Robust, High-Temperature Heat Exchangers, 08369

Cost-Effective Fabrication of Robust Thermally-Conductive Ceramic/ Metal Composites for High-Temperature Heat Exchangers

1. Impact

Thermally- and mechanically-robust, high-temperature materials are needed for compact heat exchangers that can operate above the maximum allowed stresses of stainless steels or Ni-based alloys for heat transfer to high-pressure supercritical CO_2 at ≥720°C, for lower-cost electricity from Concentrated Solar Power

2. Project Goal

To develop scalable manufacturing methods for ZrC/W composites (cermets) to allow for cost-effective compact (printed circuit-type) heat exchangers with high power densities (≥5 MW/m³) at ≥720°C

3. Methods

- Low-cost forming of thin porous channeled WC plates, then net-shape reactive melt infiltration (DCP process, Fig. 1 below), to yield thin dense channeled ZrC/W-based heat exchanger plates
- Diffusion bonding and brazing for the joining of ZrC/W-based heat exchanger plates and metal alloy headers
- Fluid dynamic and thermomechanical simulations to optimize channel patterns and header designs

WC(s) + {Zr} => ZrC(s) + W(s)
where V_m [ZrC + W] = 2.01V_m[WC]

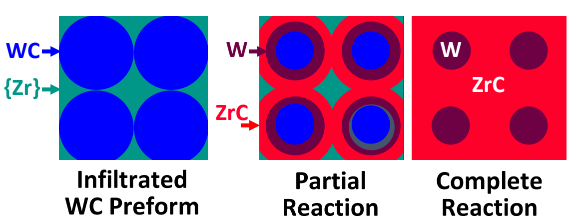

Figure 1. The shape/size-preserving Displacive Compensation of Porosity (DCP) process, which consists of the pressureless infiltration of a Zr-bearing liquid into a shaped, porous, low-cost WC preform, and the displacement reaction of this liquid with WC to yield ZrC + W solid products, so that prior pores in the preform are filled to yield a dense ZrC/W composite that retains the preform shape and dimensions to within 1%

4. Outcomes

- DCP-derived ZrC/W cermets have exhibited high values of failure strength (600 MPa) at 800°C and thermal conductivity (66 W/m-K) at 800°C and, with proper tailoring, have exhibited resistance to high-temperature corrosion in molten $MgCl_2$-NaCl-based salts (with salt purification) and to high-temperature oxidation in sCO_2-based fluid (with Cu coating and low CO addition to sCO_2)
- Thin (≤3 mm) channeled ZrC/W plates (Fig. 2 below) have been formed by scalable uniaxial compaction/stamping, binder removal, and light sintering of WC powder, followed by reactive melt infiltration (DCP process)
- Bonded ZrC/W plate:Cu:H230 header assemblies have remained hermetically sealed after thermal cycling between room temperature and 720°C

5. Conclusions

Reaction-formed ceramic/metal composites, such as ZrC/W cermets, can possess attractive properties for high-temperature heat exchangers. Further process optimization and testing are needed for scaleup and commercialization.

6. Team

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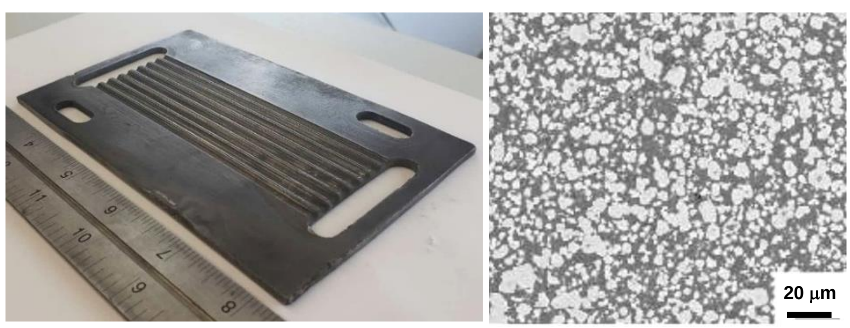

Figure 2. a) Thin (3 mm) channeled ZrC/W heat exchanger plate via the shape/size-preserving reactive melt infiltration (DCP process) of a porous, channeled WC preform plate (with the channeled WC plate formed by a scalable compaction/stamping and firing process), b) a backscattered electron image of a polished cross-section of the dense ZrC/W-converted plate revealing W-bearing particles (white) and ZrC-bearing (grey) matrix