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Determination of formability characteristics of Crofer 22 APU sheets as interconnector for solid oxide fuel cells

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ABSTRACT

In this study, the general formability characteristics of Crofer® 22 APU sheets of different thicknesses (0.2 mm–1.0 mm) are experimentally investigated via tensile, out of plane, Erichsen, cupping and springback tests for a possible application for solid oxide fuel cells in sheet form unlike the conventional bulk form. Holloman equation is also used to fit the experimental stress-strain curves and the anisotropic behavior of the material is considered by determining Lankford parameters. The tensile test results show that the formability is about 0.29 mm/mm for 0.2 mm thick sheets, indicating the suitability of these sheets for the fabrication of interconnectors by a stamping process with desired channel geometry having dimensions similar to conventional channel dimensions. In addition, for a specific combination of process parameters such as blank holder force and lubrication, the formability can be enhanced as proven by Erichsen and cupping test results. Moreover, the formability is found to increase with increasing the sheet thickness and highly anisotropic behavior is observed. In three point bending tests, the negative springback behavior, namely spring-in, is surprisingly observed for a relatively narrow shoulder distance at all thicknesses and set angle values ($\theta = 90°–120°$).

Introduction

Interconnectors are one of the critical components of solid oxide fuel cell (SOFC) stacks. They are responsible for the reactant gas distribution/removal of the reaction products and the electrical connection between each cell. Furthermore, they act as a physical separator to avoid the direct oxidation of the fuel and oxidant. Under SOFC operating conditions, they should meet the following main requirements: (i) high electronic conductivity, (ii) high chemical and mechanical stability, (ii) low permeability for the reactant gases and (iv) a coefficient of thermal expansion close to those of other stack components. The reduction of the SOFC operating temperature down to the intermediate (600–800 °C) or the low temperature ranges (<600 °C) by switching the cell design from the electrolyte supported to the anode supported or employing alternative electrolyte materials enables to use high

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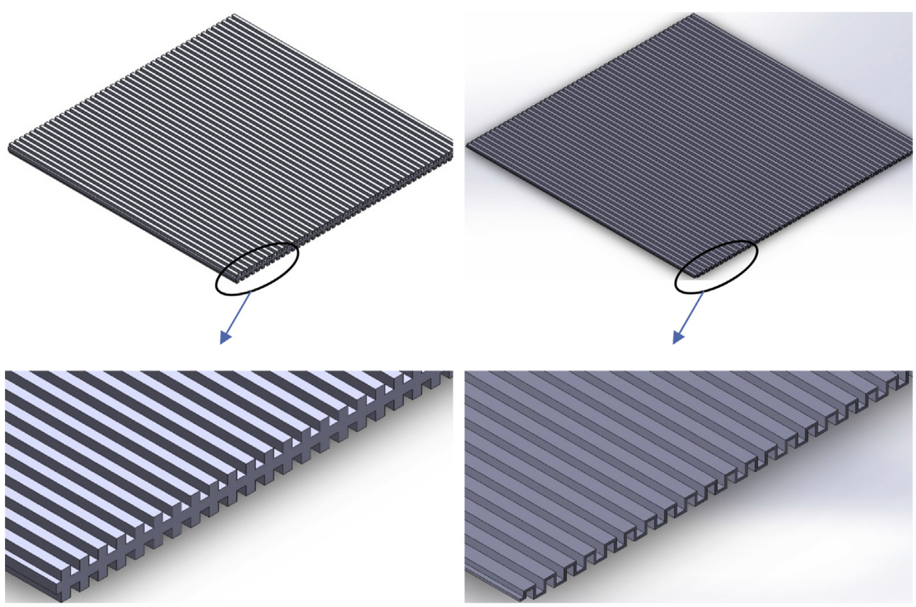
temperature resistant alloys as an interconnector material especially for the planar SOFC technology. Though they are special materials, they have relatively lower cost compared to those of ceramic based interconnector materials. Moreover, metallic interconnectors are easier to fabricate and have better mechanical properties, thus it is possible to design interconnectors with complex shapes.

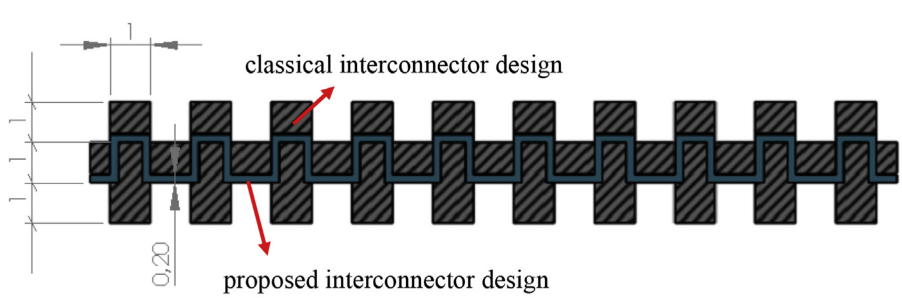
The reactant gas distribution/removal of the products for both the anode side and the cathode side is generally achieved by the gas channels machined on the bulk interconnectors [1–3]. There can be found numerous experimental and numerical studies in the literature, investigating the effects of the conventional flow field designs on the SOFC performance [4–25]. However, a typical SOFC interconnector with the conventional design should have an adequate thickness for a convenient machining, which not only increases the material/fabrication cost thus the system cost, but also reduces both the volumetric (W/m^3) and specific power (W/kg) output of the system.

Alternative to the traditional flow fields created by machining of thick interconnector materials, press-shop can be conducted to fabricate interconnectors from relatively thin sheet materials. The mass production of the interconnectors is also possible via this method, since it provides the creation of the anode and cathode flow-fields after a single-step stamping operation. Thus, it can be considered to be a low-cost and rapid production technique. The conventional and the proposed interconnector designs are illustrated in Fig. 1.

Since the amount of the material used in the fabrication is decreased due to significantly reduced interconnector thickness from 2 to 5 mm to the micrometer scale, i.e. a few hundred micrometers, it is expected to lower the material cost too and to improve the volumetric/specific power density of the stack as a result of the chips-like structure of the proposed design. This is illustrated in Fig. 1(b) which compares the cross-sections of the active zones belonging to the proposed and the classical interconnector designs having similar and realistic flow field patterns. The suggested design made of only 0.2 mm-thick sheet is placed inside the 3 mm-thick conventional one just to highlight the difference clearly. Despite the same and typical channel depth of 1 mm, the hatched regions are not required anymore in the proposed interconnector design, providing significantly reduced interconnector weight and volume. The stamping technique for



(a)



(b)

Fig. 1 – (a) Conventional (left) and proposed (right) SOFC interconnector designs and (b) Cross-section of the proposed and the classical interconnector designs (all dimensions are in mm).

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