Hydrodynamic analysis of a reverse electrodialysis device spacer

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The hydrodynamics of within a serpentine type separator with obstacles, of a reverse electrodialysis (RED) prototype were analysed. The fluid dynamics, where the fresh and salt water circulate, were measured with particle imagen velocimetry (PIV). The results were validated with a numerical solution using COMSOL Multiphysics software.

It was found that the modifications made inside the spacer, improved the ion exchange significantly due to the change in the velocities and directions of the fluid during its passage through the separator.

INTRODUCTION

Renewable energy sources such as solar, biofuels, ocean and thermal, are helping to meet the world's growing demand for energy. According to the International Energy Agency [1], 13.2% of world energy consumption in 2012 was supplied by renewable energy sources, while in 2013 this figure rose to approximately 22%.

There is therefore a need to identify more renewable energy sources as well as to improve the methods used to obtain it. Salinity gradient energy (SGE) is one of the least investigated yet most promising sources of renewable energy. In areas where rivers or lakes flow in the sea, there is a natural difference of salinity and a great potential to implement SGE technology.

To take advantage of SGE, or blue energy, Pressure Retarded Osmosis (PRO) or Reverse Electrodialysis (RED) are the techniques usually used. In the latter electrical energy is extracted directly from the chemical potential of the salinity gradients [2]. In a RED device a battery of cation and anion exchange membranes are placed, alternating with each other. The compartments between the membranes are fed two saline solutions, one concentrated and the other diluted, for example, seawater and river water [3].

The efficiency of this type of device is low and there are very few studies on the behaviour of the fluid inside the cell. The present work analyses the hydrodynamics inside a RED cell developed recently by the Mexican Centre for Innovation in Ocean Energy (CEMIE-Oceáno) [4]. The objective of the work is to optimize the RED process in order to produce more energy using the same effective area of membrane.

Flow analysis was performed through experiments using particle image velocimetry (PIV). This quantitative non-invasive measurement technique, luminous tracer particles are added to the fluid. A laser sheet was used to illuminate the water and photographs were taken by the high-speed camera. This provides information on the velocity and displacement of the particles in linear and/or rotary motion, by comparing images captured at different moments in time [5]. A linear displacement vector field produced by the pair of images, where each vector is obtained by examining the motion of the tracer particles [6].

EXPERIMENTAL SET UP

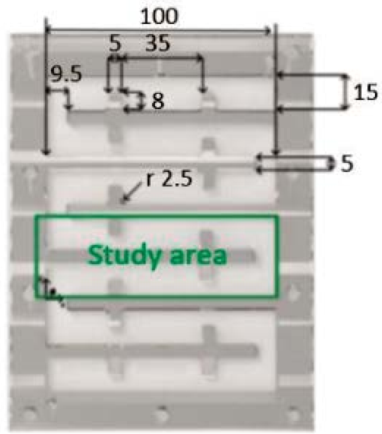


Fig. 1 Spacer front view. Dimensions in mm.

The analysis focuses on the middle part of the separator, where freshwater circulates [7]. The effective membrane area was of 100 cm^2. The separator features a serpentine of seven connected channels and rectangular obstacles, Figure 1.

The study area is the third and fourth channels from the bottom. The origin of the coordinate system is marked, where the third channel begins. The x axis is positive rightwards while the y axis is positive upwards. The spacer is made of acrylic with a thickness of 5 mm.

Figure 2 shows a schematic view of the experimental setup. The spacer was fed with water at constant velocity. A laser beam is passed through a lens to create a light sheet behind the study area. The camera captures images of the tracer particles, which are later processed in a PIV analysis.

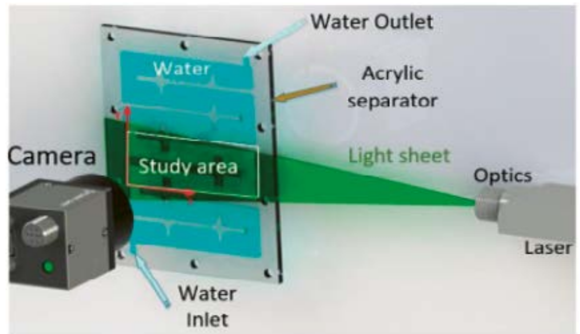
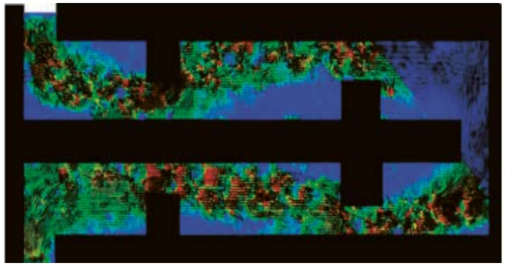


Fig. 2 Experimental setup for the PIV measurements.

a)



b)

Fig. 3 a) Tracer particles captured by the camera at t=4 s and b) PIV analysis.

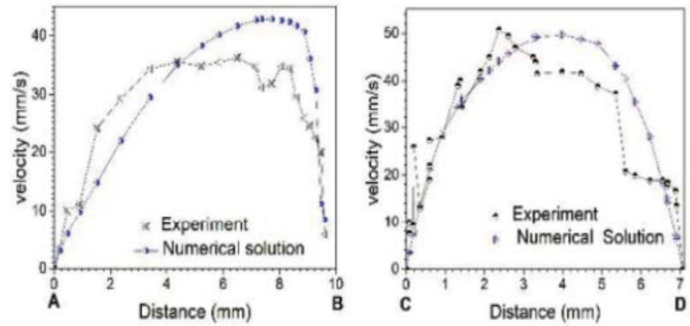


Fig. 5 Comparison of the measured (PIV) and numerical (CFD) velocity profiles between points a) A-B and b) C-D.

RESULTS

Three tests were performed with a constant flow rate of 1.3 cm^3/s. For each test 1000 images were captured at 50 hz per frame. Figure 3a) shows the reflection of the tracer particles captured by the camera at time t=4 s. Following image filtering and masking, a PIV analysis was carried out using Dynamic Studio v3.16 software. The resulting vectors are shown in figure 3b).

The validation of the experiment, a numerical simulation was made using the RANS equations [8] with Comsol Multiphysics 5.3 software. Two plane cuts were taken to compare the velocity profiles of the physical and numerical model; figure 4.a-4.b shows the control sections between points A-B and C-D, respectively, the coordinates of the points are as follows: A(0,0), B(0,9.5), C(30,28) y D(30,36). According to the experimental and numerical results, it can be seen that its have a very similar behavior.

CONCLUSIONS

In this work part of the internal hydrodynamics of a reverse electrosialysis cell spacer are analysed. The geometry of the spacer produces significantly different behaviour in the velocity and direction of the fluid, associated with contractions and expansions that exist. This configuration improves the ion exchanges, which increases the efficiency of the device.

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