THE PROPOSED INNOVATIVE MCFC

Introduction

An original cylindrical Molten Carbonate Fuel Cell is proposed. The cell main peculiarity is the original architecture which involves both elements geometry and gases arrangements. High benefits may be obtained by the proposed configuration. Cylindrical elements may be easily obtained by injection printing; this is a moulding technique which is conveniently used for large scale productions because of time and cost advantages. Moreover, cylindrical configuration produces lower heat losses because of high volume with respect to surface. Besides, sealing is enhanced and compression strain is kept uniform along cell surface. The original gases arrangement is attained by stacking circular holed thin steel rings. We carried out tests on a single cell to determine voltage/current characteristic at different conditions: with and without steam into cathodic compartment at several times along cell lifetime. It was also verified cell resuming performances when a temperature drop occurs. Maximum power density was evaluated for different conditions. Results suggest that the proposed cell design is a promising solution for FC µCHP applications because of performances, durability and low realisation costs.

The experimental cell

The original cylindrical Molten Carbonate Single Cell (Patent PG2003A0019, IPASS, 2003) test facility is made by:

1) single cell which is constituted by nickel anode, electrolyte, nickel cathode and a gas distribution system. Gas distribution system is composed by the following steel plates, rings and nettings for each electrode:

- steel disk;
- steel ring in which a steel netting is placed. Gases internal flow is kept uniform by choosing a netting diameter smaller than the ring internal one;
- steel disk which separates the electrode chamber into two subchambers; holes are realized in the plate central zone where gases flows from the external subchamber to the internal one;
- steel netting which is mounted on a ring disk;
- holed steel disk which contacts the electrode.

The distribution system is characterized by high mechanical stability for high working temperatures. Steel disks are low rigidity 1 mm thick. Sheets, rings and nettings may be easily formed by water or laser cutting methods with low realisation costs.

The proposed distribution system allows to obtain the following advantages:

- *Mechanical:* divide each electrode chamber into two subchambers with uniform stack compression strain;
- *Electrical:* reduction of internal electric resistance by enhancing the contact between two consecutive plates;
- *Fluiddynamical:* uniform gases distribution inside each chamber.

The proposed distribution system can log catalysts for natural gas reforming which will be a future cell development.

2) Mechanical frame for cell stacking which is equipped with cup-springs to compress the stack.

3) Heating system for cell conditioning (dewaxing, start-up) and gas heating which is constituted by electric resistors.

4) Exhaust and inlet manifolds. The manifold system is integrated with the steel coat which externally covers the proposed cell. Exhaust sections are twice than feeding ones both for anodic and cathodic flows; damages due to gases escapes are minimized by creating each inlet manifold and placing them between two equal outlet manifolds. Thus, a possible gas escape follows from the feeding manifold to the exhaust one, because gas pressure in the inlet manifold is higher than in the outlet one.

5) Thermal insulation panels made by ceramic fibers which guarantee external surface temperature lower than 50°C when cell temperature is 645°C.

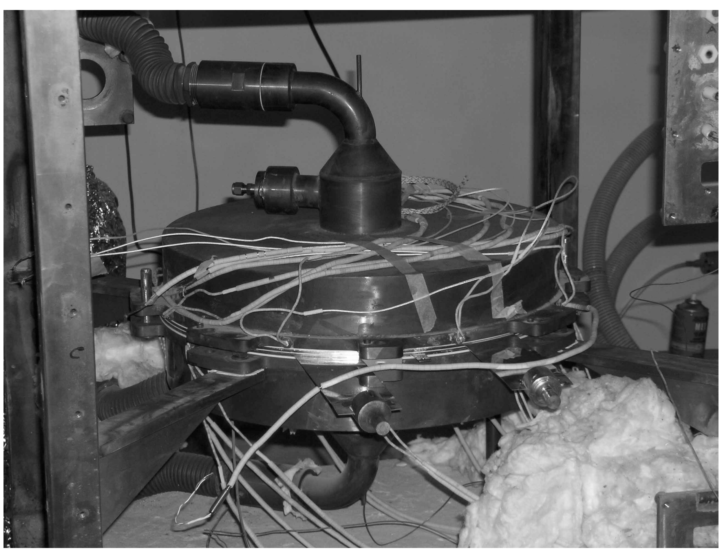

Figure 1 – The experimental cylindrical MCFC

Experimental Tests

Experimental tests were carried out to individuate a single cell Volt-Ampere characteristic with and without steam at the cathodic compartment. After dewaxing and start-up procedures, a 0.06 ohm electric load was applied to the single cell. For the first 120 working hours cell voltage diminishing rate is approximately 0,1 V/50 h when no steam is used (see Figure 2); after that period steam was injected into the cathodic compartment: voltage rose up till a constant value. Working temperatures were measured by thermocouple into anodic and cathodic external subchambers: temperatures range is [640, 645]°C during testing.

Experimental Results

Figure 3 shows Volt-Ampere characteristic for the following conditions:

a) when the electric load was applied (0 working hours, no steam at the cathodic inlet);
b) 120 working hours (no steam at the cathodic inlet);
c) 200 working hours (steam at the cathodic inlet);
d) cell temperature was reduced to 400°C and feeding gases were not supplied to the cell after 200 working hours. After 48 hours, cell temperature was increased to 645°C and gases were supplied again; steam was injected at the cathodic inlet since a 0.06 ohm electric load was applied and V-I characteristic was evaluated.

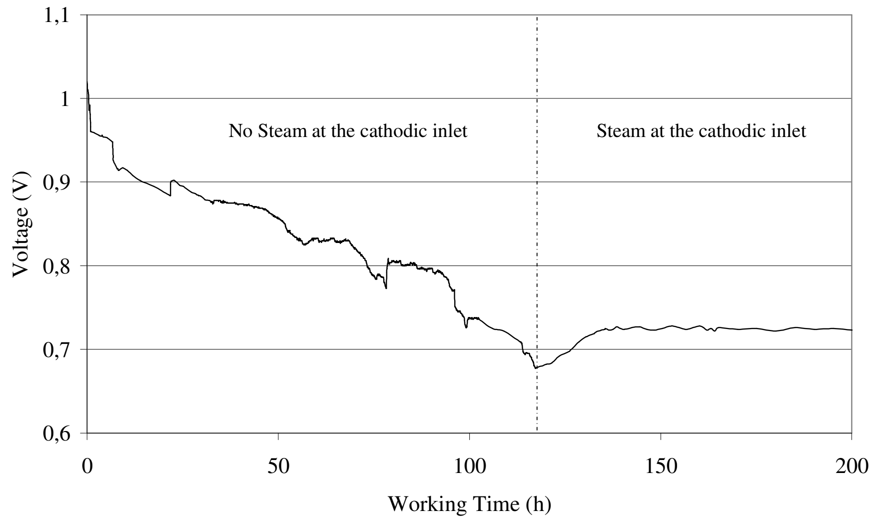

Figure 2 – Cell voltage vs. working time

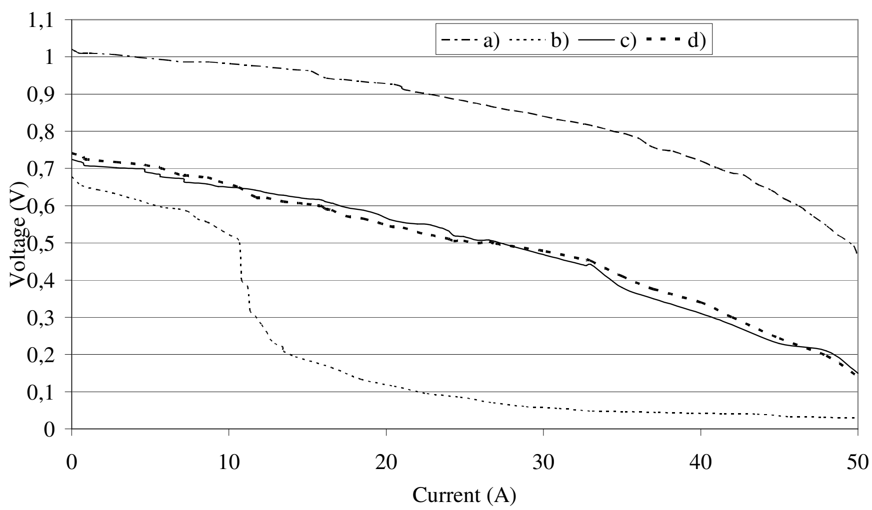

Figure 3 – Cell voltage/current characteristic curves for a), b) and c) working conditions

Figure 4 shows cell electric power versus voltage curves for a), b), c) and d) conditions. It is shown that maximum power is respectively about 29.1 W for a) condition, 5.3 W for b) condition, 14.6 W for c) condition and 14.9 W for d) condition. Single cell area is 250 cm^2. Thus, maximum power densities are respectively:

- 116.5 mW/cm^2 for a) condition, which corresponds to a 171.1 mA/cm^2 current density;
- 21.4 mW/cm^2 for b) condition, which corresponds to a 42.7 mA/cm^2 current density;
- 58.4 mW/cm^2 for c) condition, which corresponds to a 132.1 mA/cm^2 current density;
- 59.6 mW/cm^2 for c) condition, which corresponds to a 131.1 mA/cm^2 current density;

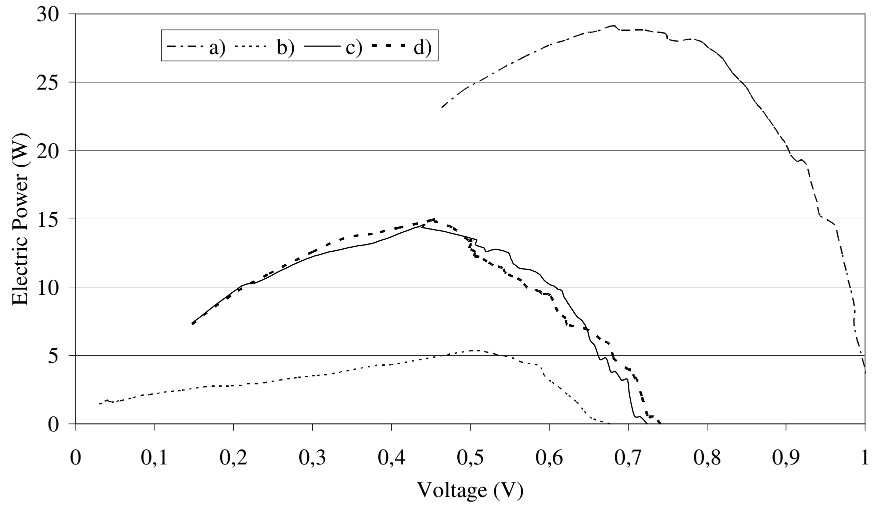

Figure 4 – Cell power density/voltage characteristic curve for a, b and c working conditions

Conclusions

Experimental tests showed the performances of the new original cylindrical cell for different working conditions. Voltage/current performances, maximum power density and current density were evaluated. High current densities (approximately 170 mA/cm^2) were obtained; furthermore, performances stabilization was achieved by steam application at the cathodic compartment. A resume test was also carried out with positive results. Findings make the proposed technology suitable for μCHP fuel cell applications because of high performances compared with low realisation costs and viability for industrialisation processes.