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The influence of ultrasound on electrical conductivity of water

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The interest in hydrogen gas as the energy carrier with rational physical and technical parameters (one cubic metre of hydrogen gas accumulates about 10^3 Ah of electricity and the heat of this gas is 3 kWh/m^3 [1]) is increased now in all the world.

Water is the colossal source of raw material for hydrogen production but the molecule of water is a stable formation and in usual conditions it dissociates badly. Chemical and physical factors are used to stimulate this dissociation. One of them is the treatment by acoustic waves, namely, sonolysis. In water treated by acoustic waves, the effect of the acoustic cavitation is observed. The cavitation is widely used in technological processes. The hypothesis that high temperatures (4000-6000K) develop in the places of a pressure gradient appeared to be useful from the point of view of stimulating the dissociation of water and encouraged to investigate the changes of electrical conductivity and hydrogen ions' concentration in water for various intensities of ultrasonic waves.

The experimental technique is described in [1] in detail. The bath used for investigations had ultrasound transducer with the frequency about 34 kHz in its bottom and generator with the same frequency. The investigations were carried out with several kinds of water: town, twice-distilled, distilled-deionized and the water with containing impurities. The estimate of hydrogen ions' dynamics is made on the basis of hydrogen potential measurements and ions' concentration was determined according to pH scale. Simultaneously the electrical conductivity for alternating current was measured.

The considerable changes of alternating current intensity (Fig. 1a, curves 1-6) and the hydrogen ions' concentration (Fig. 1, curves 7-8) versus time when water is affected by ultrasonic waves (t=0 is the moment of switching on the ultrasound) and after it (t=180 is the moment of switching off the ultrasound).are observed. When ultrasonic waves, intensity of which is higher than the cavitation threshold in tested water, are switched on (at t=0), its electrical conductivity increases 50 - 1000 times and it depends on a kind of water. The relaxation behavior of conductivity's increase was observed and this relaxation had an exponential character. The duration of relaxation time depends on the impurities' amount. The longest relaxation processes were observed in distilled-deionized water (curve 5). The peak of current's intensity between 2nd and 6th second (curve 1), observed for town water during the first measurement, disappears in the second one (curve 2). Town water has many impurities, which at the beginning increase the conductivity of water in the first case and later settle down.

That is why the peak of current's intensity disappears in repeated measurements. When acoustic waves are switched off at the moment t_1, the electrical conductivity of the water falls down and the value of alternating current's intensity decreases. The decrease's time is less than the increase's one. The behavior of the hydrogen ion's concentration in this case is similar to conductivity's one. When acoustic waves are switched on pH of tested water falls down (curves 7-8). It means that the hydrogen ions' concentration in the water increases with time approaches the equilibrium value and reaches at the time t_1. When acoustic waves are switched off, the disappearance of ions is faster than increasing of ions' concentration in the presence of the waves. It corresponds to the conductivity's changes in the same situation.

The dependencies of the alternating current's intensity (Fig. 2, curves 1-3) and the hydrogen ions' concentrations (Fig. 2, curves 4-5) in the water versus ultrasonic waves' power have been investigated too. At the beginning the alternating current's intensity (curves 1-3) and pH of the water (curves 4-5) stays constant with the increase of ultrasonic waves' power. The impurities, existing in the town water, predetermine its higher initial conductivity than distilled one, that is why the initial current intensity of the town water is higher than the distilled one. When the power is about 18W, the alternating current's intensity suddenly increases (curves 1-3) and pH of the water falls down (curves 4-5), because the power reaches the cavitation threshold and the step-like change of the hydrogen ions' concentration is observed. The beginning of cavitation is accompanied by the sound as aspecial whistle. At this moment the increase of the concentration was about 10^7 times. The cavitation threshold is different for various investigated samples of water and depends on the amount of impurities in this water.

Further, the small decrease of the current's intensity is observed, but when $P \approx 30$W, it begins to increase again. The decrease of the alternating current's intensity with the increase of the power is explained by the fact that the conductivity of electrolyte versus ions' concentration has the maximum, i. e., with the increase of ions' concentration the specific conductivity of electrolyte increases, but when the concentration is about 5-10 g-eq/ltr, it begins to decrease [2]). The higher concentration of ions is in water, the stronger ion-ion interaction reveals. It decreases the mobility of ions and leads to the formation of associates. Further, increasing ultrasonic waves' power, the influence of associates becomes relatively less and the current's intensity increases. The curves of the alternating current's intensity versus ultrasonic waves' power have a hysteresis. At the beginning, when the ultrasonic waves' power is decreased, the behavior of the alternating current's intensity is the same as one before. When the power reaches the cavitation value in its decrease, the current's intensity does not fall down as one before, but continues to increase and reaches the maximum value (when $P \approx 11$W), because the conductivity of electrolyte versus ions' concentration has the maximum. After that the current rather quickly decreases till the power reaches ≈4W, then the current's intensity step-like falls down to the initial one and cavitation disappears. The being of hysteresis can be explained by the fact that for the keeping of the cavitation needs less ultrasonic power than for creation of it. According to the cavitation theory [3], if heterogeneities exist in the water, its resistance to the rupture (i.e., to the cavitation) is much less than the homogeneous one. The bubbles, which accompany the cavitation in water, are such heterogeneity.

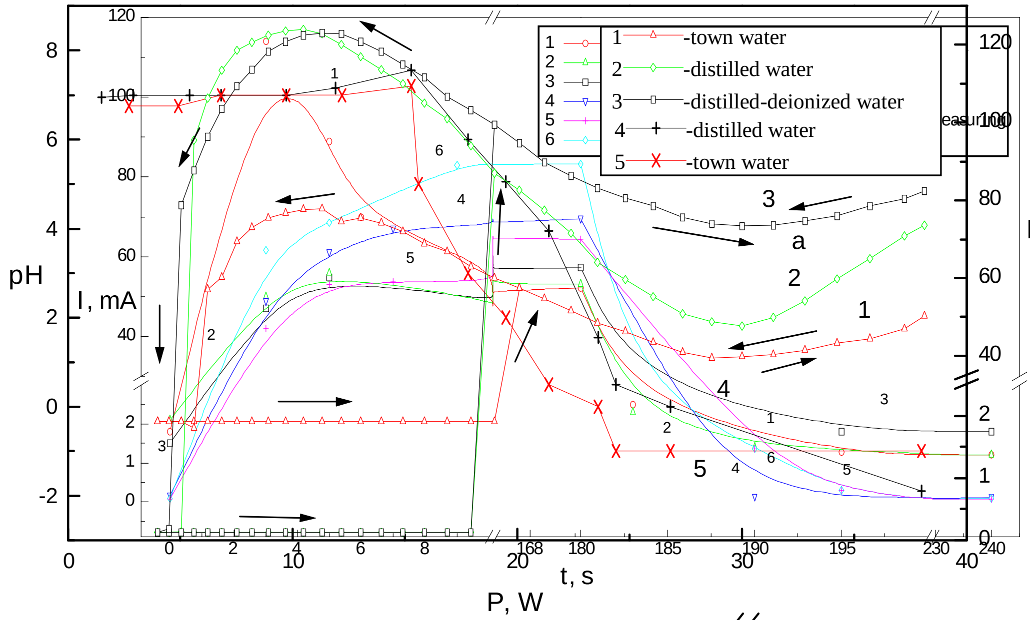

Fig.2. **The dependencies of the alternating current's intensity (curves 1-3) and the hydrogen ions' concentrations (curves 4-5) in water versus ultrasonic waves power**

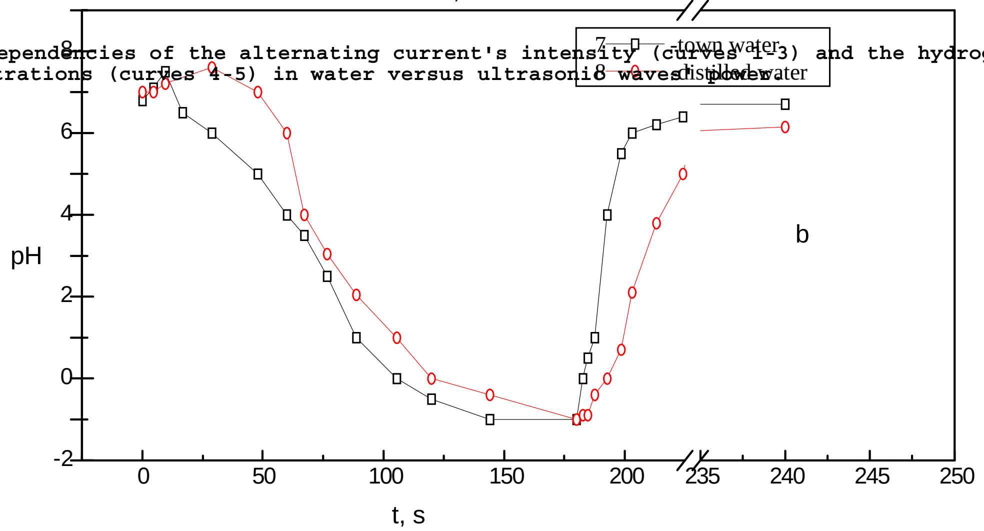

Fig.1. **The change of alternating curent's intensity (curves 1-6) and hydrogen ions' concentration (curves 7-8) in water versus time. t-0s the moment of switching on the ultrasound, t-180s the moment of switching off.**

The difference between the dependencies of the current's intensity for town water (Fig. 2, curve 1) and destilled one (Fig. 2, curves 2-3) is explained by tunnelling mechanism of the hydrogen and hydroxyl ions' motion.

Conclusion

Ultrasonic wavers, intensity of which is higher than the threshold in tested water, stimulate the disociation of water's molecules. This phenomenon can be used in electrolysers.

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Ultragarso átaka vandens elektriniam laidumui

Reziumë

Iðtirta, kaip dël ultragarso poveikio keièiasi vandentiekio, distiliuotu ir distiliuotu-dejonizuotu vandeniu tekanèios kintamosios srovës stipris ir vandenilio jonø koncentracija. Nustatyta, kad sklindant ultragarso bangai, kurios galia yra didesnë uþ kavitacijos slenkstá tiriamajame vandenyje, vandens elektrinis laidumas padidëja daugiau kaip trimis eilëmis, o vandenilio jonø koncentracija - daugiau kaip septyniomis eilëmis. Keièiasi relaksacinis laidumas ir koncentracija, ir ðio proceso trukmë priklauso nuo vandenyje esanèiø priemaiðø kiekio. Relaksacijos procesai vyksta pagal eksponentinæ priklausomybæ. Iðmatuotos vandeniu tekanèios kintamosios srovës stiprio ir vandens pH priklausomybës nuo ultragarso bangos galios. Nustatyta, kad kavitacijos slenkstá atitinkanti ultragarso bangos galia yra apie 18W. Ðià priklausomybæ matuojant atvirkðtine tvarka, t. y.

maþinant ultragarso bangos galià, atsiranda histerezë. Tai rodo, kad kavitacijai palaikyti pakanka gerokai maþesnës ultragarso bangos galios - tik apie 4W. Tai, kad didesnës negu kavitacijos slenksnis galios ultragarso banga skatina vandens molekuliø disociacijà, gali bûti taikoma elektrolizeriuose.

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