

EXPERIMENTAL ANALYSIS OF LOW VOLTAGE ARC BETWEEN CARBON ELECTRODES WITH UNKNOWN CORES

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Abstract: The paper is focused on an electric arc spectroscopy diagnostics related to electric low voltage apparatuses. Measurement of radiation spectra of the electric arc burning between carbon electrodes with unknown cores is presented. Measured radiation spectrum has a lot of suitable atomic spectra lines for comparison purposes. The problems connected with the measurements are discussed. The main part of the paper deals with a prediction of composition of the measured arc plasma. Atomic lines database of National Institute of Standards and Technology was used as a spectral data source for the calculations.

Keywords: switching arc; arc plasma composition; atomic emission spectroscopy.

1. INTRODUCTION

Atomic emission spectroscopy is a powerful tool for a prediction of an unknown plasma composition. A hot plasma between electrodes radiates a lot of energy. If the plasma contains free atoms/ions, its radiation spectra consist of narrow energy peaks. These peaks are called spectral lines. If the atom/ion accepts amount of energy which is given by the difference between two neighbouring energy levels, then the electron can jump to the higher one. This phenomenon is called excitation. Excited state is unstable. If there is lower energy income than necessary to stay excited, electron moves spontaneously back to the lower energy level while irradiating energy specific to the radiation transfer between two energy levels. We can measure this radiation energy via spectrometer. There is two main methods of the spectra measurement. The first method which is called emission spectroscopy is based on self-radiation of plasma. On the other hand in the absorption spectroscopy is used supplementary source of radiation. The radiation of this source is measured after passing through measured object. Output data from spectrometer are emission or absorption spectra, see Fig 1.

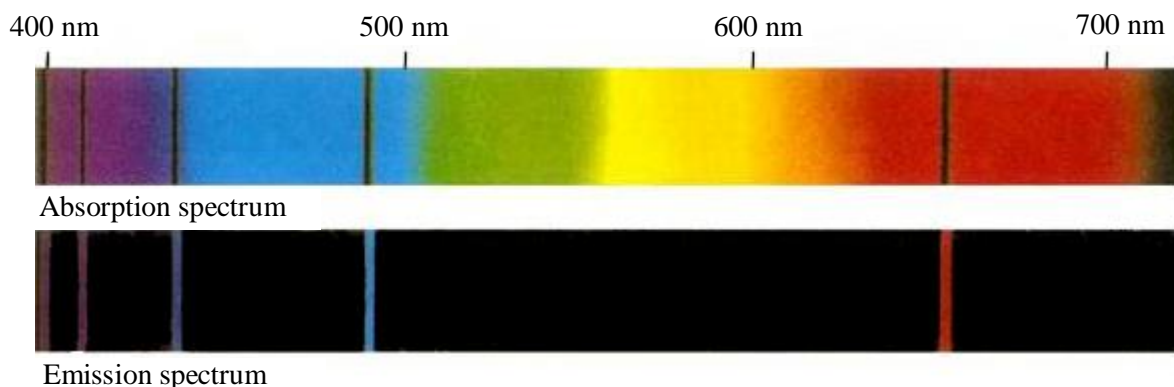


Figure 1: Absorption and emission spectra of hydrogen [1].

Atomic spectra can be described by Bohr model of atom and wave mechanics. Bohr used for his theory classic laws of motion and quantum conditions. Basic idea was placed by equation (1).

$$\Delta E = \frac{hc}{\lambda} \quad (1)$$

where h is Planck constant,
 c speed of light
and λ wavelength [1, 2].

Atomic emission spectroscopy is more suitable for an electric arc spectra measurement. It allows calculation of a plasma composition, temperature and other physical properties, respectively. An advantage of this method is that the measured object is not affected by the measuring devices. Block diagram of measuring circuit is shown in Fig. 2.

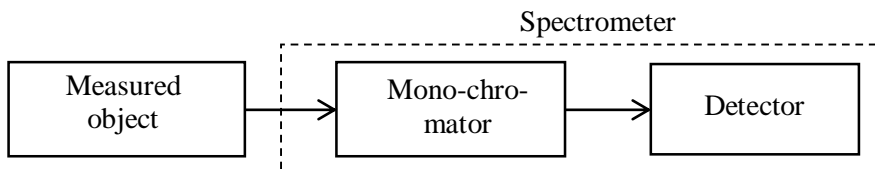


Figure 2: Block diagram of emission spectra measurement.

Spectrometer was used as measuring instrument. CCD chip is commonly used as a detector. Output from this measurement is a line spectrum which contains peaks of specific wavelengths. Peaks look like lines in global view. Shape of a spectral line is shown in Figure 3. In the Figure 3 there are labelled important properties of spectral line: maximum relative intensity of line (I_{max}), full width at half maximum ($\Delta\lambda$) and characteristic wavelength of line (λ_0).

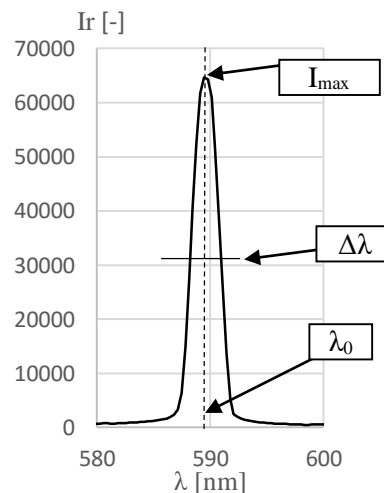


Figure 3: Spectral line shape [2].

2. EXPERIMENTAL SETUP

Measuring chain was arranged according to Fig. 4. Dynamo was used as DC power supply. Series stabilization resistor was used for the current control. Both current and voltage between electrodes were measured. Electric arc was burning between carbon electrodes with unknown stabilization

cores. The electrodes were specially treated by dipping in a salt solution because of detection of spectral shift. Load current was of 5.26 A, voltage on the arc of 56 V and power supply voltage was of 100 V. An arc was projected through set of lens to a shade. Optical fibre was used for necessary separation of measurement channel from the power circuit and transference of light from specific position to the input slit of the spectrometer. For the spectroscopy measurements we used Avantes Avaspec ULS-3648TEC spectrometer. The signal from the spectrometer was transferred via interface USB 2.0. Data were stored and processed using AvaSoft 7.7 software.

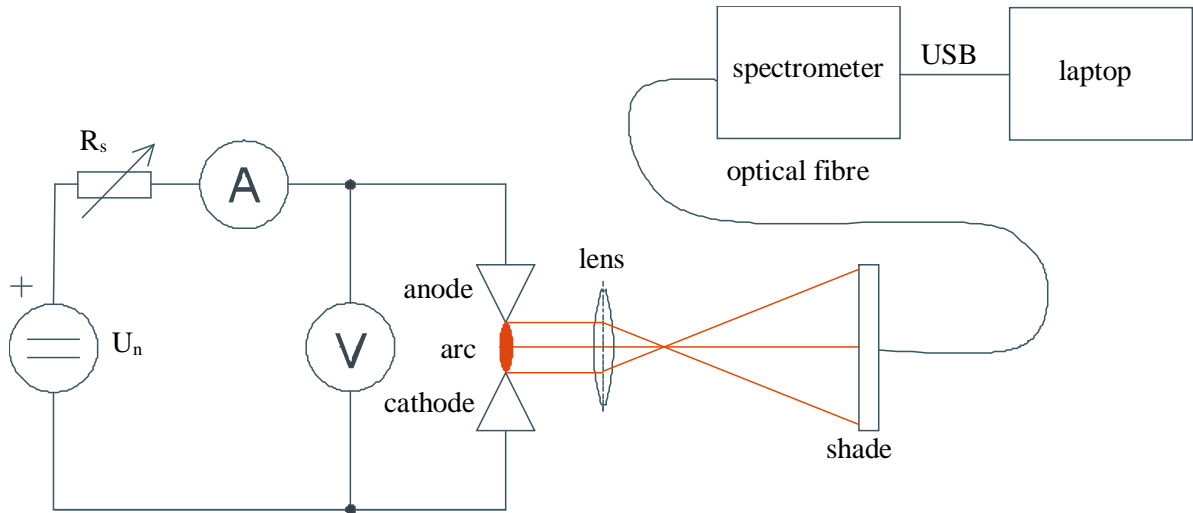


Figure 4: Simplified scheme of measurement chain [4].

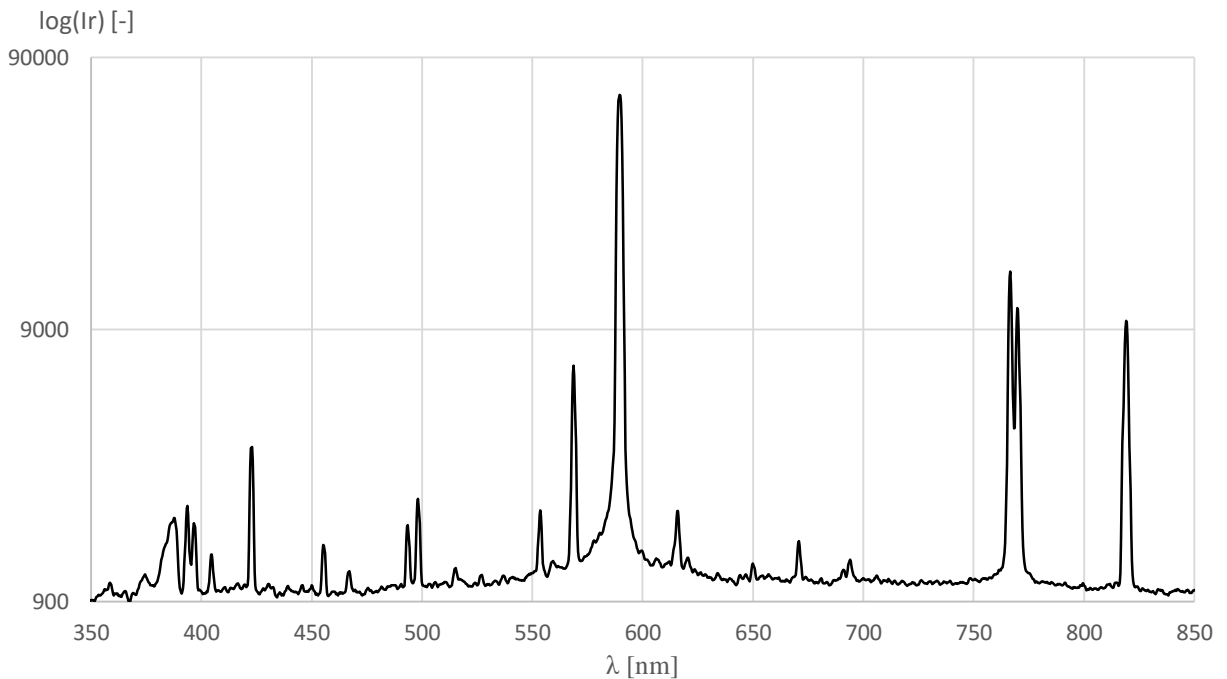


Figure 5: Radiation spectrum of the arc plasma between carbon electrodes.

The measured atomic emission spectrum of plasma is presented in Fig. 5. The plasma composition can be found by comparison of the measured spectral lines with spectral database NIST [3]. Elements assignment and corresponding wavelengths are shown in Table 1.

λ – measured	λ – database	assigned element
[nm]	[nm]	[-]
378.84 – 390.69	-	molecule of nitrogen
393.27	393.26	iron
396.56	396.55	iron
404.38	404.39	iron
422.47	422.45	iron
455.22	455.25	iron
493.28	493.21	carbon
498.02	498.17	titanium
553.40	553.43	carbon
568.39	568.65	iron
589.45	588.99	sodium
589.45	589.59	sodium
615.72	615.77	iron
766.42	766.43	iron
769.83	770.02	iodine
819.24	819.12	fluorine

Table 1: Comparison of measured wavelengths with spectral database NIST [3] and corresponding elements contained in the arc plasma.

3. RESULTS AND DISCUSSION

Results of elements assignment is presented in Table 1. If the arc burns in the air, then it contains molecular nitrogen N_2 . Fluorine, iodine and sodium come from the salt, which was evaporated from the electrodes. Carbon corresponds to the material of electrodes.

It is important to mention that the identification of plasma composition may be affected by a few complications. The first one is a spectral lines shift. It depends on spectrometer resolution. We have found the shift of 0.8 nm via spectra measurement of known plasma. This shift is already presented in the Fig. 5.

The second problem corresponds to database using. There is a lot of nearby lines in the spectrum which is sometimes very difficult to distinguish.

Another complication is connected with database using again. In the database, there are presented spectral lines for neutral elements, but also for once, twice and triple ionised elements. Probability of occurrence of neutral species is very high. For once ionised species there is a probability of their occurrence much lower. Probability that the free burning arc with temperature below 10 000 K and without any foreign ionization source contains more than once ionised species is insignificant because of high density of air. Average free path of the electron is short to reach necessary energy due to the high density of air. Also the probability of collision between electron and ionised atom is insignificant.

The problem would be also in that the NIST database cannot cover all experiment conditions in which the spectral line are measured. That means that there are lines measured under different pressures, temperature etc.

4. CONCLUSION

Aim of the measurement was to find out composition of the electrode core. From the measurements follows that the core is probably made of pressed iron powder, titanium powder and carbon powder.

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