Topic number 11

Collisional-radiative model of iron vapour released in thermal arc plasma from molten electrodes

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A collisional-radiative model for technological plasmas is set up. It considers the ground state and fifty effective levels of atomic iron, and one level for singly-ionized iron. The model provides the population of excited states of iron due to collisional and radiative processes. It is applied to a thermal argon arc plasma, in which iron vapour is released respectively from the molten steel anode in tungsten-inert gas and from the consumable iron electrode in a gas-metal welding arc. Input parameters are provided by magnetohydrodynamic simulations. The results clearly identify the conditions in the arc under which the atomic state distribution satisfies the Boltzmann distribution, with an excitation temperature equal to the plasma temperature or deviates from it.

Iron vapour is important in many arc plasma processes. The electronic structure of the iron atom is characterized by energy levels and ionization potential being lower than the energy of the first excited state of the shielding gas [1], i.e. iron atoms are more easily excited and ionized and can influence the radiative and electrical arc plasma properties. To obtain the population of excited states, cross-sections and transition probabilities for excitation and de-excitation, ionization and recombination, and radiative processes between the levels are required. However, there exists a drastic lack of data in the literature for iron atoms. Data obtained in the Opacity Project and the Iron Project is restricted to astrophysical applications [2]. For that reason, collisional data is described in the model by means of theoretical approximations [3]. Atomic transition probabilities data for allowed and forbidden transitions is critically evaluated and given in [4]. The net result of emission and absorption transitions between two levels is considered with transition probabilities modified by the optical escape factor. The model neglects the transport of excited atoms [5]. It is applicable to technological plasmas both in and out of local thermodynamic equilibrium (LTE). Magneto-hydrodynamic simulations of tungsten-inert gas and gas-metal welding arcs serve with input parameters.

The atomic state distribution (ASD) obtained for gas-metal tungsten arc is shown in Fig. 1. At low temperatures (a) observed respectively near the consumable electrode and the workpiece, the ASD deviates from the equilibrium one (straight line). Then, temperature determination from line intensity measurements can be inaccurate. Deviations from thermal equilibrium occur. In contrast, in the most of the central part of the arc column where the temperature is high (b), the excitation temperature and the plasma temperature are equal. The application of diagnostic techniques that are based on the assumption of LTE is better justified.

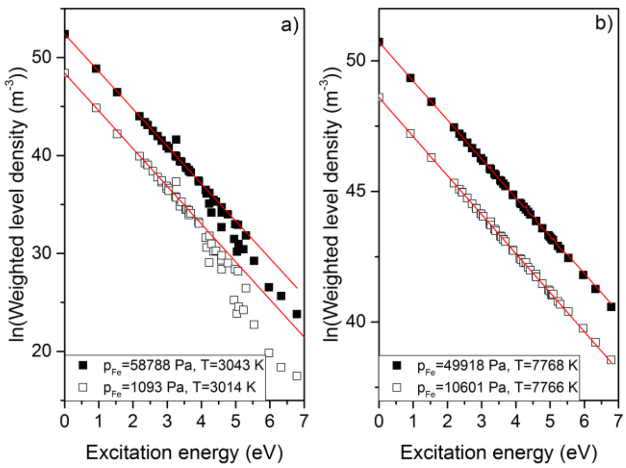

Fig.1 Atomic state distribution of iron at a) low and b) high temperatures in gas-metal welding arc plasma. In each case, results are shown for two iron partial pressures. The straight lines represent Boltzmann distributions.

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References

[1] C.E. Moore, Atomic energy levels, vol. 2, Ntl. Bur. Stand. (US) Circ. 467 (1952, repr. 1971).

[2] D.G. Hummer et al, A&A, **279**, 298 (1993).

[3] L. Vriens, A.H.M. Smeets, Phys. Rev. A, **22**(3), 940 (1981).

[4] J. R. Fuhr, W. L. Wiese, J. Phys. Chem. Ref. Data, **35**(4), 1669 (2006)

[5] B. Van der Sijde et al, Beitr. Plasmaphysik, **24**, 447 (1984)