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CHARACTERIZATION OF AN ULTRASONIC NOZZLE FOR THE MANUFACTURE OF MEMBRANE-ELECTRODE ASSEMBLIES

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ABSTRACT

One of the principal goals in the manufacturing of Membrane-Electrode Assemblies (MEAs) is to obtain an uniform and homogeneous distribution of the catalyst ink during its deposition on the membrane. When the spraying technique is used to manufacture the MEAs is very important to maintain the stability of the catalyst ink in a dispersion solution during the process. Unfortunately, most of the catalyst inks have a tendency to clump and are difficult to keep evenly dispersed in solution, due to this fact it is very common the occurrence of clogging of the air brush during the spraying process. One alternative to avoid this problem is the use of an ultrasonic nozzle which has also been reported in the literature. The characterization of an ultrasonic nozzle, that was carried out to find the optimal parameters of operation, is presented in this work.

Key words: MEAs, ultrasonic, manufacture, spraying technique.

1. INTRODUCTION

Fuel cells are energy conversion devices that transform the chemical energy of fuels such as hydrogen and alcohols and oxidants such as oxygen into electric energy. They have a high energy conversion rate and are environmentally friendly. In addition, proton exchange membrane fuel cells (PEMFC) operate at low temperatures and a high specific power. Therefore, PEMFC can be used as an independent power generator as well as a mobile power source in automobile and other transportation equipment. Membrane electrode assemblies (MEA) are the core units for fuel cells where fuels and oxidants chemically react to produce electrical energy. A membrane electrode assembly with only catalyst layers and a proton exchange membrane is called a 3-layered membrane electrode assembly or a catalyst coated membrane (CCM). A membrane electrode assembly with gas diffusion layers, catalyst layers, and a membrane is called a 5-layered membrane electrode assembly. Nowadays, many techniques have been used to fabricate MEAs, in which, the electro-catalyst could be coated either onto a gas diffusion layer, or directly onto an electrolyte membrane [1, 2].

Among the numerous fabrication techniques of MEAs, the spraying technique deposition of catalyst ink onto electrolyte membrane is relatively simple and easy to scale-up. However, one technical challenge is to obtain a thin and homogeneous catalytic layer. The ultrasonic spray technology is proven for the precise deposition of catalyst inks, electrolyte materials, slurries, and other proprietary materials, critical to PEM, DMFC and SOFC fuel cell production. As it was mentioned above, in this document the characterization of an ultrasonic nozzle to manufacture MEAs was carried out and the obtained results are presented.

2. EXPERIMENTAL

2.1 Ultrasonic coating nozzle

The characterized ultrasonic coating nozzle (model DPQ-T-95) was purchased from Siansonic Teachnology Ltd. The principal characteristics of this ultrasonic nozzle are: reduce material consumption, non wasteful overspray, very low flow rate capabilities, intermittent or continuous, non clogging, corrosion resistant, high precise etc. Figure 1 shows a view and the technical characteristics of the nozzle and the ultrasonic generator.

CHARACTERISTICS

Model	Frequency	Power	Material		Droplet Size	Max. Flow Rate**	Viscosity
	KHz	W	Horn	Housing	µm	l/h	cps
DPQ-T-95	95	10	Titanium alloy Ti-6Al-4V	Aluminium & Stainless Steel	30	1.8	<50

* Measured by water atomization

ULTRASONIC GENERATOR

Input	-	90V-240V ~ 30W, 50/60Hz, singe phase	
Output Current	A	1	
Output Voltage	V	60 ($V_{p\text{-}p}$ square wave)	
Dimension	-	mm	230×125×60
	Inc. feet	mm	230×125×75

Figure 1. View of the nozzle and the ultrasonic generator and their technical characteristics.

In order to characterize the ultrasonic nozzle a test stand was constructed. The principal components of the test stand were: ink container, several valves (needle valve, rapid action valve), plastic tubing and the ultrasonic nozzle. The first characterization experiments of the ultrasonic nozzle were carried out with deionized water. The studied parameters in these experiments were the pressure of the carrier gas (air or nitrogen), water or ink supply and the distance between the nozzle and the surface to atomizing. The supply of the ink to the nozzle during the first experiments was done manually. The operation of the ultrasonic nozzle was proved in an intermittent and continuous manner. The optimal conditions found using the deionized water were adjusted when the catalytic ink was employed. Some MEAs were manufactured using the optimal conditions found for the catalytic ink. The catalyst ink composition and the method of manufacture of the MEAs used in the experiments are described in [3]. The only change was the use of the ultrasonic nozzle instead of the airbrush. The preliminary founded results are presented in the rest of this document.

3. RESULTS AND DISCUTIONS

3.1 Preliminary experiments

Figure 2 shows the different experimental arrangements that were used for the preliminary experiments (to find the optimal operation conditions) with and without the catalytic ink.

(a) (b)

Figure 2. Experimental arrangement for the preliminary tests (a) and the implementation of a small peristaltic pump to manufacture the MEAs (b).

As can be seen in Figure 2, in the final arrangement all the valves were replaced by a small peristaltic pump and the distance between the ink container and the ultrasonic nozzle was reduced at minimum to avoid the lost of catalytic ink. From the experiments carried out it was found that the better parameters to manufacture the MEAs must be seen: around 1 cm of distance between the ultrasonic nozzle and the surface to coat, around 10 psi of air pressure and an ink flow of 0.5 ml/min. Also, it was found that the ultrasonic nozzle can be operated in an intermittent or continuous manner without problem.

3.2 MEAs manufacturing

With the obtained parameters of the preliminary experiments some MEAs were fabricated using the ultrasonic nozzle as shown in Figure 3.

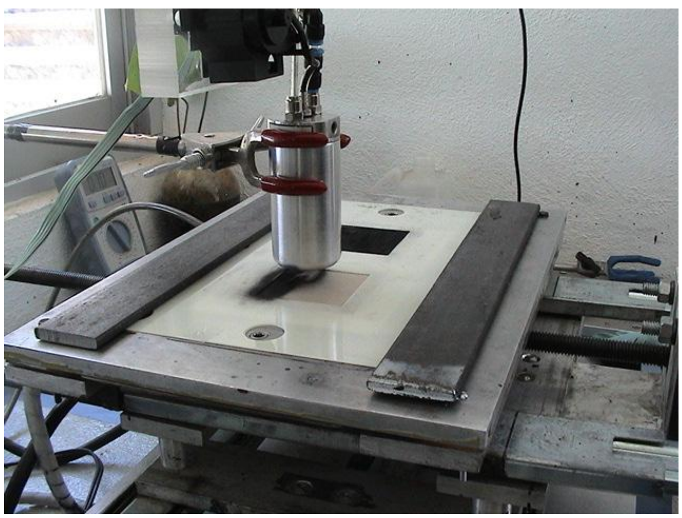

Figure 3. Photography that shows the fabrication of some MEAs using the ultrasonic nozzle.

It is important to mention that the ultrasonic nozzle was operated in a continuous form and that the table with movements in the axes ***x*** and ***y*** was operated manually. The time to manufacture an MEA of 25 cm^2 was around 15 min, instead of 30 min when an airbrush is used and operated manually. In a visual inspection, a very good distribution of the ink was observed.

Some problems were found with the ink supply to the ultrasonic nozzle. Due to the very small micro flows that must be supplied, the peristaltic pump that was implemented cannot supply the ink continuously. It has a period of time around 0.8 s in which no ink is supplied. This can be a serious problem for a completely automated system. To avoid this, it is required to implement the control of micro flows.

3.3 MEAs characterization

In this preliminary stage, the characterization of the manufactured MEAs with the ultrasonic nozzle only consisted in a digital image analysis with the software ImageJ. This was done to know if the use of the ultrasonic nozzle could improve the distribution of the catalyst ink. The Figure 4 shows a comparison between a manufactured MEA with the airbrush (a) and a manufactured MEA with the ultrasonic nozzle (b), both with their respective surface plot and an enhanced contrast view of its original image.

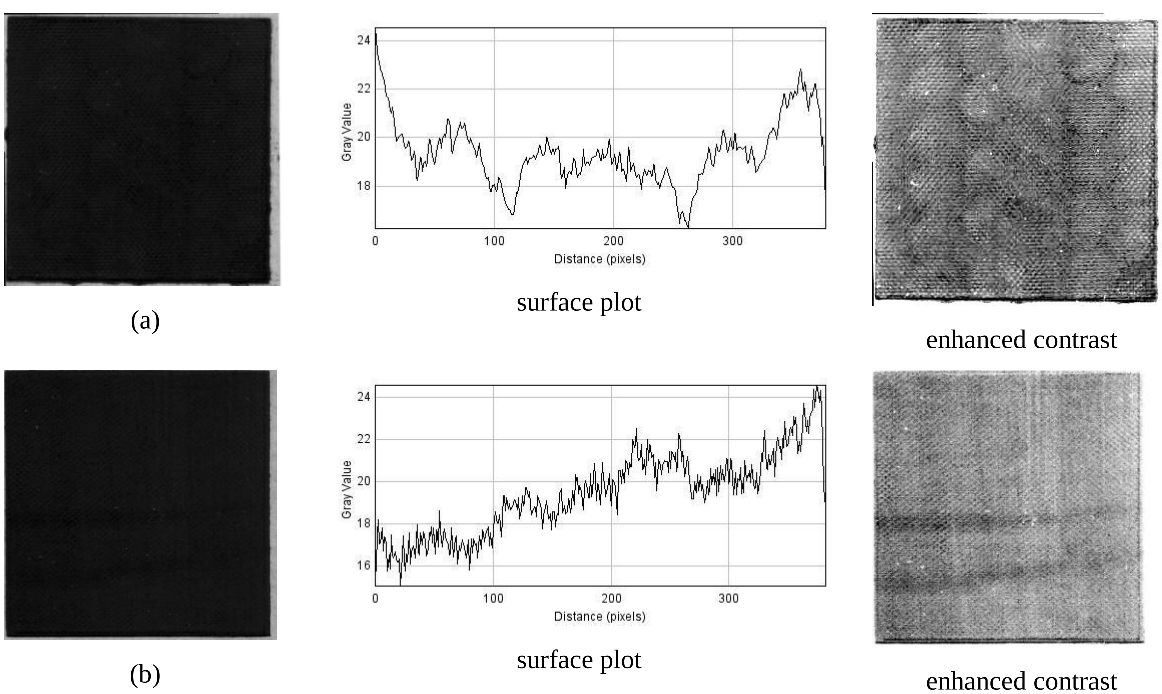

Figure 4. Comparison between a manufactured MEA with the airbrush (a) and a manufactured MEA with the ultrasonic nozzle (b).

As can be seen in the enhanced contrast view of the images (Figure 4), there is an improvement in the distribution of the catalyst ink when the ultrasonic nozzle was used. The standard deviation calculated with the software was 5.98 for the manufactured MEA with the airbrush and 4.15 with the ultrasonic nozzle. On the other hand, a different thickness of the catalyst layer was found. The average thickness of the catalyst layer when an airbrush was used is around 70µm, and around 38µm when the ultrasonic nozzle was used.

Furthermore, it is planned to analyze the microstructure of catalytic layers obtained by the use of the ultrasonic nozzle and to do an electrochemical characterization of the MEAs.

4. CONCLUSIONS

An ultrasonic nozzle was characterized and successfully implemented in the manufacturing process of the MEAs. The fabrication time of the MEA was reduced almost to the half, and the quality distribution of the catalyst ink was improved too.

5. ACKNOWLEDGEMENTS

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