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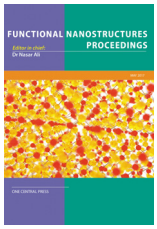

Thermal expansion modeling to predict cracks in SOFC

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ABSTRACT

In this paper we present our simulation results about 3D modeling of a solid oxide fuel cell focusing on the study of thermal stress. We compare the stresses generated in fuel cells using different potential fuel cell materials.

I. INTRODUCTION

A lot of nanocomposite materials are currently investigated for Solid Oxide Fuel Cell (SOFC) application. The operating temperature of these devices varies from 400 to 1000 °C depending of their composition, which means that the materials undergo severe structural changes. The cell is composed of three layers of nanocomposite materials, assembled together by a sintering process. However, these materials do not have the same Thermal Expansion Coefficient (TEC). These differences generate a mechanical stress during the heating or the cooling process, which can lead to cracks in the fuel cell device. The purpose of this study is to model the thermal stresses in a fuel cell with different nanocomposite materials for the electrolyte and the cathode and to analyses the induced stress of different combination. We have modeled the stresses as a result of cooling after the sintering process as the material properties are available in literature.

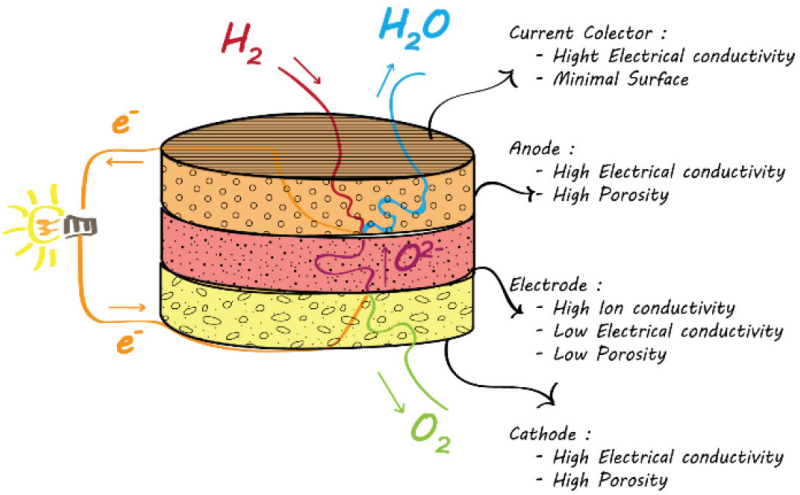

Figure 1 Schematics of a Solid Oxide Fuel Cell.

II. MODEL

Presentation. The 3D model have been built with the commercial software COMSOL multiphysics using the finite element method. The plane SOFC is modeled by three flat cylinders of 0.3 mm of radius and 13 mm of thickness. As a first step, we made a stationary study with room temperature as final condition and sintering temperature which is 690°C as initial condition.

Hypothesis. The values of the thermal and mechanical properties of the materials were taken from the literature. It is important to note that these values have been measured after a sintering process.

As these properties came from many different sources in literature, the sintering process parameters are not always the same (duration, temperature, pressure etc.). There is a room for improvement in our future work. As the materials are restructured during the sintering process, the sintering temperature is taken as a reference temperature to estimate the thermal expansion during the cooling process. This means that the initial size of the cell is assumed to be the size of the cell at 690°C. All the mechanical and thermal properties are assumed to be constant in the studied range of temperature. The materials are assumed to behave as linear elastic materials.

Parameters. The purpose of this study is to compare the behavior of a SOFC with different cathode and electrolyte materials. Three different potential materials are investigated for both the cathode and the anode materials. The different materials are listed in the Fig 2. with their TEC.

Element	Material	TEC
Anode	*Ni-YSZ*	12,50
Electrolyte	*YSZ*	10,9
	GDC	12,44
	SDC	11,4
Cathode	*LSM*	12,3
	LSC	20,5
	LSCF	17,5

Figure 2 Table of the thermal expansion coefficients of the different materials.

Equations. Two equations are used to model the thermal stress in the cells. The first one is for the thermal expansion:

$$\varepsilon_{th} = \alpha \cdot (T - T_{ref}) \tag{1}$$

With ε_{th} the strain in the material, α the TEC, T the current temperature and T_{ref} the reference temperature. The second one models elastic materials (Hook's law):

$$\sigma = E \cdot \varepsilon \tag{2}$$

Where σ is the applied stress, ε is the resulting strain and E is the young modulus or elastic modulus. Those two equations permit to estimate the stresses generated by the temperature variations.

III. RESULTS AND ANALYSES

The nine different possible combinations have been investigated and the Von Mises stress has been calculated for each of them. The following graph shows the maximal stress for all the combinations.

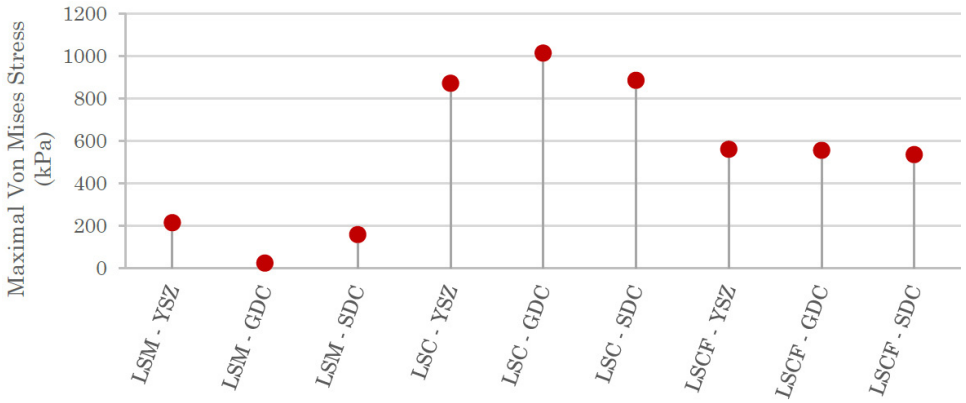

Figure 3 Maximal Von Mises Stress for different fuel cells combination.

The shape of the cell when it undergoes the higher stress is presented in the Fig 4.

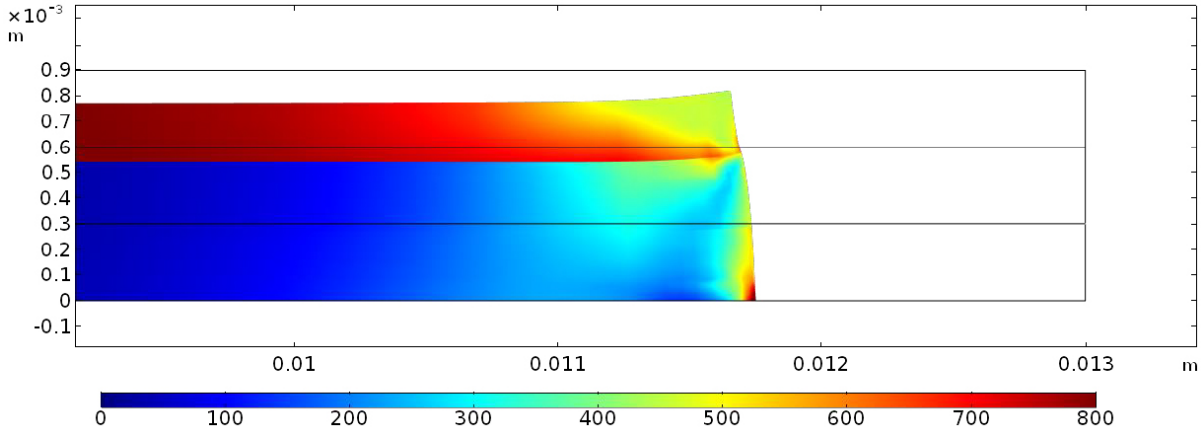

Figure 4 Von Mises stress [kPa] along a cut section of a cell: Ni/YSZ – GDC – LSC.

IV. CONCLUSION

Even a slight TEC difference generated a significant stress, e.g. 1MPa for LCS – GDC. Furthermore, the stress might be underestimated because of the strong hypothesis: isotropic model, no thermal gradient, linear elastic materials and no temperature dependent properties. Thus the TEC must be kept in mind when new materials are investigated to avoid unstable devices.

The next steps for this work will be to measure the thermomechanical properties of potential fuel cell materials with the same fabrication conditions and evaluate the elastic limit and ultimate tensile strength of these materials.

V. REFERENCES

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