Progress in Excess Power Production by Laser Triggering

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Index

- Previous results
- New cell concept for isoperibolic calorimetry with trigger
- Modelling & engineering
- Calibration
- Results
- Conclusions
Evolution of the input and output power, last 300 hr under laser irradiation (P-polarization)

Laser on-off effect

Excess of Energy and Power in Laser4 Experiment

Laser 4 experiment

4He Production
Improvement of the Cell

Old cell

Average temperature of the electrolyte vs power
Double Structure New Cell for Laser Experiments

Stainless Steel

Teflon

New double structure cell
Thermal Analysis

Heat transfer equation

\[
\text{div}(K \text{ grad}(T)) + Q = \rho c_p \frac{\partial T}{\partial t} + \rho c_p \left( V_x \frac{\partial T}{\partial x} + V_y \frac{\partial T}{\partial y} + V_z \frac{\partial T}{\partial z} \right)
\]

Boundary conditions

\[- K \frac{\partial T}{\partial n} = h(T - T_a) \quad (\text{convective heat exchange mechanism})\]

Assumptions:

- 3D transient
- isotropic (Kx=Ky=Kz)
- Steady state boundary conditions (thermostatic box) \( T_{\text{amb}} = \text{cost.}(t) \)
- Radiative heat exchange negligible
Hydrogen Bubbles at the Cathode

Gas velocity $V_{H_2}$ is calculated by means of the current density

Gas flow rate for unit area

$$K = \frac{J \cdot 22.4 \cdot 1000}{nF} \quad (cm/s)$$

Total gas flow rate

$$W = \int_0^z L \cdot K \cdot dz = L \cdot K \cdot z \quad (cm^3/s)$$

Gas velocity

$$V_{gas}(z) = \frac{W}{A} = \frac{W}{L \cdot \delta} = \frac{K \cdot z}{\delta} \quad (cm/s)$$
One fluid is moved by the other having different density and viscosity.

The electrolyte interface velocity is calculated by the average gas velocity.

\[
V_{0z}^A = 0.093 \cdot \bar{V}_H^B
\]

\[
\frac{V_z^A}{V_z^B} \bigg|_{x=0} = \frac{1}{\frac{\mu^A}{\mu^A + \mu^B} \left( \frac{2\mu^A}{\mu^A + \mu^B} \right)} = 1
\]

\[
\frac{V_{0z}^A}{V_z^B} = \frac{12\mu^B}{\mu^A + 7\mu^B} = 0.093
\]
**Equations**

\[
\left( \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial v}{\partial r} \right) \right) = 0
\]

**Motion Equation**

\[
\frac{1}{r} \frac{\partial v}{\partial r} + \frac{\partial v}{\partial r} + \frac{\partial v}{\partial z} = 0
\]

**Continuity equation**

**Assumptions**

- axial symmetry
- density and viscosity are constant
- steady state
- negligible effect of pressure and mass
**Iterative procedure for velocity field calculation**

**step 1:** Equation of motion

- Solving the equation of motion with the boundary conditions
  \[ v_z = V_0 z \quad r = a \; ; \; v_z = 0 \quad r = R \]

**Step 2: Continuity equation**

- By replacing the \( v_z \) calculated at step 1 and by solving the continuity equation **with the condition of zero flow rate** in the radial direction

\[
v_r (r) = \frac{C_{1r}}{r} - \frac{K \cdot r \cdot [2 \ln \left( \frac{r}{R} \right) - 1]}{4 \cdot \delta \cdot \ln \left( \frac{a}{R} \right)}
\]

\[
C_{1r} = -\frac{1}{{4 \cdot \delta}} \cdot \frac{K \cdot a^2 - R^2 + a^2 \ln \left( \frac{R}{a} \right)}{\left[ \ln \left( \frac{R}{a} \right) \right]^2}
\]

**Step 3: Continuity equation**

- By replacing \( v_r \) calculated at step 2 and by solving the continuity equation with the condition of zero flow rate in axial direction

\[
VV_z (r, z) = -z \cdot K_2 \cdot \ln \left( \frac{r}{R} \right) + C_{1z}
\]

\[
C_{1z} = \frac{1}{2} K_2 \cdot z \cdot \frac{a^2 - R^2 + 2 \ln R/a}{a^2 - R}
\]
FEM Domain

CAD 2D

Domain extrusion
Mesh and Velocity Field

Velocity field due to bubbles

Mesh 3D
Thermal Analysis

Temperature evolution

Isotherms axial plane

Temperature profile along 1-2

Temperature evolution

100 mW input increasing

Temperature evolution

Temperature profile along 1-2

Isotherms axial plane
Cell

Electric connections

Pt100 Thermometers
Experimental System Set up

- Thermostatic bath
- Measurement instruments
- Computer
- Thermostatic bath
- LCR meter
- Wave generator
- Power supply
- Laser
- Temperature monitor
- Multimeter
- Data Acquisition
  Switch Unit
- Thermostatic box
- Thermostatic System
Comparison between Experimental Data and Model

Calibration and Model

Comparison between calibration data and model

Models and experiment

Comparison between experimental data and model, with and without fluid-dynamics
Laser 5 Experiment: Calorimetric Results

Excess power during laser triggering (HeNe laser)

49 kJ Excess energy

R/R_0 \leq 1.74

Current inversion

Excess power during laser triggering (HeNe laser)
Excess Energy vs Excess Power Life

Energy Ex: J

Excess Power Life hr

Laser-2
Laser-4
Laser-5

Excess energy vs excess power life time
Excess energy vs experiment elapsed time
Conclusions

- The improvement of the calorimeter design allowed to obtain a satisfactory agreement between model and experiment.

- Laser trigger gave significant reproducibility: excess power in 4 out of 5 experiments

- The amplitude of the effect is not yet under control even though high loading is almost always achieved.

- Material studies are in progress to identify and control the status of the system producing enhanced values of the signal.