Contrib. Plasma Phys. **26** (1986) 1, 53—56

An Efficient Spectroscopic Control — Technique of the Parameters of Thermic Plasmas Produced under the Condition of a Variable Current

J. HALENKA, H. JANUS

Institute of Physics, Pedagogical University, 45-052 Opole, Oleska 48, Poland

Summary

The spectroscopic diagnostics has been carried out as an example for an argon plasma from Maecker-Shumaker type electric arc supplied by periodic variable current. It is shown that the time-dependent runs of intensity of the plasma light may be determined using an ordinary oscilloscope. We have stated that the electron concentration N_e in the plasma is the most sensitive quantity to the current pulsations. In the percentage, N_e variations at the arc axis are approximately the same as the current ones.

1. Introduction

The temperature and concentrations of the plasma components are the principal quantities on which plasma features depend. The quantities may be determined spectroscopically by measuring the line intensities of a well-chosen set of spectral lines (cf. e.g. [1]). The emission coefficient is usually determined using photographic or photoelectric techniques, but only the photoelectric one is of practical relevance for the time-dependent runs. This last program is the feasible one when the photomultiplier cooperates with a recorder of a time-constant much smaller then the light pulsation period.

2. The Experimental Set-up

In a standard system, the photomultiplier signal is guided to chart recorder. When a plasma is generated using a variable current, that system enables to measure the time-mean emission coefficients only. We state, however, that the time-dependent runs of the emission coefficient may also be measured — using an ordinary oscilloscope as a supplementary tool. Fig. 1 presents a scheme of such measuring set-up.

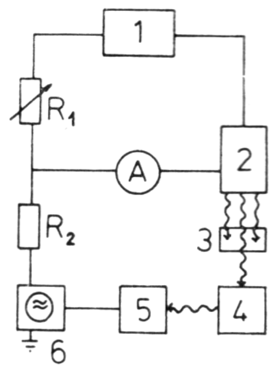
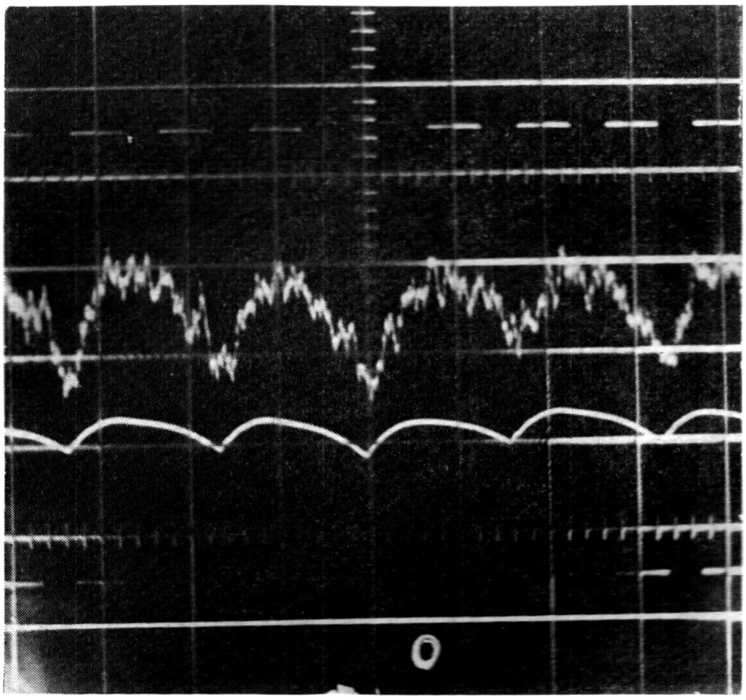


Fig. 1. The scheme of the measuring set-up for periodically changing light of plasma from an electric arc feeded by variable current. The labels: 1 — current supply, 2 — plasma source, 3 — optical system, 4 — spectrograph, 5 — photomultiplier, 6 — oscilloscope. R_1 and R_2 — ohmic resistances, A — ammeter

In the experiment, described in the paper as an example, the plasma was produced in a Maecker-Shumaker type cascade electric arc. The cylindrical discharge channel had the diameter 5 mm and the length 82 mm. As a current generator served the full — wave rectifiers in the parallel connection, feeded from the power network of the three-phase current. The ripple factor[1]) of the feed current, δi, amounted to 14% and the pulsation period — P = 1/300 s. The experiments have been carried out in an argon plasma for various arc currents. The technical argon was used; its flow was controlled using a rotameter. The plasma arc had worked at the flow 500 l/h, under the atmospheric pressure. The plasma light was splitted by a grating spectrograph PGS-2 of



Fot. 1. The oscillogram of the pulsation of both the intensity of the line ArI 4300 Å integrated in the interval ±5.5 Å (the upper run), and the feed current intensity (the lower run)

the reciprocal dispersion about 7Å/mm in the first order of interference. On the input slit of the spectrograph, the light of the homogeneous (coaxial with the discharge channel) plasma cylinder of the radius of 0.5 mm only was directed. In that way the space-averaging was eliminated and strict time-variations of the plasma radiation were observed.

The spectrum was preliminarily recorded using a chart recorder. On this basis the half-widths and the central intensities of the spectral lines were estimated. As a test line we chose the line ArI 4300 Å, being best isolated and not affected by self-absorption. (In all the experiments, the ratio of the central intensity of the line and of proper value of the Planck function did not exceed 0.02.) In the wavelength interval of ±5.5 Å around the line center, the integral intensity of the ArI 4300 line (I_l) together with the

[1]) For a periodic function $f(t)$ of time t, the ripple factor is defined as follows: $\delta f = (f_{\max} - f_{\min})/f_{\text{mean}}$, where $f_{\text{mean}} = \dfrac{1}{P}\displaystyle\int_0^P |f(t)|\, dt$.

continuous background (I_c) was recorded, $I_t = I_l + I_c$. (That spectral interval always was about tenfold greater than the half width of the line). The signal from the multiplier (FEU-97) was directed on one of two channels of the oscilloscope (DT-516 A); the signal proportional to the feed current — on the second one (via the resistance $R_2 = 10\ \mathrm{k}\Omega$). Fot. 1 presents an oscillograph record for a mean feed current 38 A as an example. On the record, the synchronous runs of both pulsating plasma light (at the top) and the feed current (at the bottom) are clearly seen.

In the same way, the nearest (free from line radiation) continuous background was recorded. (Corresponding wavelength interval was centred at λ 4315 Å; the change of the continuum intensity on that distance of 15 Å was ignored as being negligible.) The time-dependent runs of both I_t and I_c intensities have been similar. The result of substraction of the signals, $I_t - I_c$, is proportional to the integrated light in the line. Fig. 2 presents the run of such quantity in the absolute scale, for a mean feed current 38 A. The reduction to the absolute scale was carried out using the light of the low-current carbon arc and suitable data on the emission coefficients [3].

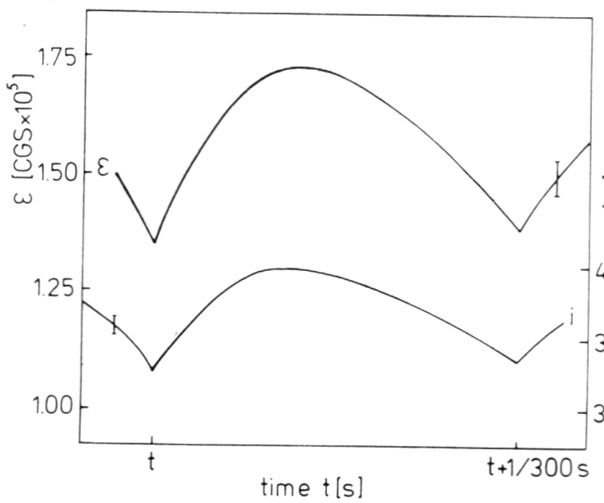


Fig. 2. The time-dependent runs of both the emission coefficient, of ArI 4300 line and the feed current intensity, i. (For details see text.)

The plasma produced in the Maecker-Shumaker type arc can be assumed as to be practically homogeneous along the channel axis (cf. e.g. [2]). We assume, furthermore, that the plasma is optically thin and satisfies the LTE hypothesis. Therefore, using the measured line intensity of ArI 4300 Å, the length of the plasma column, and the value of atmospheric pressure, the suitable equation system has been formulated and solved (cf. e.g. [1]). The main results are presented in Fig. 3. The time-mean values of the quantities plotted as a function of time amount to: $N_e = 4.65 \times 10^{16}\ \mathrm{cm}^{-3}$, $N_{ArI} = 5.56 \times 10^{17}\ \mathrm{cm}^{-3}$, $T = 11430$ K, and proper the ripple coefficient: $\delta N_e = (16.1 \pm 1.5)\%$, $\delta N_{ArI} = (5.0 \pm 0.5)\%$ and $\delta T = (2.0 \pm 0.2)\%$. The concentration of the single ionized argon is — in limits of errors — equal to the electron concentration, $N_{ArII} \approx N_e$. (The densities of higher ionized species are negligible.) According to the paper [5], in the physical conditions as the above ones, the LTE hypothesis is satisfied.

Similar courses we have obtained also for the feed currents equal to 59, 78, and 120 A. In each case the relation $\delta N_e - \delta T \simeq \delta_i$ is well-fulfilled. Because $\delta T \ll \delta N_e$, the run of δi quantity informs immediately on changes of N_e.

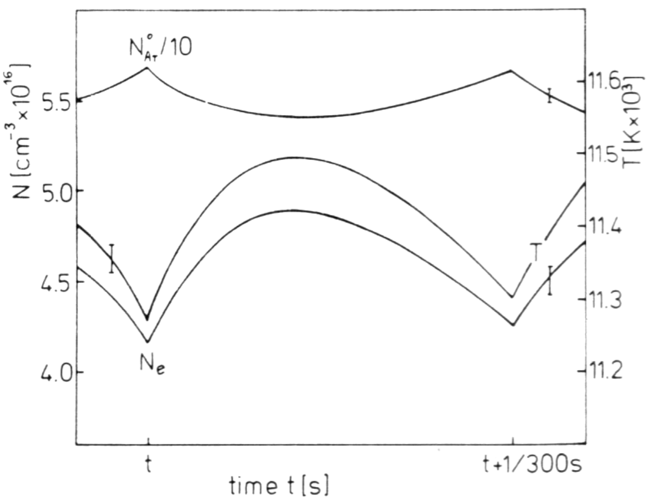


Fig. 3. The time-dependent runs of the electron concentration — N_e, the concentration of the neutral argon — N_{ArI}, and of the temperature — T

3. Conclusions

The presented measuring method of the line-intensity by means of the ordinary oscilloscope is especially useful in industrial applications where the variable-current supply is often used (in order to get high effective powers; cf. e.g. [4]). That method enables to do easy control of the plasma parameters and of the stability of the burning electric arc. High level of stability of the arc discharge is of great importance in experimental research works, e.g. in the spectral line broadening examinations.

Acknowledgements

We acknowledge the helpful discussions with drs B. Grabowski and J. Musielok.

References

[1] Lochte-Holtgreven, W., ed., Plasma diagnostics, North-Holland Publishing Company, Amsterdam (1968).
[2] Wujec, T., Musielok, J., Astron. Astrophys. **50** (1976) 405.
[3] Euler, J., Ann. der Phys. **11** (1953) 203.
[4] Contributed papers of the Conference on Applications of Low Temperature Plasmas in Industry, Częstochowa **1979**, 81, 83 (in polish).
[5] Kolesnikoff, W. N., Trudy of A C of USSR, **30** (1964) 66.

Received November 5, 1984