# Heat Transfer Modelling of Single High Temperature Polymer Electrolyte Fuel Cell using COMSOL Multiphysics®

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## INTRODUCTION

*Polymer Electrolyte Fuel Cell (PEFCs) are the best available option for automotive drive train applications. Among PEFCs,High Temperature PEFC is actively being considered as an alternative to Low Temperature PEFC due to:*

- The HT PEFC operates in the temperature range of 120 – 180º C.
  - This could possible mean that temperature of exhaust coming out from HT PEFC could be in the range of 150º C.
- Less complex cooling system design.
- Higher tolerance to CO.
- In a HT PEFC ~ 50% of the chemical energy supplied by the fuel is converted to thermal energy.
  - Possibility of CHP (Combined Heat & Power) application

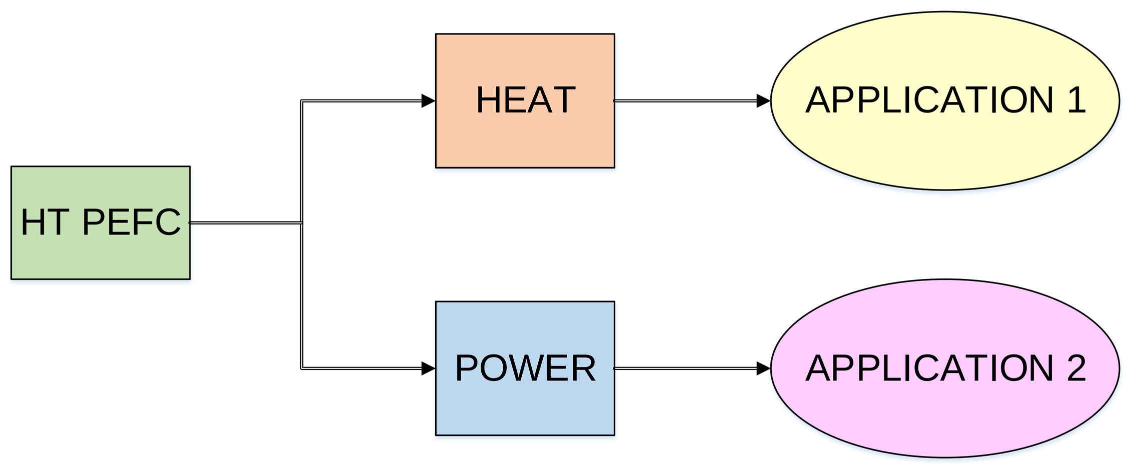


*Figure 1: Block diagram of HT PEFC in CHP mode*

### Aim & Challenges

***Aim***:

To study and compare the effect of *parallel* & *serpentine* flow field designs on temperature distribution in HT PEFC.

***Challenges***:

- To extract maximum heat from the fuel cell.
- To maintain the temperature of the fuel cell within limits (*max 473 K*).

## APPROACH & COMPUTATIONAL METHODOLOGY

*In this work a 3D model of a single HT PEFC with all components (membrane, cathode, anode & bipolar plate with flow field) was modelled for heat transfer*

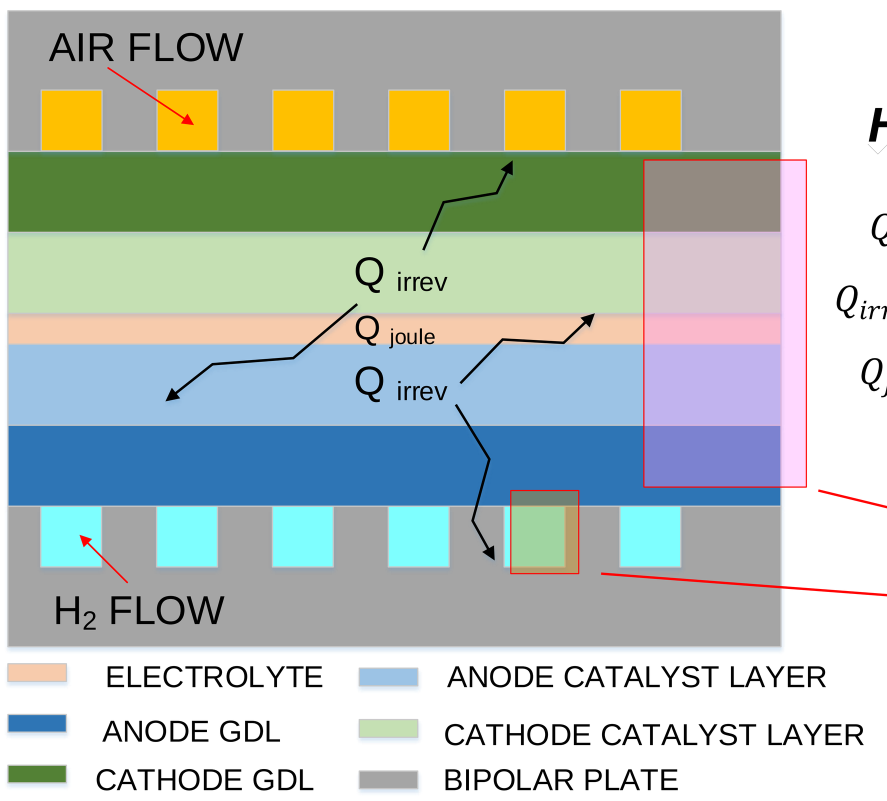


*Figure 2: Heat Generation terms in different layers within the fuel cell*

***Heat generation terms in Fuel Cell***:

$$Q_{irrev,ANODE} = (\eta_{ACT,ANODE} + \eta_{CONC,ANODE}) * j$$

$$Q_{irrev,CATHODE} = (\eta_{ACT,CATHODE} + \eta_{CONC,CATHODE}) * j$$

$$Q_{JOULE} = j^2 * R_{memb}$$

*DOMAIN 1 - SOLID*
*DOMAIN 2 – FLUID FLOW*

Total internal heat applied to model = 0.32 W cm$^{-2}$

| | |
|---|---|
| $Q_{JOULE}$ | Volumetric heat source |
| $Q_{IRREV}$ | Boundary heat source |

***Governing Equations for Conjugate Heat Transfer***:

*Momentum Equation*

$$\rho\,(u.\nabla)u = \nabla.\left[-pI + \mu(\nabla u + (\nabla u)^T) - \frac{2}{3}\mu(\nabla.u)I\right] + F$$

*Continuity Equation*

$$\nabla.(\rho u) = 0$$

*Energy Equation*

$$\rho C_p u.\nabla T = \nabla.(k\nabla T) + Q$$

| EQUATIONS APPLICABLE IN RESPECTIVE DOMAINS | |
|---|---|
| DOMAIN 1 – SOLID | Energy Equation |
| DOMAIN 2 – FLUID FLOW | Momentum + Continuity + Energy |

## 3D MODEL GEOMETRY in *COMSOL*

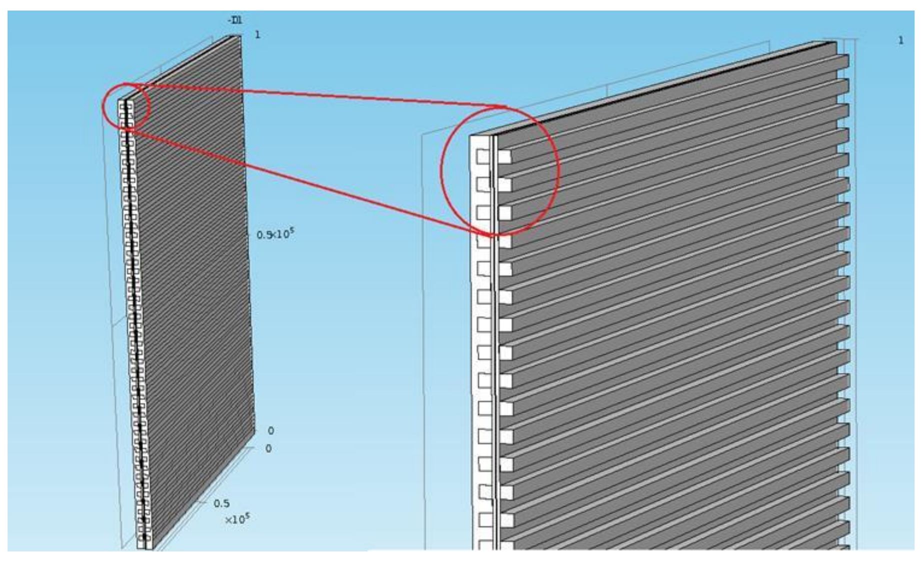

*Figure 3: HT PEFC with parallel flow field*

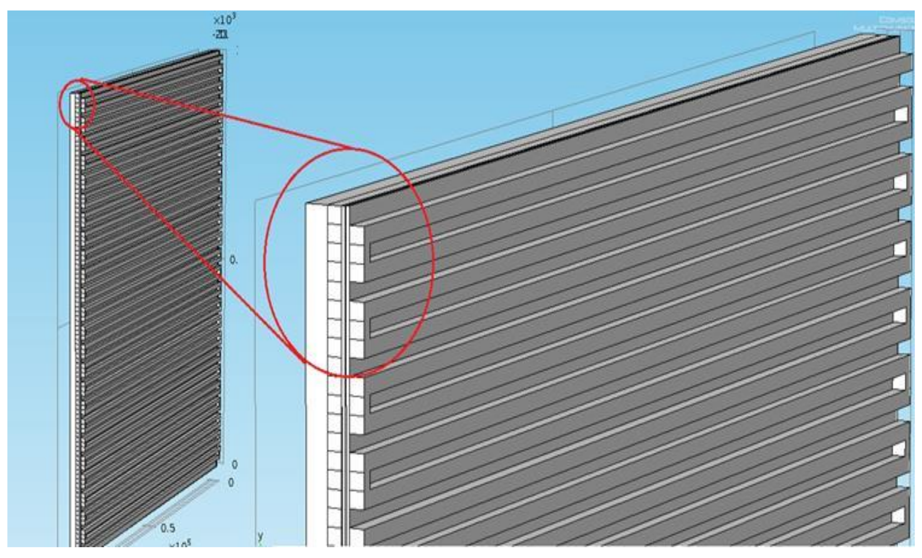

*Figure 4: HT PEFC with serpentine flow field*

***Dimensions of the cell***
Width = 10 cm, Height = 10 cm

***Dimensions of gas channels***
Width = 1 mm, Height = 1 mm

## RESULTS

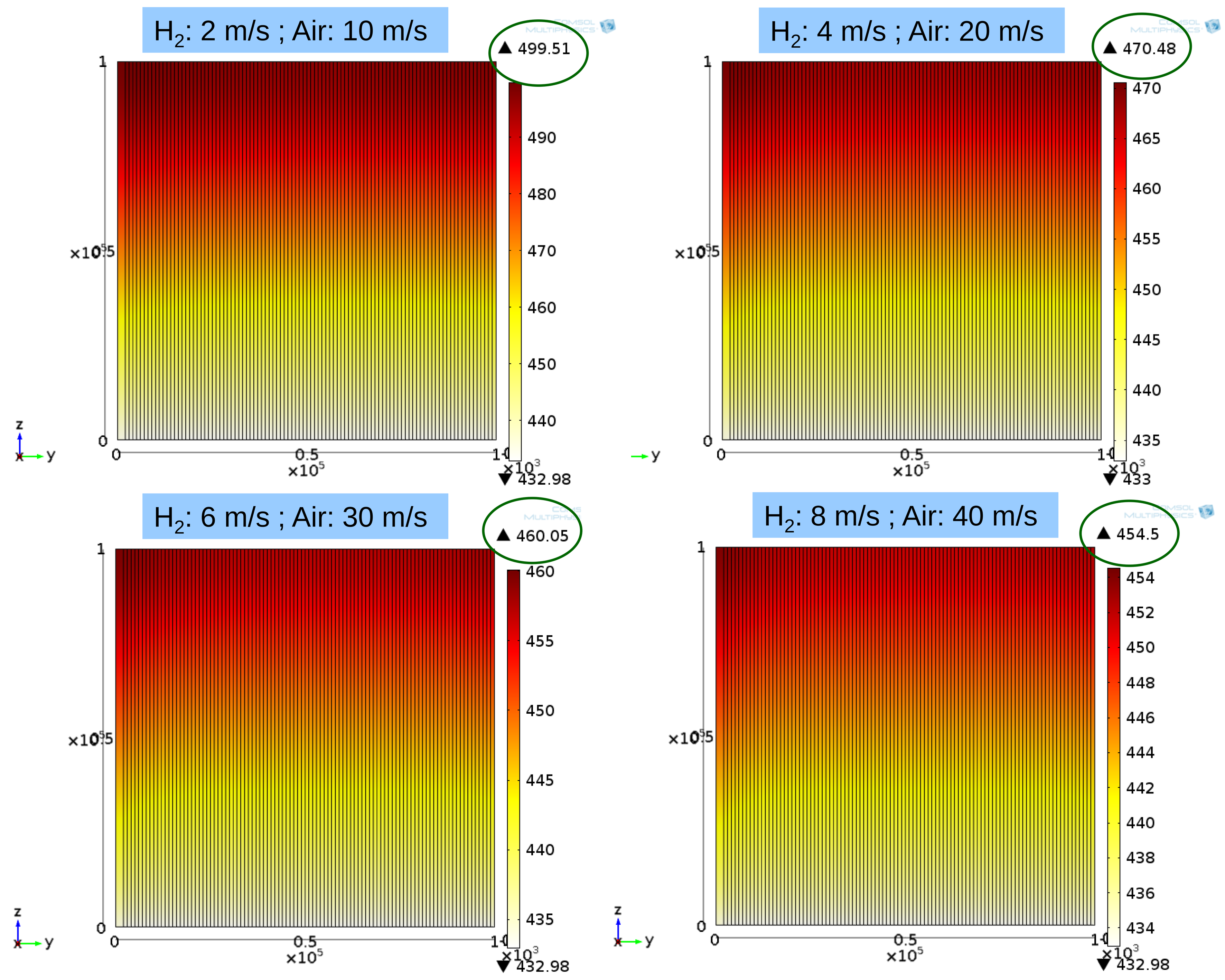


*Figure 5:Temp. distribution with PARALLEL flow field for different Air/ $H_2$ flow combinations*

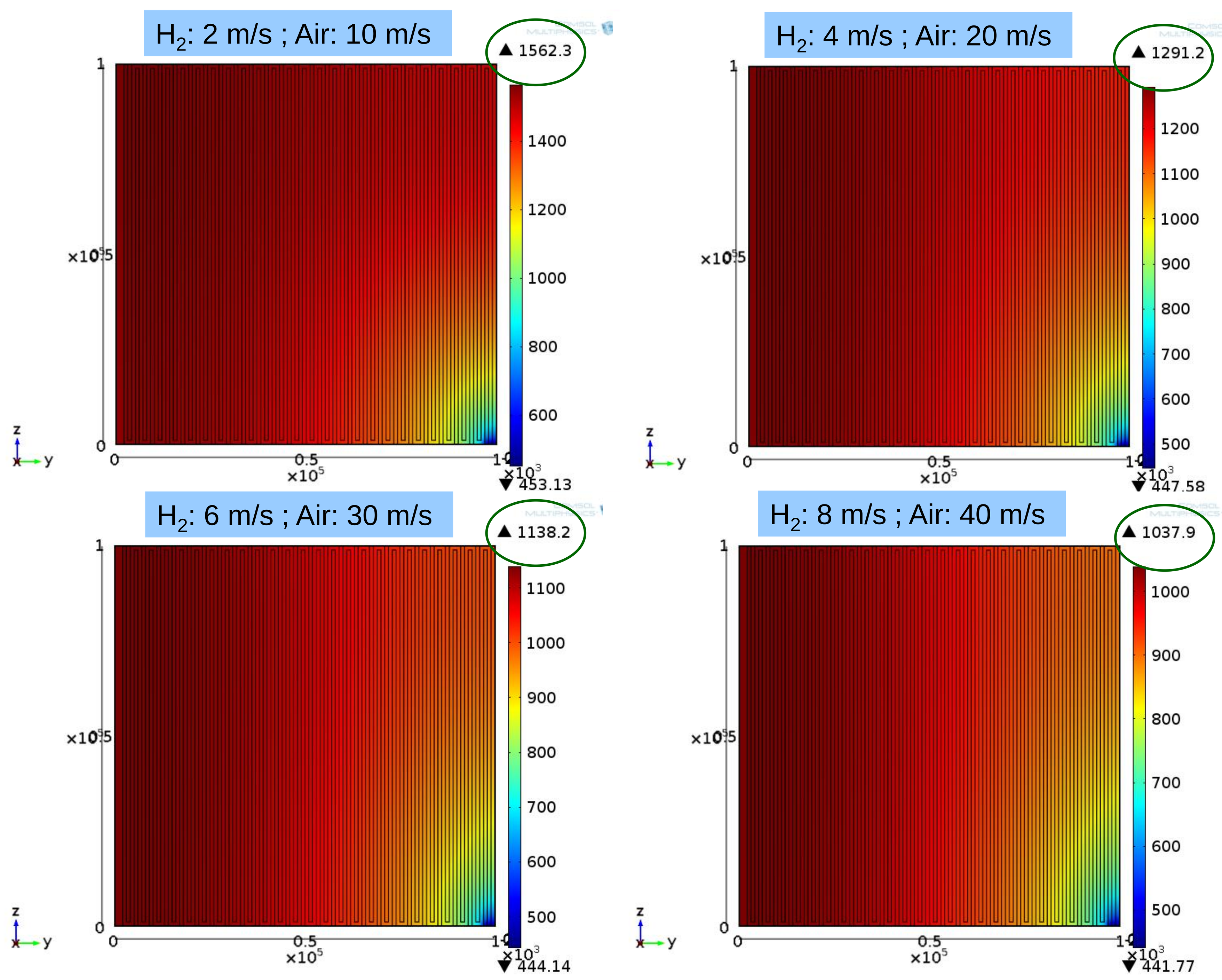


*Figure 6:Temp distribution with SERPENTINE flow field for different Air/ $H_2$ flow combinations*

## CONCLUSIONS

- Heat transfer modelling of single cell provides information on temperature distribution within the fuel cell
  - Relatively uniform temperature profile with *parallel* flow field
  - *Serpentine* flow field leads to extremely large temperature distribution
  - Aids in choosing cooling methodology for fuel cell based on flow field design
- Higher velocities of gas streams leads to lower temperature distribution in the Fuel Cell
- Basis for scaling up the model to stack level,for understanding cell to cell thermal coupling

## REFERENCES

1.Hyunchul Ju, C.Y.Wang, S.Cleghorn, U.Beuscher, *Nonisothermal modelling of Polymer Electrolyte Fuel Cells.* Journal of The Electrochemical Society, 2005. 152: p. A1645-A1653.

2.Harikishan Reddy, E. and S. Jayanti, *Thermal management strategies for a 1 kWe stack of a high temperature proton exchange membrane fuel cell.* Applied Thermal Engineering, 2012. 48(0): p. 465-475.

3. Ju. H, H. Meng and C.-Y. Wang, *A single-phase, non-isothermal model for PEM fuel cells,* International Journal of Heat and Mass Transfer, 2005. 48(7): p. 1303-1315.

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