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Investigation of The Mechanical Properties of The Carbon Steel ASTM 106A Gr B after Galvanizing Process

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ABSTRACT

The low carbon steel (ASTMA106 Gr B) has been used in this study to find out the effect of the hot dip galvanizing process on the mechanical properties and hardness. The tests were conducted at ambient temperature, and a microscopic, scanning electron microscope SEM and energy-dispersive X-ray spectroscopy EDS were examined before and after coating. The samples of the tensile test were prepared according to the ASTM (E8/E8M − 16). This study aims to increase the knowledge of the effect of HDG on the mechanical and hardness of the pipe steel, to prevent corrosion in pipes. There has been a slight decrease in the yield stress, and the ultimate stress), while % of elongation increased slightly. There has been a uniform distribution of hardness on the coated surfaces compared to the uncoated surface. The coated surface with a zinc layer is 250µm. There have been examine the chemical composition of zinc element is 96.4wt%. The coating with HDG has a nice layer of protection without any soup reduction in the mechanical properties.

1. Introduction

The petroleum sector has been suffering from the damage in pipelines for transportation in service due to corrosion problems Which causes damage to metals as a result of electrochemical interactions with the environment [1], costly and time-consuming during maintenance. Such a problem has been studied by Sukkar [2].

Corrosion problems play a role in the pipeline, especially on the external surfaces due to the severe environment. Therefore, the base material is examined before it is treated or coated through several different tests to determine the behavior and characteristics of the material [3,4]. In this research A static tensile test and MMM measurement were performed on the ASTM A106 Gr. B steel to investigate its applicability in predicting material deformation state and structural defect [5]. Some research aims to determine the difference in metal strength before and after coating or treatment, as in this research [6], where mechanical tests were used to identify the behavior of the metal, including hardness. However, in this research [7], the validity of the coating on steel was verified and

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then the mechanical properties were compared with uncoated steel. Hot-dip galvanized (HG) steel is often used in several industrial applications, zinc coatings by the hot-dip galvanizing process currently represent one of the most effective of protecting steel against corrosion. The steel is coated by immersing the steel in a molten bath, which leads to the deposition of thin layers of zinc on it [8]. Hot dip galvanizing is one of the most economically viable zinc coating techniques, developed over 200 years ago [9]. The dipping time in the zinc bath plays a major role in the coating layer thickness [10,11] . EDS examination shows the connection of steel with zinc to evaluate the coating properties and its quality [12]. In this research, electrochemical impedance spectroscopy (EIS) measurement was carried out to evaluate the barrier properties of the coating [13].

To understand the mechanical properties behavior of the ASTM A106 Gr B carbon steel after (HDG) coating, literature has studied and discussed this point by, Hakim *et al*., [11] used the hot dip galvanizing coating method of Low-carbon steel to study the effect of immersion time of 3, 6, 9 and 12 minutes in HDG on the Rockwell hardness (HRb), microstructure using (SEM) examined zeta, delta and gamma phases. Also, it was examined the elements Fe, Zn, Mn, Si and S in the specimens after coating, the maximum hardness was found to be 76.012HRb after 3 minutes of immersion in the zinc bath. Another experiment done to examine the effect of HDG for three types of high-strength steel on the mechanical properties of these types of steel exposed to high temperatures during operation and preparation noticed the impact of HDG on the (yield strength, ultimate strength and hardness) was a decreased in the mechanical properties after the hot dip galvanizing process [14]. While Elżbieta *et al*., [15] focused on the optimization of coating heat treatment and its effect on both mechanical and functional properties of steel and cast iron, microhardness and microscopic observation were also examined by EDS, It was stated that although the applied heat treatment HT results in a coating hardness increase, the too high-temperature level may cause coating cracking and delamination. As the processing temperature increases, the coating structure changes - the iron content in individual Zn phases increases. Zinc coating deposited on cast iron is more inhomogeneous.

In a separate study conducted by Adnan Calik *et al.,* [16] used three different galvanizing processes in this study. The microstructure, tensile behavior and hardness of AISI 4140 steel sheets were examined. It was observed that there was a decrease in the mechanical properties compared to ungalvanized samples of AISI 4140 steels.

In the investigation conducted by Musbah Kharis Maatgi, [17] on the low carbon steel produced by a Libyan company which is a rolling (hot and cold) process and hot dip galvanizing process as well. These studied the effect on the mechanical property and microstructure. They found an increase in the yield strength for cold rolling compared to hot rolling with HDG, A decrease in yield stress, tensile strength and hardness, increase in the extension rate for the steel created by the hot-dip galvanizing process, contributing to the growth of the granules, which allows the steel's ability to form during the following manufacturing processes.

In their study, German Pachurin *et al*., [18] focused on galvanizing as the preferred method to safeguard steels from severe conditions. Simultaneously, despite their impact on the durability of delicate samples, the endurance limit of samples with stress concentration rises. Various forms of saturation distribution enhance the corrosion resistance of steel, but there is a lack of information regarding the ideal values for coating thickness that have been investigated. The challenge lies in predicting the physical and mechanical factors of coated metals and alloys due to the difficulty in determining theoretical and experimental data.

To our knowledge there are no studies about the effects of hot dip galvanization on the mechanical properties of the ASTM A106 gr B carbon steel. This work aims to find out whether the use of the HDG process is safe and accountable for use in the sector of oil, the mechanical properties

have been analyses (yield strength, ultimate strength and hardness) of such steel, and examining the microscopic using scanning electron microscope SEM and EDX before and after coating process on the pipes.

2. Methodology

2.1 Experimental Work

The materials use in this study is from the petroleum, the pipe of the ASTM A106 Gr B carbon steel with outside dimeter 273mm NPS 40/STD as shown in Figure 1(a,b). The chemical composition of the steel compared with standard is given in table 1, It was examined at a state company for standard and measured.

The tensile samples were coated by (HDG). This is a process by which an adherent, protective coating of zinc or zinc alloy is developed on the surfaces of steel products by immersing them in a bath of molten zinc. The process (HDG) has been achieved according to ASTM A123 and consists of three basic steps (surface preparation, galvanizing and inspection). The bath temperature was 447 ˚C. The zinc bath has the chemical composition as illustrated in table 2. The time which is taken for dipping was 3 minutes. All samples were prior to dipping. For manuscript publication, all provided Figures must follow the standard of quality for publication.

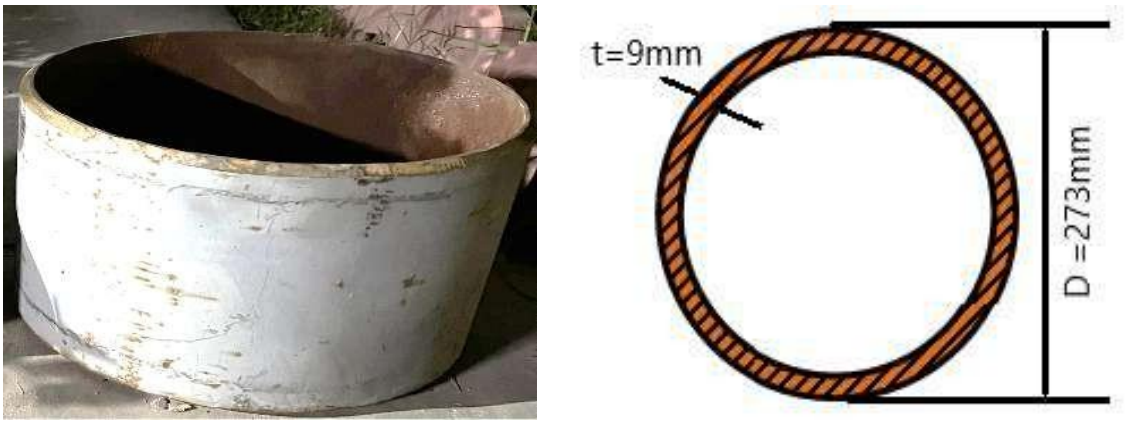


Fig. 1. (a) The pipe and (b) the front view of the pipeline part.

Table 1
The ASTM A106 Gr B chemical composition in wt. %.

Elements wt.%	C	Mn	P	S	Si	Cr	Cu	Ni
Standard the ASM	≤0.3	0.29-1.06	≤0.035	≤0.035	0.01	≤0.04	≤0.04	
Experimental T1	0.0751	0.913	0.0179	0.0056	0.161	0.0189	0.0128	0.013
Experimental T2	0.088	0.91	0.0183	0.004	0.202	0.0211	0.0161	0.011

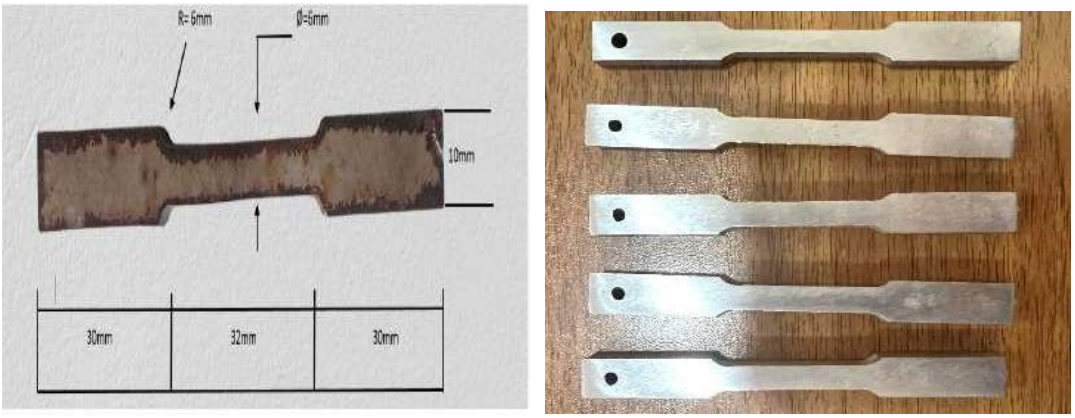
Table 2
The zinc bath chemical composition (wt.%)

Zn	Al	Pb	Cd	Mg
99.979	0.031	0.0	0.0	0.0

2.2 Mechanical Testing

The tensile samples were prepared from the pipe using CNC machine with cooling operation system in order to prevent any heat emission during cutting processes. The specimens of the tensile test were manufactured in a rectangular cross section with the required dimension according to the standard ASTM (E8/E8M − 16), as illustrated in Figure 2. Tensile test was performed at RT using the rig type (United) with a capacity of 600 kN as shown in Figure3, to obtain the mechanical properties like yield strength (Y0.2), ultimate strength (UTS) and percentage elongation (A). The measurement speed was 0.1mm/s

Rockwell Hardness test was conducted at room temperature using the machine type (United) TRU-BLUEII our square samples with dimension of (2cm x 2cm) were used to conduct the hardness test.



a) b)

Fig. 2. a) Dimensions of a tensile specimen in (mm) according to ASTM (E8/E8M − 16) b) Prepared samples



Fig. 3. The tensile test machine United



Fig. 4. United HRBW Hardness rig machine

2.3 Microscope Preparation

The specimens for analysis were prepared by grinding procedure followed by final polishing with different grinding paper (600,800.1000 and1200) followed by final polishing with polish suspension compound (OPS) suspension compound (OPS). The microstructure of steel and coated region were investigated using scanning electron microscope (SEM) FEI-Nether lands Inspect S50-Model equipped with energy-dispersive X-ray spectroscopy (EDX) detector to determine the local chemical composition. The EDX scanning overlarge area was used to measure the chemical composition of the alloy. In addition, element at line distortion for liner scan for chemical composition from the surface to (1.2 mm) was performed to determine the element's diffusion.

3. Results And Discussion

The tensile test has been conducted to determine the effect of (HDG) on the mechanical properties of the carbon steel A106 Gr B, the results are presented in Table 3 with the standard values and results from Shreyas *et al*., [9] for comparison with this study.

The strength (Yield and Ultimate) in this study is slightly decreased this is due to heat treatment by immersion of the samples in the bath of milting zinc, while the elongation is somewhat increasing for the same reason. Figure 5 shows the results as bars for the (Yield stress, ultimate stress, elongation and modulus of elasticity E). The mechanical properties and the modules of elasticity E show a slight decrease in strength while increasing in elongation. These results agree with the Musbah Maatgi, [17] study for the hot rolled steel. The application of HDG coating provides a satisfactory level of protection, ensuring that the mechanical properties remain unaffected by any significant deterioration.

Table 3
The mechanical properties for as received and galvanize steel

	Ultimate tensile strength UTS (MPa)	Yield strength YS (MPa)	Elongation %
Standard [20]	415	240	30
Ref [19] for Maximum allowable operating pressure (MAOP)	514	392	32
Exp. in axial direction	511	460	40
Galvanize	501	452	54

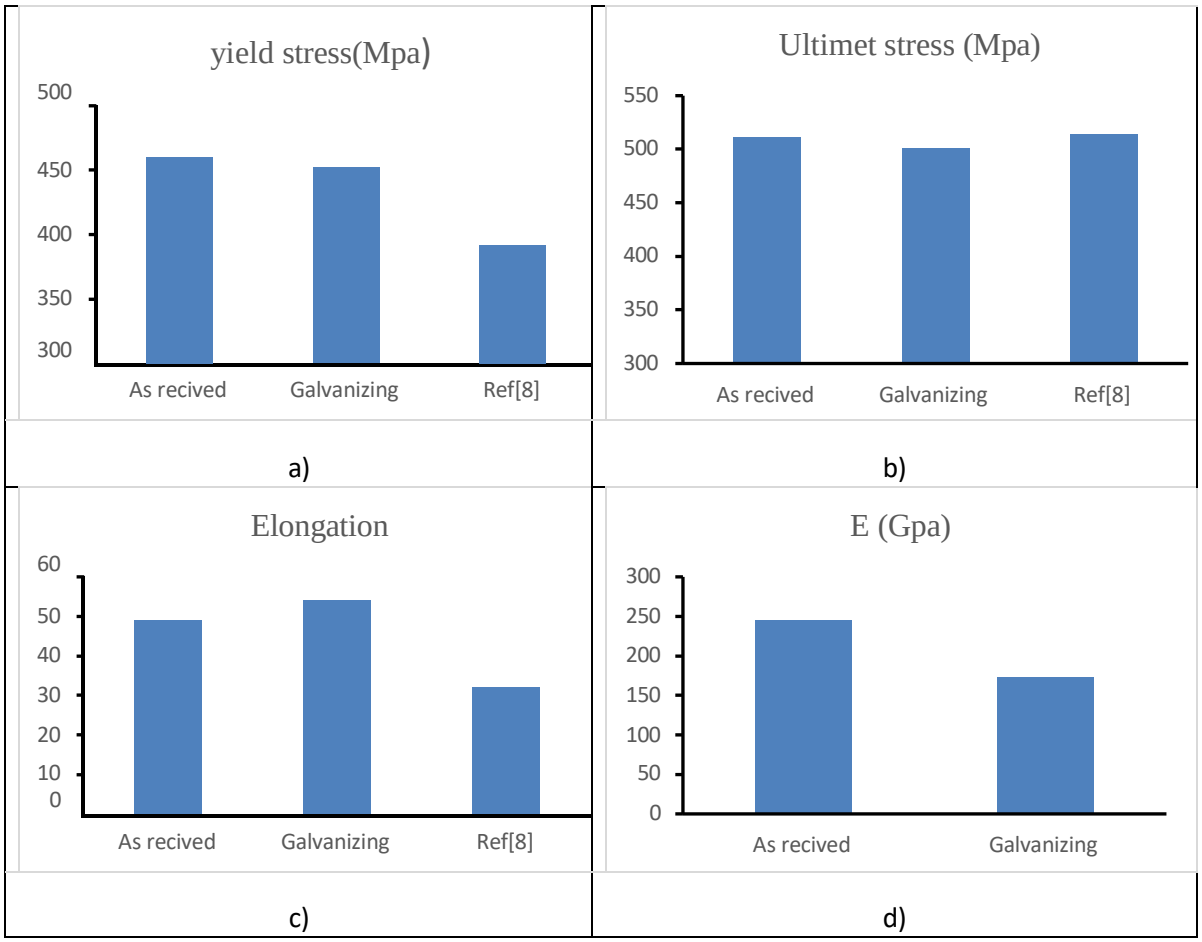


Fig. 1. The mechanical properties of the steel A) The yield stress b) The ultimate stress c) The % elongation d) The young modules

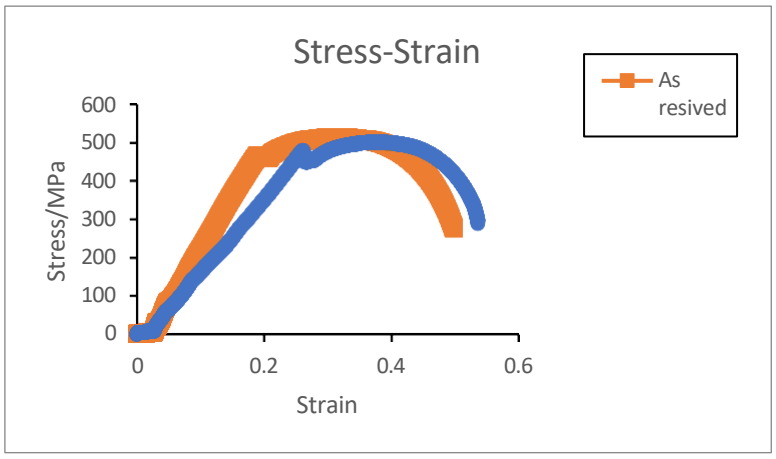
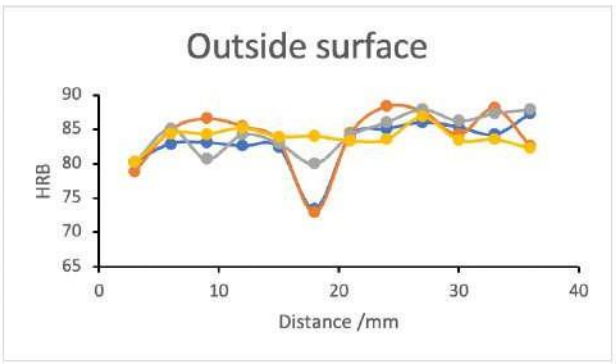


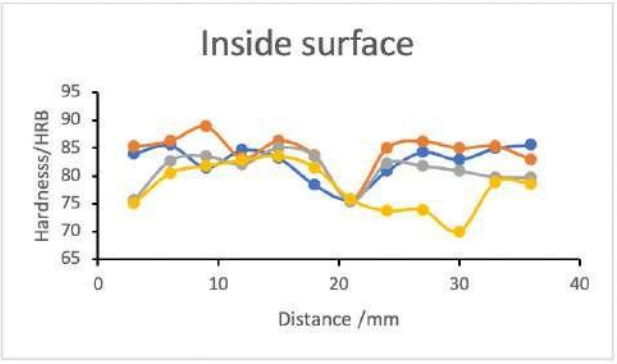
Fig.6. The stress- strain curve for as received and coated steel with HDG

3.1 Hardness test

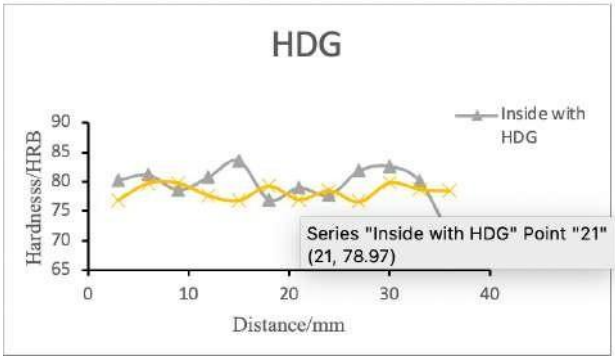
Hardness tests have been conducted to find the macro hardness distribution of the ASTM 106A Gr B, figure 7 (a) and (b) show the results of four series that measured the HBR over a length of 40mm for each outside and inside tube. It was found a uniform distribution for the outside surface that is related to appropriate manufacturing properties. While little non-uniform reading was found inside the tube this is due to the same reason manufacturing processes or residual stresses [21]. Figure 7 (c) shows the hardness distribution after coating with HDG. It was found acceptable distribution for the hardness values of outside and inside, Results have almost the same values these is due to uniform of coating of zinc to the surface of steel and the grain size release the stresses after dipping in hot mold with temperature 447˚C the material is exposed to high temperatures during the process which leads to this result the same of Šmak *et al.*, [14] study.



(a)



(b)

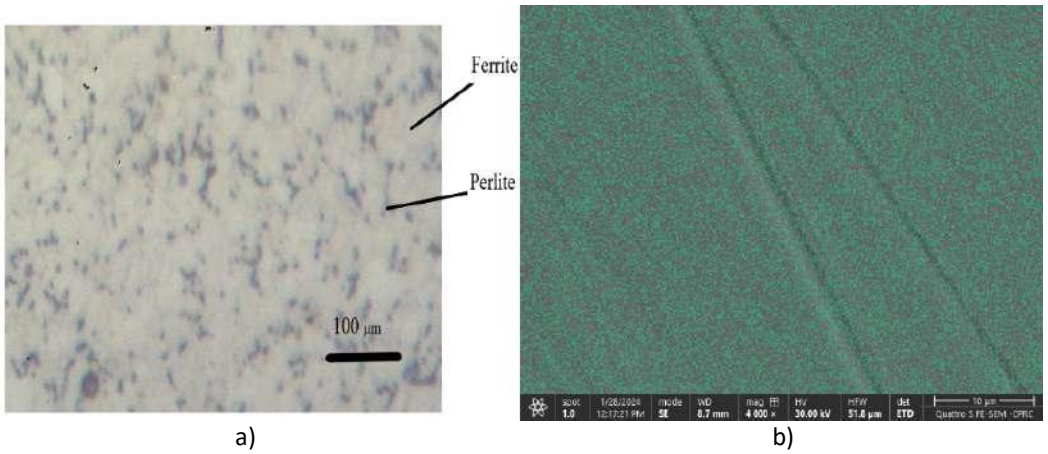


(c)

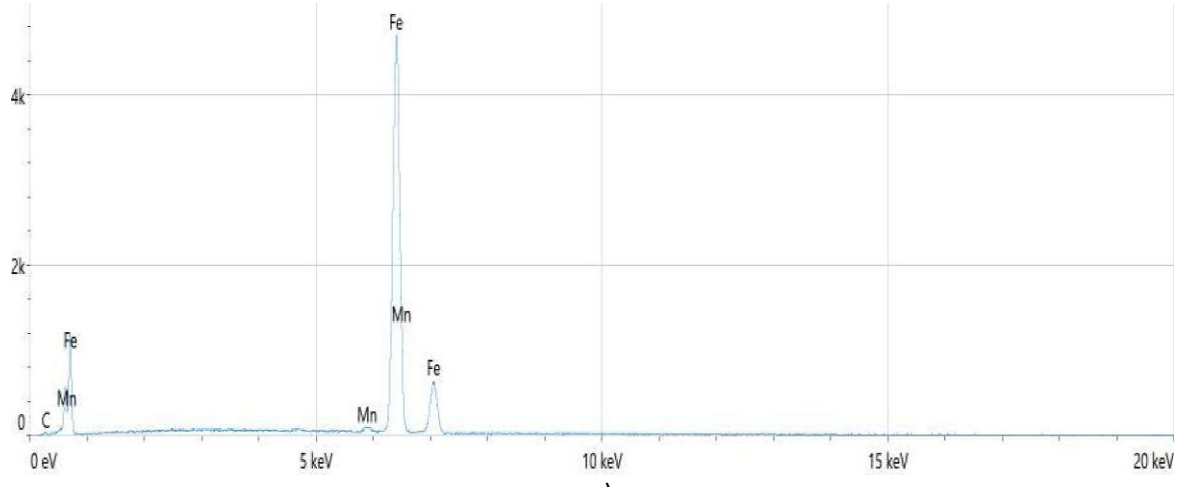
Fig. 7. The hardness distribution of the steel a) hardness for Outside tube without coating b) the hardness for inside tube without coating c) hardness of the steel with HDG

3.2 Microstructure Examination

As received microstructure is show in figure 8 (a) as well the SEM also examined before coating processes figure 8 (b), it has been shown the perlite and ferrite in the as received microstructure. The EDX also examined carbon and manganese both of these elements are the main compositions in the baes metal.



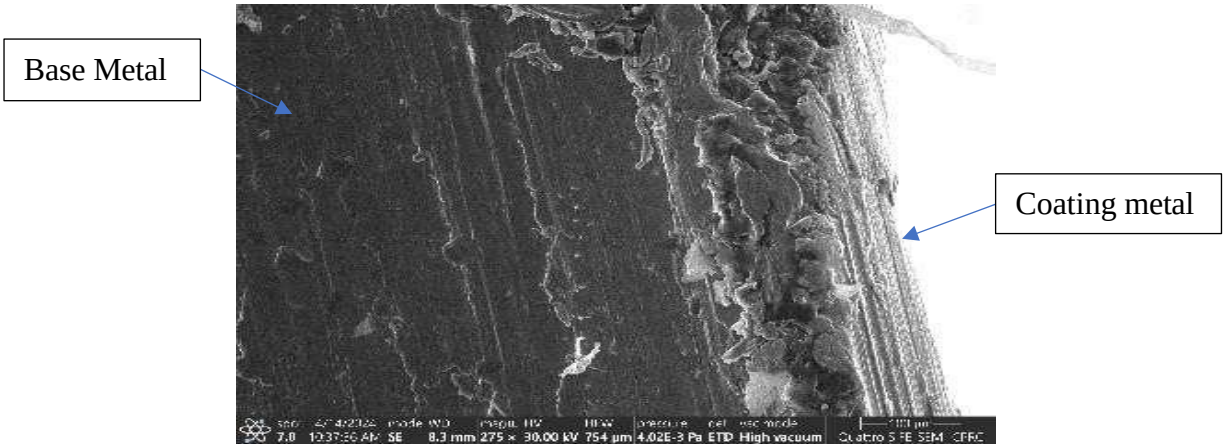
a) b)



c)

Fig. 8. a) The microstructure, b) SEM and c) EDS for the ASTM A106 Gr B carbon steel without coating

Figure 9 (a) show the coating layer in SEM, Figure 9 (b,c) and d the EDX line analyses were examined the composition distribution of element show the concentration of zinc and other elements. It is clear the homogenous distribution to coating layer. Study by Ali, [22] show the same results.



a)

Element	Atomic %	Atomic % Error	Weight %	Weight % Error
Al	4.3	0.2	1.8	0.1
Si	1.0	0.1	0.5	0.0
Ca	0.1	0.0	0.1	0.0
Fe	1.2	0.1	1.1	0.1
Ni	0.2	0.0	0.2	0.0
Zn	93.2	0.2	96.4	0.2

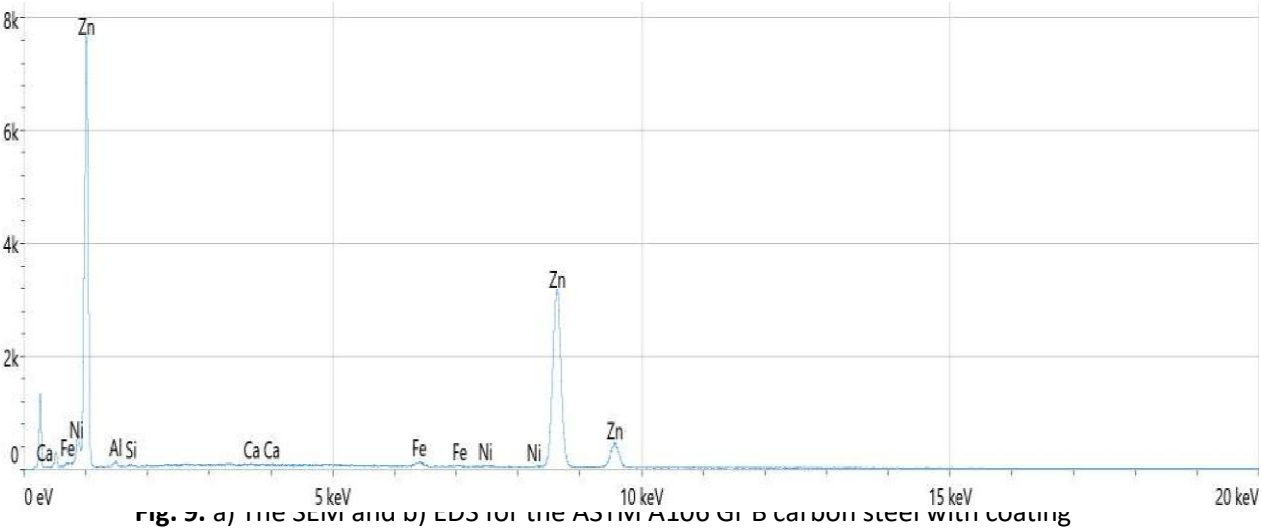


Fig. 9. a) The SEM and b) EDS for the ASTM A106 GR B carbon steel with coating

4. Conclusions

The present study characterizes the effect of coated with HDG on the mechanical and hardness behaviour of the ASTM 106 A GR B. The conclusions are listed:

1. The mechanical properties of the ASTM 106 A GR B after being coated with HDG, the ultimate stress, the yield stress, decrease slightly from non-coated metal, while the elongation has been increased.
2. The hardness of the ASTM 106 Gr B after coating with HDG has decreased slightly. There has been notice of homogenizing in the hardness values for the inside and outside of the pipe.
3. The SEM showed a smooth coating surface, the roughness of the surfaces for specimens after coating the samples is more homogenous. The EDX examined the zinc element with 96.4wt% in the chemical composition after coating.
4. The coating with HDG gives a nice layer of protection without any hash decline in the mechanical properties.

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