ON THE INFLUENCE OF ELECTRODE EROSION ON PROPERTIES OF NONIDEAL PLASMA OF UNDERWATER DISCHARGES

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It is considered the influence of electrode erosion vapors on the transport properties of a nonideal plasma of underwater discharges at high pressure. The experimental investigation is presented on erosion evaporation and penetration into plasma. The transport coefficient set based on the Grad's method is compared with the data obtained by using of the Lorentzian plasma theory at the same plasma composition. Also, the calculation data are considered to be in reference with transport coefficients obtained by using the Chapman-Enskog' method. It is pointed that the nonideality effects are needed to take into consideration under calculation of properties of underwater discharge.

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INTRODUCTION

Over the last decades a substantial growth has occurred in technological applications and researching of underwater discharges (arcs and electrical pulse discharges) [1-5]. The most important influence on the plasma of underwater discharges has the processes in a zone of its contact with condensed medium and electrode processes.

At the initial stage of electrical pulse discharges (EPD) small-scale irregularities of heat flow distribution were detected on a surface of channels [1,2]. 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. 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. On the other hand the electrode erosion leads to penetration of erosion products into plasma. All these processes caused the essential variation of plasma properties and as a consequence the discharge characteristics are complicated.

Because of that the nonideal plasma of EPD takes place in various dense states. Also, that picture is established in underwater arc discharges. In this paper it is studied the peculiarities of the transport properties of the nonideal plasma of underwater discharges due to the electrode erosion processes.

1. METHOD TO CALCULATE TRANSPORT PROPERTIES

It is considered the calculation of transport coefficients (thermal conductivity, viscosity, electrical conductivity) in dense water plasma with metal impurities. The most important factors determined the properties are the following: gaseous and plasma non-idealities, multicomponent contents. To include the factors into consideration the combined calculation procedure is used on the base of the Grad's method [6,7] and Lee-More theory [8]. The non-ideality corrections to equation of state are made according to [9-11].The obtained results are compared with the previous calculations based on the Lorentzian theory (LM) [5,12].

The algorithm of calculation consists of three 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 calculations are carried out, and the following species have been taken into account: e^-,*Me,* Me_2, Me_2^+, Me^+, Me^{++}, 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 in the , so-called, zero-density model (ZM) i.e. without consideration of the nonideality effects. At next stage the nonideality corrections are included to obtain the set corresponding to the dense model (DM).

A number of the properties are very interested in the connection of intended use to simulate underwater discharges. Therefore it is focused attention upon such properties.

2. RESULTS AND THEIR DISCUSSIONS

The results of experimental investigation of discharge are shown in Figs.1-2. The experimental installation and technique are described in [1,2,5]. One can see that the evaporated electrode materials penetrate into plasma channel in dependence on time from the beginning of discharge pulse. At a whole that caused a complicated picture of the discharge.

It should be pointed that because the electrode erosion it is the different zones of plasma channel take place. In the vicinity of electrode the metal vapors are dominated in plasma. Otherwise the pure water plasma takes place far from electrode at initial stage of discharge. This picture is realized if the exploding wire initiated the discharge in diameter is smaller than

40…50 *μm*. That is corresponded to the case of so-called 'thin' wires. If the diameter of wire is large the metal vapors should be dominated in the plasma channel.

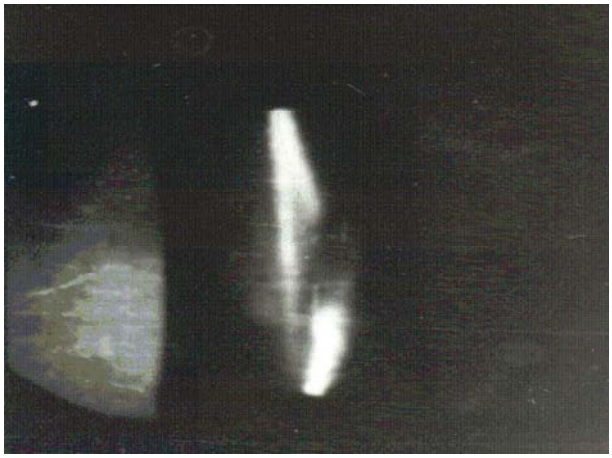

Fig. 1. Electrode plumes from copper electrode under pulse discharge in water

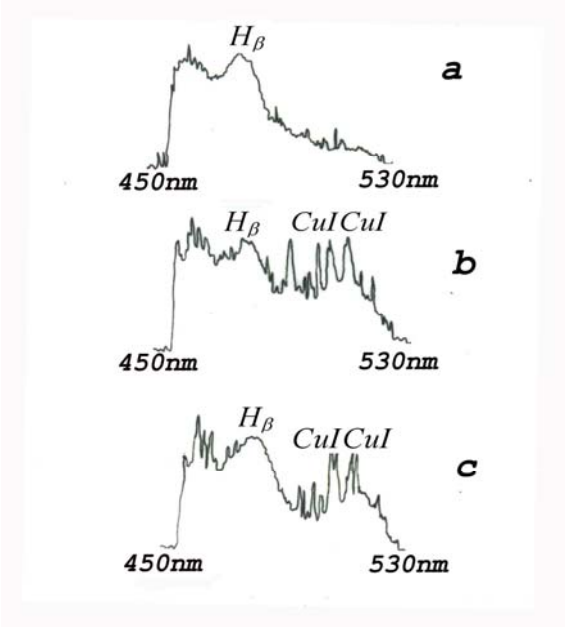

Fig. 2. Spectra of pulse discharge in water initiated by copper wire with diameter 20 μm at voltage 20 kV. Cases are a) the distance between electrodes l=50 mm, the time after initiating t=12 μs, b) l=10 mm, t=12 μs, c) l=50 mm, t=110 μ.

An example of properties calculations is shown in Fig.3. One can see that the properties of dense water plasma are strongly depended on the plasma composition, temperature and pressure range.

It should be mentioned that the plasma composition is the same that it is allowed to compare both the Grad method approach with the Lorentzian theory. The results have a similar character at normal pressure. On the other hand at higher pressure the essential discrepancy takes place. One can be deduced that the effects of nonideality have influence on the transport coefficients mainly in more dense conditions and the Lorentzian theory is suitable to calculate the transport properties of multicomponent plasma at relatively low temperature and normal pressure.

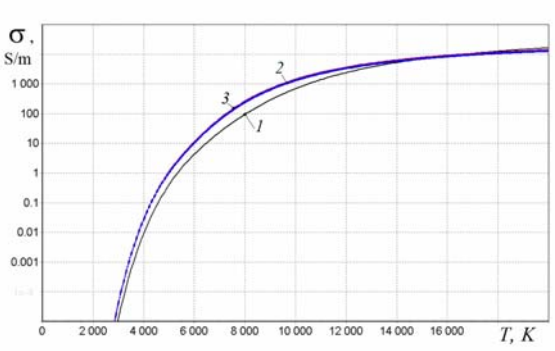

Fig. 3. Electrical conductivity of dense water plasma with copper impurities H_2O-Cu (99:1) at p =200 bar. Curves 1-LM, 2- ZM, 3-DM

CONCLUSIONS

Thus, because the electrode erosion it is the different zones of plasma channel take place.

The properties of dense water plasma of underwater discharges are essentially depended on the plasma composition, temperature and pressure conditions. The calculations are carried out on the base of the Grad's method including the nonideality effects. The nonideality effects are needed to take into consideration under calculation of properties of underwater discharge at high pressure.

The obtained results confirm the conclusion of paper [12] that the Lorentzian theory is suitable to calculate the transport properties of multicomponent plasma at relatively low temperature and normal pressure. Also, it should be born in mind that Lorentzian plasma model on the one hand takes into account the kinetic effects and on the other hand is characterized by relative simplicity, which allows its use for direct computation of the properties of plasma in the simulation of arc and pulse underwater discharges at normal pressure.

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О ВЛИЯНИИ ЭРОЗИИ ЭЛЕКТРОДОВ НА СВОЙСТВА НЕИДЕАЛЬНОЙ ПЛАЗМЫ ПОДВОДНЫХ РАЗРЯДОВ

П.Д. Старчик, П.В. Порицкий

Рассмотрено влияние материала электродов на транспортные свойства неидеальной плазмы подводных разрядов. Представлены экспериментальные результаты о проникновении продуктов эрозии электродов в плазменный канал разряда. Транспортные коэффициенты, которые рассчитывались на основе метода Грэда, сравниваются с результатами, полученными, исходя из лоренцевой теории, при одинаковом составе плазмы. Подчеркивается необходимость принятия во внимание эффектов неидеальности при расчете свойств подводных разрядов.

ПРО ВПЛИВ ЕРОЗІЇ ЕЛЕКТРОДІВ НА ВЛАСТИВОСТІ НЕІДЕАЛЬНОЇ ПЛАЗМИ ПІДВОДНИХ РОЗРЯДІВ

П.Д. Старчик, П.В. Порицький

Розглянуто вплив матеріалу електродів на транспортні властивості неідеальної плазми підводних розрядів. Представлено експериментальні результати про проникнення продуктів ерозії електродів до плазмового каналу розряду. Транспортні коефіцієнти, що були розраховані на основі методу Ґреда, порівнюються із результатами, які ґрунтувалися на лоренцевій теорії, за однаковим складом плазми. Наголошено на необхідності взяти до уваги ефекти неідеальності під час розрахунку властивостей підводних розрядів.