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Comparision of Imagej Analysis of Structure of Two Constructional Steel

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Abstract: An image analysis processing method for the measurement of structure of Federated and Ukraine steel from optical microscope images using imagej program is studied. Some parameters like calculation of area, pixel value statistics, distances and angles measurements, edge detection, such as the circularity, ferret angle, solidity and perimeter, average area and the percentage area was examined. Federated grain count was 114 with perimeter of 447.15 and also has a standard deviation of 7.306 and mean of 27.526. While Ukraine, has a grain count to be 1248 with perimeter of 67.243 and a standard deviation of 5.886 and mean of 28.039. From the mechanical analysis result, 12 mm of Federated steel has the hardness value of 150.8BHN and also has the highest impact value of 66.37J. From the Coefficient of Friction (COF) analysis, Ukraine has a better COF which means the Ukraine steel has a better wear resistance compares with Federated steel.

Keywords: Federated and Ukraine Steel, Microstructure and Imagej

Introduction

Federated steel mills is located on Block XI, Plot 3-10, Otta Industrial Estate of Idiroko Road, Otta, Ogun State, Nigeria. It manufactures all sizes of steel reinforcing Bars, Flat Bars and welding electrodes. The company is jointly owned by British/Hong Kong in partnership with Nigerians. The plant operates using Electric Arc Furnace with an installed capacity of 25,000 metric tonnes of crude steel, it uses local metal scraps and also imports Billet as well. It rolls out 8, 10, 12, 16, 20 and 25 mm reinforcement bars as its end product while Ukraine steel is sourced from the local market in Lagos, Nigeria.

There are three stages in producing final steel products. These are Iron making, steel making and rolling. The most widely used process used for the manufacture of steel are: Blast Furnace (BFM), the Direct Reduction Method (DRM), the mini mill and the COREX.

The Blast furnace is a conventional method of production. It involves heavy construction works at site and usually takes a relatively lengthy construction period while the direct reduction methods comprises a package of prefabricated components which are normally brought from the workshop and assembled at site, within a relatively shorter time. While the mini mills only is an assembly of smaller processing units designed to specifically produce smaller quantities of steel products. The corex is a rare advance in technology that is not very common (Jibrin, 2012; Shumacher and Sathaye, 1998).

The percentages of carbon and other elements such as manganese, molybdenum, vanadium, silicon, chromium, nitrogen and Sulphur in steel have a direct effect on its strength and deformation characteristics (John, 1983; Amstead, 1987; Colin, 1987; Kareem, 2009). Steel remains one of the most important engineering materials in spite of stiff competitions from other materials such as ceramic and polymer (Goto, 1971). Image analysis deals generally with acquisition of quantitative information about various parameters of microstructure of a material such as determination of percentage fraction of phases, particular size, circularity etc. Circularity can be calculated as a shape parameter index in the ImageJ software. The definition of circularity (C_1) in the ImageJ software is as follows:

$$C_1 = 4\pi \frac{A_1}{P_1^2} \quad (1)$$

where, A_1 and P_1 are the area and the perimeter using imageJ.

There are numerous commercial software such as Amira, Comsol multiphysics, etc., for analysis features (Schneider *et al*., 2012). However, this paper describes an investigation of the Federated and Ukraine steel structure analyzing from OM image using imageJ program software (Katarina and Gejza, 2009).

Materials and Method

Material

Federated and Ukraine steel were used for this experimental work. The chemical analysis of the steel is shown in Table 1and 2. The microstructure of this steel consists of Ferrite and Pearlite.

Table 1: Chemical element (weight %) of Federated steel

C	Si	S	P	Mn	Ni
0.266	0.164	0.018	0.018	0.637	0.026
Cr	Mo	V	Cu	Fe	
0.025	0.502	0.001	0.220	98.123	

Table 2: Chemical element (weight %) of Ukraine steel

C	Si	S	P	Mn	Ni
0.195	0.075	0.025	0.009	0.56	0.013
Cr	Mo	V	Cu	Fe	
0.022	0.0001	0.0001	0.018	99.083	

Metallographic Examination

Grinding

A small length of 35 cm long was cut out from a parent metal of 16 mm rod steel of Federated and Ukraine steel This operation aims at producing a perfectly flat and smooth surface Silicon carbide papers of different grades placed on the grinding machine was used in the order of 220, 320, 400 and 600, i.e., from coarse grade to fine grade. The grinding process was done under running water to wash away the grits and also to avoid overheating. The samples was turned through 90° while changing from one grit size to another in the materials laboratory at Tshwane University of technology materials laboratory, Pretoria. This is to neutralize the scratching effect of the previous grinding of the former grit size.

Polishing

A universal polishing machine was employed. A polishing cloth (selvt cloth) was placed on the polisher for the initial polishing swamped with solution of one micron of silicon carbide solution, then, followed by the final polishing stage with selvt cloth swamped with solution of 0.5 µm Silicon carbide until a mirror-like surface is attainable. It is then washed and dried.

Etching

This is done to reveal the microstructure of the polished surface. Etching is the selective attack on the grain boundaries being a region of high energy and dislocation density. The mirror-like surface was etched in 2% NITAL). The sample was again washed, dried and later viewed under the metallurgical microscope.

Optical Microscopy

The samples were etched in 2% NITAL (2% Nitric Acid and 98% Ethyl Alcohol), they were put in a desiccator and view with metallurgical Optical microscope S/N IF76768 in Tshwane University of Technology, Pretoria, South Africa.

Results and Discussion

Table 1 showed the chemical composition of Federated steel with the carbon content of 0.266% by weight, while Table 2 showed the chemical composition of Ukraine steel with the carbon content of 0.195% by weight. Figure 1 showed the flowchart of the ImageJ process of 16 mm Federated and Ukraine Steel. In Fig. 2a showed the original images of Federated and Ukraine steels taken with metallurgical Optical microscope S/N IF76768. The images were uploaded and analyzed with imageJ software. Images in Fig. 2a were thresholded by using Image-Adjust and Threshold tool. The thresholded colour images of Fig. 2c were masked to give the outlines in Fig. 2e while Fig. 2f showed the 3D interactive surface plot drawn by intensity of any colour offers a basic vision of observed surface morphology of the steel such as the grid size, the smoothing and the perspective of the minimum and maximum percentage in relation to the z-scale. This was also attested to by the work of Dang *et al*. (2014). The circularity (shape descriptors) parameter allows for evaluating the shape of grains Fig. 2g showed the *bins which* is the number used for the particle size distribution histogram. In Fig. 2h, we have the histograms of Federated steel with higher frequency compared with Ukraine steel.

By etching with 2% NITAL (2% Nitric acid + 98% Alcohol) and viewing with optical microscope, the picture was uploaded into the ImageJ software and processed using the flowchart in Fig. 1. The processed images are shown in Fig. 2 Table 3 showed the microstructural parameters of Federated steel using imagej analysis. The grain count was 114 with perimeter of 447.15, ferret diameter which is the average roundness has 64.571. The area distribution of the grains which is taken between 20 minimum and 40 maximum has a standard deviation of 7.306 and mean of 27.526. For the Ukraine, in Table 4, the grain count was 1248 with perimeter of 67.243, ferret diameter which is the average roundness has 14.243. The area distribution of the grains which is taken between 20 minimum and 40 maximum has a standard deviation of 5.886 and mean of 28.039.

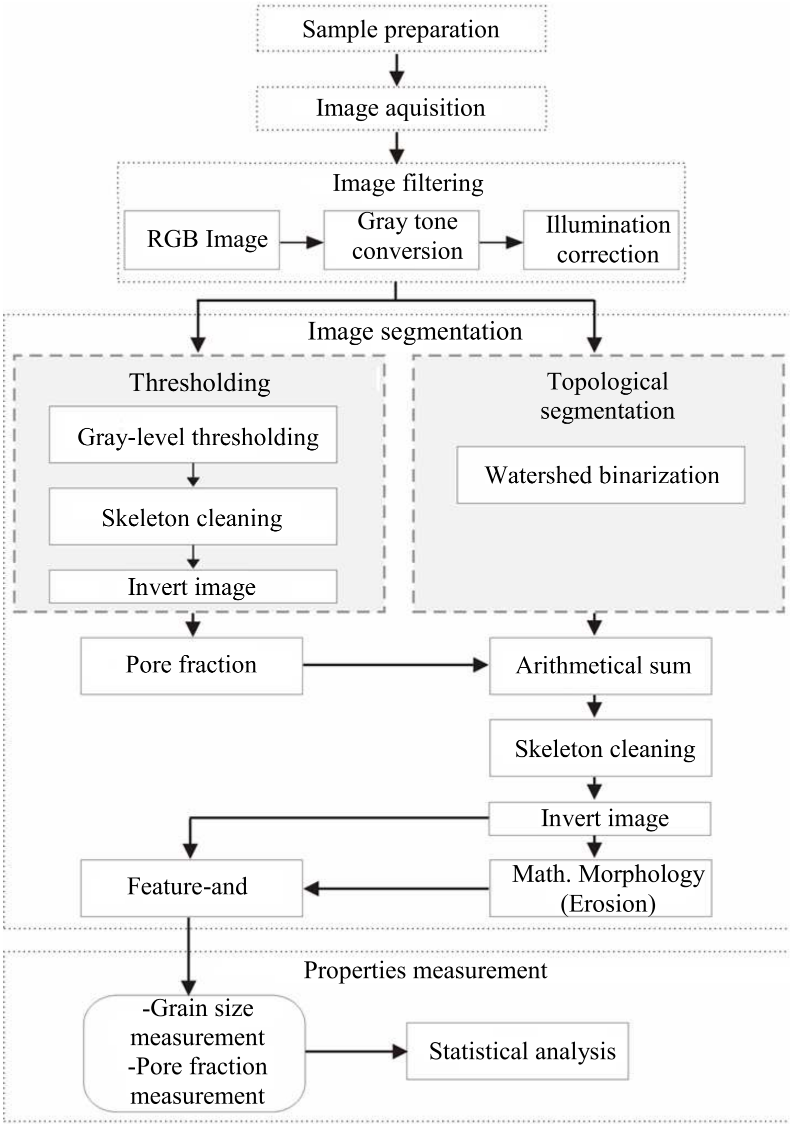
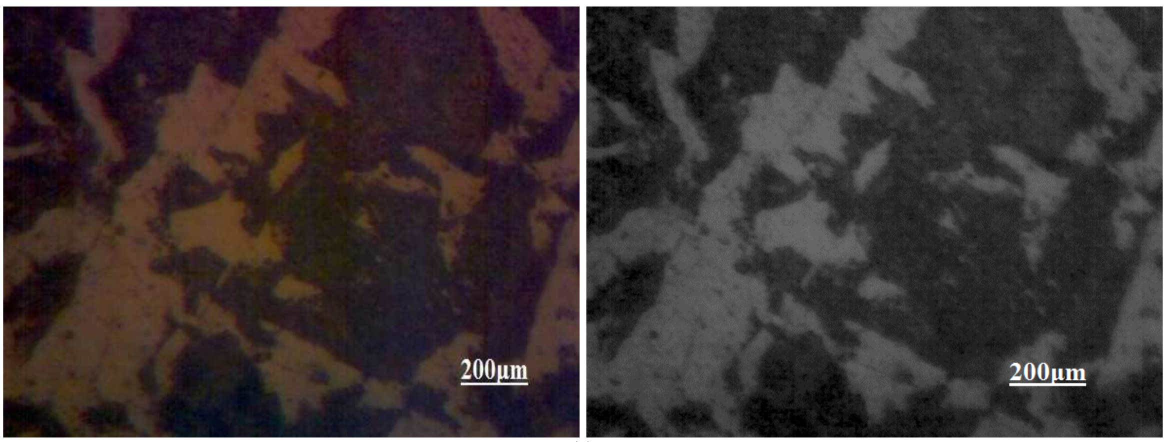


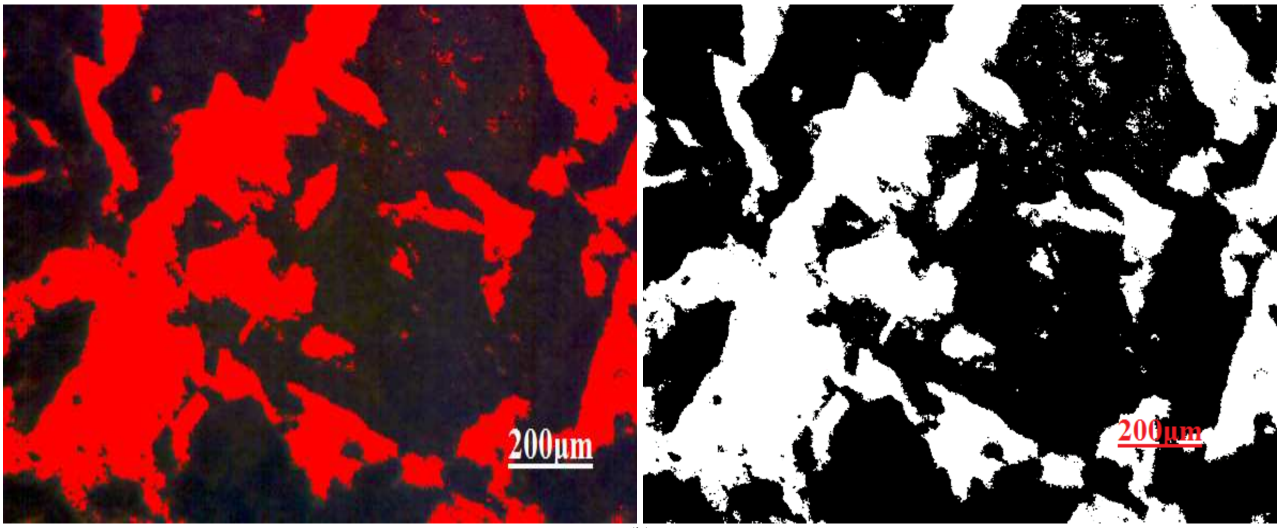
Fig. 1: Flowchart of the imagej process of 16 mm Federated and Ukraine Steel Diógenes *et al*. (2005) (11)

Federated steel



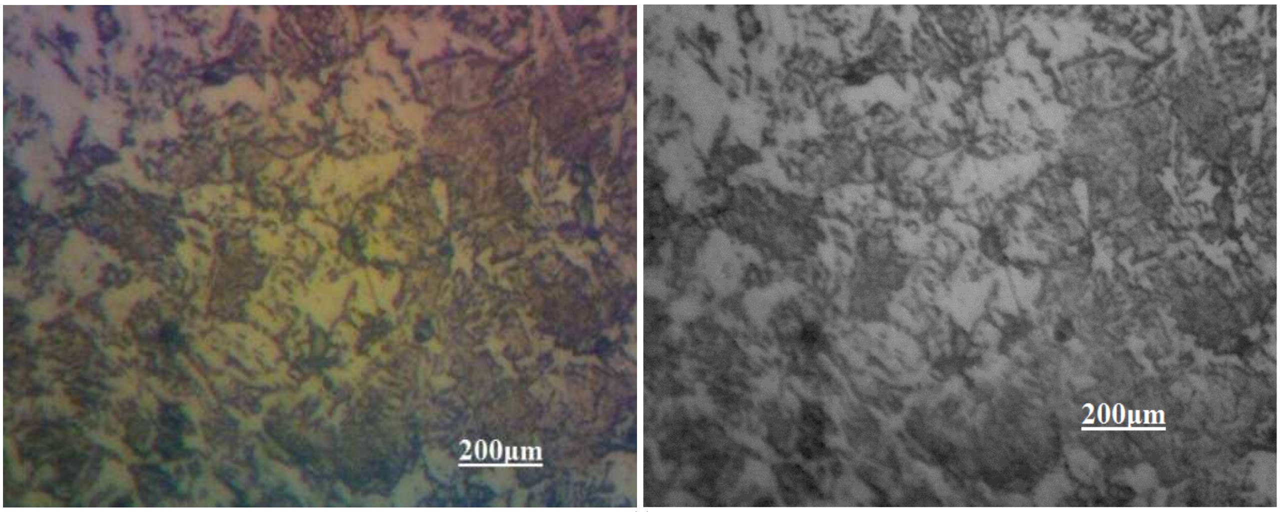
(a)

DOI: 10.3844/ajeassp.2018.318.326

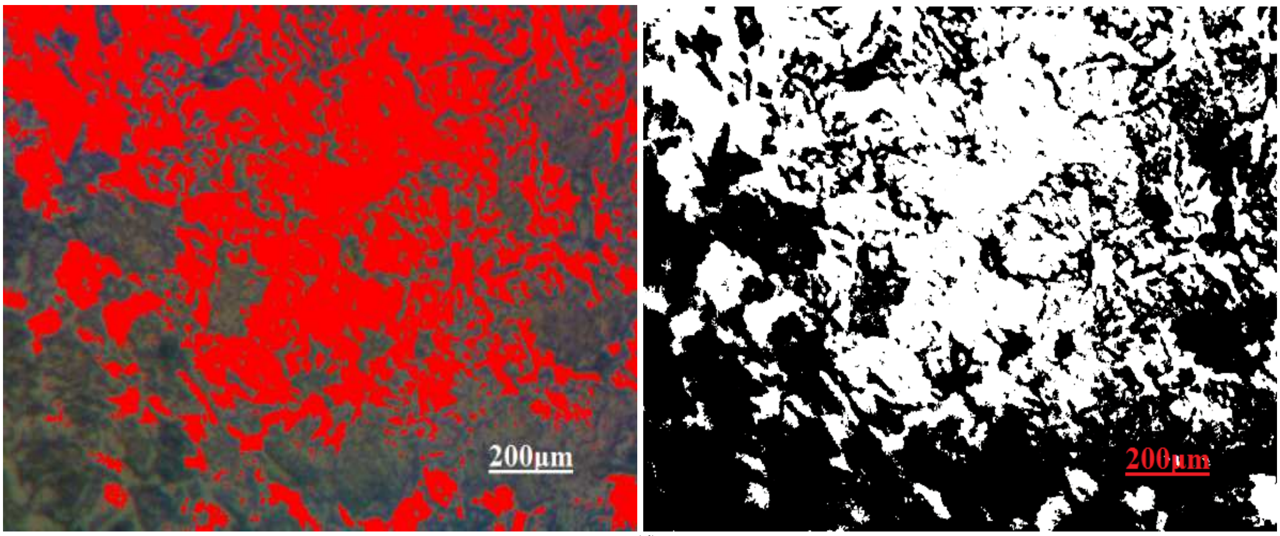


(b)

Ukraine steel

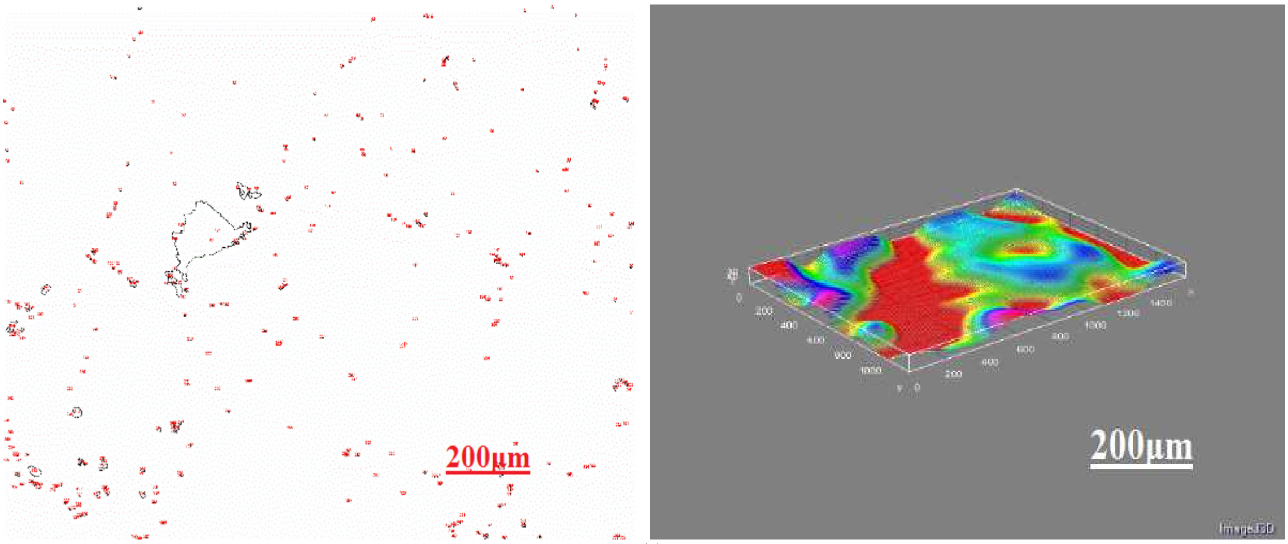


(c)

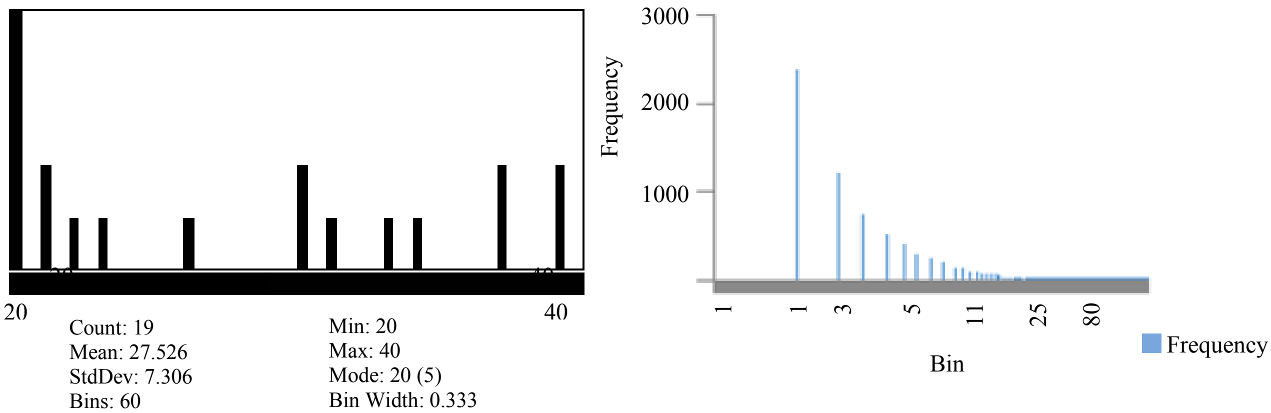


(d)

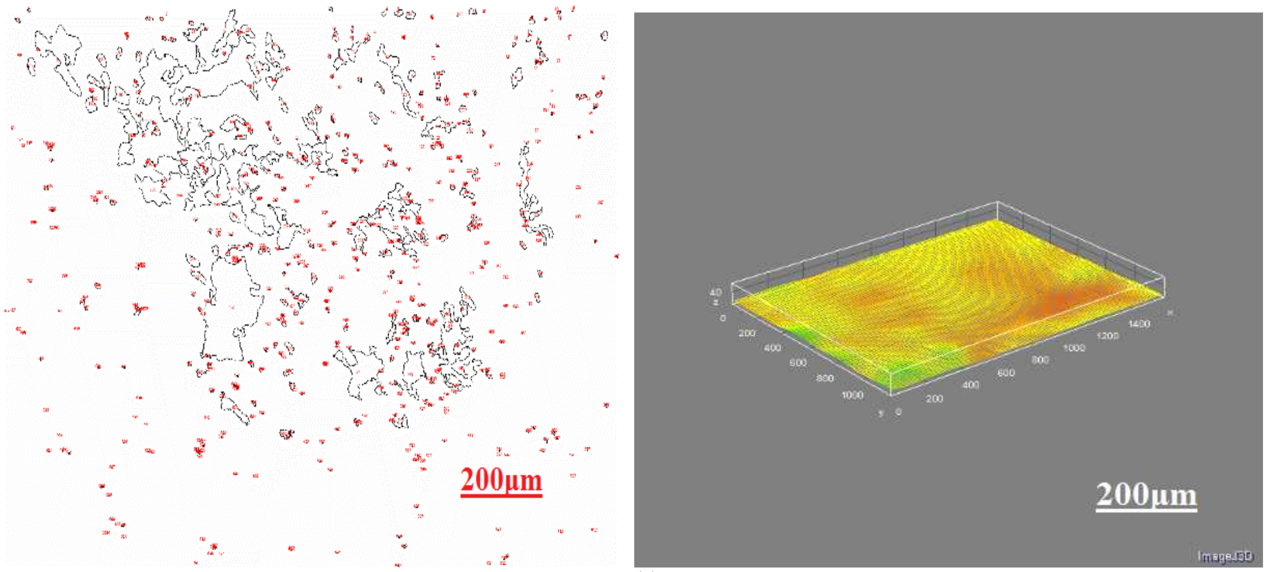
DOI: 10.3844/ajeassp.2018.318.326



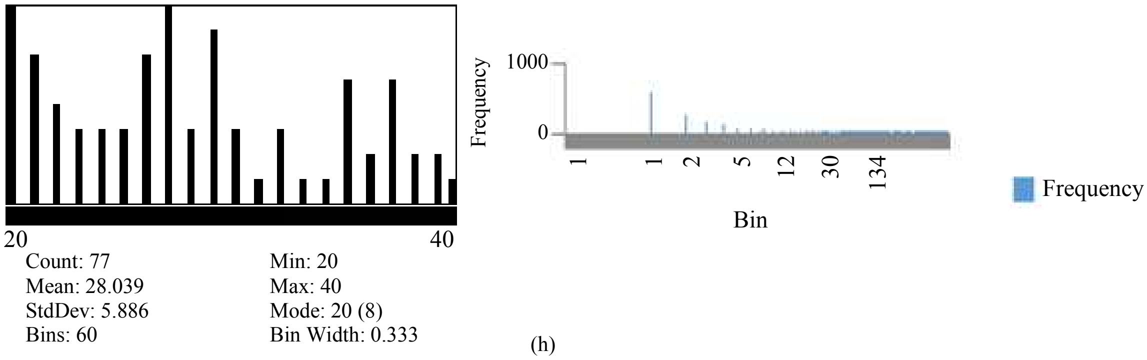
(e)



(f)



(g)



(h)

Fig. 2: Processed images of 20 mm Federated and Ukraine steel by the image analysis (using) Imagej (a) Origin image-Optical Microscope (b) processing and threshold (blue) (c) Threshold colour image after eliminating noise (d) Thresholded (black and white) (e) result of particle distribution (using Analyze tool in ImageJ) (f) Interactive 3D surface plot (g) Area of distribution (h) Histogram

Table 3: Microstructural properties of federated steel by ImageJ analysis

Slice	Count	Total Area	Average Size
Federated steel 16mm	114	1068396	9371.895
%Area	**Perim.**	**IntDen**	
55.646	447.15	2389833	
Slice	**Circ.**	**Solidity**	**Feret**
Federated steel 16mm	0.717	0.845	64.571
FeretX	**FeretY**	**FeretAngle**	**MinFeret**
772.956	639.921	101.921	35.506

Table 4: Microstructural properties of ukraine steel by ImageJ analysis

Slice	Count	Total area	Average size
Ukraine Steel 16mm	1248	920319	737.435
%Area	Perim.	IntDen	
47.933	67.243	188045.9	
Slice	Circ.	Solidity	Feret
Ukraine Steel 16mm	0.773	0.832	14.243
FeretX	FeretY	FeretAngle	MinFeret
996.824	78.01	108.67	8.366

In Fig. 3, the Impact and Hardness were conducted by using the ASTM E23 for notched bar impact testing, as the diameter of the rod increases, the hardness value increases from 8 mm until it gets to 12 mm with hardness value of 150.8 BHN and then gradually decreases to 114 BHN at 25 mm rod size. It is interesting to note that the 12 mm rod also has the highest impact value of 66.37J. Hence, Federated steel 12 mm combines impact and hardness strength together which is of great value to the construction companies.

In Fig. 4, Ukraine has the highest hardness value of 133.1BHN in 10 mm and highest hardness value of 64.87Joules in 25 mm size but has the lowest impact no of 49.68J in 16 mm steel rod, however, the hardness decreases from 16 mm as the rod size increases and the impact value increases from 10 to 12 mm but decreased in 16 mm and start to increase from 20 to 25 mm.

Figure 5 compared the hardness of Federated and Ukraine steels. The hardness of 10, 12, 16 and 20 mm of federated steel are higher compared with Ukraine. Generally, Federated steel has higher hardness values compared with Ukraine except in 20 mm where Ukraine has a higher hardness value. However, Federated steel has higher hardness value compared with Ukraine, this may be because of the carbon content in the Federated steel which is higher than the carbon content in Ukraine steel (Ponle *et al*., 2014; Calika *et al*., 2009; Zheng *et al*., 2010; Valeria *et al*., 2015).

The Impact value of Federated steel in Fig. 6 increases in 10 to 12 mm and slides down to 20 mm and moves up to 25 mm. This same pattern follows the Ukraine steel.

The Federated steel in Fig. 7 has waveforms not compacted together compare to the waveform in Ukraine steel in Fig. 8. The waveform of Federated steel 16 mm on load 5N accelerate linearly from 10 sec to 200 sec before finally reaching 0.56 and sliding to 0.47 before stabilizing and oscillating to 1000 sec. Federated steel 16 mm at 5, 15, 25 and 25 mm at 5N have a compacted waveform.

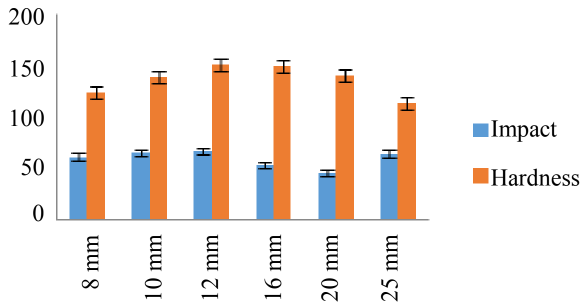


Fig. 3: Bar chat for Impact and Hardness test of Federated steel

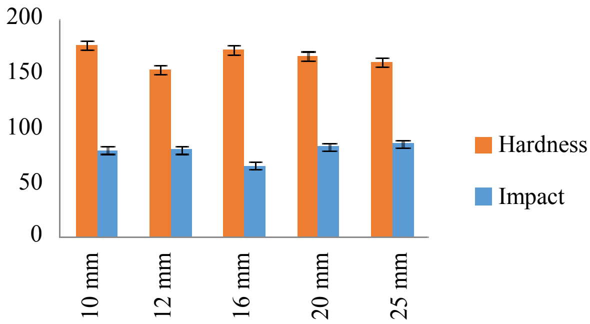


Fig. 4: Bar chat for impact and hardness test of ukraine steel

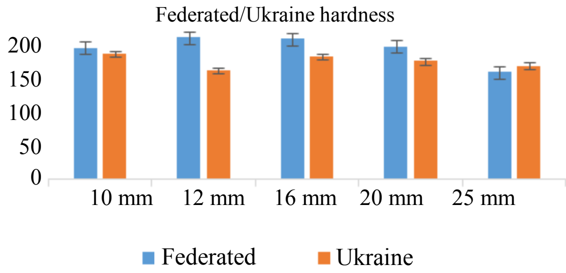


Fig. 5: Comparison of brinell hardness number of federated steel and ukraine steel

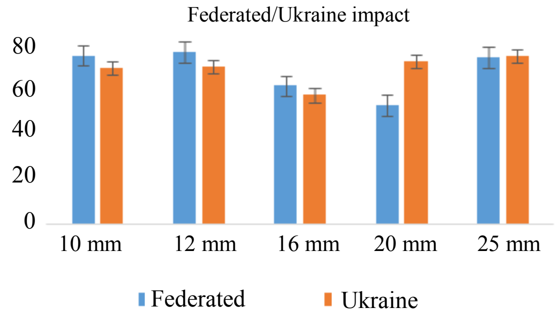


Fig. 6: Comparison of impact number of federated and ukraine steel

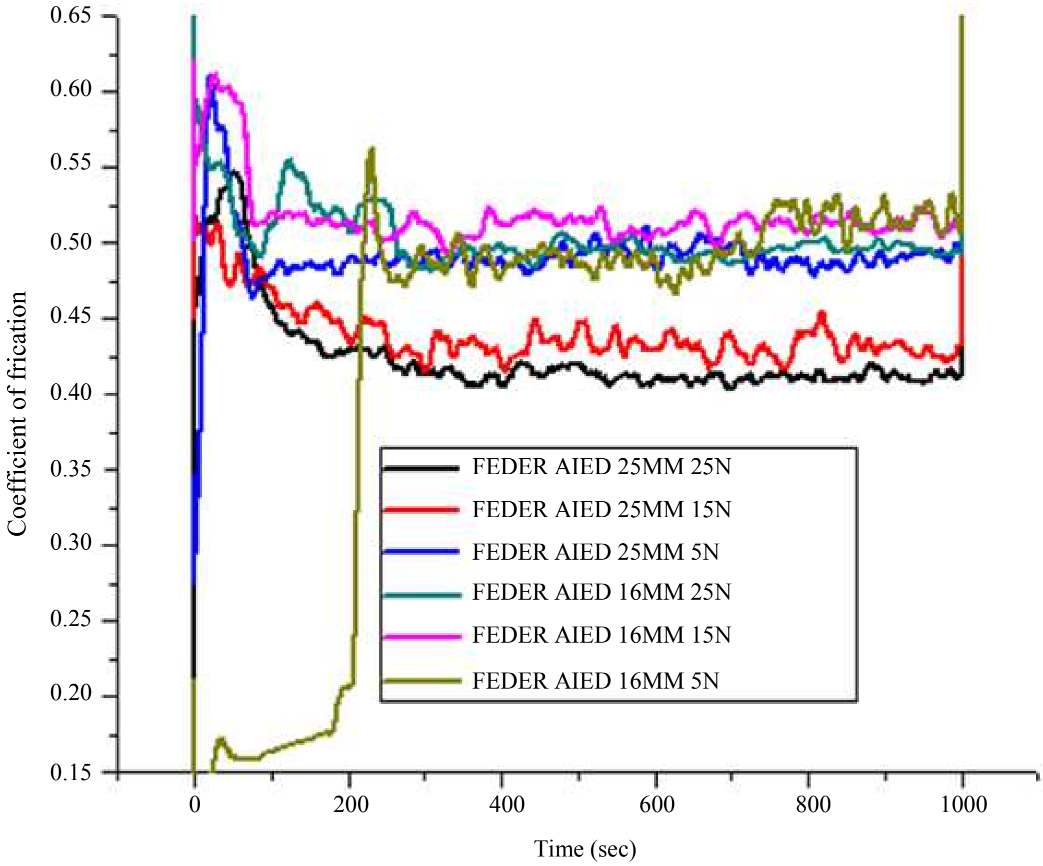


Fig. 7: Coefficient of friction of Federated Steel

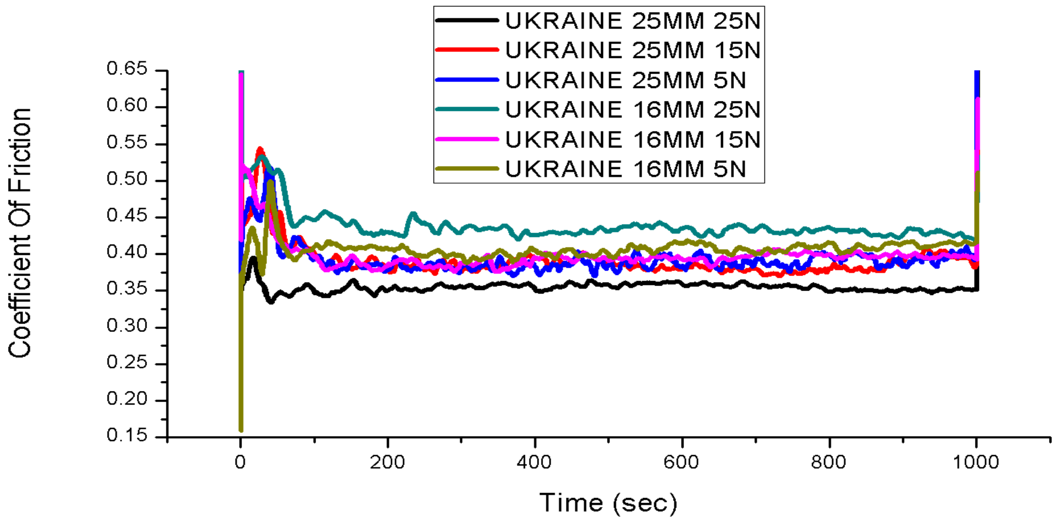


Fig. 8: Coefficient of friction of Ukraine Steel

The corrosion wear coefficient of Ukraine steel is shown in Fig.8 where the waveforms are compacted except 16 mm at 25N and 25 mm at 25N. Ukraine steel 25 mm at 25N has wear coefficient of friction of 0.35 and increased to 0.38 before sliding down to 0.34 at 40 sec and oscillate uniformly to 1000 sec. It is clearly seen that the time to reach steady friction varies for different loads, the time for higher load to reach steady friction is less. This is because the surface roughness and other parameters attain a steady level at a shorter period of time with increase in load. This result is in perfect agreement with the results of Chowdhury *et al*. (2006).

Conclusion

In this study, we have successfully analyzed some basic parameters of Federated and Ukraine steel such as the circularity, ferret angle, solidity and perimeter, average area and the percentage area using imageJ. It also showed the difference between the images of the two steels. The method is automated and very reliable, accurate, very fast and can be used for some sundry analysis. From the mechanical analysis result, 12 mm of Federated steel has the hardness value of 150.8BHN and also has the highest impact value of 66.37J. From the Coefficient of Friction (COF) analysis, Ukraine has a better COF which translates to better wear resistance.

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Author's Contributions

Alo Francis Ireti: The main author and the writer.

Ajoge Emmanuel Omeiza: Carried out the basic mechanical analysis.

Emordi Gnozi: Contributed to the writings.

Kunle Michael Oluwasegun: Contributed to the writings and reading through the manuscripts.

Isadare Dayo Adeyemi: Preparation of the samples.

Oyedele Adedayo Adewale: Sourcing of the materials.

Ethics

We are ready to address any ethical issues that may arise after the publication of this manuscript.

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