ON THE PROPERTIES OF THE NONIDEAL PLASMA OF ELECTRICAL PULSE DISCHARGES IN WATER

P.D. Starchyk, P.V. Porytskyy

Institute for Nuclear Research of NASU, pr.Nauky 47, Kyiv 03680,Ukraine,
E-mails: starchik@kinr.kiev.ua, poryts@kinr.kiev.ua

It is considered the peculiarities of the thermodynamic and transport properties of the nonideal plasma of electrical pulse discharge in water at pressure range from 1 bar up to 20 bar. The properties are calculated on the base of the two-temperature model of the thermal plasma. It is shown that the properties of dense water plasma have a pronounced non-monotone character with sharp pikes in certain temperature and pressure ranges. It is pointed that the temperature separation are needed to take into account to study the discharges in water.
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1. INTRODUCTION

The most important influence on the plasma of electrical pulse discharges in liquid (EPD) have the processes in a zone of its contact with condensed medium. At the initial stage of EPD small-scale irregularities of heat flow distribution were detected on a surface of channels [1-3]. Development of such perturbations was accompanied by space modulation of an irradiation intensity, strain of a surface of channels, drop of conductance of plasma. These excitations are connected with the development of Rayleigh-Taylor instability (RT-instability). Thus in EPD it may be realized the two different regimes of discharges the first is characterized by developed perturbation and the second is the discharges without it. Because of that the nonideal plasma of EPD takes place in various dense states. In this paper it is studied the peculiarities of the thermodynamic and transport properties of the nonideal plasma of EPD in water in the pressure range from 1 bar up to 20 bar.

2. PROPERTIES OF THE DENSE WATER PLASMA

The properties are calculated on the base of the two-temperature model of the thermal plasma [4-6]. In this way the plasma state are described by both the temperature of electrons T_e and heavy particles one T under certain pressure p .

The algorithm consists of two stages. At the first time it is needed to obtain the multicomponent plasma composition under certain pressure and temperature. This problem leads to the system of Saha equations with lowering of ionization energies supplemented by conservation of nuclei and electric charge.

The calculation are carried out, and the following 13 species have been taken into account: e^-, H_2O, H_2O^+, H_2, H_2^+, OH, OH^+, $O2$, $O2^+$, H, H^+, O, O^+.

Having been obtained plasma composition, the thermodynamic and transport properties of plasma can be calculated. A number of the properties are very interested in the connection of intended use to model the electric discharges in water. Therefore it is focused attention upon such properties.

It should be noted that the comparison with alternative calculations [7,8] can be made in the one-temperature approximation only. In this way it is considered the case when $T_e = T$. The results are shown in Figs.1-8.

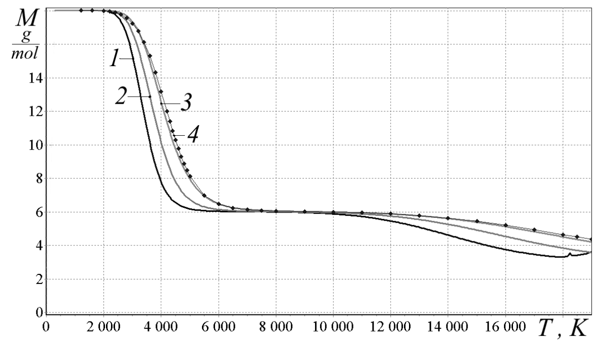

Fig.1. The molar mass for water plasma. Curve 1 corresponds the calculation under the pressure p=1 bar, 2 – p=5 bar ; 3 - p=20 bar ; 4 – data from [7] under p=20 bar

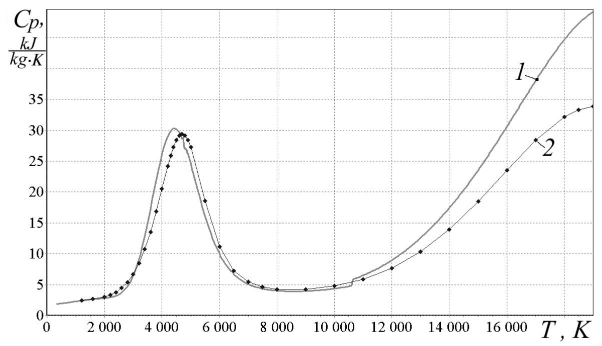

Fig.2. The specific heat capacity under constant pressure of water plasma under p=20 bar. Curve 1 corresponds to the calculations; 2 – the data from [7]

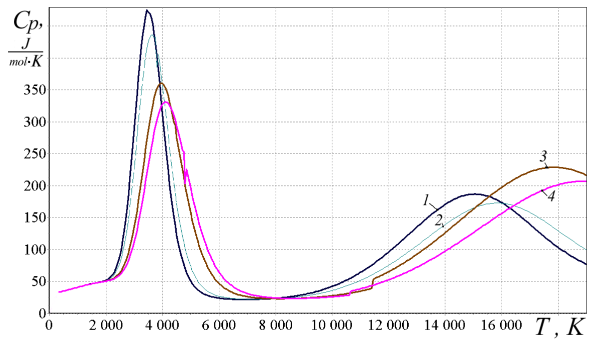

Fig.3.The molar heat capacity under constant pressure of water plasma. Curve 1 corresponds to the calculations under p=1 bar, 2 –p=2 bar, 3 - p=10 bar, 4 - p=20 bar

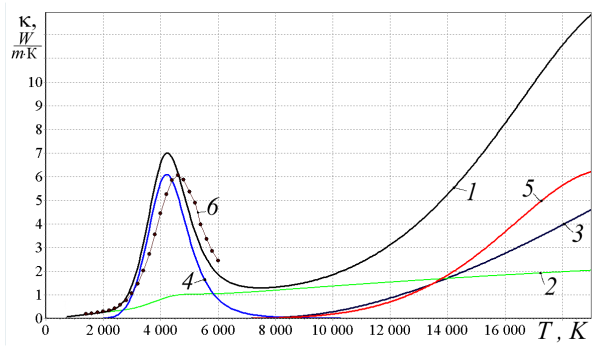

Fig.4.The heat conductivity of water plasma under p=20 bar. Curve 1 corresponds to the total conductivity, 2 – the gaseous one, 3 – the electronic one, 4 –the dissociative one, 5 – the ionization one, 6 is the data from [8]

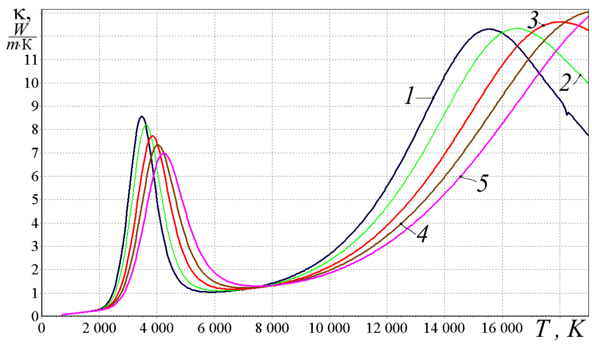

Fig.5. The heat conductivity of water plasma. Curve 1 corresponds to the p=1 bar, 2 – p=2 bar, 3 – p=5 bar, 4 – p=10 bar, 5 – p=20 bar

From Figs.1-8. we can deduced that the properties of dense water plasma have a pronounced non-monotone character with sharp pikes in certain temperature and pressure ranges, and , also, that the calculation of some properties are in a good agreement with the data from works [7,8].

The pikes are appeared due to the dissociation and from others effects. Thus, the viscosity peaks (Figs.7,8) are caused by the dissociation and the presence of minor additions of ions in gases at weakly ionization.

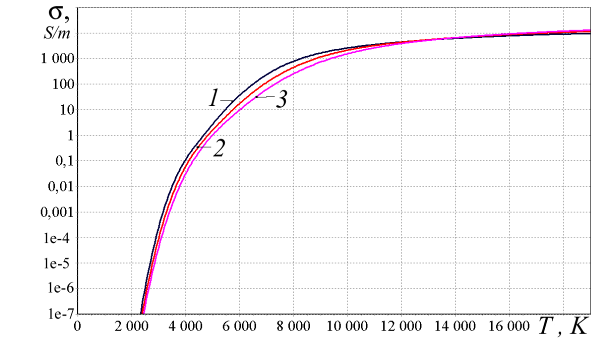

Fig.6. The electrical conductivity of water plasma. Curve 1 corresponds to the p=1 bar, 2 – p=5 bar, 3 – p=20 bar

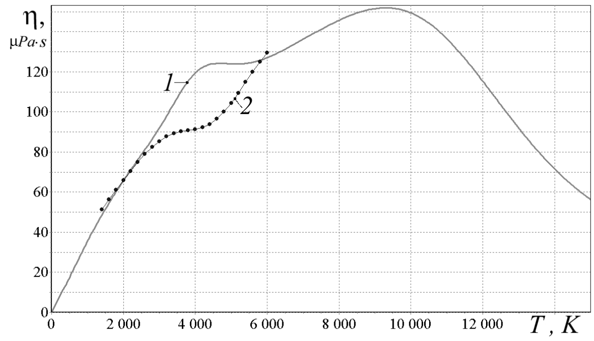

Fig.7. The viscosity of water plasma under p=20 bar. Curve 1 corresponds to the calculations; 2 – the data from [8]

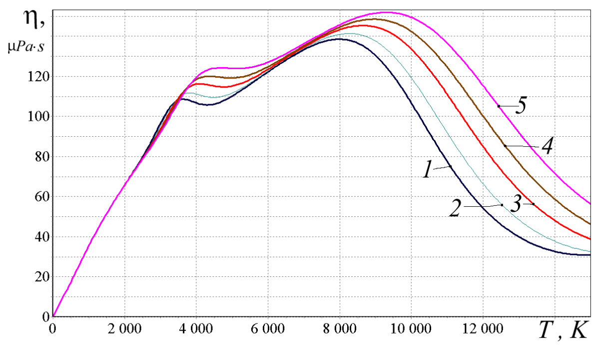

Fig.8. The viscosity of water plasma. Curve 1 corresponds to the p=1 bar, 2 – p=2 bar, 3 – p=5 bar, 4 – p=10 bar, 5 – p=20 bar

On the other hand the two-temperature case may be important to study the processes in discharge. The discrepancy between electron temperature T_e and gaseous one T is appeared due to the action of electric and magnetic fields on the particles in plasma. The value of the discrepancy is strongly depended on the kind of plasma medium and is varied in widely range [4-6].

It is considered the case when the interrelation between T_e and T is determined by electric field (Fig.9). Thus, we can see that the value of temperature discrepancy reaches a large amount in certain temperature diapasons, and this fact are needed to take into account to study the discharges in water.

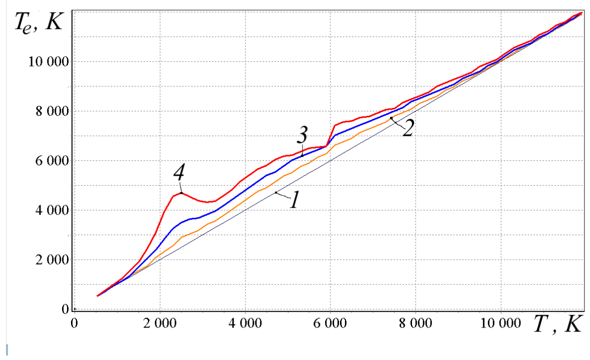

Fig.9. The calculated values of the discrepancy between T_e and T in thermal water plasma (p =1 bar), for electric field E=1 V/cm (curve 1), E=2 V/cm (2), E=10 V/cm (2), E=15 V/cm (3), E=20 V/cm (4)

3. CONCLUSIONS

The properties of dense water plasma of electrical pulse discharges are essentially depended on the temperature and pressure conditions. The properties have a pronounced non-monotone character with sharp pikes in certain temperature ranges.

The calculations are carried out on the base of the two-temperature model of the thermal plasma when the electron temperature differs from the gaseous temperature. The value of temperature discrepancy reaches a large amount in certain temperature diapasons. That fact is necessary took into account under theoretical study of the electrical pulse discharges in water.

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О СВОЙСТВАХ НЕИДЕАЛЬНОЙ ПЛАЗМЫ ИМПУЛЬСНЫХ ЭЛЕКТРИЧЕСКИХ РАЗРЯДОВ В ВОДЕ

П.Д. Старчик, П.В. Порицкий

Рассмотрены особенности термодинамических и транспортных свойств неидеальной плазмы импульсных электрических разрядов в диапазоне давлений 1-20 бар. Свойства рассчитывались на основе двухтемпературной модели термической плазмы. Показано, что свойства имеют резко выраженный немонотонный характер в определенных температурных диапазонах в зависимости от давления. Подчеркивается необходимость принятия во внимание отрыва температур при изучении плазмы разрядов в воде.

ПРО ВЛАСТИВОСТІ НЕІДЕАЛЬНОЇ ПЛАЗМИ ІМПУЛЬСНИХ ЕЛЕКТРИЧНИХ РОЗРЯДІВ У ВОДІ

П.Д. Старчик, П.В. Порицький

Розглянуто особливості термодинамічних та транспортних властивостей неідеальної плазми імпульсних електричних розрядів у воді в діапазоні тисків 1-20 бар. Властивості розраховувались на основі двотемпературної моделі термічної плазми. Показано, що властивості мають різко виражений немонотонний характер у окремих температурних діапазонах в залежності від тиску. Наголошено необхідність взяття до уваги відриву температур при вивченні плазми розрядів у воді.