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# Soaking time as a parameter of evaluating the hardness value of stainless steel type 301,304 and 316

**Amula, E[1]. Paulley, V[2]. Binaebi-Soroh, E[3].**

[1, 2, 3] *Department of Mechanical Engineering, Faculty of Engineering, Niger Delta University (NDU), Wilberforce Island Nigeria*

***Abstract**: Soaking Time as a parameter of evaluating the Hardness value of Stainless Steel Type 301,304 and 316 was looked at. After the sensitization of the specimens, corrosion rate was analyzed. The samples were welded in twos making up 15 in number from each sample squaring up to 45 in all and, the samples heated and passed through soaking at 600C for different time interval of 30 minutes, 60 minutes, 180 minutes,300 minutes and 600 minutes and followed by Normalizing, Annealing and Quenching Quenched, Annealed and Normalized respectively. Hardness test were conducted on the samples. The findings got from the hardness test reveals that the samples after the corrosion test increased in hardness than those before in all three heat treatment in an Electric Furnace i.e., Quenched, Annealed and Normalized. As regards the case of SS 316, the results indicated that its hardness reduced tremendously. This result points to the fact that some degree of weld decay has occurred in the samples. To conclude, it points to shows that annealed samples had a higher hardness than the rest of the samples before and after the corrosion test and should be adopted.*

**Key words: - Corrosion Test, Electric Furnace, Hardness, Electric Furnace, Normalized, Parameter**

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## 1. Introduction

The kind of failure produced a result of service performance in long term is as a result of decline or reduction in mechanical properties of corrosion. [1]. Corrosion is a naturally destroying phenomenon that takes effect in a material through interaction with its environment according to Kruger [2]. Corrosion has also been defined as the chemical or electrochemical reaction of a metal with its environmental leading in some cases to failure of the entire structure [3]. Corrosion directly or indirectly affects everybody, community, organization and nations in various degrees and levels. It has been a serious factor that jeopardize safety and antagonizes optimal economic and technological achievements. A lot of money equivalent ranging to several millions of dollars is been spent globally every year on researches on science and methods to negate the corrosion of steel, yet, the efforts and technological sophistication on the subject are far from the desired achievement [4]. Corrosion of materials [5] is always reoccurring is the most important setback process in industry. To make the materials outstanding, composites and polymers is added even at that, stainless steels are very useful in structural forms and edifice because of their complementing qualities and acceptable in high thermal conditions and [6]. In refineries such as those found Niger Delta Nigeria, they are still being used for instance in Vacuum Distillation Unit, Catalytic Reformer Unit, Heat Tubes and Reactor Scallops. Also used at utility and process areas of most oil producing companies in Nigeria. [7]. Stainless steels are used solely because of its corrosion resistance. However, in some environment, they are affected by certain type of corrosion and that is why care must be applied to select the best grade which will be right for the application.[8]. The heating and cooling operations as regards to metals in their solid state which gives the accepted properties is called heat treatment [9]. Heat treatment includes normalizing, annealing and quenching operations. To improve the microstructure of stainless steel, heat treatment is unavoidable to arrive at the desired state of the metal for different service conditions. This process involves different stages in which the original shape is preserved giving rise to the desired mechanical properties [10]. Properties of metals such as those related to mechanical get get better through heat treatment. Basically, when the strength of the material is enhanced, the product performance will increase. [11,12]. It can be divided into three main processes namely annealing, quenching and tempering. In general, the procedure of heat treatment process consists of three stages. First stage is heating the material. Second, hold the temperature for a period of time and third, cool down the metal to room temperature.

The medium carbon steel treatment applying thermally, can actually change the properties of mechanical materials such as durability, strength and hardness. Also, other properties such as ability to transmit heat and electricity. The art of joining metals by heating and compressing together at high temperature is called welding. A good understanding of the microstructure which is as a result of high temperature occasioned by welding is necessary for the rapid temperature rise of the heat affected zone [13,14,15]. However, with its importance, there are many problems accompanying welding issues, as the microstructure is altered when any two metal or alloy is joined by welding [16], leading to a highly varied properties of weld or defect called weld decay [17].Cracking, hardness reduction, reduction in strength, distortion, and wear properties are all aspect of Weld defects which may include Corrosion characteristics, internal stresses and etcetera.

These defects cannot be overlooked, as a means to control them is of essence to an effective design (18). These defects can however be reduced by heat treatment to obtain thus resulting in the properties that are needed. Soaking Time as a parameter of evaluating the hardness value of stainless steel type 301,304 and 316 was looked at in this paper.

## *1. Materials and Methodology*

### *1.1. Material Selection*

Special grades of austenitic stainless steel were selected at random for this test. These are the 301, 304 and 316 stainless steels. These are pure industrial and commercial specimens available as tubes as shown in Tables 3.1, 3.2 and 3.3. Type 304 and 316 stainless steel was purchased from NNPC Warri, while Type 301 stainless steel was purchased from the commercial steel market in Yenagoa Bayelsa state

***Fig.1. Showing SS 301, SS 304 and SS316 as Received***

### *1.2. Chemical Composition*

The Positive Materials Identification (PMI) test of the selected steel samples was determined at Turret Engineering Services Ltd., Port Harcourt using an Oxford instrument XRF spectrometer model X-Met 7000 with serial number 711150. Details of the chemical composition of the samples are as shown in figures 1, 2 and 3 below.

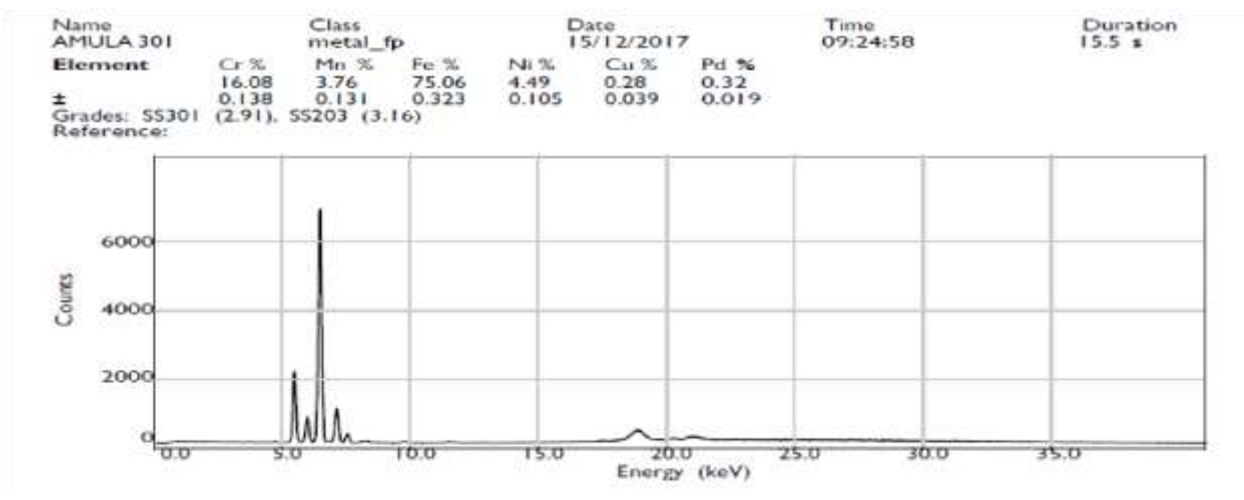


***Fig. 2. Positive Materials Identification (PMI) test of Austenitic Steel AISI 301***

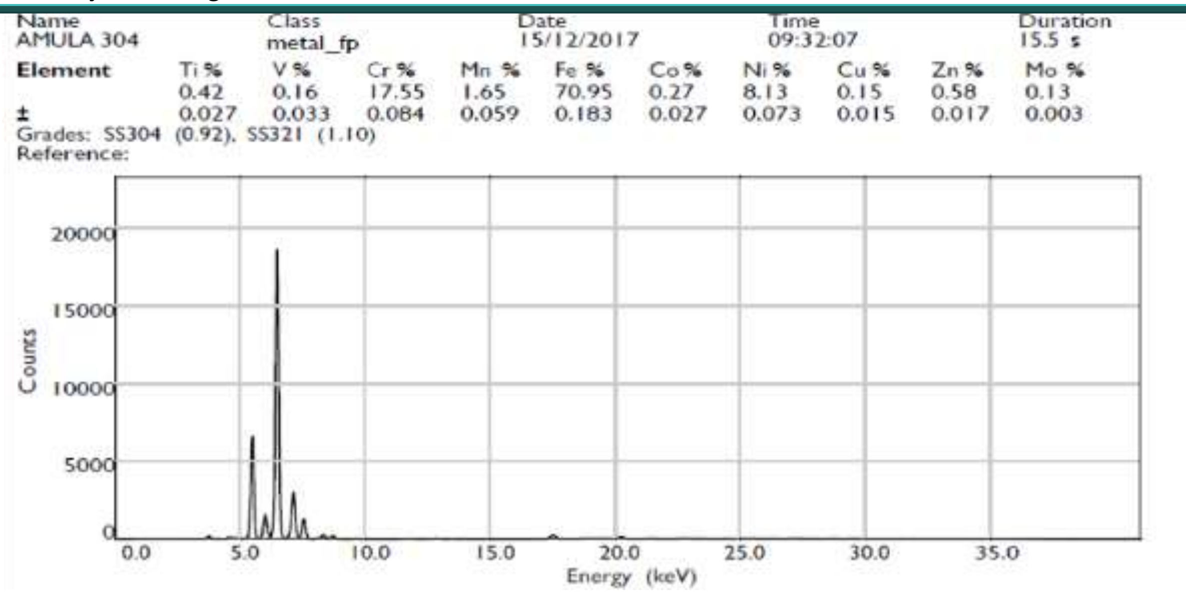


*Fig. 3. Positive Materials Identification (PMI) test Austenitic Steel AISI 304*

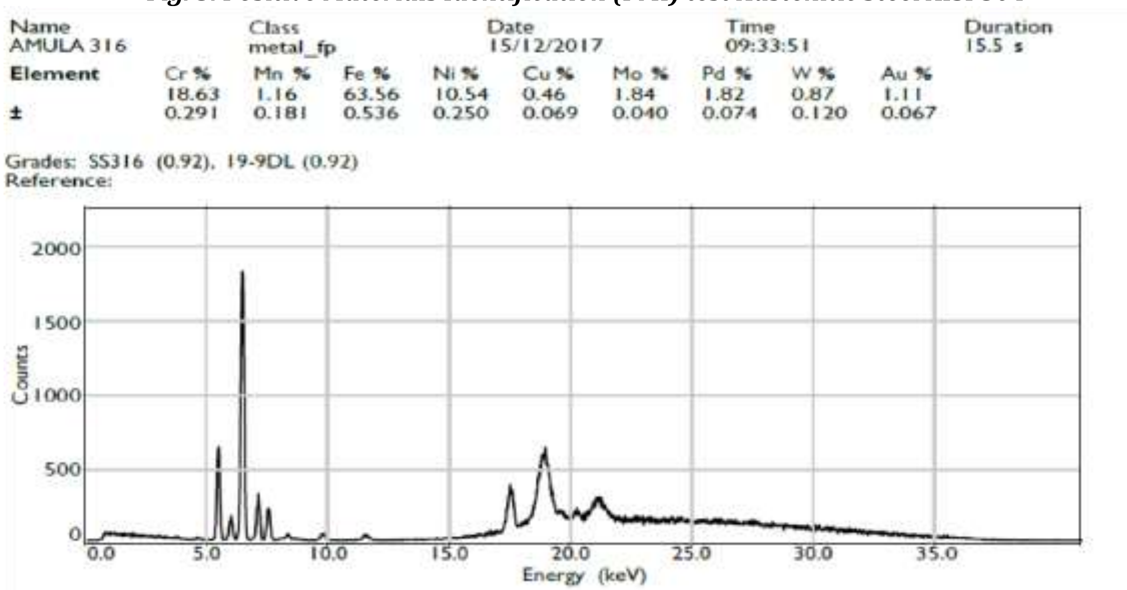


*Fig. 4. Positive Materials Identification (PMI) test of Austenitic Steel AISI 316*

### *1.3. Equipment*

The equipment used for this study includes Manual hand Hacksaws, cutting blades, welding machine, Heat treatment furnace Model ESM 9920, MITECH 320 Leeb Hardness Tester for the micro hardness test, The Inverted Metallurgical microscope,

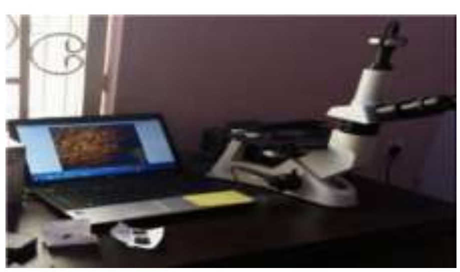

***Figure 5**: The Inverted Metallurgical microscope (IMM)*

### *1.4. Micro Hardness test*

The micro hardness test was done on all the samples using the Mitech Leeb hardness tester model MH320

***Figure 6. Mitech Leeb Hardness Tester***

## ***3.0 Results* and Discussions.**

The results obtained from the micro hardness test after the heat treatment and corrosion test of all the samples are as shown in tables 1 and 2.

***TABLE 1. HARDNESS TEST RESULTS AFTER CORROSION MONITORING***

| | EQUI PME NT; MITE CH 320 LEEB HAR DNES S TESTERS | As Receiv ed | | 30mins holding | | 60mins holding | | 180mins holding | | 300mins holding | | 600mins holding | | Welded zone before heat treatment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S / N | Speci menD escri ption | H L | H B | HL | | HL | | HL | | HL | | HL | | HL | |
| | | | | As Recei ved | Wel ded | As Recei ved | Wel ded | As Recei ved | Wel ded | As Recei ved | Wel ded | As Recei ved | Wel ded | As Receiv ed | Wel d ed |
| | ***NORMALIZING*** | | | | | | | | | | | | | | |
| 1. | A – SS 316 | | | 294 | 234 | 382 | 332 | 445 | 375 | 321 | 334 | 302 | 306 | | |
| | | | | | | | | | | | | | | | |
| 2. | B- SS 304 | | | 368 | 329 | 417 | 427 | 304 | 457 | 415 | 403 | 321 | 278 | | |
| | | | | | | | | | | | | | | | |
| 3. | C- SS 301 | | | 383 | 478 | 466 | 489 | 403 | 411 | 411 | 487 | 479 | 292 | | |
| | | | | | | | | | | | | | | | |
| | ***ANNEALING*** | | | | | | | | | | | | | | |
| 1. | D- SS 316 | | | 340 | 323 | 251 | 327 | 410 | 396 | 342 | 275 | 386 | 375 | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | |
| 2. | E – SS30 4 | | | 356 | 384 | 424 | 400 | 375 | 333 | 402 | 343 | 428 | 394 | | |
| | | | | | | | | | | | | | | | |
| 3. | F – SS 301 | | | 562 | 426 | 529 | 547 | 516 | 504 | 522 | 467 | 572 | 451 | | |
| | | | | | | | | | | | | | | | |
| | ***QUENCHING IN WATER*** | | | | | | | | | | | | | | |
| 1. | G – SS 316 | | | 322 | 385 | 252 | 297 | 317 | 294 | 328 | 379 | 310 | 332 | | |
| | | | | | | | | | | | | | | | |
| 2. | H- SS 304 | | | 396 | 307 | 404 | 290 | 386 | 386 | 302 | 257 | 303 | 327 | | |
| | | | | | | | | | | | | | | | |
| 3. | I- SS 301 | | | 454 | 423 | 529 | 452 | 527 | 403 | 562 | 368 | 584 | 427 | | |

***TABLE 2. HARDNESS TESTING RESULTS FOR THE WELDED JOINTS AFTER CORROSION MONITORING***

| | EQUIPMENT; MITECH 320 LEEB HARDNESS TESTERS | As Received | | 30mins holding | | 60mins holding | | 180mins holding | | 300mins holding | | 600mins holding | | Welded zone before heat treatment | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Specimen Description | HL | HB | HL | HL | HL | | HL | | HL | | HL | | HL | |
| | | | | | Welded Joint | | Welded Joint | | Welded Joint | | Welded Joint | | Welded Joint | | Welded Joint |
| | ***NORMALIZING*** | | | | | | | | | | | | | | |
| 1. | A- SS 316 | | | | 198 | | 325 | | 298 | | 276 | | 200 | | |
| | | | | | | | | | | | | | | | |
| 2. | B- | | | | 364 | | 206 | | 310 | | 303 | | 299 | | |

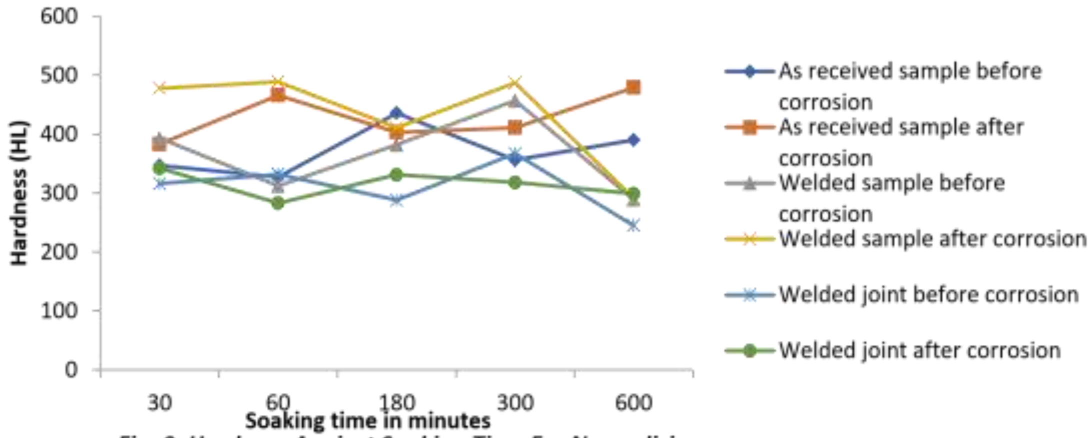


*Fig. 9. Hardness Against Soaking Time For Normalizing SS 301*

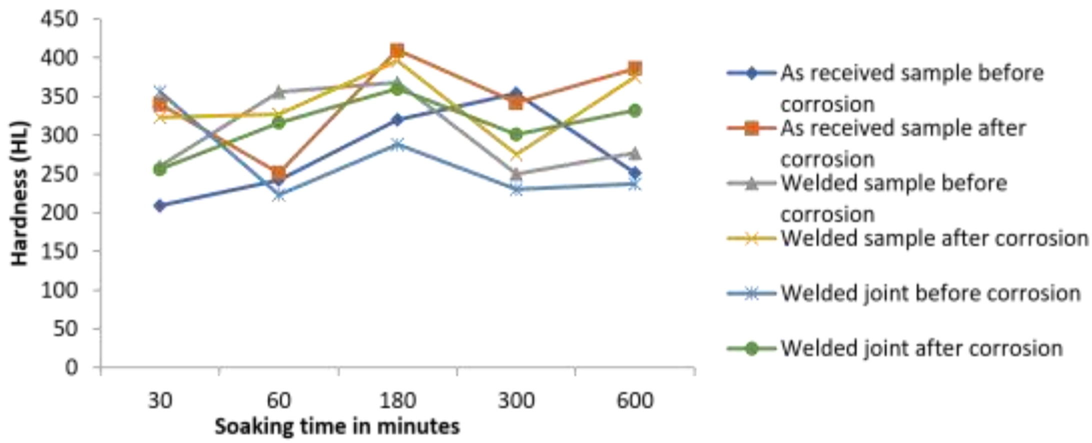


*Fig. 10. Hardness Against Soaking Time For Annealing SS 316*

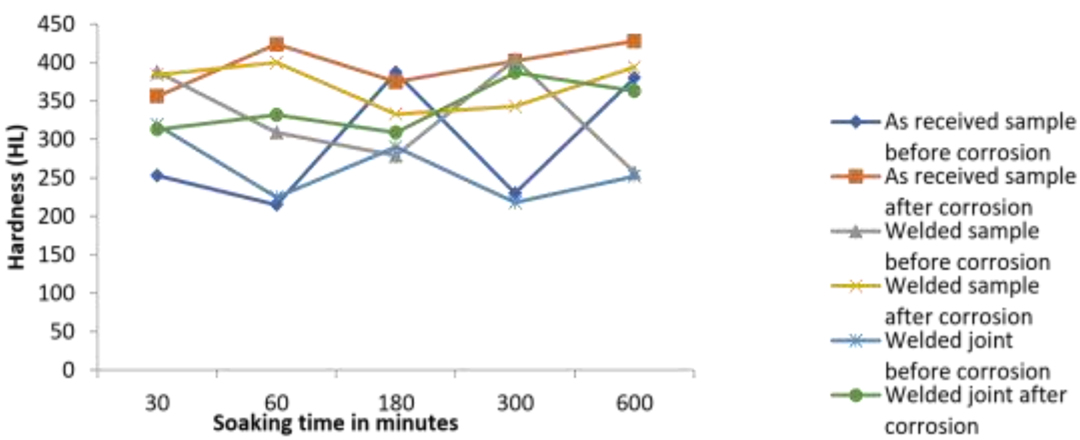


*Fig. 11. Hardness Against Soaking Time for Annealing SS 304*

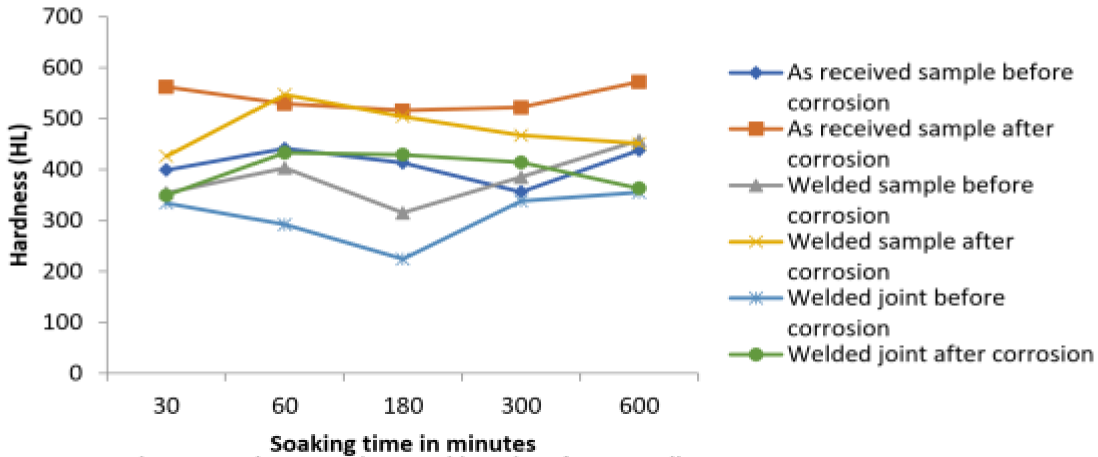


*Fig.12. Hardness Against Soaking Time for Annealing SS 301*

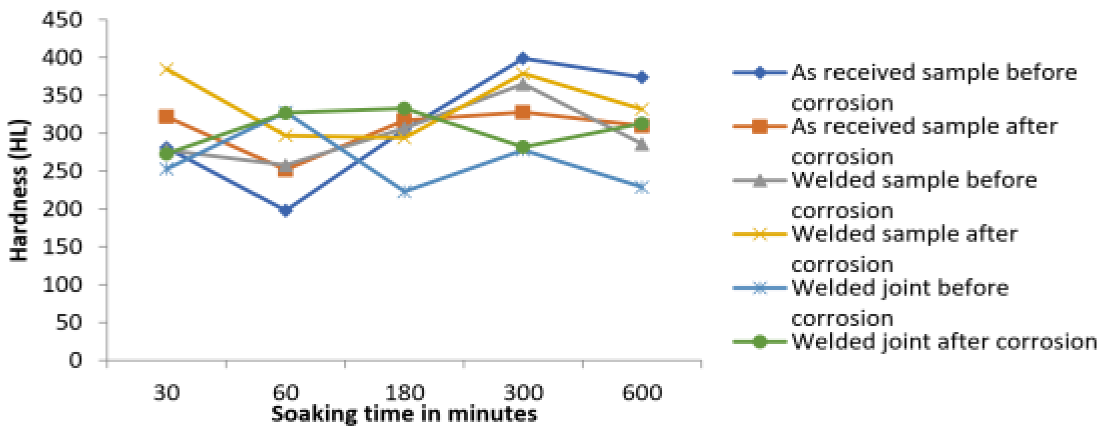


*Fig. 13. Hardness Against Soaking Time for Quenching SS316*

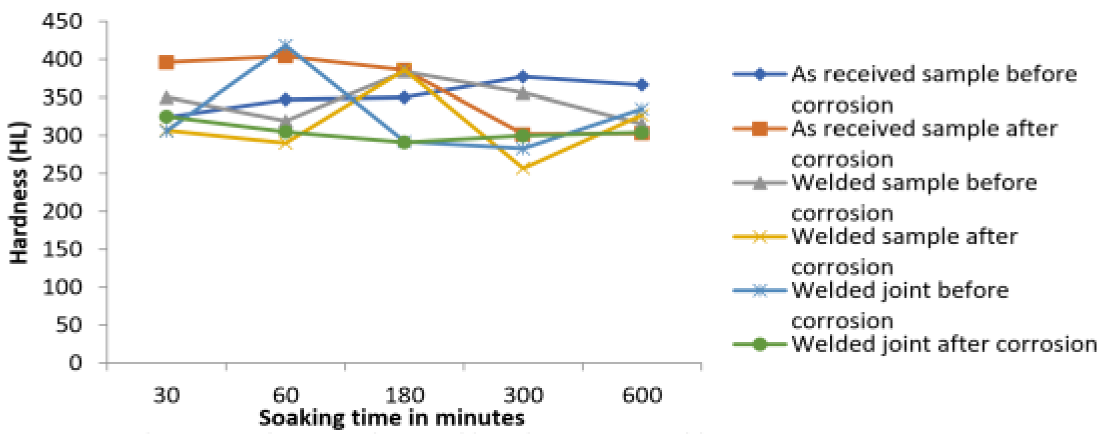


*Fig. 14. Hardness Against Soaking Time For Quenching SS304*

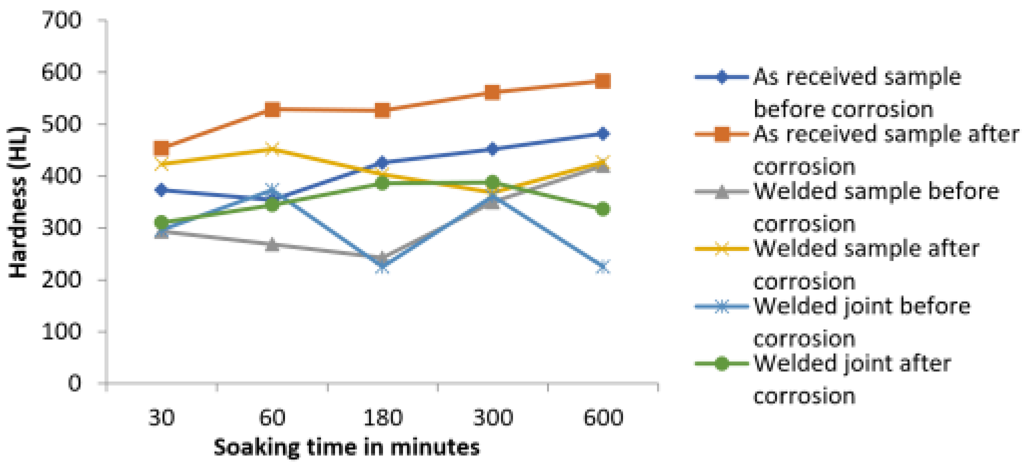


*Fig. 15. Hardness Against Soaking Time For Quenching SS301*

The Results of the hardness test after the corrosion analysis of the various samples are as shown in table 1 and 2. Figures 6 to 11 shows the changes in hardness as the soaking time progressed for SS 316, SS304 and SS301 respectively. The hardness with soaking time in the normalized, annealed and the quenched samples in the different heat treatment methods as indicated in (fig 6, 7, 8, 9, 10 and 11.). The Outcome of the Hardness Test Clearly Shows That Most of the Samples after Corrosion test were harder than before. i.e. the samples such as the obtained samples as well as the welded joints for the three samples SS316, SS304 and SS301 in the normalized, annealed and quenched cases in the two media of seawater and 1 M $H_2SO_4$ . However, in the case of SS316, the obtained result after corrosion test was lower than before corrosion test. Also the hardness of the welded areas in the various samples after corrosion test were lower than before. This clearly shows that there is some degree of weld decay in the quenched samples comparing the samples based on their heat treatment methods as is reflected in the graphs (Fig 6 -11). The annealed samples had a higher hardness than the rest of 394HL at the end of 600mins.

### *4. Conclusions.*

1.The hardness tests show that most of the samples after the corrosion test were harder than before, i.e., Samples such as the obtained welded samples, as well as welded joints (for SS 316, SS 304 and SS 301) in normalized annealing and quenched cases both in water sea, and in corrosive media 1 M H2SO4.

2. In the case of hardened SS 316 steel, the obtained specimen after corrosion was lower than before the corrosion test.

3. The hardness of the welded samples after corrosion was lower than before the corrosion.

4. There is some degree of weld loss in the quenched samples comparing the specimen based on their heat treatment can be seen in the graph, the annealed samples had a higher harness than the rest before and after the corrosion test.

5. Annealing is preferred when choosing the best heat treatment method.

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