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Assessment of Stress Corrosion Cracking (SCC) Susceptibilities of Some Outokumpu-Produced Stainless Steels in a River Harbour Mud Using Accelerated Test

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Abstract

SCC of metals as structural components can occur unexpectedly under tensile loads in environments with particular factors and its consequences are often calamitous. Metals of different types or structures have different levels of SCC susceptibility in different environments. It is desirous that this deleterious phenomenon be prevented with the understanding of relative performances of metals in all environments of their service applications. SCC susceptibilities of various ASTM-designated Outokumpu-produced stainless steels under stresses of 90% of their 0.2% offset yield strengths, with aqueous harbour mud from river Kaduna in Nigeria as the target environment were investigated in a laboratory study. A plate of each steel designation was used to produce six-bent beam corrosion test specimens in accordance with ASTM 36-99 test procedures. One specimen from each designation were submerged at a time in different admixtures of concentrated sulphuric acid and the mud at room temperature, 100oC and 200oC for one hour in each case and inspected at an optical magnification of 40 for any crack and the time at which it occurred. The obtained results for the tests gave an indication that none of the steel grades is susceptible to SCC in the mud under such working stresses and other conditions.

Keywords: Structural metalworks, environmental factors, metallurgical structure, surface conditions, chemical composition, manufacturing process, variations, hazards..

Introduction

Stainless steels find many applications in a number of industries such as chemical, petrochemical, cellulose and paper, food processing, thermal and atomic power generating, and aerospace. They are frequently used at elevated temperatures and in severe environments because they resist oxidation and maintain their mechanical integrity under such conditions. Their upper temperature limit in an oxidizing atmosphere is about 1000^{O}C. Equipment employing stainless steels include gas turbines, high temperature steam boilers, heat-treating furnaces, aircraft, missiles, and nuclear power generating units. One particular type of corrosion that limits their application and some other critical structural materials in certain environments is SCC. This type of corrosion is due to conjoint synergistic interaction of static tensile stress which is below the yield point of a given material above a critical value and corrosive environment which leads to the formation and increments in sizes of cracks which would not have developed by the action of stress or environment alone (Xiaoyuan Lou, 2010). It is an insidious form of corrosion. It produces a marked loss of mechanical strength with little metal loss. The damage done by it is not obvious to casual inspection and it can trigger mechanical fast fracture and catastrophic failure of components and structures after a period of satisfactory service. The cracks are usually intergranular or transgranular in orientation or their combinations. Several major disasters have involved stress corrosion cracking, including rupture of high-pressure gas transmission pipes, the explosion of boilers, and the destruction of power stations and refineries. The stresses that cause SCC are either produced as a result of the use of the component in service or residual stresses introduced during manufacturing. The environments under which SCC occur is either the permanent service environment such as sea water, surf beaches, acidic soils or their combinations; or a temporary one caused by operations such as cleaning of the system which can leave a residue which if stress is applied during operation of the system initiates cracking. SCC is not an inevitable process and for most metals in most environments it will not occur. The most corrosive natural environments where stainless steels are applied include acidic soils, highly saline soils and heavy clays of high electrical conductivity,

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organic deposits such as silt and harbour mud, sea water and surf beaches. Silt and harbour mud are known to be associated with microbiologically influenced corrosion that can cause various forms of localized corrosion including pitting, de-alloying, enhanced erosion and galvanic corrosions, SCC, and hydrogen embattlement in all steels. In the emerging technologies engineers have been striving to use materials more efficiently by increasing working stresses and using less expensive ones. Not all SCC problematic material-environments are known and documented. New materials are developed, old materials are used in new applications, material properties may change with time due to factors such as thermal aging and material processing like welding and cold work (Shreir, 1979; Aki Toivonen, 2004; Cottis, 2014; Sambo, 2014). There is therefore need to continue to test and identify more specific combinations of metals and environments that are subject to SCC problem and use the test information to safeguard against the problems. Some of such combinations that have been reported in the literatures include carbon steel in environments of nitrates from moderate temperatures, carbonate/bicarbonate, liquid ammonia, $CO/CO_2/H_2O$, high concentration of hydroxides, and aerated water at very high temperatures; strong steel in water under stresses greater than 1200Mpa; strong steels in chlorides under stresses greater than 800Mpa; chromium-molybdenum and chromium-molybdenum-vanadium low alloy steel in water from moderate temperatures; high sensitized austenitic steel in aerated water at very high temperatures; stainless steel in thiosulphate or polythionate; martensitic stainless steel in chlorides-hydrogen sulphide and chlorides; duplex stainless steel in high concentration of chlorides at high temperatures; high strength steels in water vapours; aluminium-alloyed-steel in chlorides; titanium-alloyed-steels in methanol; austenitic stainless steels including sensitized type in high hydroxide environments and steels generally in water at temperatures greater than 200^{o}C. Most SCC of stainless steels, however involve the presence of chloride ions in the medium; particularly if the medium is acid. Hot concentrated solutions of; chlorides of magnesium, calcium, barium, cobalt, zinc, lithium, ammonium and sodium all cause rapid cracking (Nakayama, 2006; Labanowski, 2007; Cottis, 2014; Sambo, 2014).

Kaduna is one of the top cities in the ranking of growing industrial, commercial, domestic and social activities in Nigeria. It is a noted centre for refining crude oil, automobile manufacturing, producing weapons, bottling and brewing, textile manufacturing, sand casting, metal forging, civil engineering construction works, agricultural processing, metalworking, electric power distributing, warehousing, machinery manufacturing, steel working, water treating, etc. A large quantity of steel material including stainless types find application in the city in the forms of; pipelines, machine parts, water tanks, tools, agricultural processing equipment, pressure vessels, automobile parts, pumping equipment, household appliances, civil engineering structural parts, etc. The metropolitan city of Kaduna has a population of about 760,084 people. The course of river Kaduna passes through the city and divides it into what is more or less called Kaduna North and Kaduna South. The river is valuable to people of the city in terms of cheap and dependable water supply for different domestic, commercial and industrial uses. Millions of litres of the river water is pump-supplied daily through pipelines or obtained directly from the river for household drinking, washing, bathing, cooking, sewage disposal, etc; industrial and commercial cleaning, machinery and engine cooling, admixture preparations, food preparations, etc. In all these uses of the river water and during its storage prior to use, a large quantity of steel parts or components in sizes as small as washers, bolts, nuts and household utensils to big-size ones or whole in machineries, structural works, storage and conveying water tanks, etc; are in associated direct or indirect long-time exposure to the river environment; or contact with water from it. This can expose the as-used steel materials or parts to any possible costly corrosive influence of the river environmental factors. In a developing country like Nigeria where the general level of corrosion-consciousness and counteractions is generally minimal any of such possible corrosion implications can exist consciously or unconsciously for a long time in some quarters in the city or some other locations in association with the river environmental factors (Guma and Oguchi, 2011). A previous study by Guma and Oguchi (2011) showed that, generally, the average corrosivity level of the river environmental section that adjoined the city of Kaduna is moderate but demanded greater precaution to be taken when dealing directly with factors from muddy ponds of the river which were found to exhibit relatively higher corrosivity levels. Outokumpu is one the world's top manufacturers of stainless steel. Their products are found everywhere and greatly used in Nigeria. The aim of this paper is to present a laboratory study on stress-corrosion cracking susceptibilities of various designated grades

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of Outokumpu-produced stainless steels that is based on accelerating corrosivity level of their field environmental exposures to harbour mud from river Kaduna in the vicinity of the city and the specific objectives are:

i. To have a valuable insight into relative SCC susceptibilities of different grades of the stainless steels when under elastic stresses in field exposure to the river mud.
ii. To provide more information that will contribute to in-depth understanding of corrosion risk level in association with the river environment in the vicinity of the city.

Methodology

Basic Characteristics and Classes of Stainless Steels

Stainless steels are highly resistant to rusting which is the commonest and most important form of corrosion, in a variety of environments, especially the ambient atmosphere (Shreir, 1979; Higgins, 1993; Callister, 2004). Their predominant alloying element is chromium with a constituent composition of at least 11% by weight. Their corrosion resistance is also enhanced by nickel and molybdenum additions. Stainless steels are divided into austenistic, martensitic, precipitation hardening, feritic and duplex types on the basis of the predominant phase constituents of their microstructures. Possession of a wide range of mechanical properties combined with excellent resistance to corrosion make stainless steels very versatile for engineering applications. Austenitic stainless steels make over 70% of total stainless steel production. They contain a maximum of 0.15% carbon, a minimum of 16% chromium and sufficient nickel and/or manganese. They are most corrosion-resistant because of their high chromium content and also the nickel additions. Martensitic stainless steels are capable of being heat treated like carbon steel in such a way that martensite is their prime micro-constituent. Martensitic stainless steels are not as corrosion resistant as the austenistic steels and ferritic steels but are extremely strong and tough, and highly machinable. They contain 12-14% chromium, 0.2 to 1% molybdenum, 2% nickel and 0.1 to 1% carbon. Precipitation-hardening martensitic stainless have corrosion resistance comparable to austenitic varieties and can be precipitation-hardened to even higher strengths than the other martensitic grades. Ferritic stainless steels generally have better engineering properties than austenitic grades but have reduced corrosion resistance because of their lower chromium and nickel contents. They are usually less expensive. They contain between 10.5 and 27% chromium and very little nickel. Duplex stainless steels have a mixed microstructure of austenite and ferrite. Duplex stainless steels have roughly twice the strength compared to austenitic stainless steels and also improved resistance to localized corrosion particularly pitting corrosion, crevice corrosion and stress corrosion cracking. They are characterized by high chromium 19 to 32% and molybdenum up to 5% and lower nickel content than austenitic stainless steels. Each class of stainless steel is further subdivided into grades by international and local standards based mainly on various designated chemical compositions and consequent mechanical properties, and processes used to manufacture them (Callister, 2004; INTERNET,2014a).

Test Procedures

Materials

12 Outokumpu-longitudinally-roll-produced stainless steel thin plates each of about 1000mm length by 7000mm width and 2mm-thickness were obtained from various reputable commercial sources in Kaduna, Kano, and Lagos; Nigeria for the tests together with some information from the dealers and the manufacturer's manuals on them.

Analysis of elemental chemical composition of the steel plates

The elemental chemical composition of each plate was analyzed using the Japanese-made Shimadzu-model-PDA-7000 optical emission spectrometer metal analyzer. The obtained composition of each plate was cross-checked with the compositions of different stainless steel grades designated by Outokumpu, the American Standards for Testing Materials (ASTM) and other authorities as given by Outokumpu Stainless Steel Avesta Research Centre (2013) Callister (2005) and INTERNET (2014c,d). Any plates whose analyzed compositions were found to deviate minimally from that of any steel grade were/was taken to belong to that grade, while those that did not cross-match with any grade due to appreciable differences in compositions were discarded. Compositions of the 12 plates were found to fall into seven different designations and the mechanical properties and uses of the designated taken as that of the respective plates.

Procurement of concentrated sulphuric acid

Laboratory test require severe conditions to produce cracking in reasonable time, whereas in service much milder conditions may cause cracking in the longer time available (Viswanathan et al, 1979). So, eight litres of pure concentrated sulphuric acid were procured and used to accelerate natural corrosivity of the mud for the laboratory study.

Production of the specimens

A mallet and chisel were used to cut out strips of 200mm length by 30mm width out of each plate after marking them out using a steel ruler and a thin marker to produce the specimens. Six strips were cut out of each plate. Any strip that was observed to be bent after cutting it out was discarded and replaced with another cut-out stip. The coarse edges and the entire surfaces of the strips were smoothened by polishing them with silicone carbide paper up to grit 1200. The strips were finally similarly prepared by removing any surface residual stresses in cutting them and from manufacturing processes. This was achieved by solution annealing them at 1050ºC for 45 minutes, water quenching and stress-relieving them at 150ºC for one hour. Each strip was afterwards thoroughly surface-examined for uniformity in topography, morphology and structure at an optical magnification of 40 using a handheld magnifying glass produced by Amazon company Inc United States of America. Any strip that had any scratches and other observed inconsistencies on its surface was discarded and similarly re-prepared from the plate it was cut out from until the required number of specimens were satisfactorily finish-prepared. After polishing, the strips were solution annealed at 1050ºC for 45 minutes and water-quenched. They were then stress-relieved at 150ºC for one hour to remove residual stresses from manufacturing processes and surface-preparing them. Nitrogen gas was flowed into the tube furnace to prevent the element oxidation during heat treatment process (Kitikhun Sutthiprapa et al, 2010; Sambo, 2014). The prepared strips were then used to produce 42 bent-beam specimens in accordance with ASTM-G-39-99 standard practice for preparation and use of bent-beam stress-corrosion test specimens. Six bent beam specimens were produced from each plate of the seven designated stainless steel grades for the tests. The support base of each bent beam was made of mahogany wood to prevent galvanic corrosion between it and the bent strip when immersed in the prepared mud media. All the specimens from a given steel grade were assigned one identification number chosen from numbers; 1, 2, 3, 4, 5, 6, and 7. Nails of various sizes were used to represent the numbers and nailed about half-length into the wooden base of the bent specimens. The protruding sizes of the nails were thus used to identify the specimens with their assigned numbers. The specimens were each subjected to a maximum static bending tensile stress (σ) equivalent to 90% of the 0.2% offset yield strength of the stainless steel grade it was made from in accordance with ASTM-G-39 and ISO 7539-2 and used by Dergach et al, 2010 as shown in Figure 1 below. :

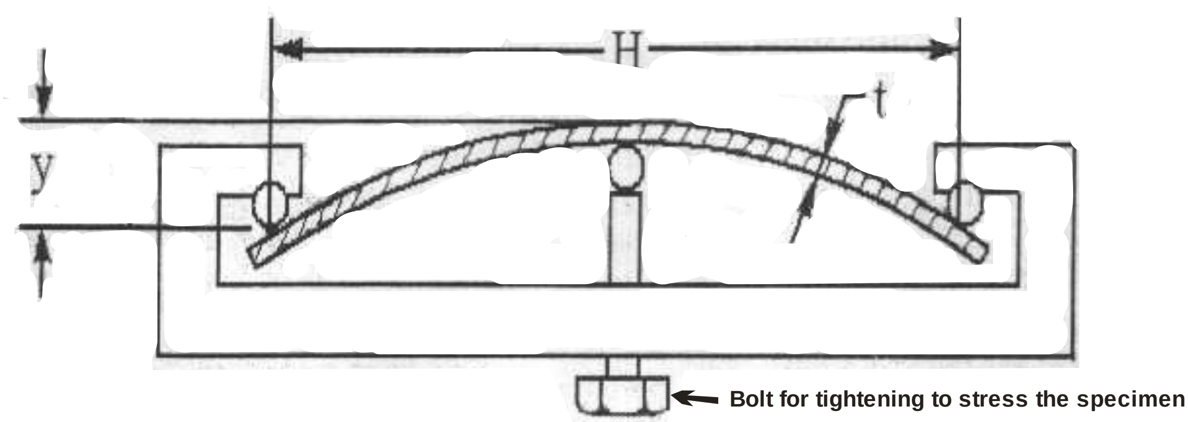

Fig. 1: Set-up stress in the specimen by bending it (Dergach et al 2010)

The maximum bending stress σ in the beam was evaluated in accordance to Dergach et al (2010) as:

$\sigma = 6Ety/H^2$ ………………..1,

where, E is the Young's modulus of stainless steels (N/mm^2), y is the maximum bend of the specimen (mm) for a stress equivalent to 0.2% offset of the yield strength of each steel grade. The values of the 0.2% offset yield strength and E for each steel grade in this study were obtained from Smith and Hashemi (2010), Outokumpu Stainless Steel Avesta Research Centre (2013) and INTERNET (2014d) and used to determine y from equation 1, t is the specimen thickness (2mm) and H is the distance between the bent beam specimen supports and equals to170mm. The determined value of y and a vernier caliper were

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used to accurately set the beam by tightening the setting bolt.

Collection and characterization of the harbour mud

The mud was collected in shallow water close to the bank of river Kaduna near Rafin Guza, Kawo new extension, Kaduna. The mud was collected under shallow water by fetching it in a metal dish and pouring into two medium-sized plastic containers with open ends. The containers were conveyed in a van to the laboratory where the tests were conducted. Determinant of mud corrosivity level such as the mean sulphate reducing bacteria (SRB) in cells/g, the mean sulphide (μg/g), nitrogen and phosphorus contents (% dry weight) and organic content of the mud were evaluated to characterize the collected mud in accordance with procedures used by Farhina (1982) and Francis et al (1999). The mean SRB count was determined by the method of serial dilution, the organic content by pyrolysis at 550ºC, the mean sulphide content by ion chromatography, the phosphorus and nitrogen contents (% dry weight) by Vanadomolydate and Kjeldahl methods respectively (AFRIS,1980, Farhina, 1982; Francis et al, 1999; and INTERNET,2014c, d).

The susceptibility tests

The as-collected aqueous harbour mud media was poured in a large steel bowl and thoroughly stirred with a hard wooden rod. One specimen produced from each designated steel grade were stressed to a maximum bending stress of 90% of their 0.2% offset yield strength in accordance with NASA (2005). The specimens were then submerged in the stirred media in the bowl at the same time at room temperature for one hour and frequently observed with an optical magnification of 40 using Amazon-produced optical glasses to find out whether any of them cracked or not and note the time at which cracking occurred. Any specimens that did not crack were taken out of the bowel at the end of the one-hour submergence and thoroughly re-inspected for any crack on each with the same optical magnification of 40 using the same magnifying glass. This was repeated with another similar set of specimens when the same aqueous media was heated to each of 100^{O}C, 200^{O}C and maintained there during specimen exposure using a 20-Kg gas-fired heating unit. The temperatures were regularly controlled by adjusting the gas flow valves to burn more or less gas. This was again repeated with an admixture that consisted of 40% concentrated sulphuric acid and 60% of the mud at each temperature. The choice of 200ºC as the maximum test temperature was intended to imitate the test temperature stipulated by ASTM G36-39 in a boiling 42wt% $MgCl_2$ at 155±1ºC with a higher factor. The temperatures were monitored with a 0-360ºC mercury-in-glass thermometer (Kitikhun Sutthiprapa et al, 2010; Sambo, 2014).

Results

Chemical Composition of the Stainless Steel Plates

The results of analyses of chemical compositions of the Outokumpu-produced stainless steel plates under section 3.2 as per ASTM or UNS equivalent grade designations of the Outokumpu-produced and graded stainless steels is shown in Table 1a while their corresponding 0.2% offset yield strengths and Young's moduli as appropriately obtained from Outokumpu Stainless Steel Avesta Research Centre (2013) and the INTERNET (2014d) are presented in Table 1b.

Table 1a: The Analyzed Percentage Elemental Weight Compositions of Plates of Stainless Steel of Various Grades used to prepare the Test Specimens (Sambo, 2014)

ASTM 409	0.019C	11.499Cr	0.410 Ni	0.492Ti	87.529Fe			
ASTM 420	0.031C	12.502Cr	40.985 Ni	0.496Mo	82.5371Fe			
UNS S32304	0.031C	22.79Cr	3.503Ni,	0.0496N,	0.012Mo	74.364Fe		
ASTM 321H	0.051C	0.149Ni	17.41Cr	9.203Mo	1.305Si	0.361Ce	71.48Fe	
ASTM 314	0.0695C	24.483Cr	19.512 Ni	2.127Si	53.765Fe			
ASTM 301	0.098C	16.4989Cr	6.96 Ni	7.895Mn,	1.707Cu,	76.421Fe		
ASTM 904L	0.009C	0.022Ni	19.991Cr	18.014Mn	6.11Mo	0.313Cu,	55.492Fe	

ASTM 409 is ferritic grade, ASTM 420 is martensitic precipitation hardening grade, UNS S32304 is duplex grade, ASTM 321H is austenitic high temperature grade, ASTM 314 is also austenitic high temperature grade, ASTM 301 is austenitic grade and 904L is high performance austenitic grade

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Table 1b 0.2% Offset Yield Strength and Young's Moduli of the Stainless Steel Grades

Designated steel grade	0.2% offset yield strength (MPa)	Young's modulus (GPa)
ASTM 409	255	20o
ASTM 42O	500	200
UNS S32304	450	200
ASTM 321H	250	200
ASTM 314	265	200
ASTM 301	300	200
ASTM 904L	260	200

Corrosivity Factors of the Mud

The analyzed f corrosivity factors of the test mud are presented Table 2.

Table 2: Corrosivity Factors of Kaduna River Harbour Mud

Nitrogen content (% dry weight) = 0.73

Phosphorus content (% dry weight) = 0.31

Organic content (% dry weight) = 9.4

Mean SRB (cells/g) < 10^6

Stress Corrosion Cracking Susceptibility Tests

Results of susceptibility tests are presented in Table 3.

Table 3: Results of Stress Corrosion Cracking Susceptibility Tests (Sambo, 2014)

Prepared mud	Specimen No	Results of crack inspection of specimens	
		Results	Temperature
Unmodified aqueous river mud	1	NCD	Room temperature
	2	NCD	
	3	NCD	
	4	NCD	
	5	NCD	
	6	NCD	
	7	NCD	
	1	NCD`	$100^{O}C$
	2	NCD	
	3	NCD	
	4	NCD	
	5	NCD	
	6	NCD	
	7	NCD	
	1	NCD	$200^{O}C$
	2	NCD	
	3	NCD	
	4	NCD	
	5	NCD	
	6	NCD	
	7	NCD	
	1	NCD	Room temperature
	2	NCD	
	3	NCD	
	4	NCD	
	5	NCD	
	6	NCD	

40% con 42s04+ 60% aqueous river harboui admixture	7	NCD	
	1 2 3 4 5 6 7	NCD NCD NCD NCD NCD NCD NCD	100ºC
	 2 3 4 5 6 7	NCD NCD NCD NCD NCD NCD NCD	200ºC

NCD = No crack detected

1= ASTM 409, 2 = ASTM 420, 3 = ASTM 321H, 4 = ASTM 314, 5 = ASTM 301, 6 = UNS S32304 and 7 = ASTM 904L

Analysis of results

Table 3 shows results of a laboratory study on SCC susceptibilities of the study stainless steels each under tensile stress of 90% of 0.2% offset of their yield strength and submergence exposure for one hour in a harbour mud from river Kaduna that was acidified and heated to various levels. From the results, no crack was detected in any of the specimens. This gives an indication that the mud and its preparations are not aggressive enough to cause stress corrosion cracking of the test stainless steels when stressed below their yield stresses. This indication is upheld by the work of Guma and Oguchi (2011) who found out that generally the average corrosivity level of the river in the vicinity of Kaduna city is moderate. Their work however cautioned when dealing directly with factors from muddy ponds of the river section whose corrosivity levels were found relatively higher than other locations of the section. The average corrosion rate of mild steel in the river ponds was found to be 0.10825mm/yr in comparison with the 0.05-0.15mm/yr for sea water environments. The greater the SRB count, the more aggressive a mud is potentially. Farhina (1982) looked at a selection of muds from around the United Kingdom coast, plus several others. The most aggressive had a summer SRB count of 10^7cells/ml. The organic content (% wt) of mud is considered very high if it is greater than 15%, high if it is from 10 to 15%, medium if falls from 5 to 10% and low if it is less than 5%. The sulphate content is considered high if it is greater than 1000 mg/l, medium if it is from 500 to1000 mg/l, low if from 200 to 500 mg/l and very low if it is less than 200 mg/l. A mud is considered to contain high phosphorus and nitrogen contents (% dry weight) if the contents are greater than 0.3% and less than 1% respectively according to Francis et al (1999) and Farhina (1982). As these factors increase the corrosivity level of mud increases. It can therefore be inferred from the results presented in Table 2 that the general corrosivity level of the mud is not much above average in comparison with the most corrosive mud. This also agrees with the work of Guma and Oguchi (2011) that the corrosivity level of the muddy ponds of the river was above average for fresh water environments. According to Viswanathan et al (1979), susceptibility to SCC increases with tensile stresses. Stresses of 82.8 to 137.95N/mm^2 readily cause cracking but cracking is rare with stresses below 82.8N/mm^2. Susceptibility to cracking increases greatly with zinc content. Alloys with 85 to 90% copper are practically immune and with 90% copper they are fairly free from cracking. In tests carried out by Drugli and Steinsmo (2014) with two highly alloyed duplex stainless steels and one highly alloyed 6% molybdenum austenitic stainless, they found that the cracking time at the lowest temperatures at which cracks were detected on the three test materials were 400 to 670 hours at 100ºC for UNS S31808 duplex stainless steel and no cracking was observed after 4100 hours at 90ºC for the steel, 2964 to 3960 hours at 100ºC for UNS S532750 duplex stainless steel and 1300 to 1992 hours at 110ºC for UNS S31254 austenitic stainless steel. Although the applied tensile stress on any of the steel was from 225 to 450/mm^2,from ASTM 321H to UNS S23204 duplex

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steel are higher in comparison with stresses levels of 82.8 to 137.95N/mm^2, duplex steel in particular are outstandingly strong and highly corrosion resistant. It is however possible to operate at such stresses without SCC, depending on the manufacturing process, chemical composition, grain boundary structures, degree sensitization of the test specimens and environmental factors. From the results it can also be seen that the test steel contained very minimal or no zinc. Although the maximum exposure temperature of 200^{o}C was reasonable the exposure time of one hour was comparatively lower compared to the study report by Drugli and Steinsmo (2014). Finally, the non-susceptibility of the steel specimens to SCC in the test media may be explained that the mud per se did not contain sufficient factors or characters that could cause SCC of any of the steel, so the only factors that were at interplay to cause any SCC were the acid contents, heat and exposure time of one hour which probably were not adequate to cause SCC of any of the specimens.

Summary and conclusion

Stress corrosion cracking of a given metal or its alloys does not occur in all environments but only in those that posses particular factors or characters. It is an unpredictable catastrophic phenomenon with calamitous effects so it should be prevented from occurrence in all quarters. Alloy composition and microstructures play important role in controlling SCC susceptibility. Sensitization, grain boundary, Cr depletion and inclusions are usually preferential crack initiation sites depending on the alloy microstructure and composition but all these are greatly influenced by the manufacturing process. SCC of austenitic stainless steel in specific environmental types is more understood and reported in the literatures. Nevertheless, there is need for information on the SCC susceptibility level of every other steel type and some other critical engineering materials in every environment. Harbour mud can be very corrosive and is generally among the most steel-corrosive natural environments. In this paper a comparative assessment of SCC susceptibilities of similarly prepared un-sensitized specimens from seven different Outokumpu-produced ASTM-designated steel grades 409, 420, 321H, 314, 301, UNS S32304 and 904L with Kaduna river harbour mud as the target environment has been investigated in a laboratory study and the results has been presented in this paper for consideration, rethinking and research interest. The obtained results for the exposure duration give an indication that none of the steel will be susceptible to SCC in the mud under such working stresses. Nevertheless; analysis of detailed microstructure of each steel grade, percentage elongation, hardness and sensitization will also need to be undertaken during test procedures in further researches to supplement the results.

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