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Turbine Airfoil Aerothermal Characteristics in Future Coal-Gas Based Power Generation Systems

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Future advanced turbine systems for electric power generation systems, based on coal-gasified fuels with CO_2 capture and sequestration, are aimed for achieving higher cycle efficiency and near-zero emission. Most promising operating cycles being developed are hydrogen-fired cycle and oxy-fuel cycle. Both cycles will likely have turbine working fluids significantly different from that of conventional air-based gas turbines. The oxy-fuel cycle, with steam and CO_2 as primary working fluid in the turbine section, will have a turbine inlet temperature target at approximately 1750 C, significantly higher than the current level of utility turbine systems. The present study begins with a CFD-based simulation on the transport phenomena around the gas side of a turbine airfoil under realistic operating conditions of future coal-gas based systems. While the external heat transfer distribution over a turbine airfoil shows a similar trend between the hydrogen-fired and oxy-fuel cycles, the overall magnitude of heat transfer coefficient for the oxy-fuel cycle is found to be about 40% higher than its hydrogen-fired counterpart - an observation attributable to the high steam concentration in oxy-fuel turbine flow. This overall suggests that advances in cooling technology and thermal barrier coatings (TBC) are critical for the developments of future coal-based turbine systems. To further explore this issue, a comparative study on the internal cooling effectiveness between a double-wall or skin cooled arrangement and an equivalent serpentine-cooled configuration is performed. The present results suggest that the double-wall or skin cooled approach produces superior performance than the conventional serpentine designs. This is particularly effective for the oxy-fuel turbine with elevated turbine inlet temperatures. The contribution of thermal barrier coatings (TBC) toward overall thermal protection for turbine airfoil cooled under these two different cooling configurations is also evaluated.

References

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Turbine Inlet Temperature and **Flow Composition**			
	Syngas IGCC Turbine 2010	**Hydrogen-fired Turbine 2015-2020**	**Oxy-Fuel Turbine 2015-2020**
Combustor Exhaust Temperature, °C (°F)	~1480 (~2700)	~1480 (~2700)	
Turbine Inlet Temperature, °C (°F)	~**1370** (~2500)	~**1425** (~2600)	~**1760** (~3200) (IPT) ~760 (~1400) (HPT)
Turbine Exhaust Temperature, °C (°F)	~595 (~1100)	~595 (~1100)	
Turbine Inlet Pressure, (psig)	~265	~300	~1500 (HPT) ~625 (IPT)
Turbine Flow Composition, (%)	**H_2O (8.5)** CO_2 (9.27) N_2 (72.8) Ar (0.8) O_2 (8.6)	**H_2O (17.3)** CO_2 (1.4) N_2 (72.2) Ar (0.9) O_2 (8.2)	**H_2O (75-90)** CO_2 (25-10) O_2, N_2, Ar (1.7)

Table 1 Projected Operating Conditions for Future Coal-Gas Based Turbines

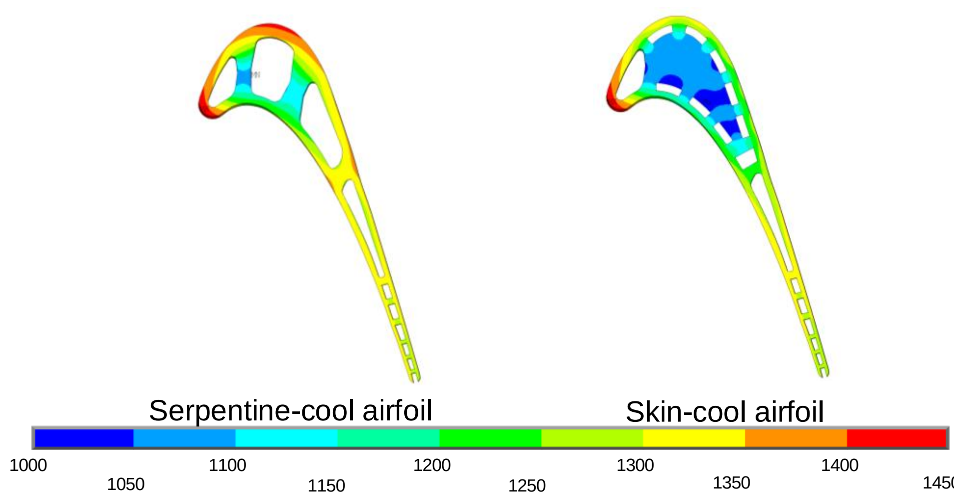

Figure 1 Airfoil metal temperature distribution (°K) in Oxyfuel Turbine, h_c=3000W/m^{2}K