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Effects of Seawater (Salt Water) to Aisi 304 Mechanical Properties

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Abstract: A study on stainless steel AISI 304 is conducted to find out its corrosion rates and the effects to its mechanical properties that occur when AISI 304 is immersed in salt water containing 30%, 33% and 35% salt within one, two and three weeks time period of immersion. About 10 specimens in tensile test specimen shape were used where nine specimens were immersed and one specimen without immersion is used as control specimen to compare the corrosion rates and the effects between specimens immersed and not immersed. CCK equipment (cell corrosion kit) was used to determine the corrosion, which the rate stated in mm/year based on tafel graph plot that created. In this study, the corrosion rate increases as the period of immersion and salt contain increases. The highest corrosion rate that was obtained is occurred with immersion of three weeks and 33% salt contain in salt water which is 0.02087 mm/year and the lowest corrosion rate is occurred with immersion of one week and 30% salt contain in salt water which is 0.001612 mm/year. The effects of AISI 304 mechanical properties were determined by tensile test and hardness test. The hardness of specimens was obtained using Rockwell Hardness Test. The hardness of specimens decreases as the period time of immersion increases and salt contain increases. The highest hardness of specimen is with immersion of one week and 33% salt contain in salt water which is 19.76HRC and the lowest hardness of specimen is with immersion of three weeks and 35% salt contain in salt water which is 13.37HRC. In tensile test, the maximum load and maximum stress were determined. The highest maximum load of specimen is occurred with immersion of one week and 30% salt contain in salt water which is 46.88kN. The lowest maximum load of specimen is occurred with immersion of three weeks and 33% salt contain in salt water which is 40.61kN. For maximum stress, the highest maximum stress of specimen is occurred with immersion of one week and 30% salt contain in salt water which is 5.38 N/mm^2. The lowest maximum stress of specimen is occurred with immersion of three weeks and 33% salt contain in salt water which is 4.66 N/mm2. According to the optical microscope, we can see the corrosion effects more clearly. The corrosion occurs with small hole and undercutting shape. Type of corrosion that occurs is pitting corrosion.

Key words:

INTRODUCTION

Corrosion process is the reaction between steel or alloy with its environment. The effects of corrosion process have given lots of problem in industrial development. Corrosion problem has given financial loss to many companies and country due to overcome this problem. This includes recognizing and understanding the corrosion mechanisms using high corrosion resistance and protections system. This study is to help the corrosion problem that occurs especially in seawater.

The main objective of this study is to assess the mechanical properties of AISI 304 stainless steel due to seawater (saltwater) effects and to study the type of corrosion that occurs after immersion in salt water. The percentage of salt in salt water, temperature and time period of immersion influences the corrosion rate of AISI 304.

In this study, there are several scopes that were fixed. The scope of this study includes temperature, percentage of salt and time period of immersion. Temperature will be the fixed parameter which is at 27°C. Time period of immersion will be done within one week, two weeks and three weeks. For the percentage of salt in the salt water, 30%, 33% and 35% of salt contain in salt water will be used. Immersion in salt water will be done replacing immersion in seawater. This is because of the percentage of salt contain can be fixed. For example in one week time period, immersion is done in salt water with percentage of salt contain 30%, 33% and 35%. Testing that has been done after immersions are corrosion testing using CCK (cell corrosion Kit) equipment, tensile test, hardness test, and microstructure analysis using optical microscope.

From related theoretical review, the main effect of corrosion is salinity.The main effects of salinity on corrosion result from its influence on the conductivity of the water and from the influence of chloride ions on

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the breakdown of passive films. Specific conductance varies with temperature and chlorinity. The high conductivity of seawater means that the resistance of the electrolyte plays a minor role in determining the rate of corrosion reactions and that surface area relation play a major role.

For example, a large area of cathodic metal such as stainless steel will produce more severe galvanic attack on an anodic metal in seawater than in freshwater because high conductivity allows the entire area of stainless steel to participate in the reaction. Similarly, pitting corrosion tends to be more intends in seawater because large areas of boldly exposed cathode surface are available to support the relatively small anodic areas at which pitting takes place.

The second effect of salinity on corrosion in seawater is related to the role of chloride ions in the breakdown of passivity on active-passive metals such as stainless steel. The higher the salinity of the water, the more readily chloride ions succeed penetrating the passive film and initiating pitting and crevice corrosion at localized sites on the metal surface. For alloys that corrode uniformly, variations in corrosion rate due to salinity changes are small compared to those caused by changes in oxygen concentration and temperature.

From related previous project, several conclusions that can be made.Highest corrosion rate occurs in seawater compared to distilled water, river water and tap water. When pH is increased, there is an increase to the corrosion rate. Weight loss is higher in seawater corrosion. Besides that, pH and salinity influences the corrosion rate. Chloride ions from water will increase the corrosion rate and the materials become corrode faster.

Methodology:

Based on the scopes of the project study, some techniques are selected to gather information and data. Compatibility in tool selection is also very important and attention should be given. This is to ensure the use of machines and experiment procedure which had been fixed.

All specimens will firstly be named for certain different specification. Nine specimens were used which are named as specimen A, specimen B, specimen C, specimen D, specimen E, specimen F, specimen G, specimen H, specimen I and specimen J. Each specimen names imply immersion hours in salt water with different percent of salt content and the temperature is fixed. Figure 1 shows specimens name that indicates the experiment scopes for the specimen.

Specimen	Salt Content (%)	Time Period of Immersion (Weeks)
A	30	3
B	33	3
C	35	3
D	30	2
E	33	2
F	35	2
G	30	1
H	33	1
I	35	1
J	-	-

Fig. 1: Specimens name that indicates the experiment scopes for each specimen.

Salt water is provided as a medium for immersion test and as a medium for corrosion test replacing seawater. An amount weight of salt is dissolved in an amount volume of distilled water. For salt water with 30% salt content, salt for 300g is dissolved in 1000ml distilled water. For salt water with 33% salt content, salt for 330g is dissolved in 1000ml distilled water. Lastly for salt water with 35% salt content, salt for 350g is dissolved in 1000ml distilled water

Immersion process in salt water was done in room temperature. Three different basin filled with different percentage of salt contain in salt water was prepared. In salt water with 30% salt content, specimen A, specimen D and specimen G is immersed. In salt water with 33% salt content, specimen B, specimen E and specimen H is immersed. In salt water with 35% salt content, specimen C, specimen F and specimen I is immersed. For one week of immersion, specimen G, specimen H and specimen I was carried out. For two week of immersion, specimen D, specimen E and specimen F was carried out. Figure 2 shows positioning of specimen immersed in salt water.

Corrosion rate was determined using CCK (cell corrosion kit). Tafel graph ware used to identify the corrosion rate of specimens. Salt water with different percentage of salt content was used as the corrosion testing medium. In current range of 1ma to 1µA was used. The output of graphical plot log current (log I) versus voltage (V) was carried out as the experiment result.

Hardness of specimens then was determined using Rockwell Hardness test. Hardness test was done by using diamond bit with load of 150 kg. Value of hardness is in HRC unit.

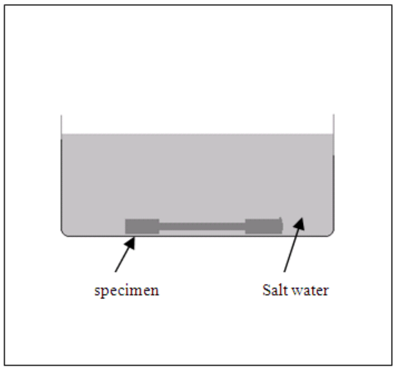

Fig. 2: Positioning of specimen immersed in salt water.

Tensile testing was done using Universal Testing Machine GOTECH Model GT-001-LC110. Specimen is assembled on framework and crosshead and a load was produced to the specimen. The movement and measurementswill directly produce experiment data to the computer.

The specimen surface photos were taken using an optical microscope. Optical microscope was used to see the corrosion effects to specimen's surface. Maximum magnification of 100x were used. The samples were conveniently prepared for observation.

RESULT AND DISCUSSION

The result of corrosion rate is shown in table in figure 3. For immersion in salt water with 30% salt content, corrosion rate for specimen J is 0.001135 mm/year. For specimen G which was immersed in salt water with 30% salt content for one week, corrosion rate is 0.001612 mm/year. For specimen D which was immersed in salt water with 30% salt content for two week, corrosion rate is 0.003446 mm/year. And for specimen A which was immersed in salt water with 30% salt content for three week, corrosion rate is0.00743 mm/year.For immersion in salt water with 33% salt content, corrosion rate for specimen J is 0.003204 mm/year. For specimen H which was immersed in salt water with 33% salt content for one week, corrosion rate is 0.009957 mm/year. For specimen E which was immersed in salt water with 33% salt content for two week, corrosion rate is 0.01191 mm/year. And for specimen B which was immersed in salt water with 33% salt content for three week, corrosion rate is 0.02087 mm/year.For immersion in salt water with 35% salt content, corrosion rate for specimen J is 0.004811 mm/year. For specimen I which was immersed in salt water with 35% salt content for one week, corrosion rate is 0.01089 mm/year. For specimen F which was immersed in salt water with 35% salt content for two week, corrosion rate is 0.01578 mm/year. And for specimen C which was immersed in salt water with 35% salt content for three week, corrosion rate is 0.01755 mm/year.

Specimen	Salt Content (%)	Immersion time period (week)	Corrosion Rate (mm/year)
A	30	3	0.00743
B	33	3	0.02087
C	35	3	0.01755
D	30	2	0.003446
E	33	2	0.01191
F	35	2	0.01578
G	30	1	0.001612
H	33	1	0.009957
I	35	1	0.01089
J	30	0	0.001135
J	33	0	0.003204
J	35	0	0.004811

Fig. 3: Corrosion rate result.

Figure 4 shows graph plot for specimen's corrosion rate value after immersion. From the graph in figure 4, graph shows an increasing in corrosion rate when immersion time period increases. Salt water contains chloride ion than can destroy the passive layer and protective film on specimen. When specimen is immersed longer, surface of specimen is longer exposed to ion chloride and this will increase the corrosion rate to the specimen.Specimens with large area of cathodic will produce severe galvanic attack on anodic areas. With ion chlorides, salt water has a high conductivity and allows the entire specimen to participate in the reaction. In theoretical, higher percentage of salt content in salt water gives corrosion rate higher to the material. In this experiment, corrosion rate for specimen B which was immersed in 33% salt content in salt water gives higher corrosion value then value of corrosion rate to specimen C which was immersed in 35% salt content in salt water. Corrosion rate value for specimen C should be higher than value of corrosion rate for specimen B in theory. In this study, it is possibly caused by any impact or vibration during shaping the specimen using lathe machine. Higher impact and vibration will make the surface of passive layer become weak. This happens to specimen B and thus gives higher corrosion rate to specimen B then specimen C. All corrosion rates are categorized as excellent and very good from Fontana's description for metal corrosion rate.

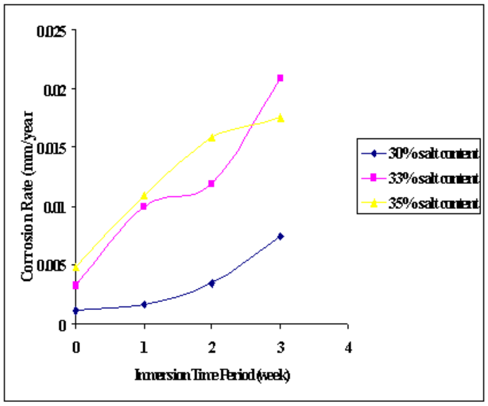

Fig. 4: Corrosion rate versus time period of immersion graph.

Specimens will weigh first before immersed in salt water. After immersion, specimens will weigh once again to find its weight loss. Table in figure 5 shows the result of weight loss of specimens after immersion. For specimen G which was immersed in salt water with 30% salt content for one week, weight loss is 0.004 gram. For specimen D which was immersed in salt water with 30% salt content for two week, weight loss is 0.014 gram. And for specimen A which was immersed in salt water with 30% salt content for three week, weight loss is 0.015 gram. For specimen H which was immersed in salt water with 30% salt content for one week, weight loss is 0.006 gram. For specimen E which was immersed in salt water with 30% salt content for two week, weight loss is 0.015 gram. And for specimen B which was immersed in salt water with 30% salt content for three week, weight loss is 0.018 gram. For specimen I which was immersed in salt water with 30% salt content for one week, weight loss is 0.008 gram. For specimen F which was immersed in salt water with 30% salt content for two week, weight loss is 0.016 gram. And for specimen C which was immersed in salt water with 30% salt content for three week, weight loss is 0.017 gram. Figure 6 shows graph plot weight loss versus time period of immersion. The shape of the graph shows when time period of immersion increases, weight loss will increase. It is the same as corrosion rate versus time period of immersion graph. This is because when corrosion rate increases, weight loss of material will also increase. Weight loss will also increase when salt content in salt water increase.

Specimen	Weight Loss (gram)
A	0.015
B	0.018
C	0.017
D	0.014
E	0.015
F	0.016
G	0.004
H	0.006
I	0.008

Fig. 5: Weight loss of specimens.

Hardness test was done after specimens were immersed in salt water. It was also done to specimen J for reference value. Three readings were taken from different spot of specimen and the average value was taken. Table in figure 7 shows the result of hardness value for each specimen. In figure 8 shows the hardness value of specimen versus time period of immersion graph. From this graph, shows a reducing value of hardness due to time period of immersion reducing. This happens when specimen is immersed within longer period of time, specimen is exposed to ion chlorides longer. When percentages of salt contain increase, the hardness value will decrease. This is because of more ion chloride in the salt water and this will increase the breakdown of passive layer and will reduce the corrosion resistance. When corrosion happens, mechanical properties of specimen will reduce and hardness of specimen will also reduce. In this study, difference between reducing of hardness value is small because AISI 304 is a good resistance to corrosion and has good mechanical properties. This is because SS has a passive layer film which will protect the steel from corrosion effects.

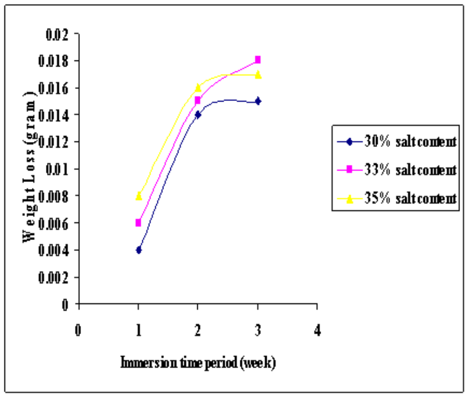

Fig. 6: Weight loss versus time period of immersion graph.

Specimen	Hardness (HRC)
A	13.47
B	13.43
C	13.37
D	16.97
E	16.97
F	15.63
G	19.73
H	19.76
I	18.73
J	19.83

Fig. 7: Hardness of specimen.

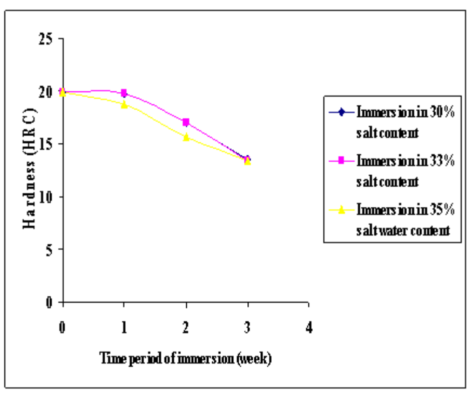

Fig. 8: Hardness versus time period of immersion graph.

Table in figure 9 shows the result of maximum load of specimens after immersion. This data is produced by tensile testing. Maximum load means the maximum load that the specimen can receive before its failure. For specimen G which was immersed in salt water with 30% salt content for one week, maximum load is 46.88kN. For specimen D which was immersed in salt water with 30% salt content for two week, maximum load is 42.34kN. And for specimen A which was immersed in salt water with 30% salt content for three week, maximum load is 44.65kN. For specimen H which was immersed in salt water with 30% salt content for one week, maximum load is 40.61kN. For specimen E which was immersed in salt water with 30% salt content for two week, maximum load is 45.69kN. And for specimen B which was immersed in salt water with 30% salt content for three week, maximum load is 45.85. For specimen I which was immersed in salt water with 30% salt content for one week, maximum load is 44.37kN. For specimen F which was immersed in salt water with 30% salt content for two week, maximum load is 45.27kN. And for specimen C which was immersed in salt water with 30% salt content for three week, maximum load is 41.92kN. Figure 10 shows graph plot maximum loadversus time period of immersion and figure 11 shows graph plot maximum stress versus time period of immersion.Maximum load value and maximum stress value of specimens gives a scatter value. This happens because effects of corrosion on surface of specimen are scatter. Effect of corrosion which happens at centre of specimens will influence tensile test data value. Corrosion affects the surface of specimen and will produce small holes. These small holes will influence the specimen's failure.

Specimen	Maximum Stress (N/mm²)	Maximum Load (kN)
A	5.12	44.65
B	5.26	45.85
C	4.81	41.92
D	4.85	42.34
E	5.24	45.69
F	5.19	45.27
G	5.38	46.88
H	4.66	40.61
I	5.09	44.37
J	5.02	43.83

Fig. 9: Maximum load of specimen.

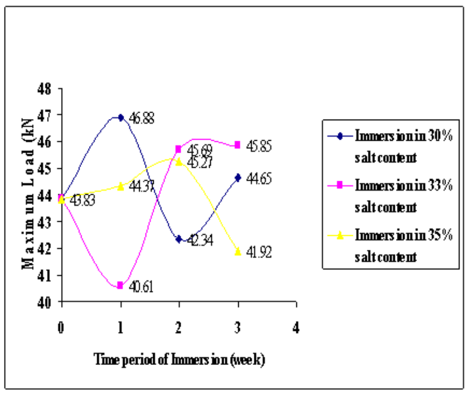

Fig. 10: Graph maximum load versus time period of immersion.

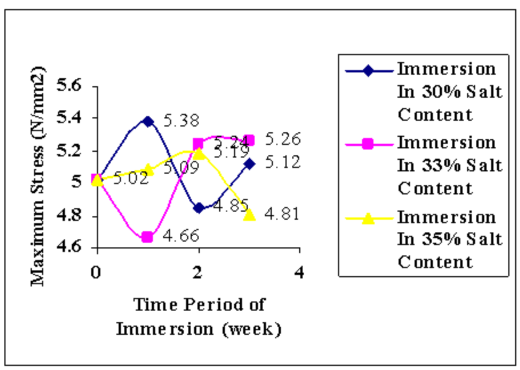

Fig. 11: Graph maximum stress versus time period of immersion.

From microstructure analysis, corrosion that occurs can be seen more clearly. This is done by using optical microscope. Figure 12, figure 13, figure 14, figure 15, figure 16, figure 17, figure 18, figure 19, figure 20 and figure 21 shows the surfaces of specimens. Figure 12-20 shows the surface of specimens that were immersed in salt water. Almost all specimens that were immersed shows small holes with undercutting shape occur. Figure 21 shows the surface of specimen J which was not immersed. It only has line surface and no small hole occurs. Pitting corrosion occurs and happens to weak part of surface. It is caused by highly localized destruction of passivity by contact with chloride ion. Small holes and bruise impact exists on certain part of specimens. Certain hole gives an undercutting shape on surface of specimen.

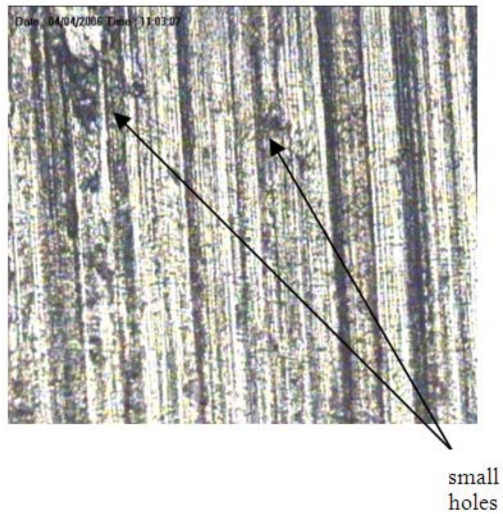

Fig. 12: Surface of specimen A.

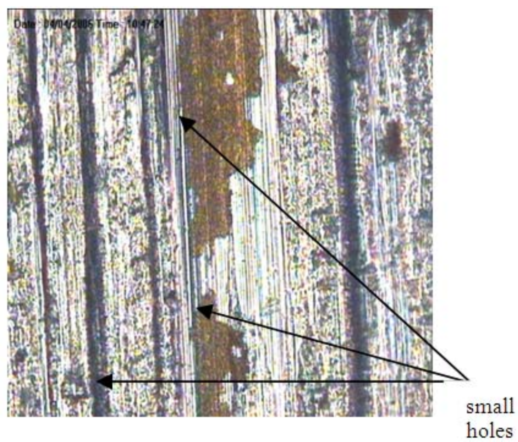

Fig. 13: Surface of specimen B.

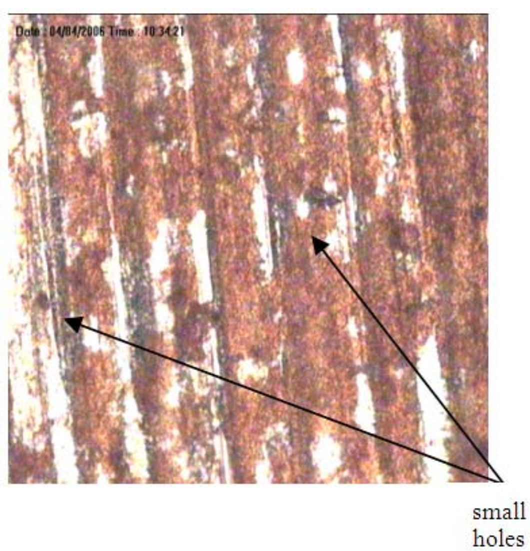

Fig. 14: Surface of specimen C.

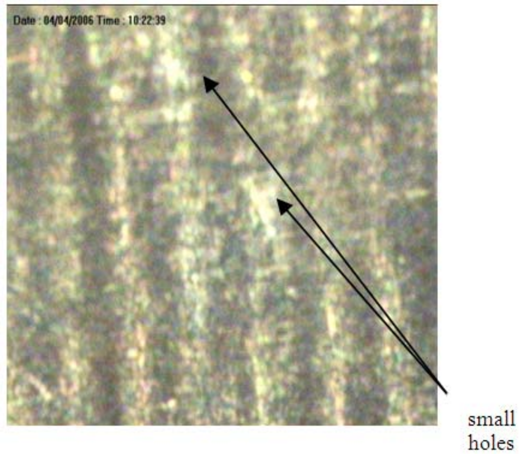

Fig. 15: Surface of specimen D.

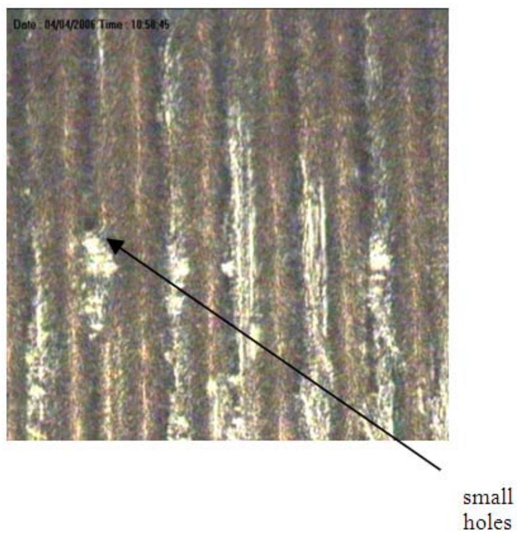

Fig. 16: Surface of specimen E.

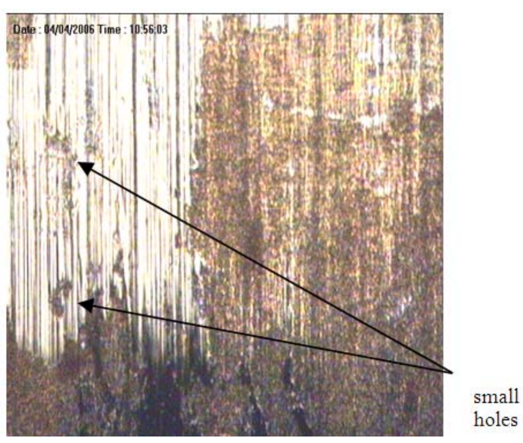

Fig. 17: Surface of specimen F.

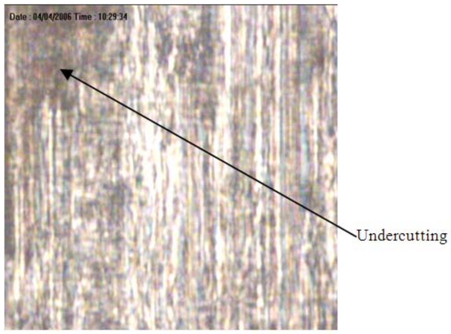

Fig. 18: Surface of specimen G.

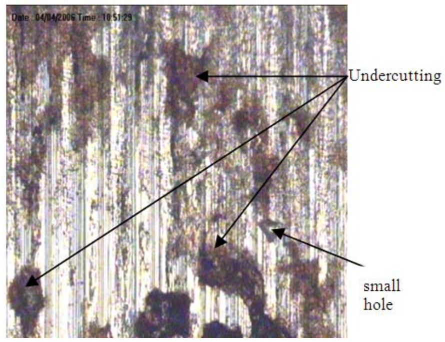

Fig. 19: Surface of specimen H.

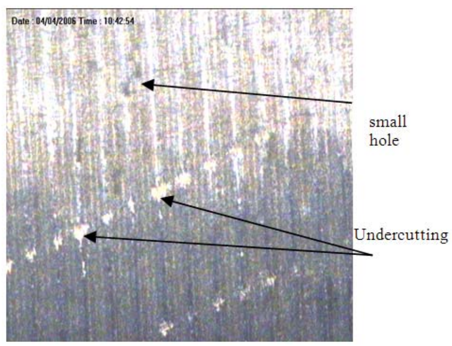

Fig. 20: Surface of specimen I.

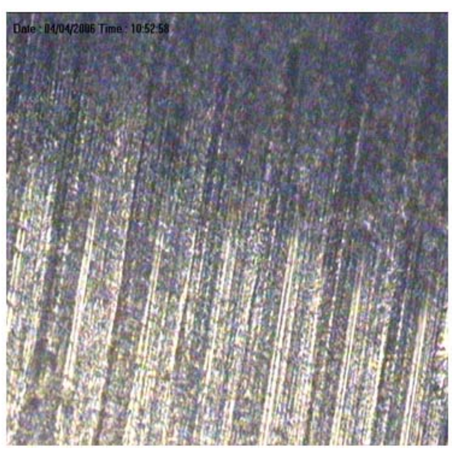

Fig. 21: Surface of specimen J.

Conclusion:

Base on data and analysis which been done, conclusion can be made that stainless steel AISI304 having excellent and very good corrosion resistance. In this experiment, salt water is used as corrosion medium with percent salt content 30%, 33% and 35%. Immersion time period is for one week, two week and three week. The highest corrosion rate happens on medium salt water with content percent salt of 33% which was immersed within 3 weeks. Corrosion rate increases due to percent salt content increase. Corrosion rate also increases with immersion time period increasing.

After immersion in salt water with percent salt content 30%, 33% and 35% for one week, two week and three week afterwards be done hardness test. Hardness value for specimen without been immersed in salt water indicates the highest value of hardness. For specimens which be immersed, specimen G which was immersed in salt water with salt content 30% for time period of one week indicates highest value of hardness. The lowest value of hardness is specimen C which was immersed in salt water with 35% salt contains within time period for three weeks. Hardness value decreases with percent salt content increasing. Hardness value decreases with percent salt contain increasing. Hardness values also decrease with immersion time period increasing.

After immersion in salt water with 30%, 33%, 35% salt content for one week, two week and three week, tensile test has be done. Value for tensile test is gives a scatter value. This happens because effects of corrosion on surface of specimen are scatter. Effect of corrosion which happens at centre of specimens will influence tensile test data value.Corrosion affects the surface of specimen and will produce small holes. These small holes will influence the specimen’s failure. Specimen which has the highest maximum load value and maximum stress value is specimen G which was immersed in salt water with 30% salt content for one week time period of immersion. Specimen which has the lowest maximum load value and maximum stress value is specimen H which was immersed in salt water with 33% salt content for one week time period of immersion

From observations from pictures taken using optical microscope, pitting corrosion occurs and happens to weak part of surface.

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