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Generation of water plasma and its applications in high concentration organic wastewater treatment

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Water plasma (WP) has significant characteristics of high enthalpy, high activity and ecological compatibility. It has been considered as an important means for the abatement of pollutants and for promoting reforming reaction in gas or in liquid, converting organic pollutants into synthesis gas (syngas, mixture H_2 and CO). We had developed dc arc plasma torch for generation of WP, in which the pure water or contaminated water can be directly used as a plasma-forming medium[1-4]. In the present work, three modes for the high concentration organic wastewater treatment was developed and investigated, in order to comprehensively evaluate this technique and to understand the mechanism of organic degradation[1]. The three treatment modes are: (a) treatment of organic pollutants in plasma jet channel; (b) treatment of organic pollutants by pure WP jet; and (c) combination of both (a) and (b), in which waste water was not only used as working medium for WP jet generation, but also treated by WP jet injection into it. The operational features of the torch and characteristics of WP jet are presented. The operation of the torch has experienced a very short period of time (about tens of seconds) for stability of water vapor production, which influences the length and working state of jet plasma[2]. The thermal efficiency of the torch can reach 90 %, and the specific enthalpy of water plasma is approximately (18.7 ± 1.0) MJ/kg. The restrike mode is identified as the fluctuation of the WP arc, which contributes significantly to the instabilities of the WP jet. Moreover, the frequency of fluctuation increases, while the amplitudes decrease with increasing the arc current. The WP jet at atmospheric pressure was found to be close to the local thermodynamic equilibrium state in the range of axial distance from nozzle exit to 20 mm. The gas temperature along the jet axis drastically decreased from 5300 K at nozzle exit to 1000 K at a distance of approximately 75mm, while the excitation temperature and electron number density have weak axial gradient[3]. The content of organic pollutant in water has little effect on gas temperature of WP[1].

Several organic pollutants, such as phenol, 1,4-dioxane, pyridine, naphththalene-2-sulfonic acid and 2,6-Dichlorophenol, were chosen as model organic pollutants to investigate the performance of this technology. It was found that the organic pollutants are rapidly decomposed in the channel of plasma jet, due to the high temperature and high-energy electron impact, and those are mainly degraded in aqueous solution by neutral and ionic radicals with high oxidative potential, i.e. OH*, O atom, H_2O_2 attack. The main element of organic pollutant, such as C, H, N, S, Cl, in product distribution and its occurrence form are investigated. Elemental carbon in organic pollutants is mainly converted to CO and CO_2 in gaseous products. Hydrogen is mainly gaseous product, mostly from water decomposition[4]. The possible mechanism of these organic pollutants degradation both in gas and liquid phase by WP technique was also discussed. Furthermore, the raw coking wastewater was employed to evaluate performance of the WP technique application in the actual wastewater treatment. The energy consumption is 0.38 kWh $gCOD^{-1}$ for a total COD removal of 90 % with initial value 10370 mg L^{-1}. These results showed that the WP technology has great potential for treatment of high concentration and refractory of organic polluted wastewater, or as an auxiliary unit in emergency situations, pretreatment option for biodegradability enhancement, instead of a full treatment for organic wastewater treatment.

References

[1] Guohua Ni, Yin Zhao, Yuedong Meng, Xiangke Wang, Hirotaka Toyoda, Steam plasma jet for treatment of contaminated water with high-concentration 1,4-dioxane organic pollutants, *EPL.* **2013**,*101*, 45001

[2] Guohua Ni, Yuedong Meng, Cheng Cheng, Yan Lan, Characteristics of a novel water plasma torch, *Chin. Phys. Lett.* **2010**, *27*, 055203.

[3] Guohua Ni, Peng Zhao, Cheng Cheng, Ye Song, Hirotaka Toyoda, Yuedong Meng, Characterization of a steam plasma jet at atmospheric pressure, *Plasma Sources Sci. Technol.* **2012**, *21*, 015009.

[4] Guohua Ni, Guixia Zhao, Yiman Jiang, Jiaxing Li, Yuedong Meng, Xiangke Wang, Steam plasma jet treatment of phenol in aqueous solution at atmospheric pressure, *Plasma Process. Polym.* **2013**, *10*, 353-363.

Figure xx