# MODELING THE MECHANICAL INTEGRITY OF AIRFOIL PRINTED CIRCUIT HEAT EXCHANGERS

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**ABSTRACT**

Printed Circuit Heat Exchangers (PCHEs) are an integral part of supercritical carbon dioxide (s-$CO_2$) Brayton power cycles in advanced reactor designs. Better thermal efficiencies at higher source temperatures make the s-$CO_2$ Brayton cycle attractive for use with the High-Temperature Gas-cooled Reactor, the Sodium Fast Reactor, and the Fluoride-salt cooled High-temperature Reactor. In these reactor systems PCHEs would be used as Intermediate Heat Exchangers between the reactor coolant and the power cycle's s-$CO_2$ working fluid. PCHEs fulfill this role better than traditional shell and tube heat exchangers by being more compact and having greater heat transfer surface area per unit volume.

Novel PCHEs designs have the potential to increase heat transfer while decreasing pressure drop across the heat exchanger. Experimental work at the University of Wisconsin has identified these benefits in airfoil-fin channeled PCHEs. Greater surface area and the streamlined airfoil shape of conducting fins give the design an advantage over standard zig-zag and straight channel PCHEs. Despite better thermohydraulic performance, the structural integrity of airfoil-fin PCHEs is not yet quantified.

Validation of structural integrity of the airfoil PCHE design is necessary before its use in the nuclear industry. These heat exchangers will transfer heat between s-$CO_2$ and fluids such as helium, fluoride salts, and sodium. The high operating temperatures and pressures presented in coupling these disparate fluids in the compact PCHE make an investigation into structural integrity necessary.

Models are been developed at the University of Wisconsin to assess the structural integrity of airfoil-fin PCHEs. With high temperature mechanical performance data readily available for PCHE alloys, computer models of plasticity and creep are readily applicable to PCHE geometries. Results are presented for preliminary elastic and plastic models of the air-foil PCHE design that is being tested at the University of Wisconsin. The models provide failure predictions and an understanding of localized stress distributions that will drive eventual experimental efforts.

**KEYWORDS**
Printed Circuit Heat Exchanger
Mechanical Integrity
Stress Modeling

## CONCLUSION

Finite element analysis (FEA) models were developed to assess the structural integrity of airfoil-fin PCHEs. Airfoil-fin geometries were modeled because they achieve better thermohydraulic performance than other leading PCHE designs but have not had their mechanical strength verified. To properly model the airfoil-fin PCHE, plastic properties of 316 stainless steel were adapted for use within ANSYS Mechanical's iterative force based FEA solver. Although stress concentrating geometries reached the yield point of 316 stainless steel at channel pressurizations below 20 MPa, airfoil-fin strength is maintained with further loading due to the dispersion of the yielding stress concentration. Total yielding of the airfoil-fin's diffusion bond was found to be below 20% at 20 MPa of channel pressurization if adequate air-foil coverage of 13% of more is maintained. Pressurized air-foil fin PCHE channels can be kept safe from total plastic failure by ensuring adequate airfoil-fin coverages or 13% of the bond surface or more.

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