Mobile Technology Applied to the Analysis of Thermochemical Treatments

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In this work, the viability of the use of Mobile technologies with a digital microscope, that conducts the analysis of the growth of boride layers on AISI 12L14 steel, is evaluated. An image of the Fe2B phase from the boride layers on steel was obtained with the proposed device, later used to measure the thickness of the boride layers. A comparison of the data with images obtained using a Scanning Electron Microscope (SEM) is also conducted. In the results it can be observed how the measured thicknesses were similar and are both within the standard deviation in both cases.

INTRODUCTION

In recent years, the use of mobile technologies in research and industrial applications has been of great interest, for example, converting a smartphone into a portable microscope (Yu-Lung, et al., 2015 & Tesng, et al., 2010). Currently, several low-cost technologies which could be useful for laboratories, schools, and businesses, are being researched and developed. Some examples include the Cell Scope portable digital microscope (Switz, et al., 2014); the development of low cost lenses and the devices to adapt them to smartphones (Yu-Lung, et al., 2015 & Navruz, et al., 2013 & Giardini, 2015); the study, by Durdu Güney, of the development of the perfect lense whose intention is to allow seeing micro-organism in plain sight (Sadatgol, et al., 2015). The application of portable microscopes is rather broad. Nonetheless, the focus of research has been on: 1) biological sciences, such as in detection of bacteria and certain cells (Subash, et al., 2014); 2) health sciences, such as in the visualization of stereoscopic ophthalmic surgery (Philbrick, et al., 2017), or anthrax detection in the palm of the hand (Erikson, et al., 2015); 3) chemical engineering, such as in the study of dissolution and crystallization of sodium chloride (Lumetta, et al., 2016). However, there are no such studies with digital microscopes in the field of thermochemical treatments or metallurgy. The purpose of the present study is to verify the capabilities of mobile devices when conducting analysis of materials in places of difficult access or that do not have a SEM, which currently have an elevated cost.

EXPERIMENTAL PROCEDURE

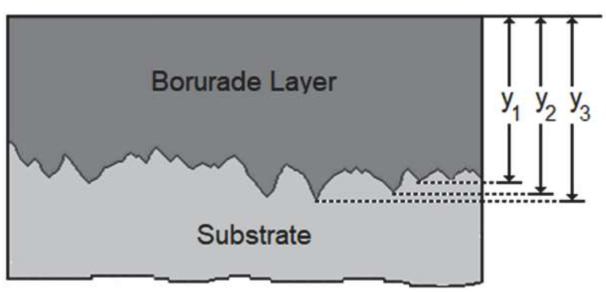
To verify the ability to use digital microscopy for the analysis of thermochemical treatments, a powder-boriding process was made, which is used to harden the surface of ferrous alloys (Matuschka, 1980). In the boriding process, the boron atoms are diffused, which generate a layer on the surface of the substrates that increases the surface's hardness, reduces wear and corrosion (Fitchl, 2014 & Shingal, 1977). The growth of boride layers can be affected by the alloy elements of the substrates, and by the variables of treatment: time and temperature (Geouriot, et al., 1981 & Gunes, et al., 2015 & Topuz, et al., 2016).

The borided material was AISI 12L14 steel with a chemical composition of 1.40–1.60% C, 0.85–1.15% Mn, 0.15–0.35% Pb, 0.04-0-09 % P and 0.26-0.35% S. The samples were cubic with a dimension of 8.5 mm x 8.5 mm x 5 mm. Before the boriding process, the samples were rectified and polished, and a pickling and passivated were performed with sulfuric acid, to remove oxides and other contaminants, such as grease, oil, and paint. To perform the thermochemical treatment, the powder packing technique was applied: the samples were embedded inside a container with powder rich in boron. The treatment was performed in a conventional oven with: four values of temperature (1123, 1173, 1223 y 1273 K) and four times of treatment (2, 4, 6 y 8 hrs). Once the treatment was completed, the container was withdrawn from the oven, and was let to cooled at room temperature. Then, the samples were transversally sectioned, mounted, and polished (Topuz et al. 2016) as is stablished in the Metallographic Preparation of Specimens ASTM E3-11, followed by a chemical attack to reveal the microstructure of the samples, which was conducted with nital (2% de HNO3 diluted with 98 % ethanol) for an exposition time of approximately 5 sec, based on the norm ASTM E407-07. To observe the boride layers, a SU3500 Hitachi SEM was used.

The depths of penetration of the boride layers observed in the SEM were obtained as an average of more than 50 measurements and using Equation 1, the measurements used were obtained taking as reference the surface of the sample and the peaks of the penetration profile of the Boron as you can see in Figure 1.

$$\textit{Layer Thickness} = \frac{y_1+y_2+y_3+y_4+\cdots+y_n}{n} \qquad (1)$$

FIGURE 1
GRAPHIC METHOD TO MEASURE THE AVERAGE OF THE GENERATED LAYERS ON TOP OF THE SURFACE OF THE SUBSTRATE

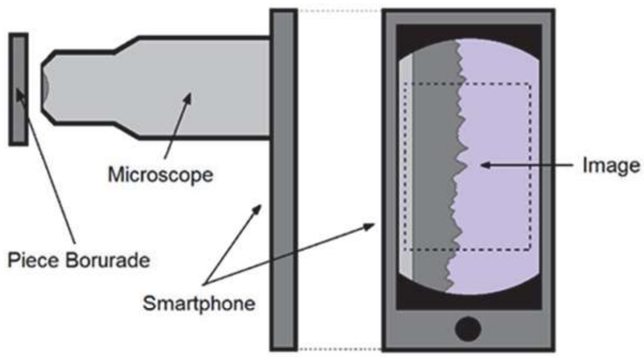


To observe the boron layers, a mobile device was also that consists of two parts was used: a HIROX model MXG-2500REZ digital microscope which was connected to a Sony Ericsson smartphone with an Android based image analysis system.

The depths of penetration of the boride layers observed in the mobile device (see Figure 2) were obtained using the same methodology performed in the images obtained by SEM, it was an average of more than 50 measurements and using Equation 2, the measurements used were obtained taking as reference the surface of the sample and the peaks of the penetration profile of the Boron.

$$Layer\,Thickness = \frac{\sum_{y=1}^{n}(y_i)}{n} \qquad (2)$$

FIGURE 2
DIAGRAM OF THE MOBILE SYSTEM: MICROSCOPE AND SMARTPHONE



RESULTS AND DISCUSSION

In Figure 3, the micrographs of a transversal section of the AISI 12L14 steel sample, which was boriding for 4 hours at a temperature of 1173 K, obtained by both SEM and by Mobile system are presented. The images show a sawn morphology of the boride layer (Matuschka, 1980). The thickness of the boride layers for both the SEM and Mobile system are presented in Table 1 and Table 2, where it can be appreciated that the growth of the bororized layers (the thickness of the layers) is a function of time and temperature (Matuschka, 1980 & Geouriot, et al., 1981 & Gunes, et al., 2015 & Topuz, et al., 2016).

FIGURE 3
MICROGRAPHS AT 200X OF THE TRANSVERSAL SECTION OF THE BORIDING AISI 12L14 STEEL: (a) SEM, (b) MOBILE SYSTEM

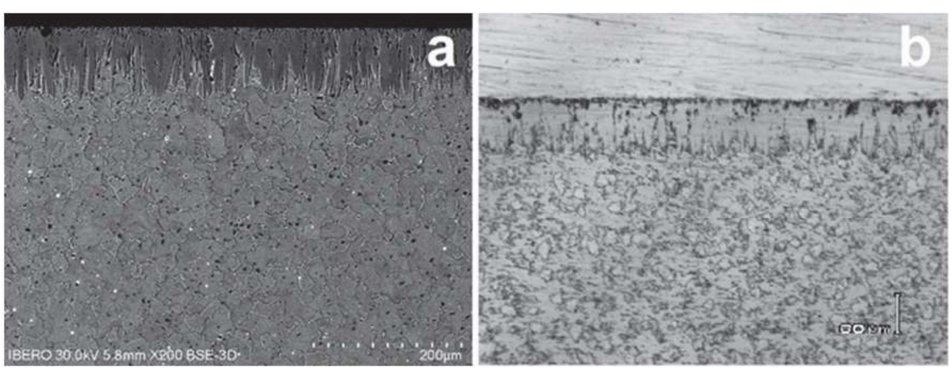


TABLE 1
OBTAINED THICKNESSES BY SEM AS A FUNCTION OF TIME AND TEMPERATUREFOR THE BORIDING PROCESS

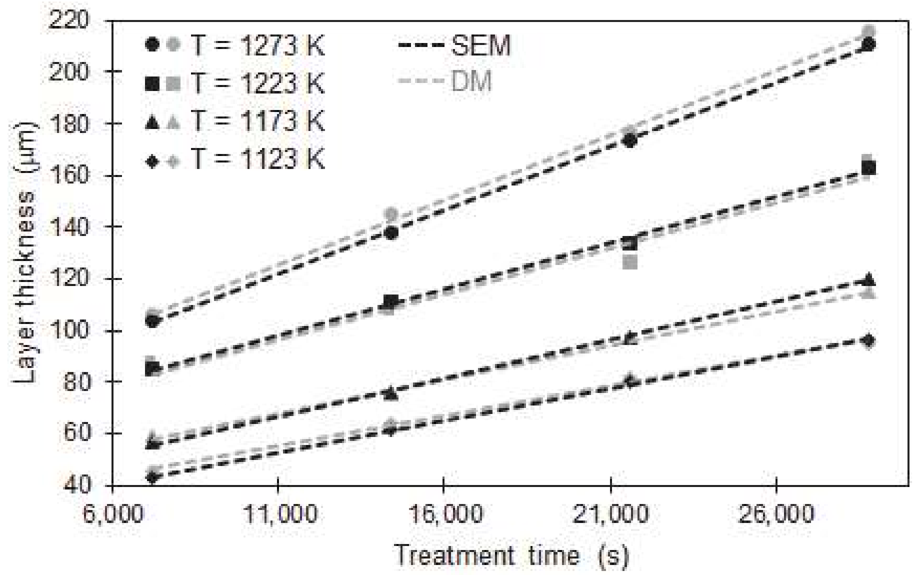
Time (h)	Thicknesses obtained through SEM (mm ± S.D.[a])			
	1123 K	1173 K	1223 K	1273 K
2	44.954 ± 8.36	58.935 ± 10.7	87.097 ± 12.4	106.17 ± 13.8
4	64.068 ± 11.8	75.687 ± 8.40	107.16 ± 14.9	145.10 ± 19.8
6	82.209 ± 17.4	96.848 ± 17.5	126.29 ± 13.1	176.47 ± 27.7
8	95.082 ± 17.9	114.80 ± 19.3	165.33 ± 21.6	215.56 ± 43.2
	[a] Standard Deviation			

TABLE 2
THICKNESSES OBTAINED FOR THE MOBILE SYSTEM AS A FUNCTION OF TIME AND TEMPERATURE FOR THE BORIDING PROCESS

Time (h)	Thicknesses obtained through Mobile system (mm ± S.D.[a])			
	1123 K	1173 K	1223 K	1273 K
2	42.638 ± 5.98	56.639 ± 9.71	84.836 ± 14.4	103.76 ± 12.3
4	61.736 ± 9.58	75.936 ± 9.36	110.95 ± 11.6	138.21 ± 17.6
6	80.301 ± 15.6	97.425 ± 10.7	133.49 ± 17.3	173.74 ± 21.4
8	96.079 ± 16.8	119.71 ± 16.6	162.96 ± 18.6	210.97 ± 36.9
	[a] Standard Deviation			

Figure 4 shows the trend of the thickness of the boride layers as a function of time and temperature of the process, and it can be observed how the measured thicknesses were similar and are both within the standard deviation in both cases. One advantage of digital microscopy over SEM is that it presents a better trend of the line growth in the obtained data due to a uncertainty on the part of the SEM operator when taking the measurements.

FIGURE 4
THICKNESS OF THE BORORIZED LAYERS AS A FUNCTION OF TIME AND TEMPERATURE



CONCLUSIONS

Based on the obtained results, it is possible to use mobile technology for the measurement of boride layers, and thus reduce, or even substitute, the use of costly laboratory equipment; this is a considerable advantage when conducting experiments. The size, portability, and handling of the mobile device minimized the uncertainty of the measurements on the part of the operator and allowed a faster taking of measurements due to the automation of the system. Finally, the proposed device is inherently ergonomic, making it easier and more comfortable to use, and giving users the freedom and capacity to both take and document the measurements.

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