*International Research Journal of Innovations in Engineering and Technology (IRJIET)*

ISSN (online): 2581-3048

Volume 6, Issue 10, pp 19-28, October-2022

https://doi.org/10.47001/IRJIET/2022.610004

# Testing of Corrosion Rate in Orthodontic Devices with Stainless Steel Material 316L on the Application of Saliva Solution and Surface Roughness

**[1]Gunawan Dwi Haryadi, [2]*Dwi Basuki Wibowo, [3]Agus Suprihanto, [4]Joshua Misael**

[1,2,3,4]Mechanical Engineering, Diponegoro University, Semarang, Indonesia

*Corresponding Author E-mail: dwibasukiwibowo@lecturer.undip.ac.id

***Abstract*** **- Currently, more and more people in Indonesia and even the world are experiencing malocclusion, both women and men. According to WHO in 2003, the results of a survey through the Dental Aesthetic Index (DAI) showed the incidence of malocclusion was 66.67% [1]. Orthodontic wire (arch wire) is an active component of fixed orthodontic appliances that are used to move teeth. Stainless steel orthodontic wire is the wire that is most often used today in orthodontic treatment. Stainless steel orthodontic wire is more widely used because of its super elastic properties[2]. One type of stainless steel used for orthodontic wire is type 316L. In the oral cavity 316L stainless steel wire is always in direct contact with saliva and can cause corrosion, therefore the test was carried out using the weight loss method and the linear polarization method.**

**The difference in surface roughness in 316L stainless steel affects the corrosion rate of the specimen. Surface roughness with a roughness value of 0.172µm produces a corrosion rate of 0.1629 mm/y, while a surface with a roughness value of 0.042µm produces a corrosion rate of 0.0815mm/y in artificial saliva immersion for 8 weeks using the weight loss method. For the linear polarization method, the corrosion rate value of 0.00067mm/y was found at the surface roughness with a value of 0.024µm, while for the surface roughness with a value of 0.176µm, the corrosion rate value was 0.16356mm/y. This indicates that the rougher the specimen surface, the higher the corrosion rate value obtained.**

**The use of 316L stainless steel material can be used for orthodontic wire as long as it has a surface roughness value not exceeding 0.051µm.**

***Keywords:*** Corrosion, Stainless Steel 316L, Weight Loss Method, Linear Polarization Method.

## I. INTRODUCTION

Nowadays, more and more Indonesians and even the world are experiencing malocclusion, both women and men. Malocclusion is a condition of discrepancy in both the location of the teeth and the relationship between the upper jaw and the lower jaw to their normal condition. According to WHO in 2003, the results of a survey through the Dental Aesthetic Index (DAI) showed a malocclusion incidence rate of 66.67%[1].

*Orthodontics* is one of the branches of dental science that studies the growth, development, variation of the face, jaw and teeth and their repair treatments for the achievement of normal occlusion[3]. Orthodontic treatment is a treatment that aims to correct various malocclusion problems and their impact on problems in the oral and maxillofacial cavity area[4]. Orthodontic treatment done early on will prevent complex orthodontic treatment at an advanced age[5].

Orthodontic wire (arch wire) is an active component of a fixed orthodontic appliance used to move teeth. *Stainless steel* orthodontic wire is the most commonly used wire today in orthodontic treatment. Stainless steel orthodontic wire is more widely used due to the super elasticity properties it possesses [2]. The selection of *stainless-steel*brackets is often used because it has several advantages such as better mechanical components, a more economical price, and resistance to corrosion. This advantage is not possessed by brackets made of plastic or ceramics [6]. 316L *stainless steel* orthodontic wire contains 75% *Ferrum*, 16% *Chromium*, 2%, 10% *Nickel*, 0.03% *Carbon* and other components.

Inside the oral cavity *316L stainless steel* wire is always in direct contact with saliva. The degree of acidity of saliva may change at any time. One of the things that causes changes in the pH of saliva is the consumption of carbonated drinks that have an acidic pH[7]. The presence of 316L *stainless steel* wire and an acidic atmosphere in the oral cavity that occurs continuously can cause many detrimental impacts for the use of orthodontic wire. In *the stainless-steel* wire submerged in carbonated drinks, there will be a release of ions from the metal that makes up the wire. The effect of releasing ions on the wire causes the deformation of the wire so that it can change the characteristics of the wire[8].

 

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Corrosion is the result of the interaction of metal materials with the surrounding environment. This corrosion can occur due to the presence of two reactions, namely oxidation and reduction reactions. In oxidation reactions, there will be a release of electron ions by anodic materials, while in the process of reduction, there will be the capture of electron ions by cathodic materials[9]. The corrosion rate that occurs in 316L stainless steel braces in the oral cavity can be caused by several factors, one of which is temperature. An increase in temperature can affect the reaction rate of the oxide on the bracket or increase the environmental ability to oxidize the metal. This is because the increase in temperature is directly proportional to the increase in the corrosion constant. In addition to temperature, the degree of acidity also affects the corrosion rate. Acids are an indicator of corrosion in metals. The lower the acid value in an environment, the more it will increase the release of electron ions contained in the metal in the corrosion process[10].

The bracket placed in the oral cavity for a long time will affect the *surface characterization* of the bracket, which was originally smooth to rough due to the corrosion process. The occurrence of corrosion in the metal bracket, will affect the level of roughness on the *surface characterization* [11][12]. This can affect the effectiveness of tooth movement. In addition, the formation of a gap in the bracket due to changes that occur in *surface characterization*, can provide an opportunity for the attachment of *Streptococcus mutans* bacteria to the bracket[13][14]. This condition is also able to have a detrimental impact on friction on the bracket, thereby affecting the quality of performance and biocompatibility of the orthodontic bracket[15].

Corrosion rate is the event of propagation of corrosion processes that occur in a material. It can be interpreted as material that is lost in units of time. The method that can be used to measure the corrosion rate of metals is the method of losing weight, measuring the dimensions and density of corrosion currents. Some alloys already have a potential corrosion value in materials that are generally used in the manufacture of structures so that we can take data on the potential corrosion value of existing materials to be used as a reference in the selection of materials to be used in research[16].

### 1.1 Method

The process of preparing the test sample has 3 stages, namely cutting the test sample, making the corrosion test mounting, roughing the test sample. For each of the preparation processes, it is described below:

*Stainless Steel* 316L plates are cut into several parts with dimensions of 10 x 10 x 6 mm. The cut 316L *Stainless Steel* Plate is then *polished* with sandpaper gradually from *grit* 240 to 1200, adjusting to the variation in roughness that is in demand for this test.

The manufacture of corrosion test *mounting* is carried out so that the test sample is placed on a medium to facilitate handling without damaging the sample. Mounting manufacture *using* 11/2 Inch PVC pipe with a height of 20 mm per test specimen. The test sample will later be soldered with an electrical cable for the corrosion rate testing process of the test sample.

The roughing of the test sample is carried out as a variation in the test, the roughness variation used in this test consists of 3 different roughness, that are grit 400, 800, and grit 1200 sandpaper.

The next process is testing test samples; this process has 3 types of testing, namely surface roughness testing, corrosion rate testing with *weight* loss method, and corrosion rate testing with linear polarization method. For each of the testing processes, it is described below:

Surface roughness testing is carried out to determine the effect of differences in roughness on the surface on the corrosion rate that occurs. The roughness measurement parameter is measured by calculating the difference in the deviation of the original surface from the ideal surface by the magnitude of the distance. Large deviations can be known that the surface is rough, and vice versa small deviations indicate that the surface is smooth.

The method used to calculate the corrosion rate is the weight loss method. This method involves the process of cleaning and weighing before corrosion and cleaning and weighing after corrosion[17]. Calculation of the corrosion rate of weight loss by weighing each specimen of the initial and final weight after soaking for 6 weeks or 1008 hours.

Corrosion testing on metals or alloys can be carried out by the method of linear polarization curves. The effect is that if the anode and cathode present in an electrolyte are briefly connected, then anodic and cathodic reactions will take place and the electrochemical cell system will come out of equilibrium. The polarization test is carried out by changing the electrode potential then monitoring the voltage generated to find out the average corrosion and the level of resistance to corrosion[18].

### 1.2 Theoretics

Corrosion rate is the event of propagation of corrosion processes that occur in a material. It can be interpreted as material that is lost in units of time. The corrosion rate units

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vary according to the units used, including mm / y (international standard or mpy (British)).

**Table 1: Table of Corrosion Rate Unit Constants**

| Corrosion Rate Unit | Constant (K) In Corrosion Rate Equation |
|---|---|
| Mils per year (mpy) | $3{,}45x10^6$ |
| Inches per year (ipy) | $3{,}45x10^3$ |
| Inches per mounth (ipm) | $2{,}87x10^2$ |
| Milimetres per year (mm/y) | $8{,}76x10^4$ |
| Micrometres per year (µm/y) | $8{,}76x10^7$ |
| Picometres per second (pm/s) | $2{,}78x10^6$ |

The method that can be used to measure the corrosion rate of metals is the method of losing weight, measuring the dimensions and density of corrosion currents. Some alloys already have a potential corrosion value in materials that are generally used in the manufacture of structures so that we can take data on the potential corrosion value of existing materials to be used as a reference in the selection of materials to be used in research[16].

The calculation method in accordance with the weight loss method testing standard refers to ASTM G31-72 *Standard Practice for Laboratory Immersion Corrosion Testing of Metal*. The data obtained will be used as a reference in the corrosion rate analysis testing process. The calculation method used refers to the calculation of the formula of erosion corrosion rate in general with the equation CR (mm / y) = (K x W) / (A x H x D). This analysis aims to obtain comparative data from the calculation of weight loss of each sample[19].

$$CR = \frac{K \ x \ W}{A \ x \ t \ x \ D}$$

Where *CR* is the corrosion rate of the tested material (mmpy), W is the weight lost during corrosion (mg), K is the constant (mm/y), A is the cross-sectional area ($cm^2$), *t* is the corrosion/soaking test time (hours), and D is the density of the test material ($gr/cm^3$).

The polarization test is carried out by changing the electrode potential then monitoring the voltage generated to find out the average corrosion and the level of resistance to corrosion[18]. In the polarization test, a measurement of the corrosion rate is carried out based on changes in the electrical potential for changes in current. Then the test results will appear in the form of data which are then processed into curves. This curve shows the corrosion activity on the metal surface. This test is carried out with a test tool, namely Galvanostat or Potentiostat. This technique is used to measure resistance polarization (polarization resistance). Polarization resistance is the resistance of a sample to oxidation as long as it is given an outer potential. Rp is used to measure the speed of corrosion. Before measuring the corrosion speed should determine the Icorr (immersion corrosion) first.

The following formula describes the relationship between Rp and lcorr[20].

$$\frac{\Delta E}{\Delta I} = Rp = \frac{\beta_A \cdot \beta_C}{(\beta_A + \beta_C)(2{,}3.Icorr)}$$

Where, Icorr is the corrosion current (mA), Rp is the polarization resistance, $\beta_A$ is the anodic table constant, and $\beta_C$ is the cathodic table constant.

The amount of Rp is calculated analytically through the relationship between current and voltage, which is depicted by a graph as in Figure 2.

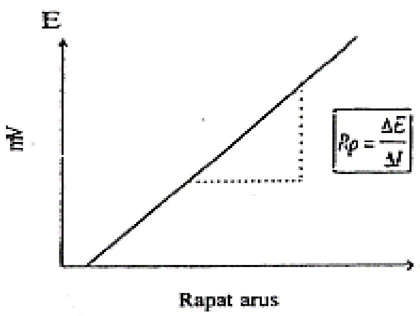


**Figure 1: Polarization Resistance Curve**

From the obtained Icorr entered into the Icorr formula determination of the corrosion rate: The result of corrosion testing with the linear polarization curve method will produce a polarization curve, namely the curve between the potential and the current density (log i). From the polarization curve, the corrosion rate can be calculated by determining the meeting of the exchange current for the electrolyte metal system. The corrosion rate (Cr) in units of mils per year (milli inch per year) can be calculated based on the following equation:

$$CR = \frac{0{,}1279\text{ai}}{\eta D}(mpy)$$

Where (a) is the atomic weight of the corroded metal (grams/mol), (i) is the density of the corrosion current ($\mu A/cm^2$), (n) is the number of electrons per mole involved, and (D) is the specific gravity of the corroded metal ($gr/cm^3$). In addition to its corrosion rate, the tendency of metals to experience one form of corrosion attack can also be foreseen from the shape of its polarization curve. Based on the polarization curve, it can be seen whether the metal or alloy is subjected to even corrosion, passivation, or experiences both[21].

 

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## II. SPECIMEN CORROSION TESTING

Corrosion testing is carried out by 2 methods, the first method is *the weight loss* method and the second method is by the linear polarization method using the Corrtest CS300H corrosion test equipment.

### Corrosion Test of Weight Loss Method

Specimen preparation and corrosion test with weight loss method is carried out by cutting 316L stainless steel plates with a size of 10 x 10 mm as many as 9 pieces, then polished using sandpaper starting from grits 400, 800 and 1200, before starting soaking the specimen must first be cleaned with distilled water and acetone to remove residual dirt. The test was carried out in 3 variations of roughness: 400, 800, 1200. Calculation of the corrosion rate of weight loss by weighing each specimen of the initial and final weight after soaking for 6 weeks or 1008 hours.

Specimens are immersed in an artificial saliva solution (pH 7) using a plastic vessel container. Data collection is carried out once a week, each specimen is re-weighed using an analytical balance with a level of accuracy reaching 0.01 gr so that later it gets a lost weight value (W), then it can calculate the corrosion rate with the equation according to the applicable standards.

### Electrochemical Corrosion Testing Linear Polarization Method

Corrtest CS300H corrosion test equipment uses 3 electrode cell type electrochemical methods (accelerated corrosion rate testing) with polarization of free corrosion potential. The scheme of the corrosion test equipment type 3 electrode cells will be described as follows:

1. *Working electrode*. The working electrode as an electrical will be studied using 316L *stainless steel*.
2. Auxiliary electrode (*counter electrode*). The auxiliary electrode serves to transport current in the circuit formed in the study but the auxiliary electrode cannot be used for potential measurement. The material of this auxiliary electrode usually uses a carbon rod, in addition to a carbon rod, it can also use platinum and gold.
3. Reference *electrode*. The reference electrode is an electrode that is used as an excellent base point to refer to the measurements of the potential of the working electrode. The current flowing through this electrode is very small otherwise it will participate in the cell reaction, so the potential is no longer constant.

## III. RESULTS AND DISCUSSIONS

### Roughness Test Results

This test is carried out to determine the surface roughness value of the specimen after the sanding process. To obtain the profile of a surface, in this experiment a measuring instrument called the Portable Surface Roughness Tester was used by the Mitutoyo SURFTEST SJ-210 model measuring range of 17.5 mm (X axis) and 260 µm (Z axis). Where the touching needle of the measuring instrument moves along a trajectory in the form of a straight line with a distance determined in advance, which is 4 mm. The length of the trajectory is called the measurement length immediately after the needle moves and shortly before the needle stops, then electronically the measuring instrument performs calculations based on data obtained from the touching needle.

The surface roughness value for specimens using the *weight loss* method that has been sanded by sanding with 400 grit sandpaper produces three different values, namely, 0.171 µm, 0.179 µm, and 0.172 µm, with an average roughness value of 0.174 µm. For specimens with grit sandpaper 800, it produces values of 0.032 µm, 0.033 µm, and 0.032 µm, with an average roughness value of 0.032 µm. Specimens the last with 1200 grit sandpaper yielded values of 0.019 µm, 0.014 µm, and 0.016 µm, with an average roughness value of 0.016 µm.

The results of the specimen surface roughness test for testing by the linear polarization method after going through the sanding process with grits of 400, 800 and 1200. Sanding with 400 grit sandpaper produces three different values namely, 0.169 µm, 0.184 µm, and 0.176 µm, with an average roughness value of 0.176 µm. For specimens with grit sandpaper of 800 produce values of 0.051 µm, 0.052 µm, and 0.051 µm, with an average roughness value of 0.051 µm. The last specimen with grit sandpaper 1200 produced a value of 0.029 µm, 0.019 µm, and 0.025 µm, with an average roughness value of 0.024 µm.

**Table 2: Roughness Test Results**

| Grid Amplas | Metode *Weight Loss* | Metode Polarisasi Linear |
|---|---|---|
| | Rata-Rata Ra(µm) | |
| 400 | 0.174 | 0.176 |
| 800 | 0.032 | 0.051 |
| 1200 | 0.016 | 0.024 |

### Weight Loss Method Corrosion Testing Results

The results of the *weight* loss method corrosion testing were obtained by studying the behavior *of* 316L stainless steel specimens by calculating the weight loss of the specimen

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Volume 6, Issue 10, pp 19-28, October-2022
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against the length of time of immersion in an artificial saliva solution. The pattern observed for cumulative specimen weight loss versus dyeing time as in figure 1 shows the relationship between roughness and corrosion rate of 316L *stainless steel* specimens after exposure to artificial salivary solutions.

The effect of immersion time on the corrosion rate of 316L *stainless steel* specimens in artificial Saliva solution is shown in figure 1 below.

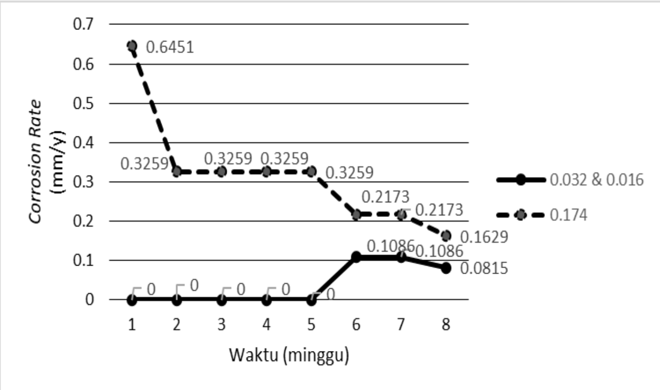


**Figure 2: CR vs Time Weight Loss Corrosion Test Results**

Figure 3 explains the relationship between immersion time and corrosion rate in 316L *stainless steel* specimens in saliva solution. The corrosion rate for surface roughness with sandpaper grit 800 and 1200 has the same result, where there is no change in the corrosion rate at week 1 to week 4 and only begin to show changes in week 6. The highest corrosion rate was experienced by 316L *stainless steel* specimens with a sandpaper grit of 400 of 0.6451 mm/y in the first week and decreased over time. However, the corrosion rate resulting from the surface roughness of the sandpaper grit is 400 higher than the surface roughness of the 800 and 1200 grit is because the coarser *stainless steel* metal surface will cause potential differences and tend to become a corroded anode. The rougher the surface of a metal causes in homogeneness on the surface; this is one of the main causes of corrosion.

The passive layer is formed because the longer the steel is corroded, the thicker the rust layer. The thick layer of rust caused the electrochemical reaction not to go well. So that the content of pollutants dissolved in artificial salivary solutions cannot attack the metal. The presence of a passive layer plays a role in protecting this stainless-steel material from corrosion attacks in the artificial saliva water environment. However, over time the layer will disappear and cause corrosion.

The effect of immersion time on the surface roughness of 316L *stainless steel* specimens in an artificial saliva solution is shown in figure 2 below.

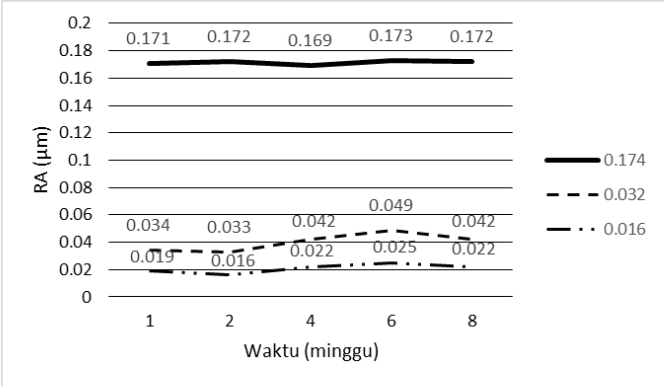


**Figure 3: Ra vs Time Weight Loss Corrosion Test Results**

As time goes by the soaking, the tendency of surface roughness will increase; this is due to the rough corrosion layer that covers the surface of the 316L*stainless steel* material.

### Corrosion Test Linear Polarization Method

The polarization test is carried out to obtain the corrosion rate using the principle of three electrode cells consisting of three kinds of electrodes. The first electrode is a working electrode (Working electrode), which is a designation for the electrode being tested. The surface area of this electrode affects the rate of corrosion that will occur. Then there is a counter electrode that plays a role in lifting the current in the circuit. Usually, these electrodes use carbon or platinum rods. But in this study, the auxiliary electrode used was a platinum type. Furthermore, there is a reference electrode which acts as the base point for referring to the measurements of the potential of the working electrode. The current flowing in this electrolysis should be very small. Therefore, auxiliary electrodes are needed in these three-electrode cells. The reference electrode used is Ag/Agcl. The electrolyte solution used is an artificial saliva solution (Artificial Saliva). From testing the corrosion rate this time using the CORRTEST CS300H Potentiostat tool, a corrosion rate value will be obtained on each specimen tested.

The results of this experiment were then processed using NOVA software and obtained a potential vs current graph. Then a tangential slop line is created on the graph so that the observational Ecorr and calculated Ecorr values have close to the same value. Furthermore, the value of the corrosion current is obtained which is then divided by the value of the surface area dipped in the electrolyte solution. After that, the results are made in the form of logarithms so that a potential graph vs. I/A logs is obtained as shown in Figures 6 and 7.

### Grit 400 Corrosion Testing Results

The corrosion rate is determined by drawing a tangential line on the table diagram with the help of four points to create

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**ISSN (online): 2581-3048**

**Volume 6, Issue 10, pp 19-28, October-2022**

https://doi.org/10.47001/IRJIET/2022.610004

two lines whose meeting points are the value of the corrosion rate that occurs.

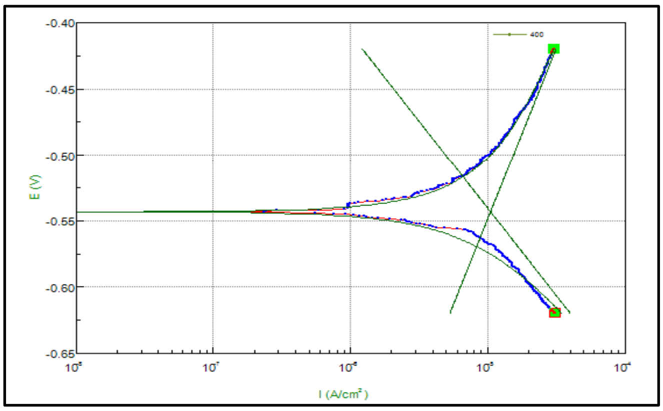


**Figure 4: 400 Sandpaper Grit Roughness Table Graph**

Graph The table obtained for testing the specimens above is an overview of the test results with variations in the type of roughness using a sandpaper grit of 400. For testing other specimens with 2 specimens of the same roughness can be seen in the attachment, a graph will appear as above. From the lines formed in the graph will be done fitting as precisely as possible to get the midpoint which is the intersection point of the two graphs, so that a green line will appear that also intersects each other. After the cut line is formed, the software will show the result of the corrosion rate value that occurred in the specimen.

The final value of the corrosion rate of specimens with roughness using grit 400 can be seen in the table below,

**Table 3: Corrosion Test Results of Linear Polarization Method Grit Sandpaper 400**

| Material | Ecorr (V) | Icorr (A/cm²) | Ba (mV) | Bc (mV) | CR (mm/y) | CR Rata – Rata (mm/y) |
|---|---|---|---|---|---|---|
| 400 A | -0,543 | 1,051 | 77,696 | 52,29 | 0,10948 | 0,16356 |
| 400 B | -0,585 | 2,094 | 60,948 | 67,373 | 0,21807 | |
| 400 C | -0,585 | 1,566 | 97,466 | 48,273 | 0,16313 | |

From the data in Table 2, it can be seen that the potential, current density and corrosion rate can change in each specimen. This can occur due to several factors such as differences in surface roughness in each specimen. However, these values do not change significantly from other values. In specimen 400A the corrosion rate value in the specimen is 0.10948 mm/y, in specimen 400B it has a corrosion rate of 0.21807 mm/y, and in specimen 400C it has a corrosion rate of 0.16313 mm/y so that the average value of the corrosion rate that occurs in the specimen tested is 0.16356 mm/y.

## Grit 800 Corrosion Testing Results

Graph The table of corrosion tests using linear polarization with a sandpaper grit roughness of 800 can be seen in figure 7 below.

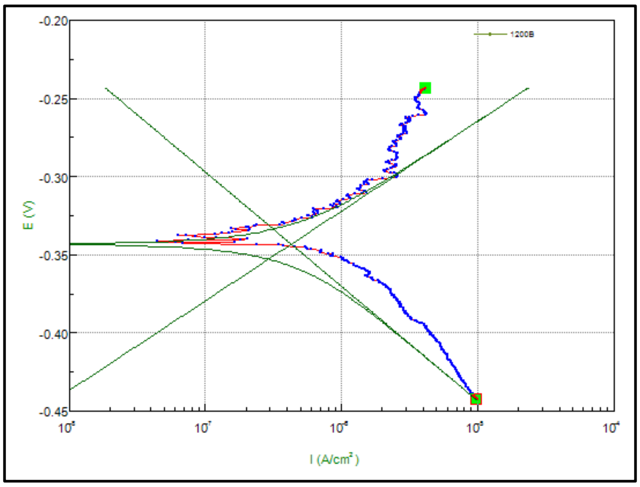


**Figure 5: 800 Sandpaper Grit Roughness Table Graph**

Graph The table obtained for testing the specimen above is an overview of the test results with variations in the type of roughness using grit sandpaper 800. For testing other specimens with the same roughness specimens can be seen in the attachment, a graph will appear as above. From the lines formed in the graph will be done fitting as precisely as possible to get the midpoint which is the intersection point of the two graphs, so that a green line will appear that also intersects each other. After the cut line is formed, the software will show the result of the corrosion rate value that occurred in the specimen.

**Table 4: Corrosion Test Results of Linear Polarization Method Grit Sandpaper 800**

| Material | Ecorr (V) | Icorr (A/cm²) | Ba (mV) | Bc (mV) | CR (mm/y) | CR Rata – Rata (mm/y) |
|---|---|---|---|---|---|---|
| 800 A | -0,033 | 1,894 | 28,107 | 167,91 | 0,00197 | 0,00249 |
| 800 B | -0,343 | 4,286 | 57,382 | 73,184 | 0,00446 | |
| 800 C | -0,246 | 1,019 | 67,231 | 63,051 | 0,00106 | |

From the data in Table 3, it can be seen that the potential, current density and corrosion rate can change in each specimen. This can occur due to several factors such as differences in surface roughness in each specimen. However, these values do not change significantly from other values. In specimen 800A the corrosion rate value in the specimen is 0.00197 mm/y, in specimen 800B it has a corrosion rate of 0.00446 mm/y, and in specimen 800C it has a corrosion rate of0.00106 mm/y so that the average value of the corrosion rate that occurs in the specimen tested is 0.00249 mm/y.

 

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### Grit 1200 Corrosion Testing Results

Table graph of corrosion tests using linear polarization with a sandpaper grit roughness of 1200 can be seen in figure 5 below.

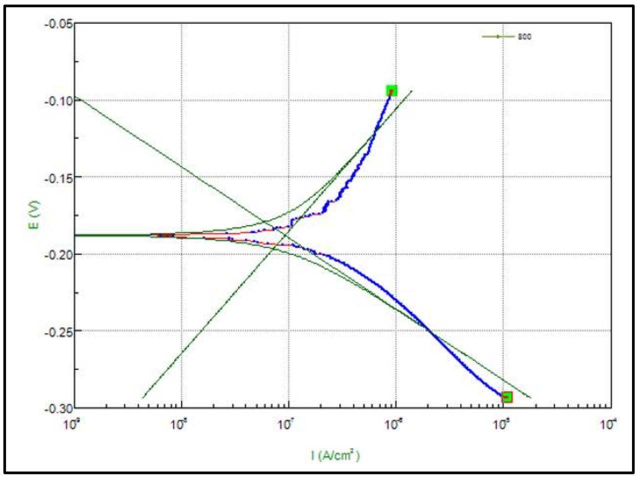


**Figure 6: Grit Sandpaper 1200 Roughness Table Graph**

Graph The table obtained for testing the specimens above is an overview of the test results with variations in the type of roughness using grit sandpaper 1200. For testing other specimens with the same roughness specimens can be seen in the attachment, a graph will appear as above. From the lines formed in the graph will be done fitting as precisely as possible to get the midpoint which is the intersection point of the two graphs, so that a green line will appear that also intersects each other. After the cut line is formed, the software will show the result of the corrosion rate value that occurred in the specimen.

**Table 5: Corrosion Test Results of Linear Polarization Method Grit Sandpaper 1200**

| Material | Ecorr (V) | Icorr (A/cm²) | Ba (mV) | Bc (mV) | CR (mm/y) | CR Rata – Rata (mm/y) |
|---|---|---|---|---|---|---|
| 1200 A | -0,188 | 9,254 | 79,46 | 46,173 | 0,00096 | 0,00067 |
| 1200 B | -0,099 | 2,706 | 42,958 | 65,86 | 0,00028 | |
| 1200 C | -0,189 | 7,492 | 70,959 | 50,386 | 0,00078 | |

From the data in Table 4, it can be seen that the potential, current density and corrosion rate can change in each specimen. This can occur due to several factors such as differences in surface roughness in each specimen. However, these values do not change significantly from other values. In specimen 1200A the corrosion rate value in the specimen is 0.00096 mm/y, in specimen 1200B it has a corrosion rate of 0.00028 mm/y, and in specimen 1200C it has a corrosion rate of 0.00078 mm/y so that the average value of the corrosion rate that occurs in specimens with surface roughness using grit sandpaper 1200 is 0.00067 mm/y.

### Linear Polarization Method Corrosion Testing Results

The curve of this table is current vs potential. The x-axis is the value of the corrosion current, while the y-axis is the corrosion potential. So, the x/y axis is an interpretation of i/v, it shows the value of conductivity. So that the more upright the line formed, the more conductive the material will be. Figure 7 shows the corrosion rate of different surface roughness using the linear polarization method.

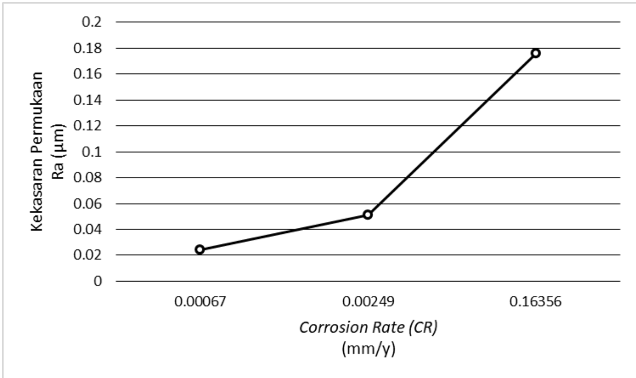


**Figure 7: Linear Polarization Corrosion Test Results**

The uneven surface of the metal will facilitate the occurrence of the poles of charge (positive and negative charges), which will eventually play the role of anode and cathode in electrochemical reactions. A smooth and clean metal surface will cause corrosion to occur, because it is difficult for poles to occur that will act as anodes and cathodes. An uneven surface facilitates the occurrence of poles – charge poles, which will eventually act as anodes and cathodes. A rough metal surface will cause potential differences and is more likely to be an anode[22]. Therefore, the corrosion rate will increase as the metal surface gets rougher. This is in line with the results of previous studies [23], when the surface roughness value increases, the corrosion rate will also be greater (directly proportional).

### Material Resistance to Corrosion Rate

The results of the material's resistance to corrosion rates can be seen from the provisions that have been regulated by one of the reference books used[24], the category of damage incurred by a corrosion attack is regulated by the magnitude of the value of the corrosion rate that occurs in the test specimen. The unit used in this test is mm/y.

**Table 66 Levels corrosion resistance *Weight Loss* Method**

| Spesimen | Kekasaran Permukaan (µm) | Laju Korosi (mm/y) | Level Ketahanan Korosi |
|---|---|---|---|
| 400A | 0,171 | 0,1629 | *Good* |
| 800A | 0,032 | 0,0815 | *Excellent* |
| 1200B | 0,014 | 0,0815 | *Excellent* |

 

*International Research Journal of Innovations in Engineering and Technology (IRJIET)*

ISSN (online): 2581-3048

Volume 6, Issue 10, pp 19-28, October-2022

https://doi.org/10.47001/IRJIET/2022.610004

In Table 5, the corrosion resistance level for *316*L stainless steel material was obtained by testing *the weight* loss method with the levels of "Good' and "Excellent". For 400A specimens with a corrosion rate of 0.1629 mm /y within a period of 8 weeks or 1344 hours, the corrosion resistance level is "*Good*" where the level shows quite satisfactory results, while for specimens 800A and 1200B with a corrosion rate value of 0.0815 mm / y within a period of 8 weeks or 1344 hours geta satisfactory "*Excellent*" corrosion resistance level.

**Table 7: Levels corrosion resistance Linear Polarization Method**

| Spesimen | Kekasaran Permukaan (µm) | Laju Korosi (mm/y) | Level Ketahanan Korosi |
|---|---|---|---|
| 400A | 0,169 | 0,10948 | *Good* |
| 800A | 0,051 | 0,00197 | *Outstanding* |
| 1200A | 0,029 | 0,00096 | *Outstanding* |

In Table 6, the corrosion resistance level for *316*L stainless steel material was obtained by testing the linear polarization method with the levels of "*Good*" and "*Outstanding*". For 400A specimens with a corrosion rate of 0.10948 mm / y based on the reference table, they get a corrosion resistance level of "*Good*" where the level shows quite satisfactory results, while for specimens 800A and 1200A with corrosion rate values of 0.00197 mm / y and 0.00096 mm / y respectively get an "Outstanding" corrosion resistance level where the level shows very satisfactory results.

From table 5 and table 6, it can be interpreted that the use of 316L stainless steel material can be applied as one of the braces materials where on the surface saliva is directly exposed with a high level of intensity but with a surface roughness of at least 0.051 and below.

**Comparison of Corrosion Test Results *of Weight Loss* Method with Linear Polarization**

From the results of the study and analysis of corrosion rate resistance to the difference in surface roughness that has been carried out on 316L stainless steel material, it is obtained that surface roughness greatly affects the level of corrosion rate of *stainless-steel* material 316L. Where the greater the roughness values of *stainless-steel*material 316L, the higher the corrosion rate that occurs. From the test results using 2 different methods, it was found that significant differences in results were found for specimens with surface roughness using sandpaper grit 800 and grit 1200.

It can be seen in Figure 7 where the comparison of corrosion rates between *Weight Loss* and Linear Polarization tests with surface roughness using grit sandpaper 400 there was a difference at the beginning of the test but over time it showed almost the same results.

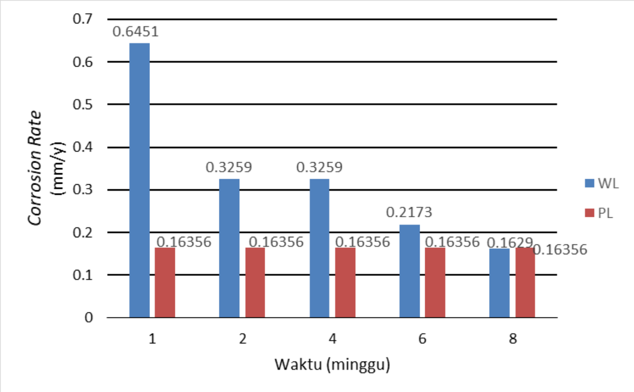


**Figure 8: Comparison of Corrosion Test Results *of Weight Loss* Method and Linear Polarization of 400A Specimens**

In 800A specimens using 800 sandpaper grit, a significant difference was seen between the two test methods carried out, this occurs because the time for *weight loss* testing is less long so that the corrosion rate obtained is only limited to 8 weeks, which for a longer time is expected to produce smaller corrosion rate results and can be close to the results of testing linear polarization methods. The difference in the results of the corrosion rate using *the weight loss* method and linear polarization for the 800A specimen can be seen in figure 8 below.

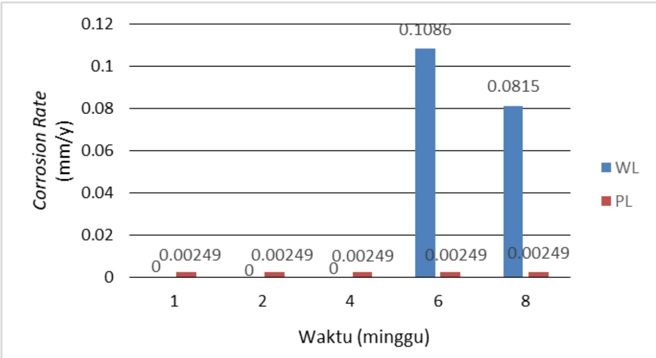


**Figure 9: Comparison of Corrosion Test Results *of Weight Loss* Method and Linear Polarization of 800A Specimens**

A smooth and clean metal surface will make it difficult for corrosion to occur, because it is difficult for the poles to act as cathodes and anodes. Therefore, the corrosion rate will increase as the metal surface gets rougher.

## IV. CONCLUSION

Based on the results of the research that has been done, some conclusions can be drawn as follows:

1. Surface roughness greatly affects the corrosion rate of *stainless-steel* material 316L. The rougher the surface of the material, the higher the corrosion rate will be and

ISSN (online): 2581-3048
Volume 6, Issue 10, pp 19-28, October-2022
https://doi.org/10.47001/IRJIET/2022.610004

vice versa if the surface of the material is smoother, the corrosion rate will be lower.

2. The best results of this study were in the 1200B specimen for *the weight loss* method with a corrosion rate value of 0.0815 mm / y with a surface roughness value of 0.014 μm and for the linear polarization method in the 1200B specimen with a corrosion rate value of 0.00028 mm / y with a surface roughness of 0.019 μm. The rougher the surface of a metal causes inhomogeneness on the surface which causes potential differences and tends to become a corroded anode.
3. 316L stainless steel material gets an "Outstanding" corrosion resistance level which means that the use of 316L stainless steel material can be applied as one of the orthodontic aids materials where on the surface is exposed saliva directly with a high intensity level.

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*International Research Journal of Innovations in Engineering and Technology (IRJIET)*

**ISSN (online): 2581-3048**

**Volume 6, Issue 10, pp 19-28, October-2022**

https://doi.org/10.47001/IRJIET/2022.610004

**Citation of this Article:**

Gunawan Dwi Haryadi, Dwi Basuki Wibowo, Agus Suprihanto, Joshua Misael, "Testing of Corrosion Rate in Orthodontic Devices with Stainless Steel Material 316L on the Application of Saliva Solution and Surface Roughness" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 6, Issue 10, pp 19-28, October 2022. Article DOI https://doi.org/10.47001/IRJIET/2022.610004

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