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Limit of detection and hardness evaluation of some steel alloys utilizing optical emission spectroscopic techniques

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ABSTRACT

Steel alloys are of the most useful materials utilized in the manufacture of various industrial components. In this work, Laser-induced breakdown spectroscopy (**LIBS**) and spark-induced breakdown spectroscopy (**SIBS**) techniques have been used as diagnostic tools for the elemental composition of steel alloys and determination of the limit of detection (**LOD**). Also, the surface hardness of these alloys was measured using the ratio between the Calcium ionic and neutral lines (Ca II/Ca I) as well as the well-known method of mechanical Vickers one. The self-absorption of silicon, copper and calcium lines under investigation was corrected via comparison of the electron densities. The densities have been measured from these lines to that calculated from the hydrogen Hα-line at 656.27 nm which are in the same spectra under the same condition. Calibration curves were achieved for Si and Cu with linear regression coefficients about 0.99 and limits of detection values were 147 and 89 ppm respectively. Also, high accuracy linear relations have been obtained between Vickers mechanical hardness, the ratio between the Calcium ionic and neutral lines (Ca II/Ca I) and the plasma temperature. These results proved the importance of correcting the spectral intensity line for the self-absorption effect before the LOD measurement. Also, they confirmed the correction importance before evaluation of the hardness in LIBS experiments.

1. Introduction

Elemental analysis via identification and quantification of elements can be used to determine elemental compounds, molecular species regarding the weight percent of each component, and their purity. This significance is due to the non-metallic elements influence the physical properties of metallic materials. For that, studying the manufactured metal parts is a target field that needs to be analyzed primarily [1,2]. In the field of spare parts and manufacturing of heavy industries, steel alloys represent the most suitable composites in the engineering field with specific properties. Structural, industrial and spare part manufacturing are among the applications in which these alloys have been implemented [3]. Classification of steel alloys is controversial especially in spare parts manufacturing to differentiate between different types [4]. Metal testing services help in identifying and evaluating the properties of metal parts to determine their safety, reliability, and integrity. Moreover, the chemical analytical techniques are commonly used to measure the chemical composition, material classifications then correlation all parameters with quality control [5].

LIBS technique is the most promising method used to collect high-quality information. It is a fast, semi-nondestructive, non-complicated and remote method. It is an analytical technique based on analysis of laser spectral line of different types of matter (solid, liquid, gas or aerosol) produced from plasma state formed by focused high power laser mater interaction [6–8]. Recently, it can be used to measure some physical properties of solid materials like surface hardness [9–14], and determine the limit of detection [15,16]. Along with the LIBS technique, SIBS was used as an effective method to enhance material classifications. It is a high-quality spectroscopic method enabled metal analysis for all metal industry process stages, from metal production through processing and recycling [17].

In the present work, LIBS and SIBS techniques were used as a method to enhance discrimination between different steel alloys used in spare parts manufacturing materials. Then, LOD, the surface hardness, and the plasma temperature were measured before and after correction from the self-absorption effect. Moreover, the surface hardness of the target materials was calculated and compared using mechanically surface Vickers method.

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