A Study on Abrasive Wear and Corrosion Behaviour of Boronized AISI 8640 Cast Steel

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Abstract

The aim of this study was to investigate the effect of boronizing heat treatment on the wear properties and corrosion behaviour of the AISI 8640cast steel. X-ray results show that boride film contained FeB, Fe_2B phases. The boride layer thickness and hardness raised with an increasing boronizing temperature and time.it has been found that the abrasive wear loss of the boron steels decreases because of wear tests. As a result, the boronizing process contributed positively on the change of wear mechanism of the AISI 8640 steel. Severe plastic deformation wear mechanism was observed on samples, whereas micro-*ploughing wear mechanism was observed on samples boronized at 950^{o}C for 2h and 8h. Boronized steels exhibited a higher corrosion resistance than that of unboronized steels.*

Kerword: AISI 8640 steel, Boronizing, Corrosion, Abrasive wear.

1. Introduction

8640 steel was widely used and relatively cheap material for aircraft parts, war effort and other products for forged hand tool. Its offers high hardenability, low distortion after oil-quenching, high resistance to softenting and wear resistance [1]. Theuse hard coating on 8640 steel can further improve its wear resistance. Surface treatment provided improved triboligical and corrosion performance. Surface modification is the act of changing surface topography of the materials to increase the resistance of the materials against corrosion and tribocorrosion environments, excellent wear resistance and strong chemical stability. Many surface enhancement processes applied to steels can be present at the literature [2–9] induction hardening [5,6], electrolytic-plasma treatments, laser heat treatment, vibration peening [8], normalizing, nitriding and boronizing [9] are some of the preferred forms. Although each process has their own advantages and disadvantages, boronizing has become prominent due to high resistance against tribo-corrosion environments and for high temperature applications [9]. Boronizingis a chemical heat treatment method in which boron atoms diffused into the external surface of the metal [10]. When the atoms diffuse into the matrix, metal and boron atoms form mechanically bonded hard phases (FeB, Fe_2B) [11]. For an appropriate boride layer, temperature during the process and duration of the process is of the essence. Generally, at temperatures 973-1273 K boronizing is applied for the period between 30 minutes to 12 hours [12–14]. Different boron compounds are preferred for the different boriding techniques. Pack boronizing [15], molten salt boronizing [16], gas boronizing [17], paste boronizing [18], and plasma boronizing [19] are the some of boronizing methods. Because of simplicity of the technique, technology and cost effectiveness, box baron technique comes to the forefront rather than other ones [20-22]. In general, boriding is used for ferrous alloys such as low C steels, C steels, stainless steel and tool steels [15,23,24]. Boronizing method is one of the most important means used commonly on steels and iron to increase surface quality and performance. Boronizing process gives many advantages such as high hardness, low coefficient of the friction. Due to performance benefits derived by boronized layer is better than the nitrided, carburized, carbonitrided or hard chrome plated materials [9,25-30] so that boriding is widely preferred in mechanical engineering and automotive sector. In addition to surface hardening and low coefficient of friction, boriding provides defianceanti acids, means and high temperature corrosion. It improves the resistance to scratches, abrasion and corrosion on the surface of the material [10,31,32].

In the literature, number of works [32-41] on abrasion wear and corrosion behaviour of stainless steels and highalloy steels and a boronizing surface are found. However, studies that handle the abrasive wear and the corrosion behaviour of boronized AISI 8640 steel has a restrictedin the literature. In this study, the abrasive wear and the corrosion behaviour of iron boride layers attained via the pack boriding process in AISI 8640 steel isestimated. Their abrasive wear behaviour on two different Al_2O_3 abrasive papers having different loads. The corrosion data were found complete the linear polarization and the open circuit electrochemical method and analytical techniques: optical, scanning electron microscopy (SEM) and X-ray analyses.

2. Experimental Procedure

The alloy prepared in this study was melted in a 100 kg-capacity medium frequency induction furnace. Primary charge material was AISI 8640 stainless steel scrap. The melt was then super-heated to 1635^{o}C and transferred into a pre-heated teapot ladle. After removal of any dross and slag, the melt was poured at 1490^{o}C into the CO_2-silicate moulds to produce cylindrical specimens with 20 mm diameter and 120 mm length. The results of the spectral analysis of the cast 304 stainless steel with material used in the experimental work is illustrated in Table 1[42].As-cast steel specimens was homogenised at temperature of 1150 C for 3 hours. Commercial EKABOR 2 powder was used as boronizing agents and to prevent oxidation, ceramic crucible used during heat treatment. Boronizing treatment was carried out at temperatures of of 850°C,900°C and 950 °C for 2, 4, 6 and 8hours, and then borided samples were cooled to room temperature in open air.

Table 1. Chemical composition of cast AISI 8640 steel (weight%) [42]

C	Si	Mn	P	S	Cr	Mo	Ni
0.40	0.24	0.72	0.024	0.017	0.52	0.16	0.45

Through metallographic examination, SEM, X-rays analysis and hardness measurements, characterisation of the steels was examined. For the microstructural examination of the steels, they were polished by standard metallographic processes, etched as electrolytic in the etchant (oxalic acid) with 1.5V for 15 seconds and after that they were inspected through a MEIJI model optical microscope and a LS10ZEISS SEM - EDS. To perform structural analyses of the steels, exposed to boriding heat treatment, Rigaku D/Max-2200/PC model XRD device was used. XRD devices were conducted through the Cu- Kα radiation at the current of 40 m A under 40 k V voltage in the angle range 10-90 and with a scan rate 0.02 degree/s. To measure of hardness throughout the section of all metallographically prepared samples, Schimadzu HMV2 model Vickers hardness device was used under 2000 g load. To determine hardness values, average of at least 10 measurements was used.

Abrasive exams of the specimens were carried outwitha pin-on-disc apparatus [43], under 10 N and 20 N of loads at the speed of 0.1 m/s, by rubbing the specimens having 6,25 mm diameter and 50 mm length, on bonded 1000 and 1200 mesh aluminium oxide Al_2O_3 abrasive. During the experiments, samples that were running over the abrasives were stepping perpendicular to the sliding direction, so they contact with the undeformed abrasives. The total amount of running distance of the samples on the abrasives were 10 m. Specimen weights were measured, before and after the test by an electronic scale with a resolution of 10^{-4} g to see wear losses as lost weight. The surface roughness measurement in R_a scale was as well carried out on the worn surfaces using a Mitutoyo Surftest 211 instument. After wear tests, worn surfaces of the AISI 8640 steel was analysed by using SEM.

To conduct potentiodynamic corrosion tests, Gamry PC4/300 mA potentiostat-galvanostat machine and DC105 analysis software was used. Corrosion test specimens, bonded with a 1.5 mm diameter and 150 mm long copper rod on the back surface to allow conductivity, were prepared with resin mould to take out only the faces which were essential to contact with electrolyte. The samples were prepared with standart metallographic processes. Solutions that contain 10% HNO_3 was used as the corrosive mediumover experiment cell. For the electrochemical test at room temperature was preferred. The steels having a stable surface area of 0.785 cm^2 as the electrode, a carbon electrode with 6 mm diameter stand-in as counter electrode and the saturated calomel electrode (SCE) as reference electrode were located within the cell. While the surfaces of the electrode and carbon electrode were jointly facing placed at determined distance, the reference electrode was located closer to the working electrode in the cell.Throughout the corrosion experiments, next working and reference electrodes were immersedin the electrolyte, the modification in corrosion capacities regarding mV between these two electrodes was measured for the first 45 minutes. Accomplishment the equilibrium potential, potentiodynamic polarisation curves were drawn via scanning the potential from -1.00 V to 1.00 V in the range of 1 mV/s, from cathodic route to anodic route.

3. Results and Discussion

3.1 Microstructure

Optical images of the boronized AISI 8640 steelis shown in Figure 1. As we can see in the Fig.1, the boride layers formed on the AISI8640 steels at 950^{o}C temepareture boronized have a saw-tooth morphology [20,44] like boride layers attained in the low-alloy steels and some porosity and grain growth [22] were encountered in the boride layers with increased with boronizing time and temperature [31-33] (Table 2). By means of boronizing is a thermochemical diffusional process, the boride layer thickness must increase with both tempareture and time. This is revealed in Fig.1, for the 8640 steel boronized at 850^{o}C boride layer was relatively thin, but boronizing at 900^{o}C the layer thickness was maximum. By boronizing at 950^{o}C for 8h, layer thickness attained a value 172μm (Fig. 1 and Table 2). Additionally, FeB and Fe_2B were clearly divided from each other and the coating layer consist of three regions. These regions, as described in the previous studies, are boride layer, transition region or diffusionzone and matrix [20,44-47]. Figure 1 reveals that increasing boronizing temperature and the duration time of treatment rises the boride layer thickness. Boride layer thickness is examined to rise more than twice reliant on boronizing time (Fig.1). In the same way, the inspection of within Fig.1reveals that the Fe_2B essential formed in accordance with the composition of the base material and technical environments is layer out along the boron gradient. For this reason, the high-tension areas and coop distortions that appear near the point of the Fe_2B main permit the layer to grow colonically. The growth mechanism of FeB portions parallel with that of the Fe_2B phase. The colonical establishments between the FeB/Fe_2B layers are fewer than those seen between the Fe_2B/matrix layers. This is because the Fe_2B phase is established a more ductilematerial compared to the FeB phase, resulting with the accomplishment in a harder FeB phase [2].

Table 2. Change of boride layer and thickness based on temperature and duration for the AISI 8640 Steel

Temperature (^{o}C)	Boriding powder	Boronized time (h)	Thickness (μm)	Microhardness ($HV_{0.02}$)
850	EKboron 2	2	40	1093
		4	65	1152
		6	100	1312
		8	148	1456
900	EKboron 2	2	45	1243
		4	80	1437
		6	116	1687
		8	158	1861
950	EKboron 2	2	65	1317
		4	100	1770
		6	133	1993
		8	172	2067
Non-borided AISI 8640				333

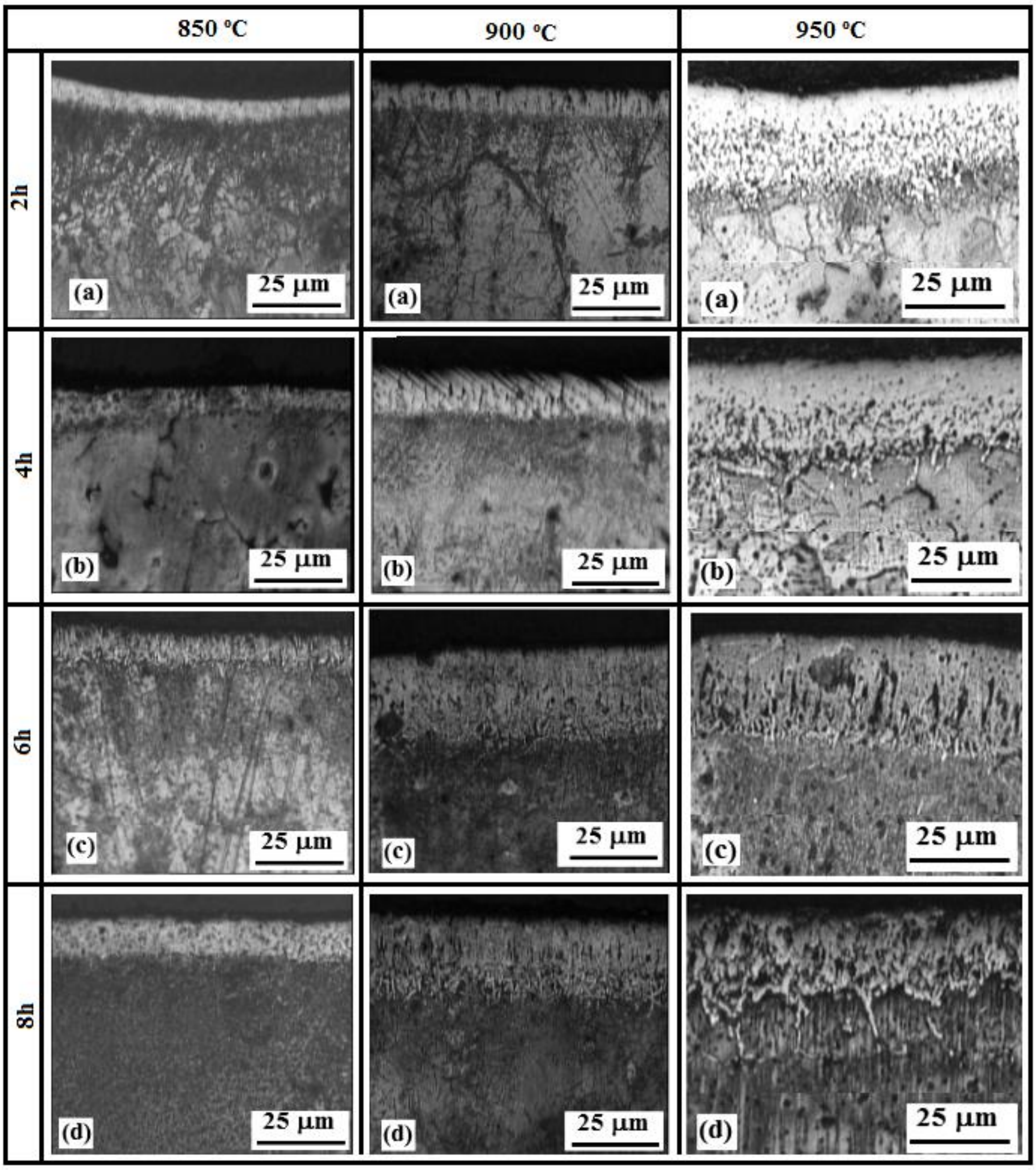

Figure 1. Cross section optical micrographs of the boride layer at different temperatures and hours.

Figure2(a–b) shows the X-ray diffraction pattern of the AISI 8640 steel samples which were boronised at 850^{o}C for 2h and at 950°C for 8 h.Inall test conditionsdual-phases ($FeB+Fe_2B$) microstructurewasdetected (Fig. 2 (a–b)).Uslu et al. [46] have similarly indicated in them examine on P 20 steel that the Fe_2B phase is produced before FeB phase. It must be observed that the establishment of the Fe_2B phase with saw-tooth form is desired for industrial aplications since its excellent wear resistance and mechanical properties [46].

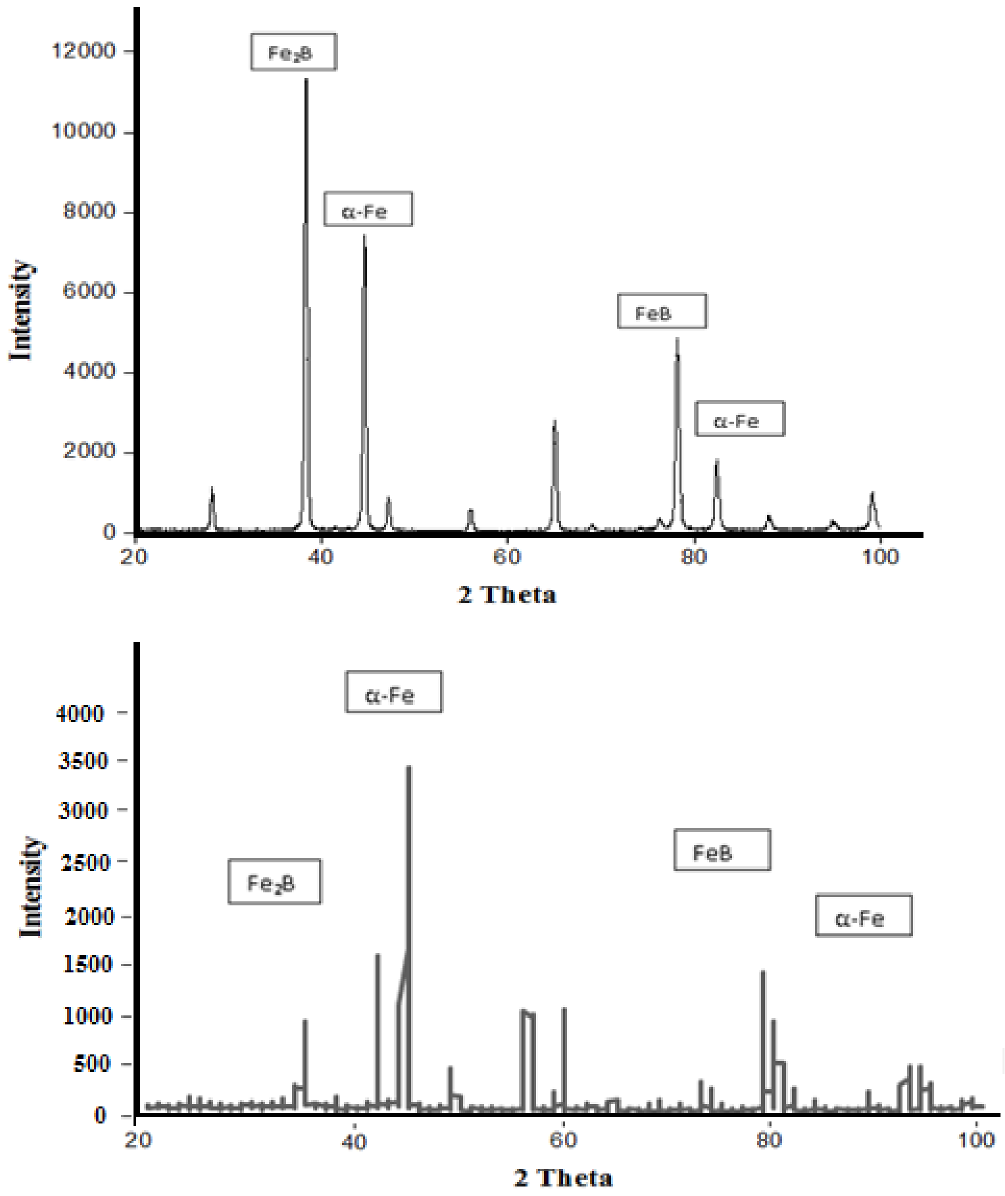

Figure 2. X-ray analysis of AISI 8640 steel sample boronized at (a) 850°C for 2 h and (b) 950°C for 8 h

Surface hardness means of the borides formed on the surfaces of the boronized AISI 8640 steel is very higher than those of the substrate as can be shown in Figure 3 and Table 2. Variation in the Vickers micro-hardness of the AISI 8640 steel from surface distance of layer to center of the matrix is indicated in Fig.3. It is confirmed the high value of toughness near the surface for all layers, occurring a steady decline until the substrate. The hardness of the untreated AISI 8640 steels were got to be 333 $HV_{0.02}$. By way of canbe observed on the hardness curves, the hardness of the boride layers is very higher than those of the matrix. Hardness reduces due to gap into the matrix. The operation forms, layer thicknesses and surface hardness of the boronized AISI 8640 steels are given in Table 2.The depth of boride layers achievemented by means of a optical micrometer attached to optical microscope showed that the depth of boride layer formed on the surface of 8640 steels are strongly dependent on process time and temperature. It was comformed that the longer boronizing time and higher process temperature result in the thicker boride layer. Both boride layer thicknesses and hardness values increased with temperature and time. The obtained results are in agreement with the literature [9,20,31-33, 44,45]. The layer thicknesses of boronized at temperature of 850^{o}C sample sranged from 40 to 148µm, while $HV_{0.02}$ hardness values varied between1093 to 1456. The layer thicknesses of boronized at temperature of 900^{o}C sample sranged from 45 to 158µm, while $HV_{0.02}$ hardness values varied between 1243 to 1861. The layer thicknesses of boronized at temperature of 950^{o}C sample sranged from 65 to 172µm, while $HV_{0.02}$ hardness values varied between1317 to 2067. These results in dicate that the process conditions have a greater effect on the layer thickness than microhardness. The obtained results are in agreement with the literature [9,20,44,45]. There are three regions indicated in the hardness distribution diagram; (i) borides, (ii) boron rich transition zone, and (iii) matrix [37]. Because boronizing is a thermo-chemical treatment, boride layer thickness increases due to treatment time and temperature. Uslu et al.[46] and Bejarand Moreno [11] have registered that the boride layer thickness rises under higher temperatures and longer times. In addition, Özdemiret al. [48] and Şahin [49] have similarly stated that the boride layer thickness rises collected with the boronizing time. Due to the rising temperature, the boride layer thickness was clearly seen to rise. The layer thicknesses of the AISI 8640 steel samples boronized at temperature of 950^{o}C for 8h and 2h was obtained to be 172µm and 65 µm, respectively, the layer thicknesses of the AISI 8640 steel samples boronized at temperature of 900^{o}C for 8h and 2h was obtained to be 158µm and 45 µm, respectively, the layer thicknesses of the AISI 8640 steel samples boronized at temperature of 850^{o}C for 8h and 2h was obtained to be 148µm and 40 µm, respectively.

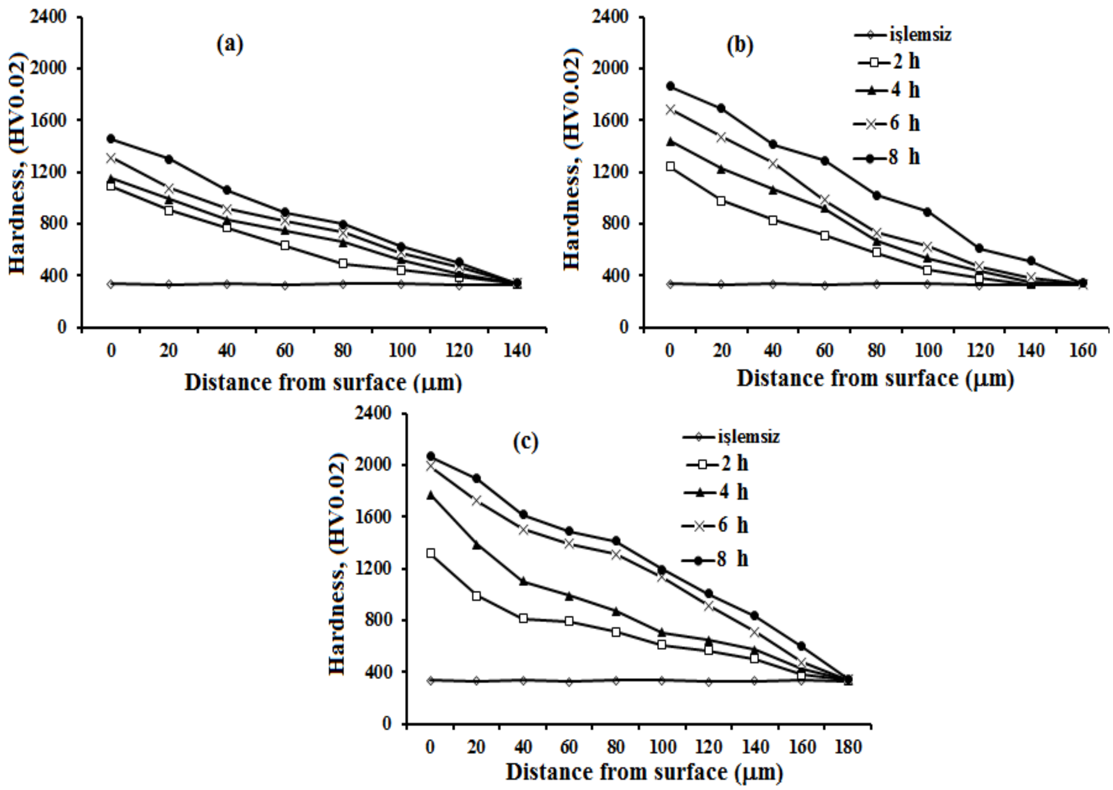

Figure 3. Microhardness value of the AISI 8640 steel samples untreated and borided at (a) 850^{o}C for 2,4,6 and 8h, (b) 900^{o}C for 2,4,6 and 8h, and (c) 950^{o}C for 2,4,6 and 8h.

3.2. Wear

In this study, Figure 4 reveals the wear loss of the AISI 8640 steel inspected on two abrasive Al_2O_3 paper under 10N and 20N loads. As illustrated in Fig.4, the wear loss decreased approximately in a linear way due to increasing bronzing time under 10N and 20N load. Wear loss in AISI 8640 steels boronized at temperature of 950^{o}C for 2,4, 6 and 8 hours are less than the samples boronized at 850 C for 2,4, 6 and 8 hours for two abrasive Al_2O_3 paper under 10N and 20N loads. This is because the FeB layer on the surface prevented on the sample boronized for a lengt hier time has a brittle and cips [50-53] structure. Wear loss in AISI 8640 steels boronized at temperature of 950 C for 2 hours are fewer than the samples boronized at 850 C for 8 hours (Fig.4). The reduce in wear on the steel sample boronized at 850 C for 8 h is explicated through the thichness of the boride level is decreased at the same tempureture by means of the prolongation of boronizing time (Table 2). As understood in Table 2 thickness of the FeB layer rises at higher boronizing temperatures, running to improved wear measured in samples boronized at higher temperatures. For this result, it is valuable to wait for a long time at low temperature in the boriding process. Tabur et al. [31] in their study have decided that the wear rate is astronomical abrasive situations since the brittle outer layer with irrgularcrytal structure over boride coating. While the wear behaviour of AISI 8640 steel as boronized was examined, wear loss showed a tendency to decrease due to increased abrasive size from 1000 to 1200 mesh. In the results of the experiments conducted, wear losses of the samples were observed to decrease while abrasive grain size was increased (Fig.4). The present results are consistent to the literature on this subject [11,31,50,51,53]. Wear losses of the samples evaluated according to load increase revealed that wear losses were found to increase under higher loads (Fig.4). Wear losses of the samples decreased with increasing duration of the treatment. The lowest value of wear loss was observed for the samples boronized at temperature of 950 ^{o}C for 8 hours. The reason is that depending on the duration of the boronizing treatment, FeB that increases hardness and abrasive resistance of the material [46,47] was formed on the surface of the material (Fig. 2(b) and Fig. 3(c)). For AISI 8640 steel, the samples boronized at 850 C for 2 hours were observed to have the highest value of wear loss (Fig.4). Wear lose of the unboronized AISI 8640 steel samples given in Figure 5. While the wear behaviour of AISI 8640 steel as cast was examined, wear loss showed a tendency to decrease due to increased abrasive size from 1000 to 1200 mesh. Çetin and Gul [53-58] achieved that the wear behavior changes with the regular grain size of the abrasive matter and that wear lose is decrease with the decreasing grain size.

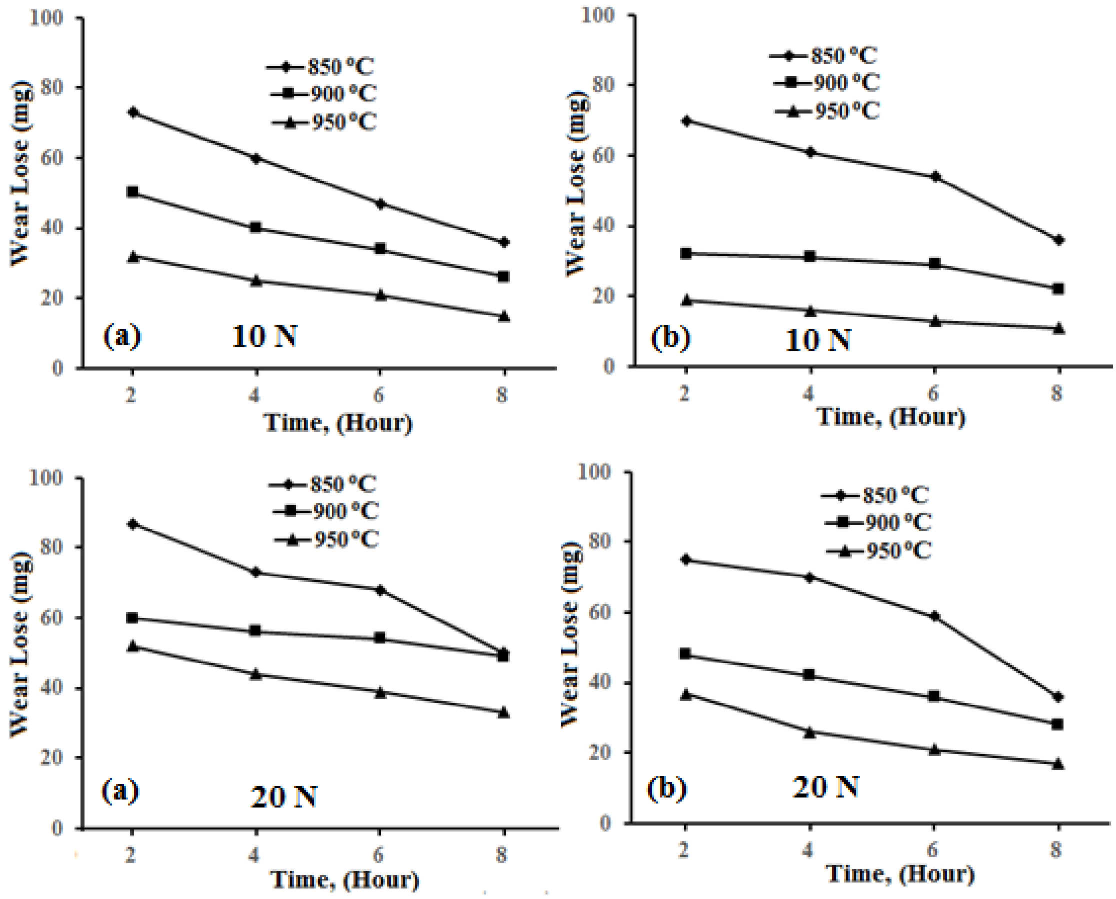

Figure 4. The influence of bronzing time and the bronzing temperature on the wear loss of AISI 8640 steel for different abrasive Al_2O_3 paper (a)1000 mesh and (b) 1200 mesh.

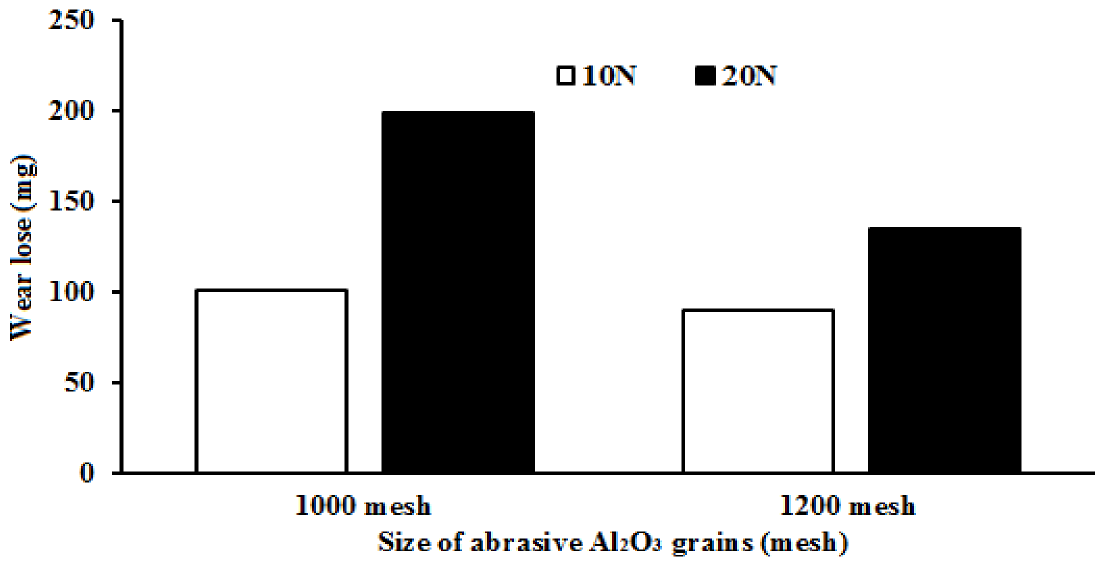

Figure 5. The change in wear loss of the examined AISI 8640 steel with abrasive Al_2O_3 grains size and applied load on the unboronized samples.

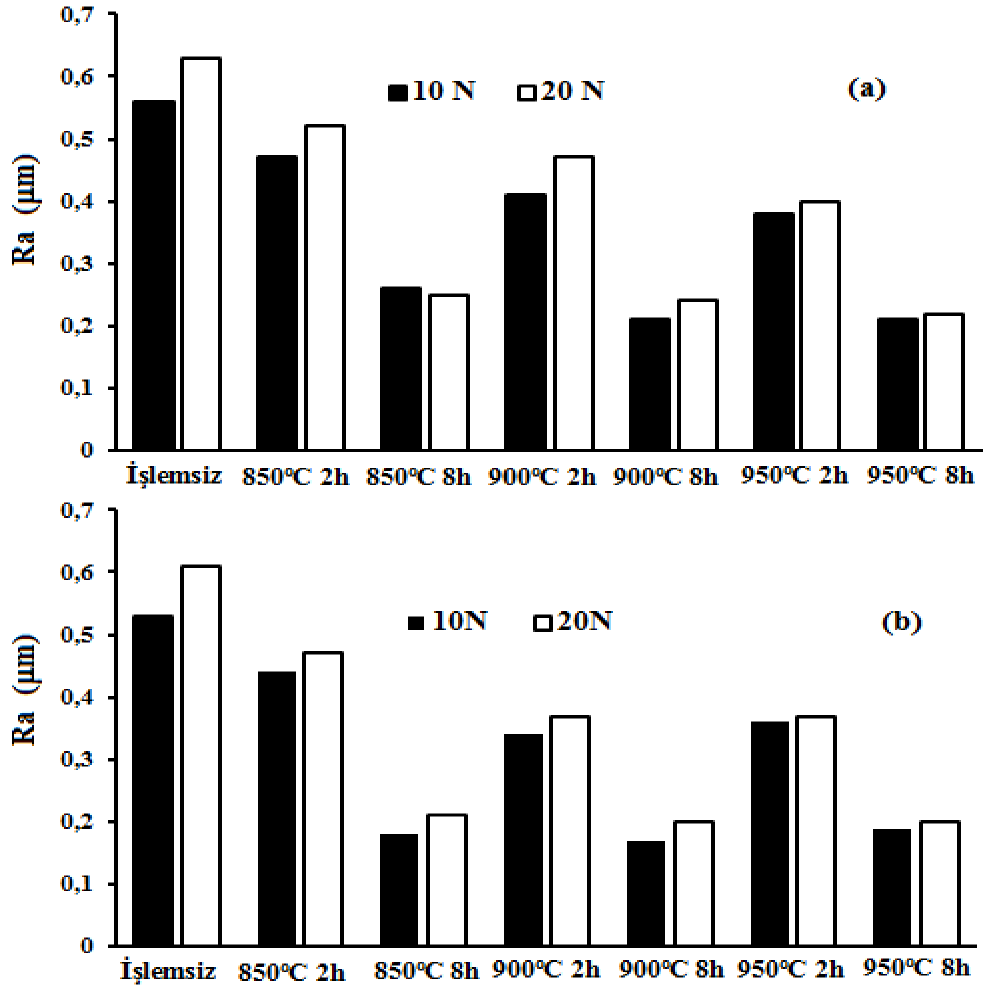

Figure 6. Surface roughness of the cast AISI 8640 steel samples after the wear test for different abrasive Al_2O_3 paper (a)1000 mesh and (b) 1200 mesh.

The surface roughness of the cast AISI 8640 steel samples after the wear test is showed in Figure 6. The surface roughness of the samples boronized at 950^{o}C for all the test conditions lower than the samples without unboronized and boronized samples at 850^{o}C and 900^{o}C for 2 and 8h, (Fig.6). While the surface roughness values were the boronized AISI 8640 samples for all the test conditions varied between 0.19 and 0.52 om, the unboronized of AISI 8640 samples, the surface roughness values 0.53 and 0.63 om. the decreases of the the surface roughness may be the results of the mechanical on the compound layer of the boronized specimens. Roughness measurement of the worn surface also indicated that specimens at 900^{o}C for 8h boronized had lower surface roughness value compared to specimens unboronized cast AISI 8640 corroded for 1000 mesh and 1200 mesh abrasive Al_2O_3 paper for applied load 10N and 20 N. Also, the abraded surfaces are examined, as the abrasive grain size 1000 mesh to 1200 mesh increases, lower surface roughness appear. That is because, surface hardness of boronized cast AISI 8640 steel much higher than that of unboronized cast AISI 8640 steel (Fig.3). These materials with different hardness values will result in different wear behaviour, originates from the earlt repot of Archard [59], indicating that wear rate is inversely proportional to the hardness of a material.

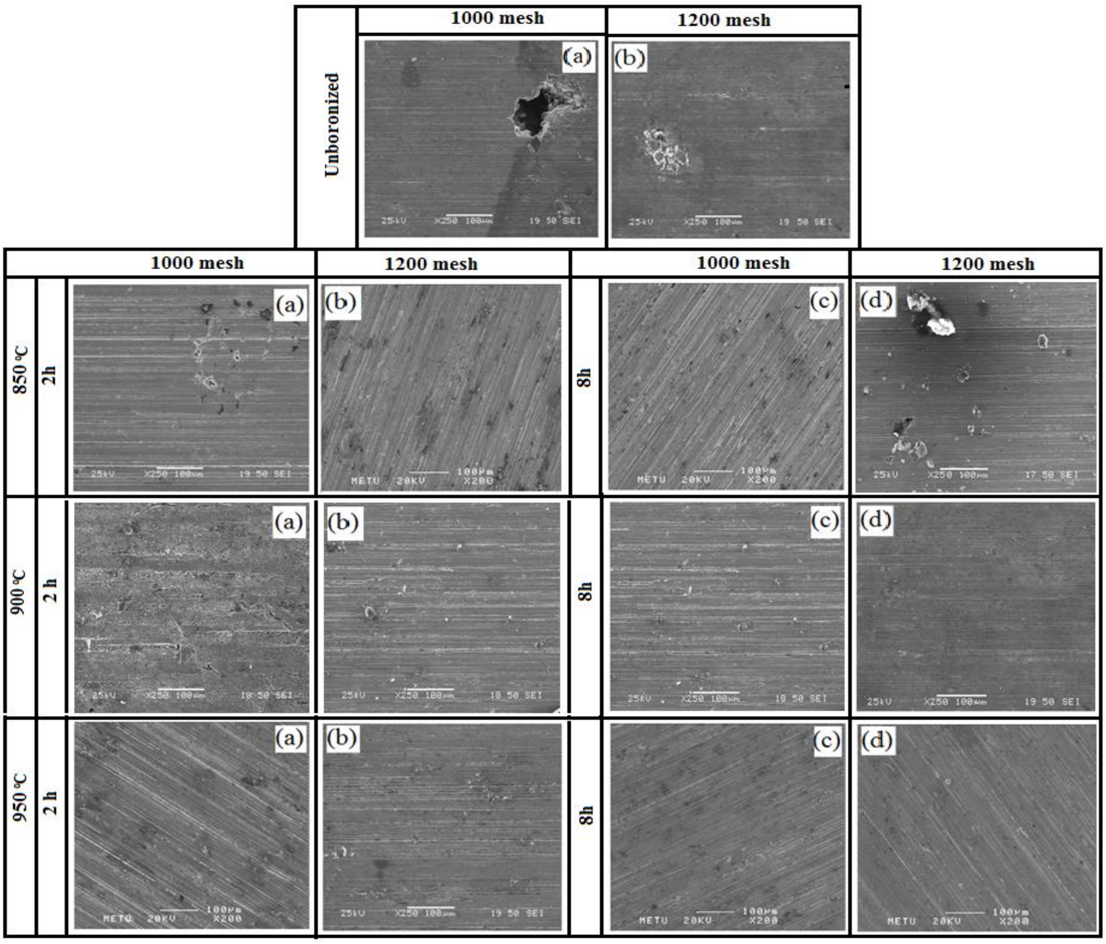

Figure 7. SEM images of worn surface of the unboronized and boronized AISI 8640 steel abrasion test on 1000 mesh and 1200 mesh

Wear surface images of the AISI 8640 steel exposed to the abrasion test is given in Figure 7. The wear surfaces of the samples boronized at 950^{o}C for all the test conditions (Fig.7) appear smoother and smoother and deeper than the samples without unboronized and boronized samples at 850^{o}C (Fig.7). This is due to the rise in the thickness of the boron layer (Table2), and the current experimental results are consistent with the literature [9,20,44,45]. It is seen that the largest and deep wear grooves of the 1000 mesh abrasive and the abrasive machined sample under 20 N load are seen (Fig.7). On both abrasives, the wear surfaces of the samples boronized at 950^{o}C appear to have a thin small and smoother / smooth wear surface (Fig.7). From Fig.7, when the non-boronized AISI 8640 steel was examined for worn surface images under 20 N loads, the sand paper size was larger, wider and deeper in the channels. When images are examined, it seems that there are more breaks and breaks in parallel with the increase of the sand paper size (Fig.7). When the abraded surfaces are examined, as the abrasive grain size increases, uneven rough and deep grooves appear. It is seen that the abrasion traces are thinner with increasing boronizing time at the same temperature. When Fig.7 is examined, it is seen that when the boronized abrasion surface images of AISI 8640 steel is examined for 2 hours and 8 hours, the wear resistance is raised with rising boronizing time at the same temperature, and the abrasion grooves are thinner and smaller at boronized samples 8 hours. In the same way, it is seen that the wear resistance is raised by increasing the boronized temperature and the wear grooves are thinner and smaller than the boronized samples at 850^{o}C to 950^{o}C. It can be argued that this is due to the lower boron layer thickness at lower temperatures (Table 2). Compared to the worn surfaces of the boronized specimens of the steel, it is seen that the AISI 8640 steel for 2 hours at 850 °C has deeper and wider grooves of wear scars, with more surface fracture and deformation. The best wear resistance showed 8 hours boronized AISI 8640 steel at 950°C (Table 2). Since the hardness values of the materials have changed as can be understood from the wear surface images, it is understood that the abrasion is more likely to occur in the soft materials as expected.

3.3. Corrosion

Figure 8 demonstrates potentio dynamic polarisation curves derived from the corrosion exams of AISI 8640 steels, which were shown with distilled water and 10% HNO_3 solutions. Table 3 shows the current density (Icor) and corrosion potential (Ecor) values calculated from these curves by DC 105 corrosion analysis software. While corrosion potential values of AISI 8640 samples examined approximately changed, corrosion current of the samples showed a tendency to decrease due to increase in duration of boronizing and the treatment temperature. The highest current value was observed in the boronized samples at temperature of 850 ^{o}C and 950^{o}C for 2 hours and the lowest current value was observed in the samples boronized at temperature of 900^{o}C for 2 and 8 hours. Figure 8 and Table 3 show that samples boronized at temperature of 850 ^{o}C and 950 ^{o}C for 2 hours current a further positive corrosion potential compared to that of samples at 850 ^{o}C for 8 hours, signifying that the strength of the coating on samples boronized at 850 ^{o}C for 2 hours decreased evidently because of the corrosions at the coating substare interface [60]. This a characteristic change of samples boronized at 850 ^{o}C and 950 ^{o}C for 2 hours to further negative potential correspondingly happens inplasma boronizing [61]. The highest current value for AISI 8640 steel samples was observed in the boronized 850 ^{o}C for 8 hours, signifying that the strength of the coating on samples boronized at 850 ^{o}C for 2 hours decreased evidently because of the corrosions at the coating substare interface [60]. This a characteristic change of samples boronized at 850 ^{o}C and 950 ^{o}C for 2 hours to further negative potential correspondingly happens inplasma boronizing [61]. The highest current value for AISI 8640 steel samples was observed in the boronized samples at temperature of 900 C for 2 hours AISI 8640 samples and the lowest current value was detected in the samples boronized at temperature of 950 C for 2 hours. While the corrosion potential values were the boronized AISI 8640 samples varied between -201 mV and -396 mV, the current values of the samples decreased from 34.3µA/cm^2 to 4.45µA/cm^2. While the corrosion current value was 62.60 µA/cm^2 for the unboronized of AISI 8640 samples, the corrosion potential values 299mV. In comparison to the unboronized steel, while the corrosion resistance of the steel subjected to the boronizing treatment increased in 32% for AISI 8640 samples. The corrosion current density reduced approximately 3 times for AISI 8640 samples. The corrosion damage of the unboronized AISI 8640 steel corroded inthe solution of 10% HNO_3 (Fig. 9) were suffer extensive corrosionas staining of the matrix and carbides later atching of the steel with etchant solution. Moreover, and 850^{o}C 8h and 900^{o}C 8h boronized AISI 8640 steela localised corrosion occurred as severely pitting on the surface in the solution of 10% HNO_3 (Fig. 9). The corrosion images of the 950^{o}C 8h boronized AISI 8640 steel in the solution of 10% HNO_3 was uniform corrosion. Then, difference was that the uniform corrosion of the boronized AISI 8640 steel was not as etching of the matrix. The corrosion tests of the 900^{o}C and 950^{o}C 8h boronized achieved in 10% HNO_3 soliton showed that the boride layer locally flaked from surface, which depicted both a rise in the corrosion current density and a bit decrease in the corrosion potential. The existence of the corrosion damage as flaking of the boride layer was the pitting mechanism. Thus, the galvanic corrosion cell formed on the interface after the pits occurring on the surface reached to the coating interface [33].

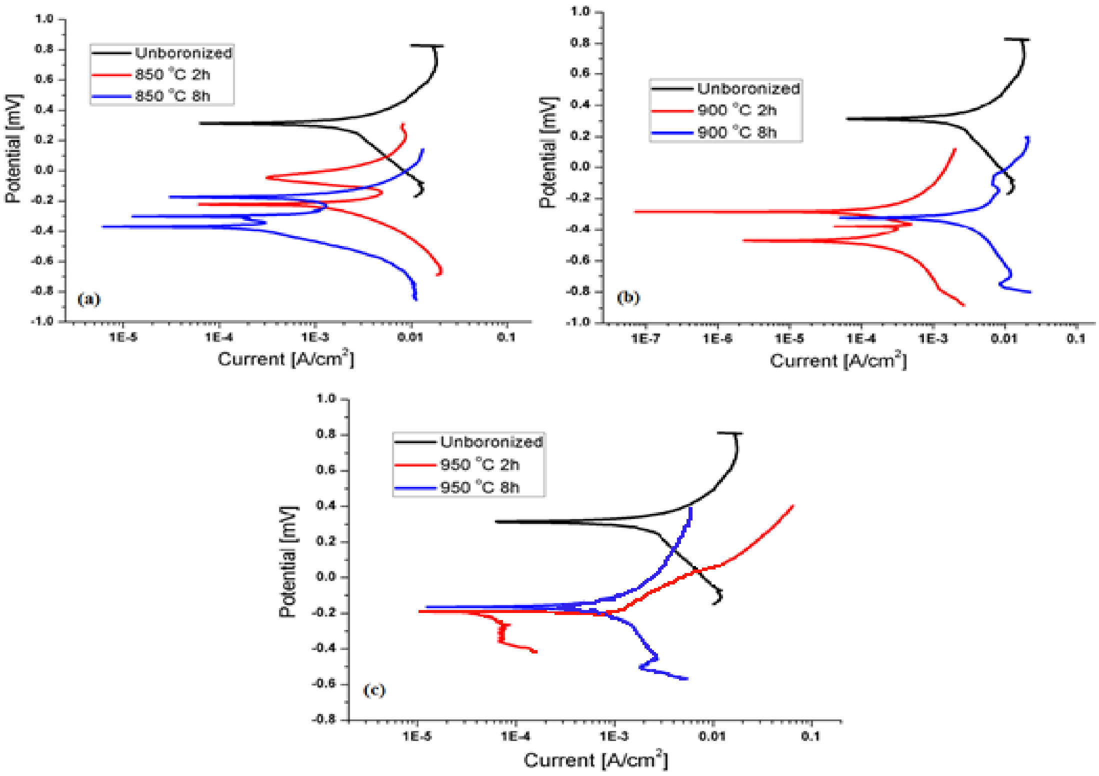

Figure 8. The potentiodynamic polarisation curves of the AISI 8640 steel samples in10% HNO_3 unboronized and borided (a) 850°C for 2 and 8h, (b) 900°C for 2 and 8h, and (c) 950°C for 2 and 8h.

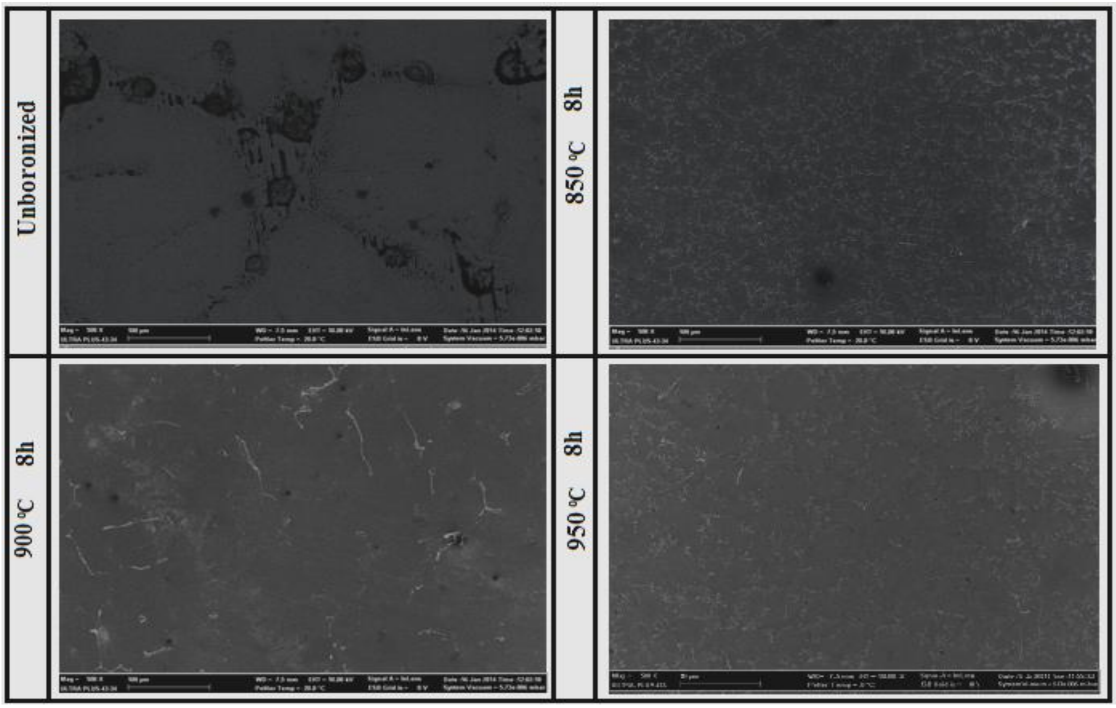

Figure 9. SEM images of the unboronized and boronized AISI 8640 steel corroded in 10% HNO_3 solutions.

Table 3. The potentiodynamic polarization result of the boronized and unboronized AISI 8640 Steel in %10 NHO_3corrosive media

Steel	Conditions	Boronized Time(h)	E_{cor} (mV)	I_{cor}(μA/cm^2)
AISI 8640	Non-boronized	Uncoated	299,0	62,6
	Boronized 850°C	2h	-204,0	23,80
		8h	-389,0	14,5
	Boronized 900°C	2h	-396,0	4,45
		8h	-390,0	2,90
	Boronized 950°C	2h	-201,0	34,3
		8h	-226,0	7,17

4. CONCLUSIONS

In this study, AISI 8640 steel specimens was box boronized at temperatures 850°C, 900°C and 950°C for 2h, 4h, 6h and 8h by commercial EKa boron 2 powder. Then microstructural characteristics and wear and corrosion behavior of borided specimens were investigated. The main results can be summarized as:

1- The morphology of boride layers was in a saw-tooth shape like boride layers obtained in the AISI 8640 steel and some porosity and grain growth were encountered in the boride layers with increasing temperature and time.

2- The hardness and thickness of the boride layer increased with boriding temperature and time. The layer thicknesses of the AISI 8640 steel ranged from 40 to 172 µm, while $HV_{0.02}$ hardness values varied between 1093 to 2067. The hardness and thickness of the boride layer increased with boriding temperature and time.

3- X-ray results showed that FeB, Fe_2B phases exist on the AISI 8640 steel surface because of the boronizing.

4- Although all the boronized specimens showed lower wear lose than non-boronized ones, the boronized specimens have demonstrated different wear lose at different wear test conditions. The wear loses of specimen reduced by increasing boronizing temperature and time. The best wear lose was obtained from the AISI 8640 steel borided for 8h at 950°C following 1200 mesh abrasive Al_2O_3 paper wear test performed with a load of 10N and 20N.

5- Surface roughness value of the worn boronized cast AISI 8640 steels lower than unboronized cast AISI 8640 steel. This was attributed to their different hardness values.

6- Process of boronizing process was effective on the change of wear mechanism of the AISI 8640 steel. Severe plastic deformation wear mechanism was observed on samples unboronized for AISI 8640 steel, whereas micro-ploughing wear mechanism was observed on sample boronized at 950°C for 2h and 8h.

7- In corrosive environments, in which %10 NHO_3 solution used, unboronized AISI 8640 steel exhibit inferior corrosion resistance compared to boronized AISI 8640 steel. Corrosion resistance of investigated boronized steels in %10 NHO_3 solution increased by boronizing heat treatment.

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