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Determination of the Effect of Soaking Time on the Hardness of Austenitic Stainless Steel

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Abstract: The determination of the effect of soaking time on the hardness of Austenitic stainless steel type AISI 301, AISI 304 and AISI 316 was determined. After the sensitization and corrosion rate test were carried out 10 induce sensitization, 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 respectively.

The resultant samples were tested for micro hardness test. The results obtained from the micro hardness test shows that the samples after the corrosion test were harder than those before in all three heat treatment cases i.e., Normalized, Annealed and Quenched case. In the case of SS 316, the obtained results showed that its hardness after corrosion was lower than before. This showed that there is some degree of weld decay in the samples. Of all the heat-treated samples, the annealed samples had a higher hardness than the rest of the samples before and after the corrosion test and so should be preferred.

1. Introduction

One of the most common causes of production failure or impaired service performance in the long term is due to its degradation in mechanical properties by corrosion [1]. Corrosion is a natural destructive attack of 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 affect 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 and most important failure mechanism in industry. For improved material qualities, polymers and composites were introduced but despite their introduction, stainless steels still remain very important in structures, because of their add qualities and tolerance at high temperatures [6]. In refineries such as those found Niger Delta Nigeria, they are still being used for instance in Vacuum Distillation Unit, Reactor Scallops, Heat Tubes and Catalytic Reformer Unit. They are also in used at process and utility areas of Mobil producing Nigeria unlimited and other liquid gas plants found 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]. Mechanical properties of the metal alloys get better through heat treatment. Basically, the product performance will improve when the strength of material increased [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 treatment of medium carbon steel with heat can significantly changes the mechanical properties, such as ductility, hardness and strength. Heat treatment of steel slightly affects other properties such as its ability to conduct heat and electricity as well. 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].

Weld defects may include: cracking, hardness reduction, reduction in strength, distortion, wear properties. 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 the desired properties. The effect of soaking time on the hardness of SS 301, SS 304 and SS 316 was looked at in this study.

2. Materials and Methodology

2.1. 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

2.2. 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.

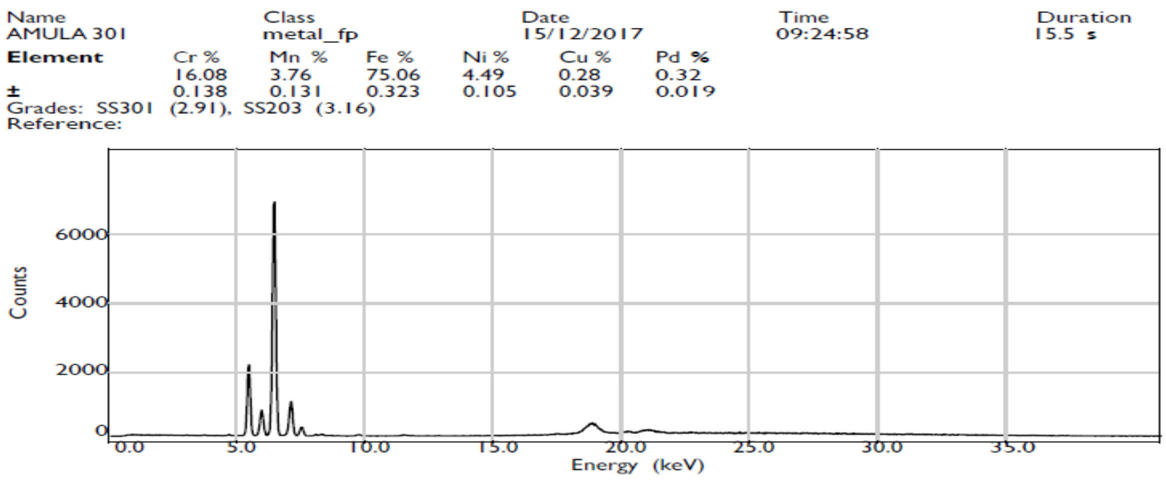

Fig. 2. Positive Materials Identification (PMI) test of Austenitic Steel AISI 301

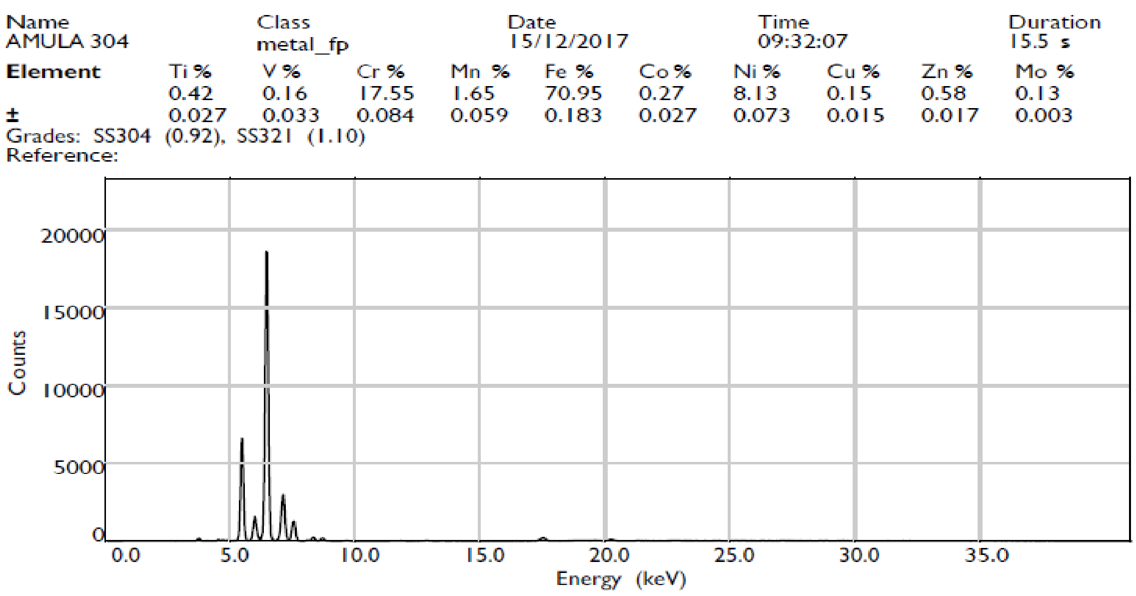

Fig. 3. Positive Materials Identification (PMI) test Austenitic Steel AISI 304

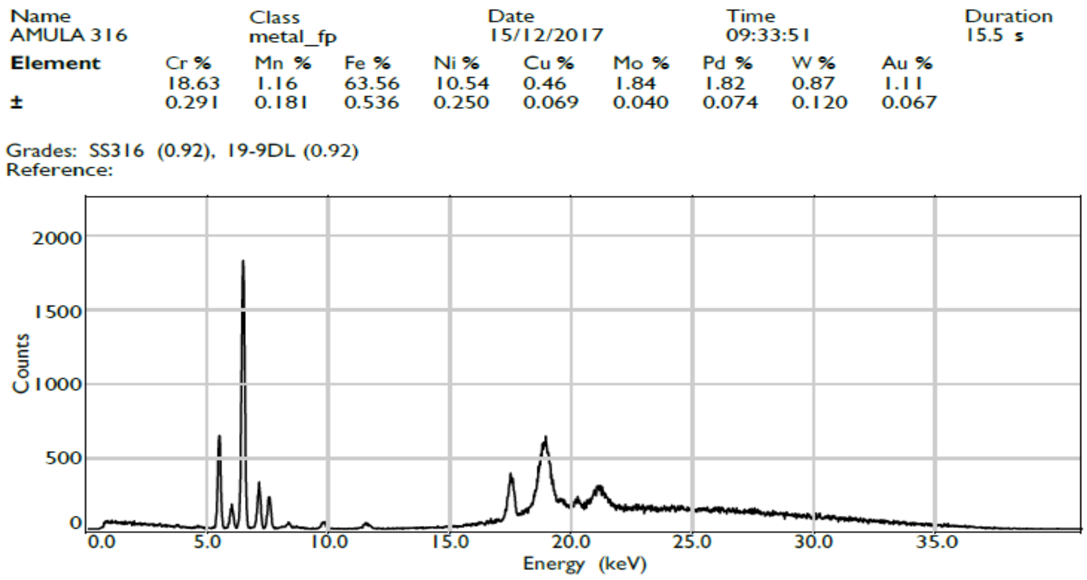

Fig. 4. Positive Materials Identification (PMI) test of Austenitic Steel AISI 316

2.3 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)

2.4. 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

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

	EQUIPMENT; MITECH 320 LEEB HARDNESS TEST	As Received	30mins holding	60mins holding	180mins holding	300mins holding	600mins holding	Welded zone before heat treatment

	ERS														
S/N	Specimen Description	HL	HB	HL		HL		HL		HL		HL		HL	
				As Received	Welded	As Received	Welded	As Received	Welded	As Received	Welded	As Received	Welded	As Received	Welded
	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 – SS304			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	

	SS 304														
3.	C- SS 301				342		283		331		318		229		
	ANNEALING														
1.	D- SS 316				256		316		360		301		332		
2.	E- SS 304				313		332		309		387		363		
3.	F- SS 301				349		433		429		414		391		
	QUENCHING IN WATER														
1.	G – SS316				273		327		333		282		313		
2.	H- SS 304				325		305		291		300		304		
3.	I- SS 301				310		344		386		388		336		

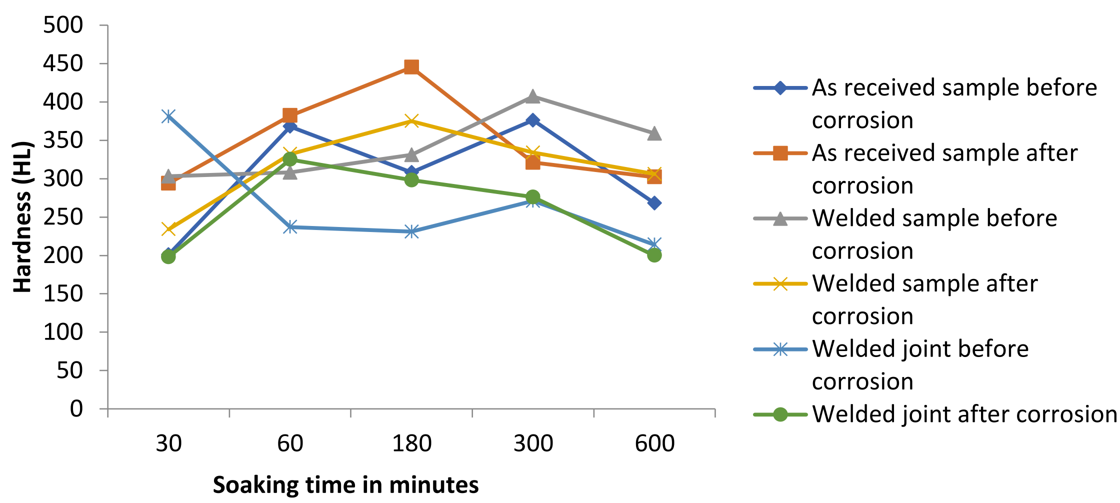

Fig. 7. Hardness Against Soaking Time For Nomalizing SS 316

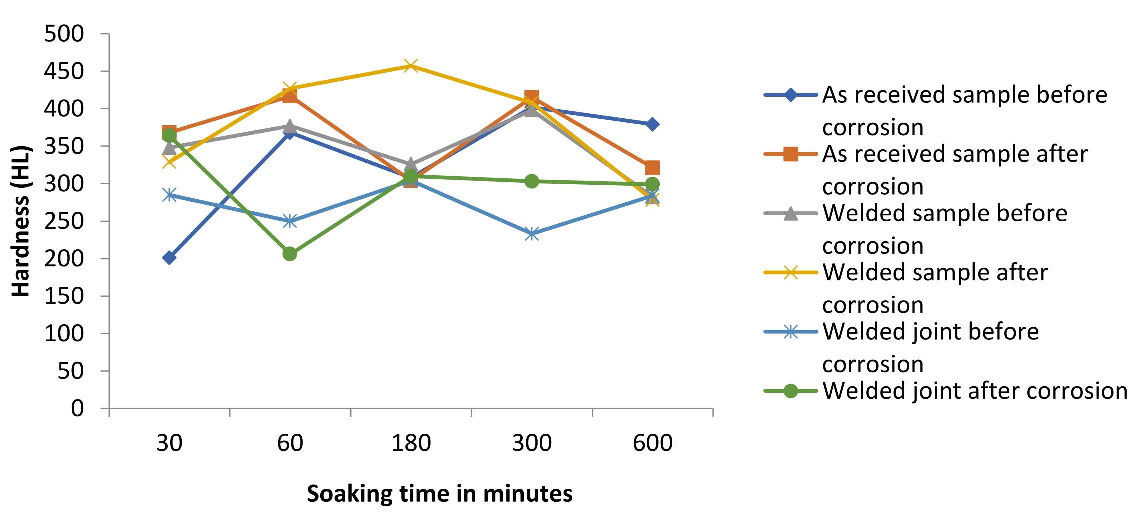

Fig 8.Hardness Against Soaking Time for Normalized SS304

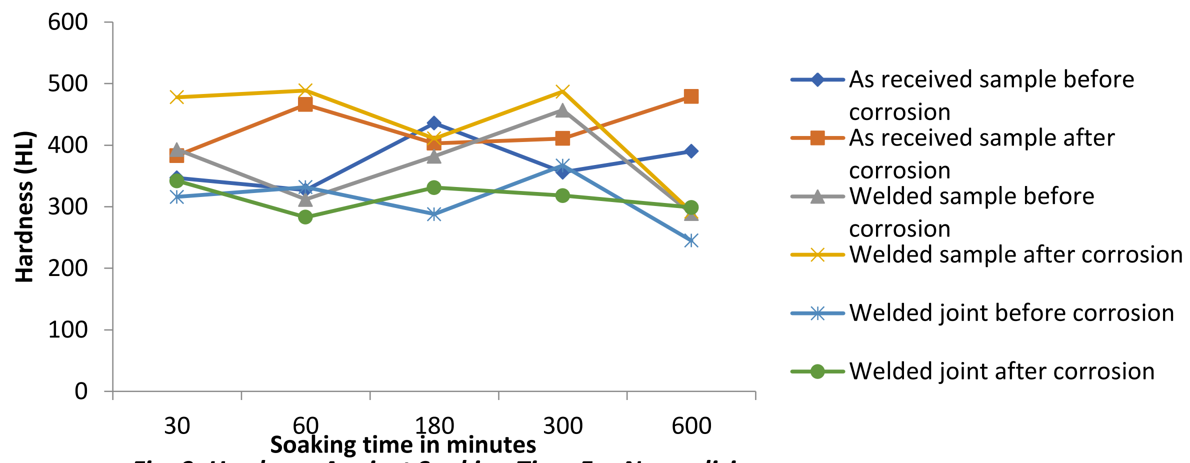

Fig. 9. Hardness Against Soaking Time For Normalizing SS 301

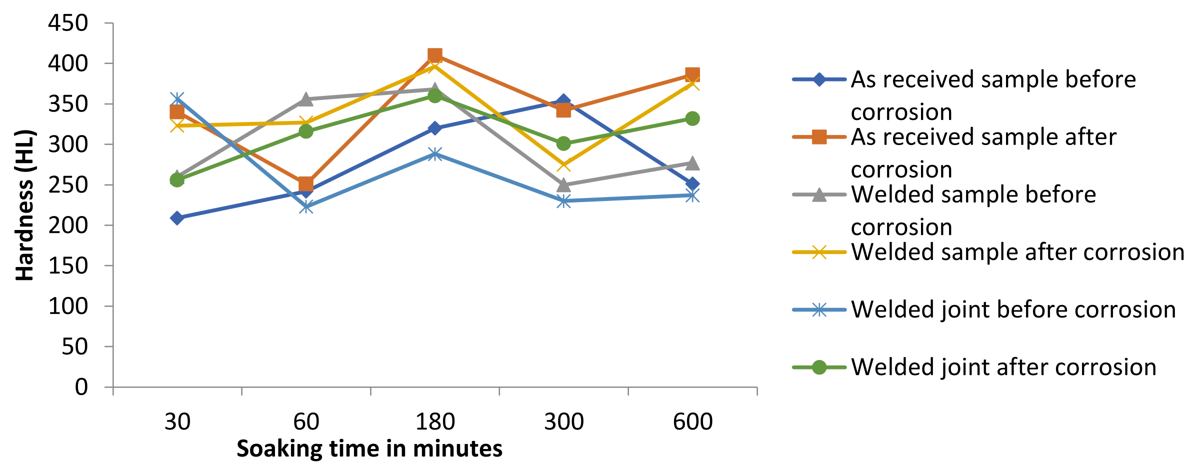

Fig. 10. Hardness Against Soaking Time For Annealing SS 316

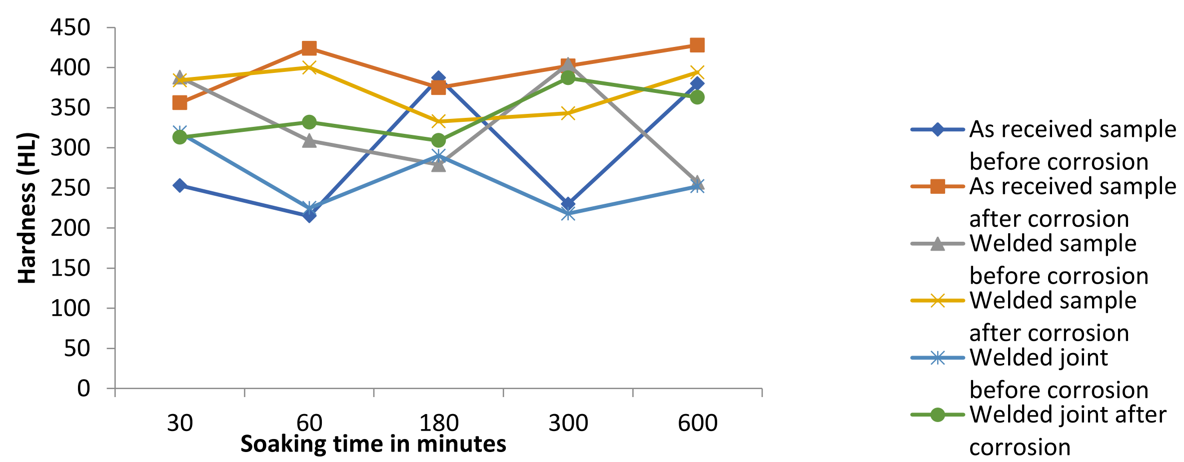

Fig. 11. Hardness Against Soaking Time for Annealing SS 304

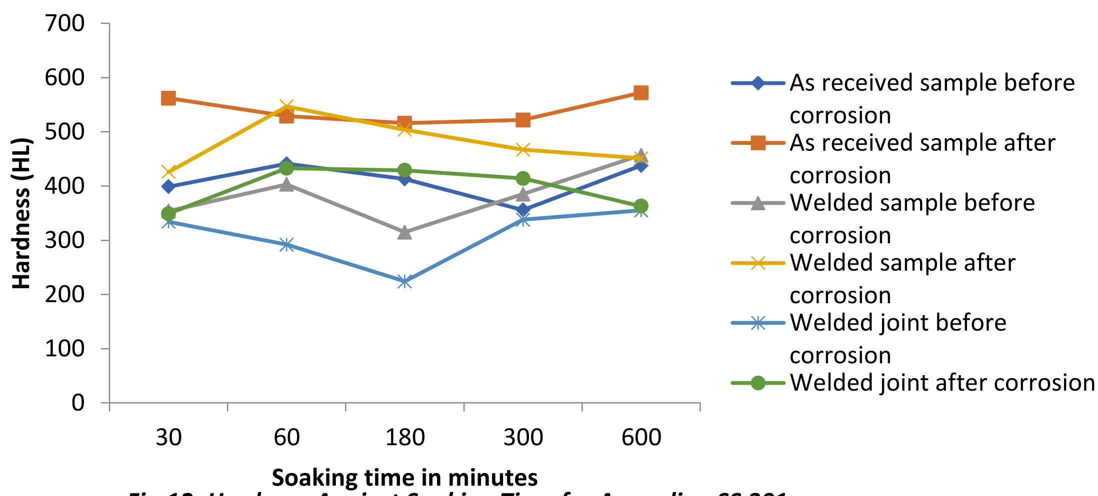

Fig.12. Hardness Against Soaking Time for Annealing SS 301

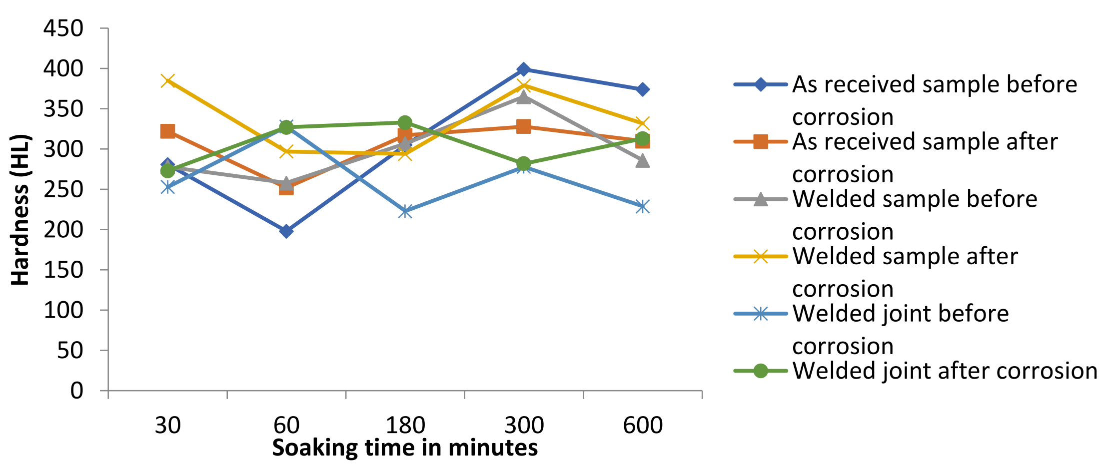

Fig. 13. Hardness Against Soaking Time for Quenching SS316

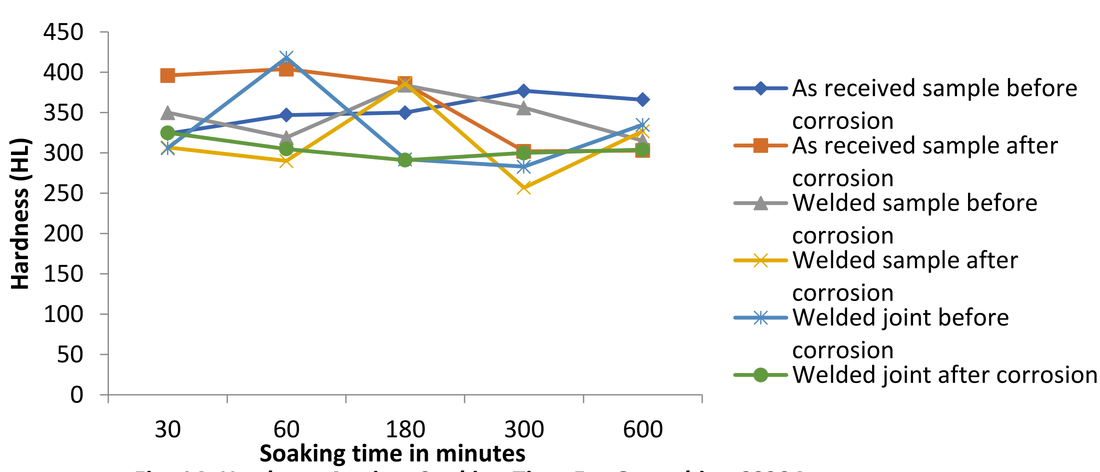

Fig. 14. Hardness Against Soaking Time For Quenching SS304

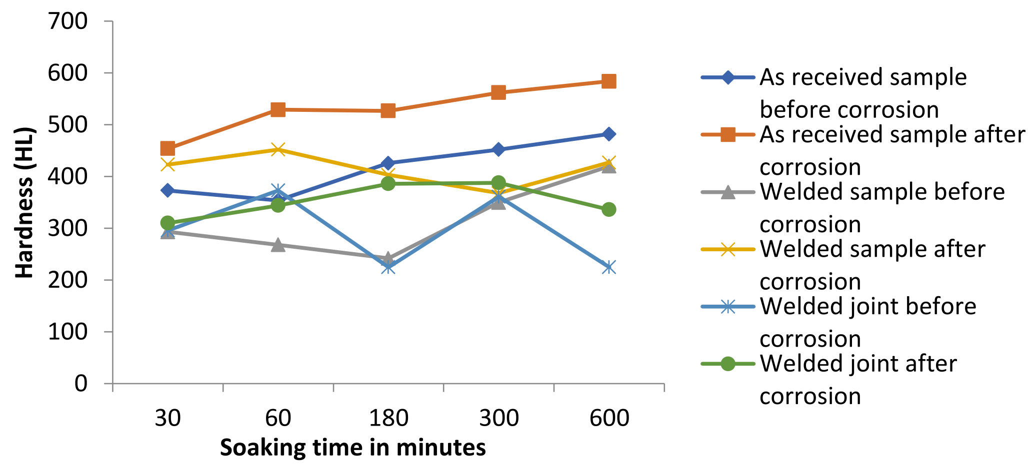

Fig. 15. Hardness Against Soaking Time For Quenching SS301

4. Discussions

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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