A 1kW Cylindrical Molten Carbonate Fuel Cell

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Introduction

An original cylindrical Small Size Molten Carbonate Fuel Cell (SSMCFC) was presented [1-3]. The cell main peculiarity is the original architecture which involves both elements geometry and gases arrangements. High benefits are obtained by the proposed configuration. Higher mechanical stability is now obtained by an innovative cell configuration. An innovative tie system was designed and realized. Cell elements (electrodes, electrolyte and distribution plates) are placed into a cylindrical vessel. Sealing is enhanced and compression strain is further kept uniform along cell surface by the tie system and an original stacking frame. The original system contributes also to reduce heat losses. Tests are carried out on a 1kW stack constituted by 15 single cells. Voltage/current characteristic is obtained at different working conditions. Maximum power density was also evaluated. Tests were carried out by realizing a control and monitoring system for SSMCFC. New methodologies were proposed to optimize cell realization times and reduce industrialization costs: the target customer and the target price were established by an economical study. Results confirm the cell design as a promising solution for µCHP applications because of performances, durability and low costs.

SSMCFC Development Chronology

A cylindrical Small Size Molten Carbonate Fuel Cell (SSMCFC) was patented [4]. The proposed new geometry for SSMCFC was analyzed by thermofluidodynamic simulations which verified the suitability of the proposed cell design solutions [1]. Materials, treatments and procedures suitable for SSMCFCs were investigated by manufacturing a single cell facility which was used as test bench (see Fig. 1-a) [2]. The single cell facility was constituted by a single MCFC, exhaust and inlet manifolds, a frame for cell elements stacking and a heating system. The individuated materials and procedures were tested on a cylindrical Molten Carbonate Single Cell (see Fig. 1-b) [3].

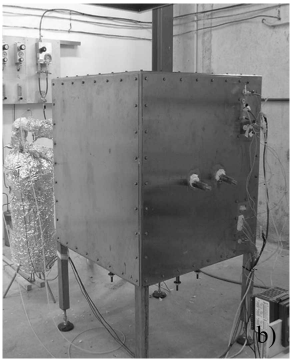

Figure 1 – a) SSMCFC single cell facility [2]; b) a SSMCFC configuration [3]

Cylindrical elements were obtained by a new injection printing patented technique which may be conveniently used for large scale productions because of time and cost advantages. Moreover, the proposed cylindrical configuration produced lower heat losses because of high volume with respect to surface. The original gases arrangement was attained by stacking circular holed thin steel rings. Tests were carried out to determine voltage/current characteristic at different conditions: with and without steam into cathodic compartment at several times along cell lifetime. Cell resuming performances were also verified when both a temperature drop and a switching off event occur [3]. A three cells SSMCFC was also tested by using the Figure 1-b configuration; results confirmed the single cell ones. This paper deals with an innovative configuration for SSMCFC: a 1 kW stack made by 15 single cells was tested. Voltage/current characteristic and maximum power density were measured. A durability test was made. The new cell is scalable up to 5 kW; the reported tests are relative to a hydrogen supply. Tests are going on with positive performances by supplying the proposed SSMCFC with methane or ethanol; Ni-Al_2O_3 catalyser is used in the internal reformer stage.

The innovative SSMCFC configuration

The new tested SSMCFC configuration is made by [4]:

1) 15 single cells which are constituted by nickel anode, electrolyte, nickel cathode and a gas distribution system. Gas distribution system is composed by low rigidity steel plates and nettings [3]. The proposed distribution system is characterized by high mechanical stability for high working temperatures. It allows to obtain uniform stack compression strain, uniform gases distribution and the reduction of internal electric resistance by enhancing the contact between two consecutive plates. Besides, the distribution system can log catalysts for natural gas reforming which are under test. Sheets and nettings may be easily formed by water or laser cutting methods with low realisation costs.

2) Mechanical frame for cell stacking which was equipped with cup-springs to compress the stack [3]. The compression system was modified to improve the uniformity of the compression strain given by the headboards to the stack. Four external ties were added which acts in the plate central area. Thus, compression strain is uniformly distributed among the ties in the external stack area and eight ties in the plate external edge. This is obtained by a leaf spring system. In this way compression strain distribution may be regulated in the conditioning phase, when organic bindings are eliminated.

3) Heating system for cell conditioning (dewaxing, start-up) and gas heating is constituted by ceramic band resistors applied on the stack external surface. Thus, a uniform heat distribution is achieved also for stacks constituted by a great number of single cells.

4) Exhaust and inlet manifolds [3].

5) Thermal insulation panels made by ceramic fibers which guarantee external surface temperature lower than 50°C when cell temperature is 645°C [3].

The new proposed stacking system scheme is reported in figure 2-a. Figure 2-b shows the proposed 1kW SSMCFC equipped by a metallic vessel and the control and monitoring system.

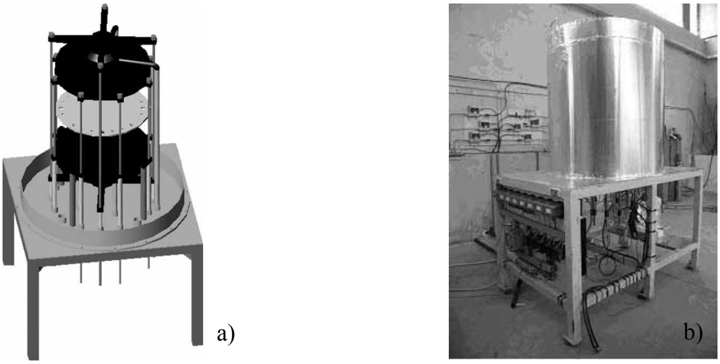

Figure 2 – a) new SSMCFC scheme; b) 1kW SSMCFC picture

Experimental Tests

Experimental tests were carried out to individuate the 1kW SSMCFC Volt-Ampere characteristic. Tests are carried out by supplying steam at the cathodic compartment after dewaxing and start-up procedures. Working temperatures were measured by thermocouples into anodic and cathodic external subchambers: temperatures range is [645, 650]°C during testing.

Experimental Results

Figure 3 shows Volt-Ampere characteristic after about 1500 working hours. The proposed SSMCFC is actually under duration test: no technical problems are actually occurred after about 4500 working hours. It is obtained that maximum power is about 996 W. A single cell area is 706 cm^2. Thus, maximum power density is 94.0 mW/cm^2; maximum current density is 136.9 mA/cm^2.

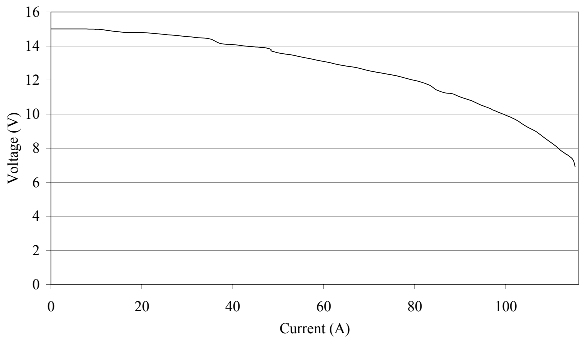

Figure 3 – 1kW SSMCFC voltage/current characteristic curve after about 1500 working hours

SSMCFC Control and Monitoring system

A control and monitoring system for SSMCFC was built. A graphic interface was also implemented (see Fig.4). The realized system is constituted by the following subsystems:

a) thermal subsystem (see Fig. 4-a): it is able to monitor stack internal temperatures by thermocouples and a data acquisition module. A PID regulation is also applied to the stack heating system.

b) electric subsystem: it monitors single cell voltage, stack current and voltage by Hall effect probes, inconel wires and data acquisition modules.

c) flow rate subsystem: it controls and monitors the supplying gas flow rates by mass-flow probes, electrovalves and data acquisition and control modules (see Fig.4-b).

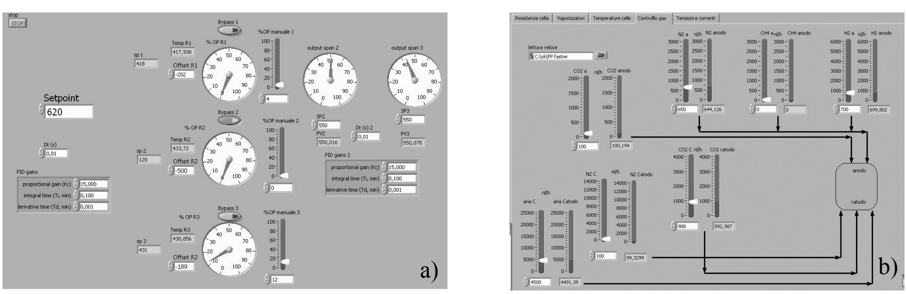

Figure 4 – control and monitoring system: a) temperature control mask; b) gas flow rate monitoring mask

Conclusions

Voltage/current performances, maximum power density and current density were evaluated for a 1kW cylindrical SSMCFC. The presented SSMCFC is the result of pluriannual activities carried out at the Fuel Cell Laboratory of University of Perugia headquartered in Terni (Italy). SSMCFC is patented and commercialized by IPASS [4]. IPASS is a partnership between CIRIAF (interuniversitary research center on physical agent pollution) and FN S.p.A. (an industrial partner). IPASS fuel cell technology has recently moved from laboratory scale stacks to commercial prototypes suitable for μCHP application. IPASS already received orders for furnishing SSMCFC supplied by waste biogas and agriculture wastes. SSMCFC main peculiarity is the innovative stack architecture which involves cylindrical compact geometry, non-direct internal reforming and original gases arrangements. Main SSMCFC technology benefits are:

- high electrical efficiency (up to 40%);
- thermal self-sustain conditions kept down to kW-size stack because of very low heat losses due to cylindrical geometry and innovative gas recirculation;
- multy fuel supply because of original high surface/volume ratio catalyzers;
- low cost components;
- not pressurized devices;
- long-life (the proposed SSMCFC is still going on after 4500 working hours)
- sealing is enhanced because of the absence of edges;
- counter-flow gas feeding and gas exhausting;
- compact design;
- modularity thank to internal manifolds;
- low external temperature;

SSMCFC characteristics make the proposed technology suitable for μCHP fuel cell applications because of high performances compared to low realisation costs and viability for industrialisation processes. An economical evaluation was carried out to individuate the SSMCFC target price which is about $ 2000/kW (see Table 1). Target price is to be achieved in about 5 years if over 10000 target customers have to be covered.

Table 1: SSMCFC target price

SSMCFC Components	Plates (sheets, nettings, laser cutting, electrochemical cleaning)	Compression system, headboards, vessel, assembling	Band resistors	Thermal insulation panels	Electrodes, matrices, carbonates	TOTAL
Target Price ($/kW)	650	600	150	250	350	2000

References

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