluminum excellent corrosion resistance in a wide range of water and soil conditions [1]. oxide layer can become unstable exposed to extreme PH levels when the environment is highly or basic acidic. Protective oxide film is generally stable in the PH range of (4.5 to 8.5). The PH of seawater remains within the domain of stability of the natural oxide film. This explains the good corrosion resistance of aluminum in seawater [2].

This resistance associated with its composition, structure, defect, surface condition and the various types of environments in seawater we can see that many variable parameters are affecting the corrosion resistance like speed of media and temperature, which was aim of this study: moving water is always better than stagnant water if all the parameter are kept constant.

Water movement regularly eliminates corrosion products and uniforms the cathode and anodic zones by removing a possible local excess of H^+ and OH^- ions in an open circuit moving water is aerates and oxygen up take the mission in repairing the oxide layer in closed circuit the movement of the liquid prevents the formation of deposits under which corrosion can easily develop aluminum can without any risk of corrosions from other hand the temperature of seawater [3]. Has also affect corrosion resistance as decrease with arise in temperature because temperature prevent oxygen from dissolve in water and thinning the protective layer or removed.

Many studies have investigation the corrosion resistance of aluminum studies alloy in seawater.

Majed and Huni (2009), [4]. Studied the effect of solution heat treatment on corrosion resistance in seawater at multi variables (speed and temperature) for 7020-T6 they found that corrosion resistance decrease in both variable because of intermetallic phases which obtained by heat treatment.

Mi nua, shao yu-Hua (2003), [5]. Studied the localized corrosion of aluminum alloy 2024 -T6 in chloride solution they indicated that localized Corrosion occurred on all 2024 -T-6 surface immediately because of increasing in potent ional, with increasing of immersed time.

Farouk and lamia (1999) [6]. studied the temperature effect on pitting corrosion resistance of pure aluminum 1100, it was Studied in temperature range (293 – 353) K using potentiodynamic and it is found that the temperature rise causes decrease of corrosion resistance and this behavior was attributed to the change in the oxide film nature and characteristics of the electrolyte.

In this present we study the effect of temperature and velocity of electrolyte (seawater) on corrosion resistance of aluminum alloy 2024 - T6.

Experimental Work

1- Metal Select

Aluminum alloy AA 2024 T6 was select Its chemical analysis is indicated in **Table (1)** which was conducted by ARL Spectrometer in the specialized institution of engineering industries of Industry ministry.

Table 1: Chemical composition for Aluminum Alloy AA (2024-T6)

Element	Al %	Ti%	Cr%	Zn%	Si%	Fe%	Mn%	Mg%	Cu%
Real value	92.6	0	0.05	0.1	0.4	0.3	0.6	1.5	4.4
Standard value	Rem.	0.15	0-0.1	0.25	0-0.5	0.5	0.3-0.9	1.2-1.8	3.8-4.9

2- Samples Preparation

Specimens were cut from sheet metal Al 2024 - T6 in dimensions (15 x 15 x 2) mm according ASTM (G71-30). The surface of all Specimens was grinded using emery papers of grad (400, 600 and 1000) and polished with alumina paste having 5 μ , and 0.5 μ the then cleaned with acetone then dried and placed in a sealed container for next step

3- Categorizations of Specimens:

After preparation, the specimens were categorized in the groups as shown in table (2).

Table (2): Categorization of specimens

Group	Solution temperature	Solution speed
A	Sea water at 25°C	1 m/min 2 m/min 3m/min
B	Sea water at 50°C	1 m/min 2 m/min 3m/min
C	Sea water at 75°C	1 m/min 2 m/min 3m/min

4- Electrochemical Tests

The prepared specimen in table 2 was fixed in the holder shown in Fig. (1). the reference electrode was fixed about 1 mm apart from the surface of the specimen to be tested.

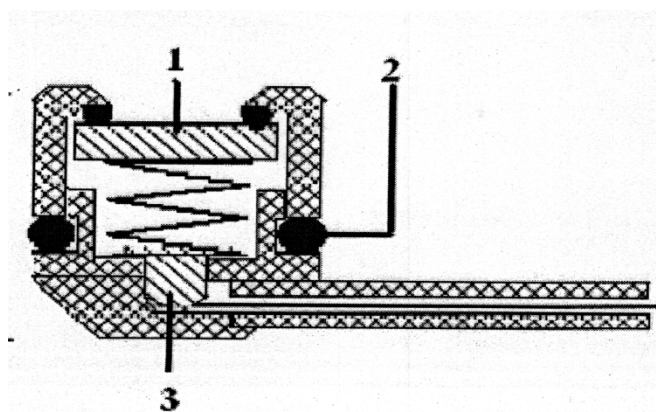


Fig (1): The specimen holder 1. Specimen 2. Seal 3. Electrical connection

The reference electrode used in this study was saturated calomel electrode (SCE). The auxiliary electrode used in the electrochemical cell was platinum type. The specimen holder (working electrode), together with the reference and auxiliary electrode were inserted in their respective positions in the electrochemical cell used for this purpose that can fit all these electrodes as shown in Fig.(2). The cell used was made of glass.

Constant potentials (anodic or cathode) can be imposed on the specimen, by using the potentiostat (Mlab200 of Bank Elect .Germany). This potentiostat is able to induce a constant potentials ranging from (-1 + I v). The potentials of the standard reference electrode used in this study (SCE).



Fig (2): A photograph of the electrochemical corrosion unit

The potential difference between the working and the reference electrode (WE - RE) and any current passing in the circuit of working electrode were the auxiliary electrode can be measured by using the SCI Computer Software. Any potential difference between the working and reference electrodes and also any current in the working electrode circuit can be automatically recorded. The results and plots were recorded using window XP.

Polarization resistance tests were used to obtain the micro cell corrosion rates. In the tests, cell current reading was taken during a short, slow sweep of the potential. The sweep was taken from (-100 to +100) mv relative to (OCP) [7, 8]. Scan rate defines the speed of potential sweep in mv /sec. In this range the current density versus voltage curve is almost nearly linear. A linear data fitting of the standard model gives an estimate of the polarization resistance, which used to calculate the corrosion current density (I_{corr}) and corrosion rate, and then corrosion rate is calculated using Tafel equation:

$$(C.R=0.13 \cdot I_{cor} \cdot \text{eq. Wt/d}) \quad [9] \text{-----} \quad (1)$$

i.e Corrosion rate (C.R) = $0.43 \cdot I_{cor}$

Where

mpy = milli – inchs per year

I_{cor} = corrosion current density ($\mu A/cm^2$)

d = density of corroding species (g/cm^3)

C.R= corrosion rate

wt. = weight

Results

Results are shown in Table (3), parameters such as corrosion potential (E_{corr}) and corrosion current (I_{corr}), of different temperature and velocity.

Table (3): E_{corr} , I_{corr} and corrosion rate for different samples

Sample	Temperature °C	Velocity m/min	E_{corr} [mV]	I_{corr} [$\mu A/cm^2$]	corrosion rate (Mpy) = $0.43 I_{corr}$
A	25 °C	1	-707.0	50.57	21.7451
	25°C	2	-687.2	11.76	5.0568
	25°C	3	-699.5	5.37	2.3091
B	50 °C	1	-747.0	65.54	28.1822
	50 °C	2	-738.1	12.87	5.5341
	50 °C	3	- 755.9	11.35	4.8805
C	75°C	1	-776.2	233.48	100.39
	75°C	2	- 766.5	95.34	40.9962
	75°C	3	- 757.5	66.81	28.7283

Discussions

From chemical composition , in table (1) it is clear that copper is the controlling main element with percentage 4% , this was giving alloys good electrical conductivity but poor corrosion resistance, it is often clad with aluminum or Al-1Zn for protection [10] because copper made for lower the hydrogen over voltage values since the hydrogen over voltage for copper and intermetallic compound is much lower than for aluminum in this case too the final corrosion potential is less noble than the initial value this might indicate that the material changed from the passive to the active state in further more.

This alloy shows much more general corrosion because copper waked the protective properties and anodizing use to improve the surface oxide stability when oxygen present in the aggressive medium is negligible [8, 11].

Fig (3) shows the corrosion behavior polarization curve for aluminum alloy 2024 - T6 in In sea water 3, 5 % Nacl and we see from cathode and anodic polarization curves different corrosion current density and potential for all specimens.

From table [3] which represents the corrosion rate calculations by using Tafel equation. We observed that when temperatures are increase cause decreasing in corrosion resistance for all specimens this because temperature prevent oxygen from dissolved in water and thinning the oxide layer when AL automatically combined, when it combine with oxygen and this layer never be combined after 120 °C [2]. The corrosion becomes continually on the other hand we see when velocity increase causes increasing in corrosion resistance for all specimens because velocity uniforms the cathode and anodic zones by removing possible local excess of H^+ and OH^- ions in an open circuit moving water is a crated and oxygen uptake contributes movement of liquid prevents the formation of deposits under which corrosion can easing develop AL can with is tend a water flow speed up to (2,3 - 3) m/s with out any risk of corrosion [12] .

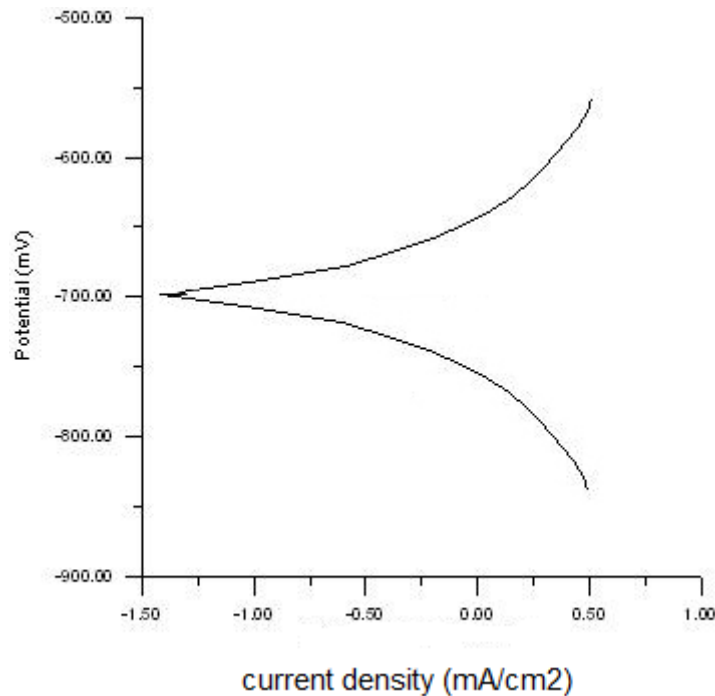


Fig (3): Sample A at 25°C in sea water, vel. 1

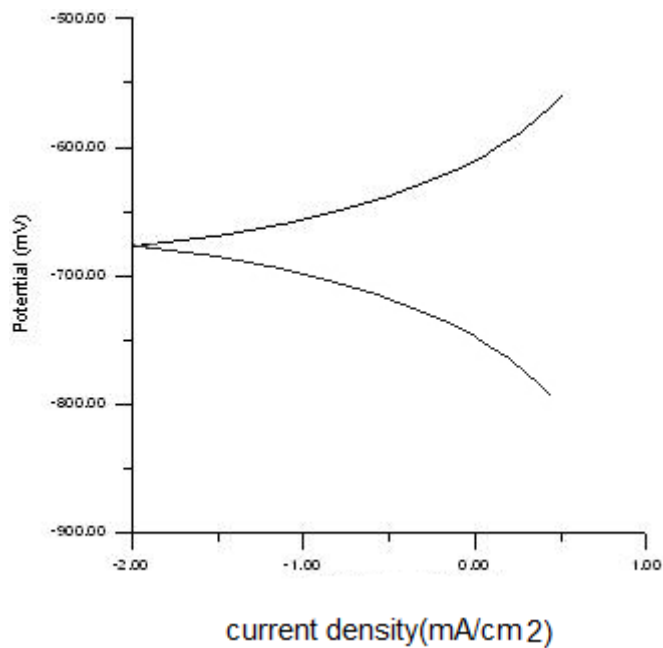


Fig (3): Sample A at 25°C in sea water, vel.2

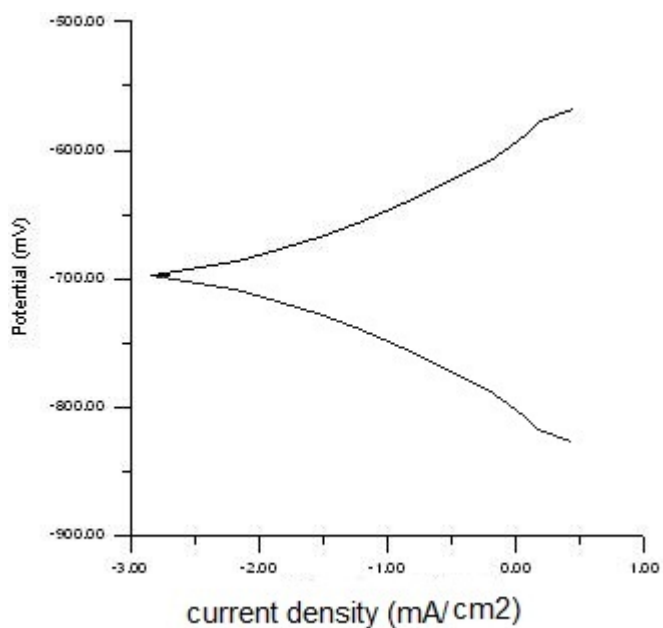


Fig (3): Sample A at 25°C in sea water, vel. 3

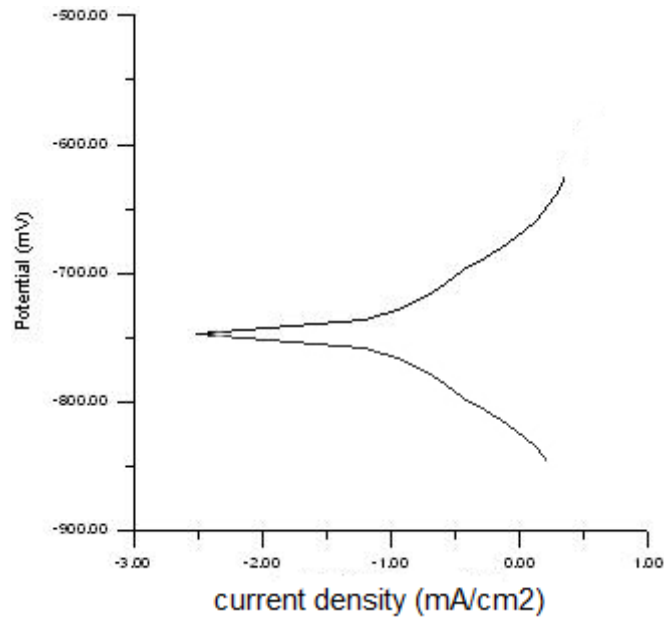


Fig (3): sample B at 50°C in sea water, vel. 1

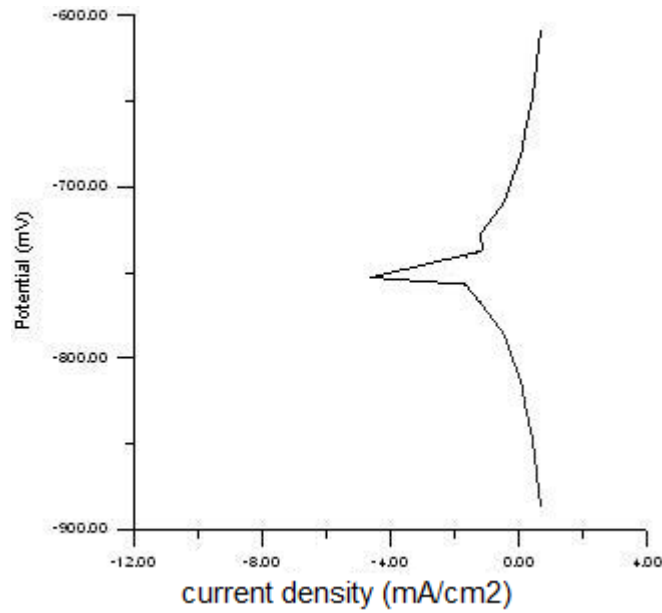


Fig (3): Sample B at 50°C in sea water, vel.2

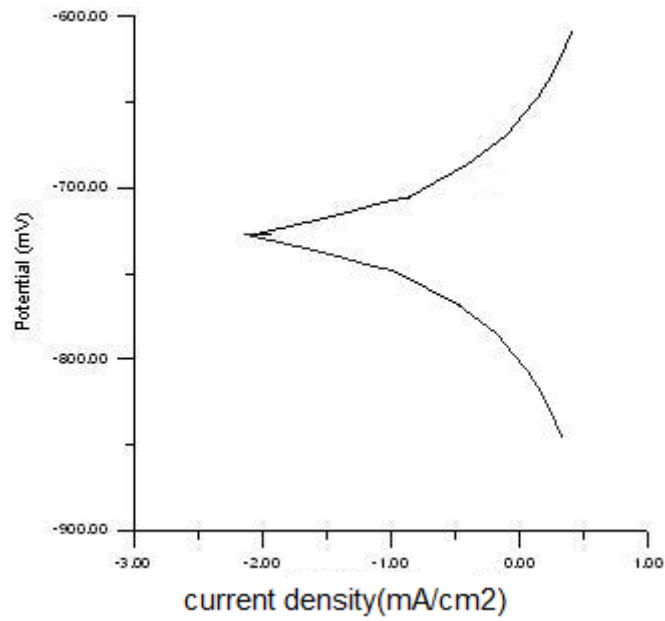


Fig (3): Sample B at 50°C in sea water, vel. 3

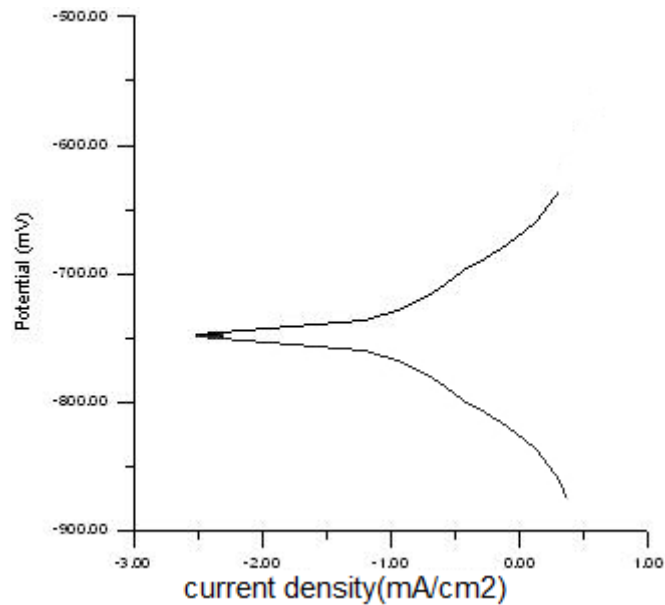


Fig (3): Sample C at 75°C in sea water, vel. 1

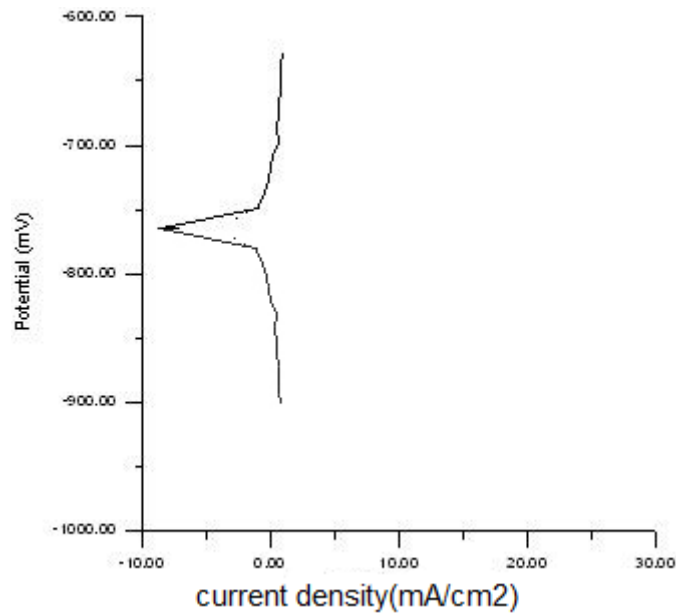


Fig. (3) Sample C at 75°C in sea water, vel. 2

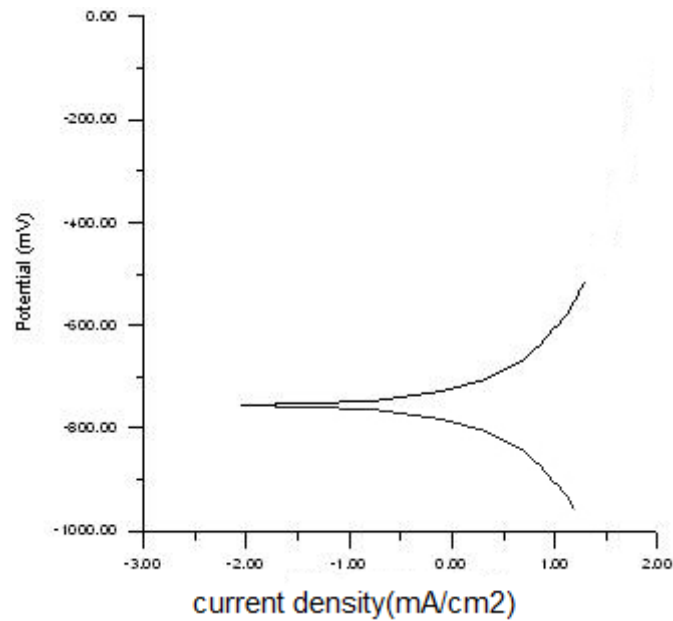


Fig (3): Sample C at 75°C in sea water, vel. 3

Conclusions

The results of this study tend to the following conclusions:

- 1 -As temperatures increase corrosion resistance decrease while increasing media velocity the corrosion resistance increased

1. The best temperature that gives the highest corrosion resistance is 25 °C
2. The best media velocity is 3m/min at 25 °C gives the best corrosion resistance

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