Corrosion Inhibition by *Tithonia diversifolia* (Hemsl) A. Gray leaves extract for 304 SS in hydrochloric acid solution

S Firdausi and F Kurniawan

Laboratory of Instrumentation and Analytical Sciences, Chemistry Department, Faculty of Mathematics and Natural Sciences, Institut Teknologi Sepuluh Nopember, Arief Rahman Hakim, Surabaya, 60111, Indonesia

*fredy@chem.its.ac.id

Abstract. The inhibition effect of *Tithonia diversifolia* (Hemsl) A. Gray leaves extract on the corrosion phenomena of 304 SS in 1 M HCl has been studied by polarization potentiodynamic. The powder of *T. diversifolia* was extracted by demineralized water which was cultivated in East Java, Indonesia. The extract was characterized by FTIR spectrophotometer. The presence of *T. diversifolia* can inhibit the corrosion rate of 304 SS. The efficiency inhibition value of 2 g/L *T. diversifolia* leaves extract reached up to 77.27% at room temperature.

1. Introduction
Many metals and alloy which used in human activities are susceptible to different mechanisms of corrosion due to their exposure in different corrosive media or environment to form a stable compound [1,2]. Each metal is subjected to its own unique corrosion process and it occurs very fast and continuously. Sometimes it is difficult to eliminate completely [3,4]. Corrosion problems cause economic losses in industry [5]. Stainless steel (SS) is a material which frequently used due to its resistant properties against corrosion. It was widely applied in industries and machinery [6-10]. In the other hand, acid solution can accelerate corrosion process on the surface of stainless steel and it had been a concern in industry [11]. Hydrochloric acid solutions are a chemical which commonly used for the removal of undesirable scale and rust in metal finishing industries, i.e. cleaning of boilers and heat exchanger [8,12-17]. So in order to prevent corrosion process in cleaning step, inhibitor corrosion is inevitably needed. It can be one of the best method in practice to protect metal surface from aggressive solution [12,18-21]. *T. diversifolia* is one of shrub plant which abundantly can be found in Indonesia. There is no report which uses the leaves as green corrosion inhibitor for 304 Stainless Steel in HCl. The aim of this research is to study the inhibition effect *T. diversifolia* leaves extract on the surface of 304 SS in 1M HCl.

2. Experimental

2.1. Specimen Preparation
The composition (wt%) of 304 SS specimens was as follows : 0.08% C, 2.00% Mn, 0.045% P, 1.00% Si, 18.00% Cr, 8.00% Ni and the balance Fe. The specimen was cut into dimension 4.0 cm × 1.0 cm × 1.0 mm with only 1 cm² exposed surface areas were used as working electrode in polarization measurement.
2.2. Electrolytic Solution
An aggressive solution was made from AR grade hydrochloric acid. 1 M HCl was prepared by dilution of 37% HCl (purchased from Merck, Germany) with demineralized water. A 50 mL aggressive solution was used in each polarization measurement.

2.3. Inhibitor
Fresh *T. diversifolia* leaves were collected from Institut Teknologi Sepuluh Nopember garden, Surabaya, Indonesia. The collected leaves were cleaned with water to remove small particle on the surface of it prior to use. Then they were dried for a weeks in air at room temperature. The dry leaves were grounded to powder. All the leaves powder obtained was dissolved in 90 °C of demineralized water (800 mL). These aqueous extract was stirred at 80 rpm for 30 minutes, then filtered using Buchner. The brown filtrate obtained was evaporated by hot plate for 4 h to remove the water as small as possible (not completely dry). Then the result obtained was dried in freeze dryer (FD-1A-50 Series) for 24 h. The extract obtained was stored in desiccator at room temperature before used.

2.4. Characterization of *T. diversifolia* leaves extract
The *T. diversifolia* extract, which was obtained from 2.3, was characterized using FTIR (Shimadzu-FTIR-8400S). The small amount of the extract was mixed with KBr powder until homogeneous. The mixture obtained was flattened and placed onto the sample holder for analysis.

2.5. Electrochemical measurement
Three electrode cell system were carried out for electrochemical measurement. It consists of specimens (304 SS) as working electrode (WE) with exposed area of 1cm², Ag/AgCl (KCl 3 M) as reference electrode (RE) and Platinum as counter electrode (CE). All electrochemical measurement was performed by Autolab PGSTAT128N which is provided by Nova 1.11 software. The potential was scanned from -700 mV to 700 mV with scan rate of 1 mV/s. The inhibitor effect was monitored by performing polarization potentiodynamic measurement on 304 SS in the absence and presence of 2 g/L of the inhibitor in 1 M HCl at room temperature.

3. Result and discussion

3.1. Characterization of *T. diversifolia* leaves extract
FTIR spectrum of *T. diversifolia* leaves extract is shown in Figure 1. The spectrum shows that *T. diversifolia* leaves extract has absorption of several functional groups. The 3398.8 cm⁻¹ band is assigned to O-H functional group. The 1124.54 cm⁻¹ is assigned to C-O functional groups, both of them indicate of alcohol groups and assumed as phenolic compounds. The peak at 2974.33, 1384.94 cm⁻¹ can be assigned to stretching and bending of C-H groups respectively [22]. It can be observed that there is an absorption at 1599.04 cm⁻¹ which assumed as C=C stretching which indicates for aromatic groups. The presence of electronegative atom (i.e O) and the double bond of aromatic group give potency of *T. diversifolia* as corrosion inhibitor. The free electron pairs from hydroxyl groups are able to interact with 304 SS surface to form thin protective layer which can inhibit the corrosion process.
3.2. Polarization potentiodynamic study

The study of *T. diversifolia* leaves extract inhibition on the surface of 304 SS was conducted using polarization potentiodynamic measurement. The Tafels obtained in the presence and in the absence were compared to see the effect of the inhibitor. The result can be seen at Figure 2. The corresponding electrochemical parameters including Tafel slopes ($b_a$, $b_c$), corrosion potential ($E_{corr}$), corrosion current density ($i_{corr}$) and inhibition efficiency ($\eta\%$) are given in Table 1. The inhibition efficiency ($\eta\%$) was calculated using expression given in Eq. (1) from the values of corrosion current density in the absence ($i_{corr}^0$) and presence ($i_{corr}$) of *T. diversifolia* [23]. The inhibition efficiency ($\eta\%$) is defined as:

$$\eta\% = \frac{i_{corr}^0 - i_{corr}}{i_{corr}^0} \times 100$$

(1)

The inhibition efficiency value indicates the capability of inhibitor to reduce the corrosion rate on the surface of 304 SS in 1 M HCl. There is the significant difference between corrosion current density of blank and inhibitor. The $i_{corr}^0$ is corrosion current density for the blank, which has a higher value (109.830 µA) and the $i_{corr}$ is the corrosion current density for 304 SS in the presence of inhibitor (24.962 µA).
The polarization curves show a clear difference between the 304 SS in absence and presence of inhibitor. The black line shows the polarization curve of 304 SS in the absence of inhibitor. In the other hand, the red line shows the polarization curve of 304 SS in the presence of *T. diversifolia* leaves extract. The corrosion potential ($E_{corr}$) shifts to cathodic as 48.41 mV. Furthermore, it has been observed that the corrosion rate decrease in the presence of 2 g/L *T. diversifolia* leaves extract. The *T. diversifolia* leaves extract provides protection up to 77.27% at room temperature.

| Concentration (g/L) | $b_a$ (mV/dec) | $b_c$ (mV/dec) | $E_{corr}$ (mV) | $I_{corr}$ (µA) | $C_R$ (mmpy) | $\eta$% |
|---------------------|---------------|---------------|----------------|-----------------|---------------|---|
| Blank               | 982.240       | 74.666        | -384.060       | 109.830         | 109.830       | 1.27620 | - |
| 2                   | 956.060       | 600.662       | -335.650       | 24.962          | 24.962        | 0.29006 | 77.27 |

## 4. Conclusion

The *T. diversifolia* leaves extract can be used as green corrosion inhibitor for 304 SS in 1 M HCl at room temperature. The presence of electronegative atom (i.e O) and the double bond of aromatic group give potency of *T. diversifolia* as corrosion inhibitor. The inhibition efficiency of *T. diversifolia* leaves extract reach up to 77.27% which achieved by addition 2 g/L *T. diversifolia* leaves extract.

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