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WP3 – Stack and System Test Evaluation

D3.8

Recovery strategy recommendations and its validation

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Table of Content

1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

The aim of this deliverable is to present possible options for stack "recovery" in case one of the phenomena studied in DIAMOND is diagnosed in the future on an operating stack/system. For this purpose a short stack from SOLIDpower has been tested during more than 6000 h. A short description of this stack is given, then, results on actions/strategies for operating the stack are presented.

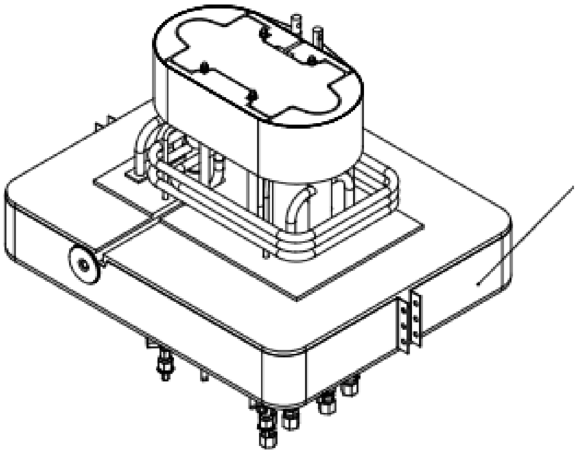
1.2 Major results

The information originating in this well-instrumented short stack experiments has allow to get a better understanding of the actual damages created by leakage and high FU, and their impacts on the stack.

Two actions/strategies on operating conditions have enable to operate this short stack during more than 6000 h in relatively safe conditions and to enhance its lifetime. The first one was to equilibrate pressure of the 2 chambers in order to manage with a leakage issue of one cell. The second one was to mitigate degradation rate by tuning Fuel Utilization (FU).

2 Description of the short stack from SOLIDpower

Short-stack G8-80 (Figure 1) was received from HTCeramix at the beginning of February 2015. It is a 6-cells short stack and each cell has an active surface area equal to 80 cm^2. 7 voltage wires are implemented (one probe per cell). Thermocouples and pressure probes are also implemented at the inlet and the outlet of both anode and cathode. A durability test on this short-stack has been performed during more than 6000 h, operated under H_2/N_2=60/40 at 750°C.



(a) (b)

Figure 1. Photo of the stack G8-80 in the furnace (a) and schematic view of the stack from SOLIDpower (b).

3 Results and discussion

The stack has been operated under H_2/N_2=60/40 at 750°C. First i-V curves have been measured in order to check the performance and the comparison with those obtained at SOLIDpower before the shipping of the stack was good.

3.1 Equilibration of pressure

Unfortunately a rapid and unexpected decrease of cell#4 voltage under galvanostatic condition i=0.31A/cm² happened at t=350 min. This point has induced a rapid increase of air and fuel temperature outlet. Figure 2 shows the evolution of cell voltage, pressure, temperature and flow rates measurements during this incident. When U4 was lower than 0.65 V, the electronic load was shut down automatically at t=550 min. The Open Circuit Voltage (OCV) of cell#4 was very low (around 1 V) compared to the 5 other cells (around 1.1 V) and moreover, this OCV was decreasing continuously. At t=900 min, it was decided to decrease the air flow rate by a factor 2 (from 1920 to 960 NL/h) in order to decrease the pressure inside the air channels. This action had a positive impact on OCV of cell#4 and it can be seen on Figure 3 that it was possible to operate the cell#4 again. The i-V curve obtained on cell#4 is lower than other cells with a lowest OCV and limiting current at high FU, indicating a probable leakage.

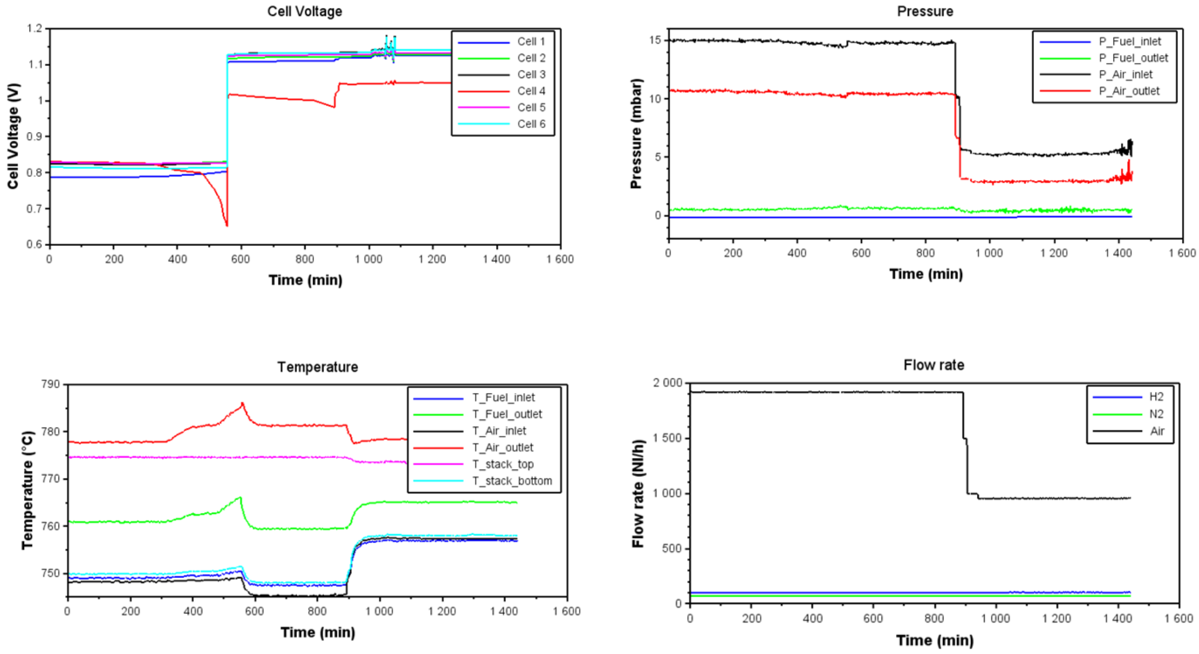


Figure 2. Cell voltage, pressure temperature, and flow rates measured as a function of time during the start of the stack under galvanostatic mode i=0.31A/cm², FU=60%. An incident happened at t=350 h inducing a rapid decrease of cell#4 voltage.

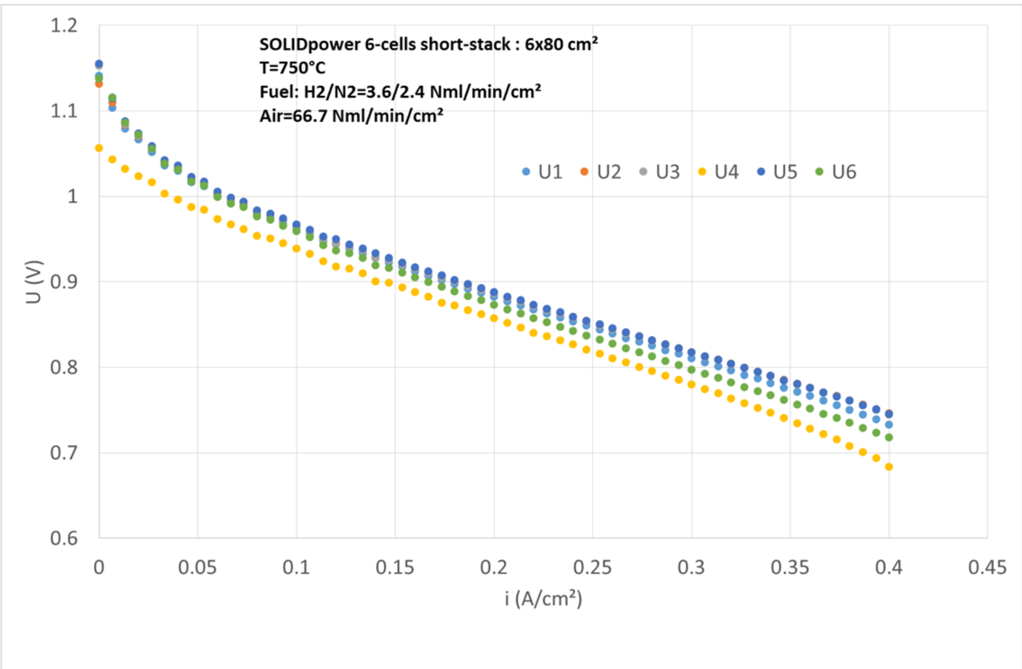


Figure 3. i-V curves obtained for H_2/N_2=3.6/2.4 NmL/min/cm² at T=750°C after the incident and equilibration of pressure (air flow rate divided by 2).

3.2 Mitigation of the degradation rate by tuning Fuel Utilization

Thanks to the equilibration of pressure, it was possible to operate the stack during more than 6000 h under H_2/N_2=60/40 at 750°C. Figure 3 shows the 6 cell voltage measurements as a function of time. A first step at FU=60% was achieved during 2200 h, then FU was increased at 70% by increasing current density, keeping H_2 flow rate constant during around 3000 h and finally, FU was decreased to 60% during 1000 h. It can be noticed also that 3 particular events are identified in red circle: 1=fault on H_2 supply, 2=step @OCV, 3=shut-down and thermal cycling of the stack. From this figure, it was easy to diagnose that cell#4 voltage was very low (around 0.67 V) at the end of the step at FU=70% thanks to individual cell voltage measurement. This low value is considered as a critical one and that is why FU was set back to 60% by decreasing current density. This last step allows to recover a cell#4 voltage constant and equal to 0.71 V during more than 1000 h.

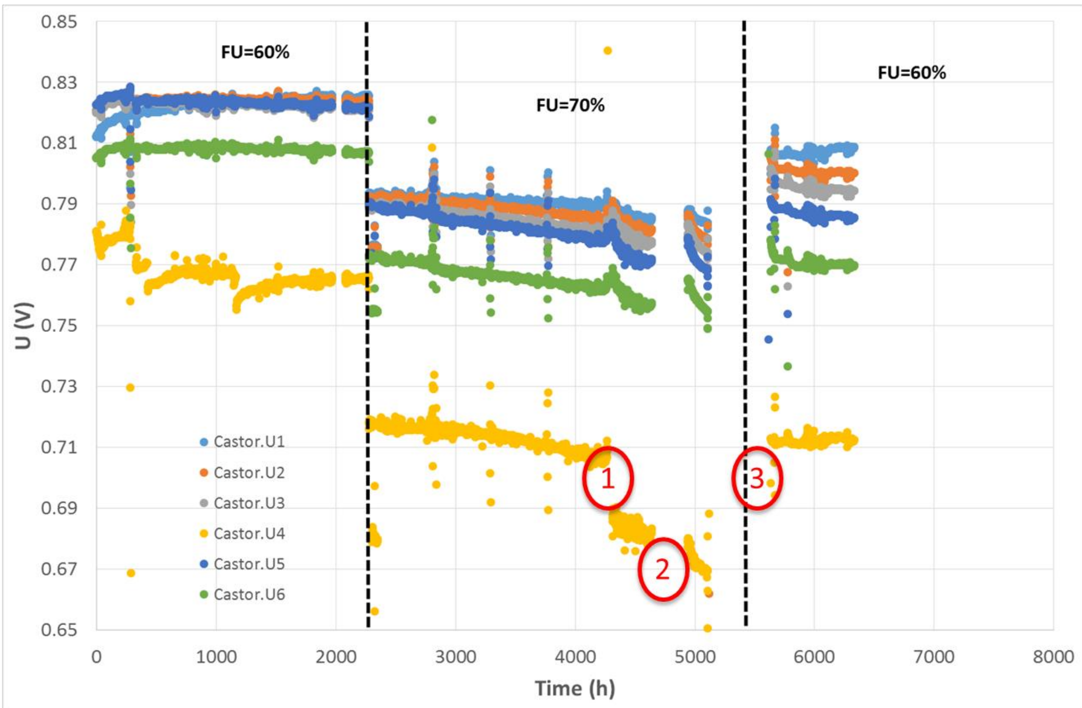


Figure 3. Duration test of the 6-cells short stack from SOLIDpower at FU=60 and 70% by varying current density, keeping H_2 flow rate constant. Three particular events are identified in red circle: 1=fault on H_2 supply, 2=step @OCV, 3=shut-down and thermal cycling of the stack.

Figure 4 presents the power density of the stack as a function of time. It can be seen that at t=0 h, the stack delivers 121 W and this value is relatively constant during the step @FU=60. When the FU is increased to 70%, power density is reaching 134 W (t=2200 h) but this value is decreasing with time and is around 131 W at t=5000 h, i.e. a degradation rate of less than 1%/1000 h. When FU is set back to 60%, the power density of the stack is around 116 W and relatively constant, meaning that the stack is operated again in relatively safe conditions.

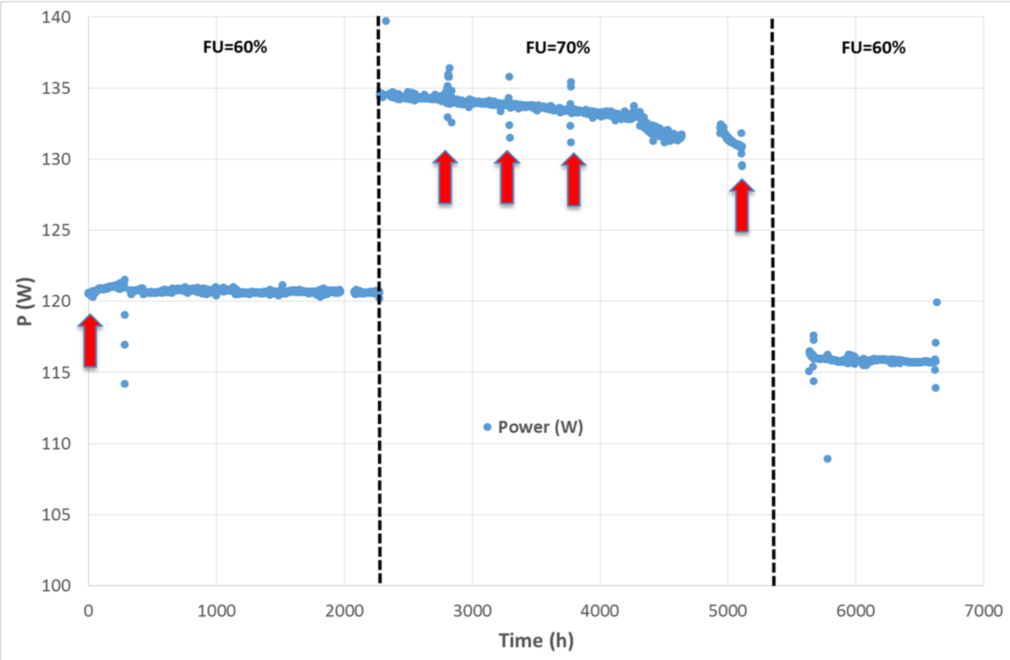


Figure 4. Power density of the stack as a function of time operated at FU=60 and 70% by increasing current density keeping H_2 flow rate constant.

4 Conclusions and perspectives

The information originating in this well-instrumented short stack experiments has allow to get a better understanding of the actual damages created by leakage and high FU, and their impacts on the stack. Two actions on operating conditions have enable to operate this short stack during more than 6000 h in relatively safe conditions and to enhance its lifetime. The first one was to equilibrate pressure of the 2 chambers in order to manage with a leakage issue of one cell. The second one was to mitigate degradation rate by tuning Fuel Utilization (FU).

This work has to be continued with other stack tests and by simulating other faults in order to increase experience and reproducibility. In particular, the work done with THD analysis (D3.5 and D3.6) could increase the quality and sensitivity of fault detection when only stack voltage is measured.