sCO_2 Cooling Performance in Turbomachinery

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Real gas effects of sCO_2 provide additional design variables to improve cooling performance

ABSTRACT

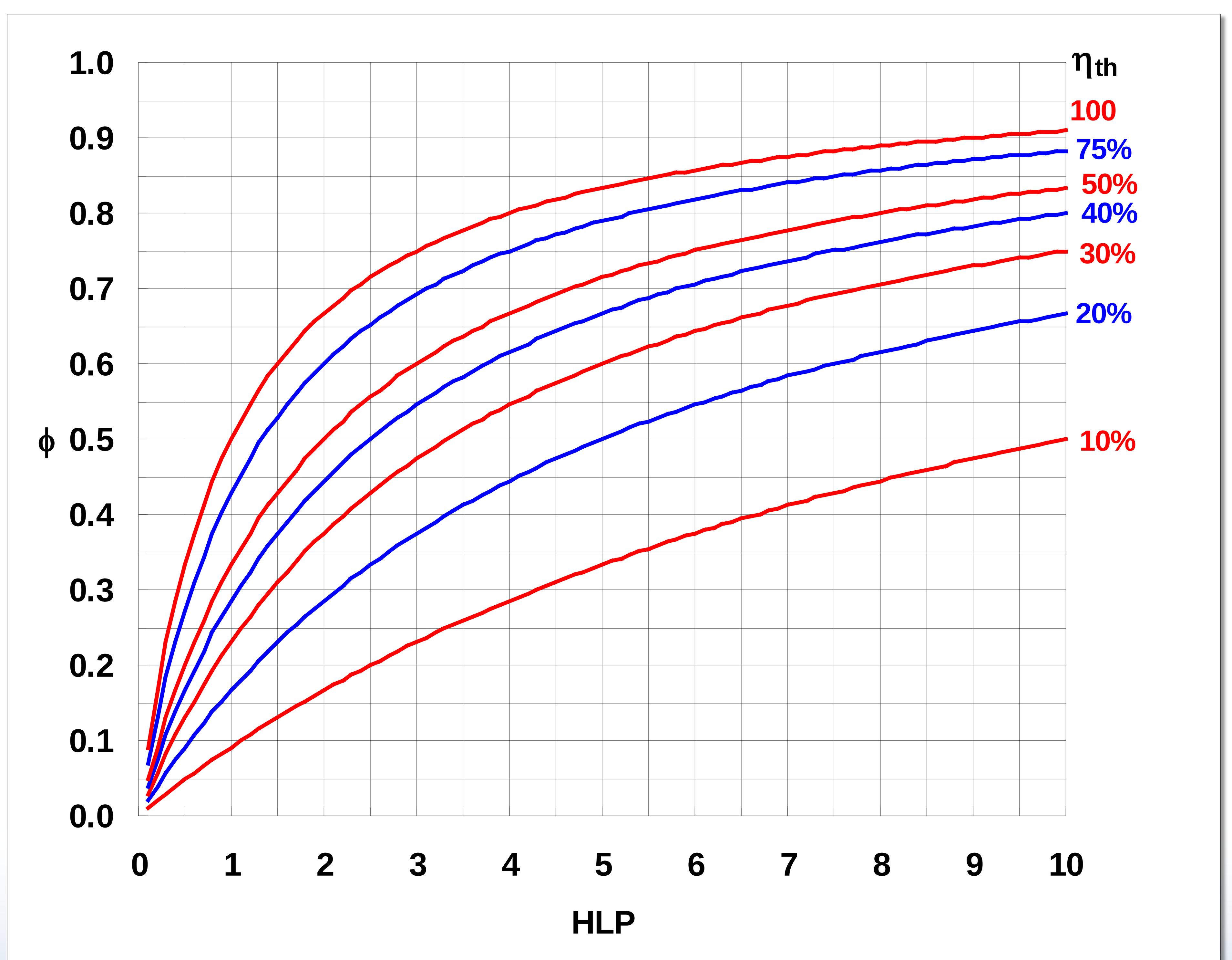
Current designs for sCO_2 power cycles use indirect heating to achieve turbine inlet temperatures of 775°C, which requires the use of advanced nickel alloys in the turbine. Because cycle efficiency is closely tied to the turbine inlet temperature, higher turbine inlet temperatures will be needed in the near future. In fact, temperatures as high as 1,200°C are already being achieved using oxy-combustion technology that is expected to be used in sCO_2 power cycles. To withstand higher inlet temperatures, the simplest solution is to integrate internal cooling into the sCO_2 turbine similar to conventional gas turbines in power generation and propulsion applications. Because the cooling fluid would be sCO_2 instead of air, the real gas effects must be included in the cooling design. In this paper, the real gas effects of sCO_2 are discussed using a cooling effectiveness chart, which is commonly employed to evaluate cooling designs in air-cooled gas turbines.

CONCLUSIONS

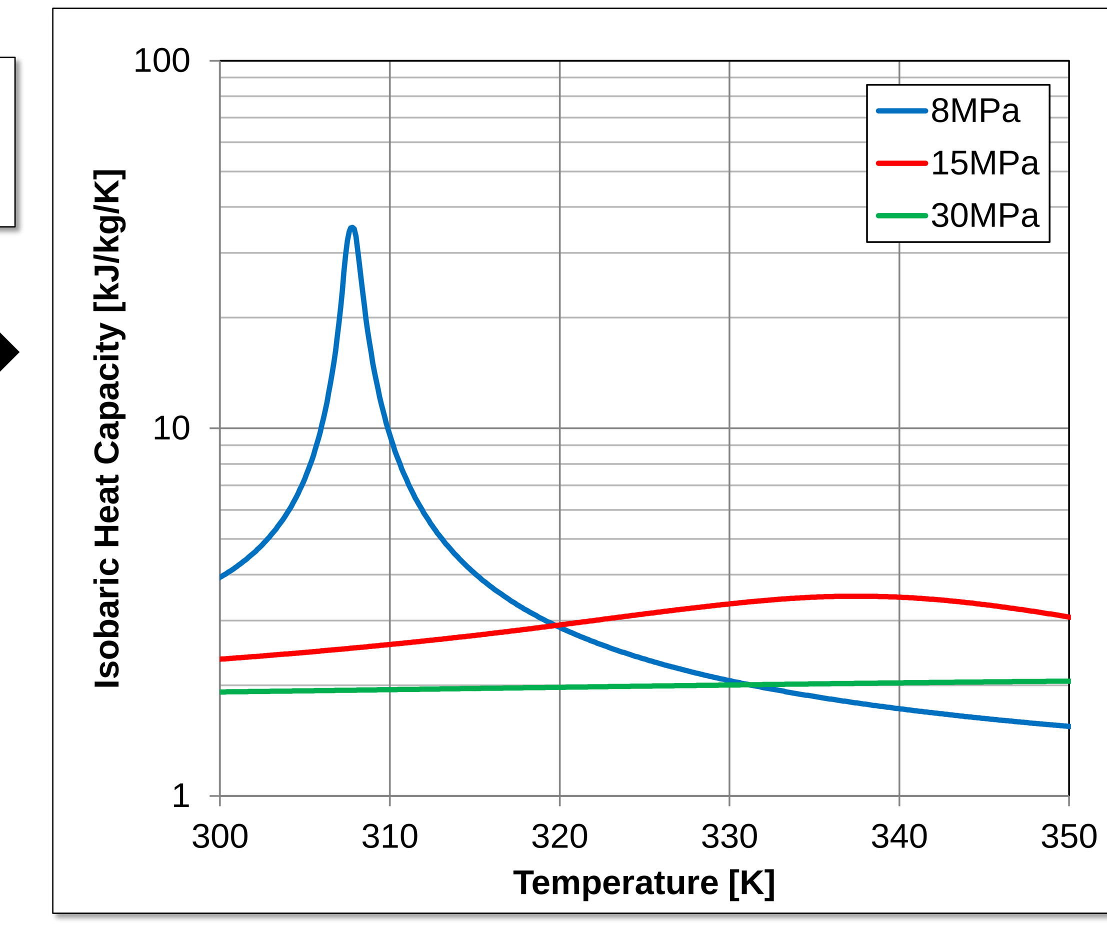
- The high specific heat of CO2 near the critical point increases turbine cooling effectiveness
- sCO_2 cooling designs could utilize a closed-circuit to recuperate heat gained by the coolant
- The pressure of the coolant flow can be modified to affect the overall the cooling performance

$$\phi = \frac{T_g - T_m}{T_g - T_{c,in}} \qquad HLP = \frac{T_g - T_m}{T_{c,out} - T_{c,in}} \qquad \eta_{th} = \frac{T_{c,out} - T_{c,in}}{T_m - T_{c,in}}$$

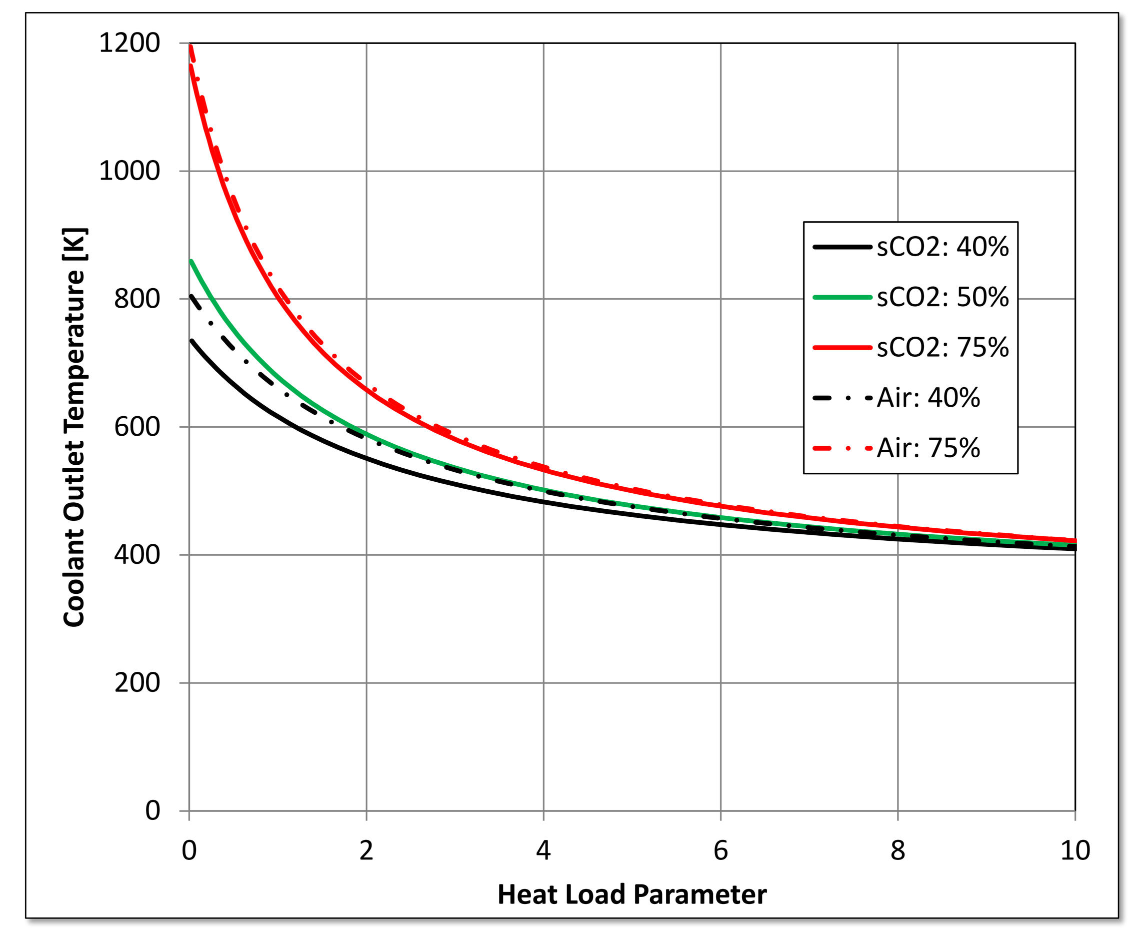
Cooling effectiveness **Heat Load Parameter** **Thermal Efficiency**



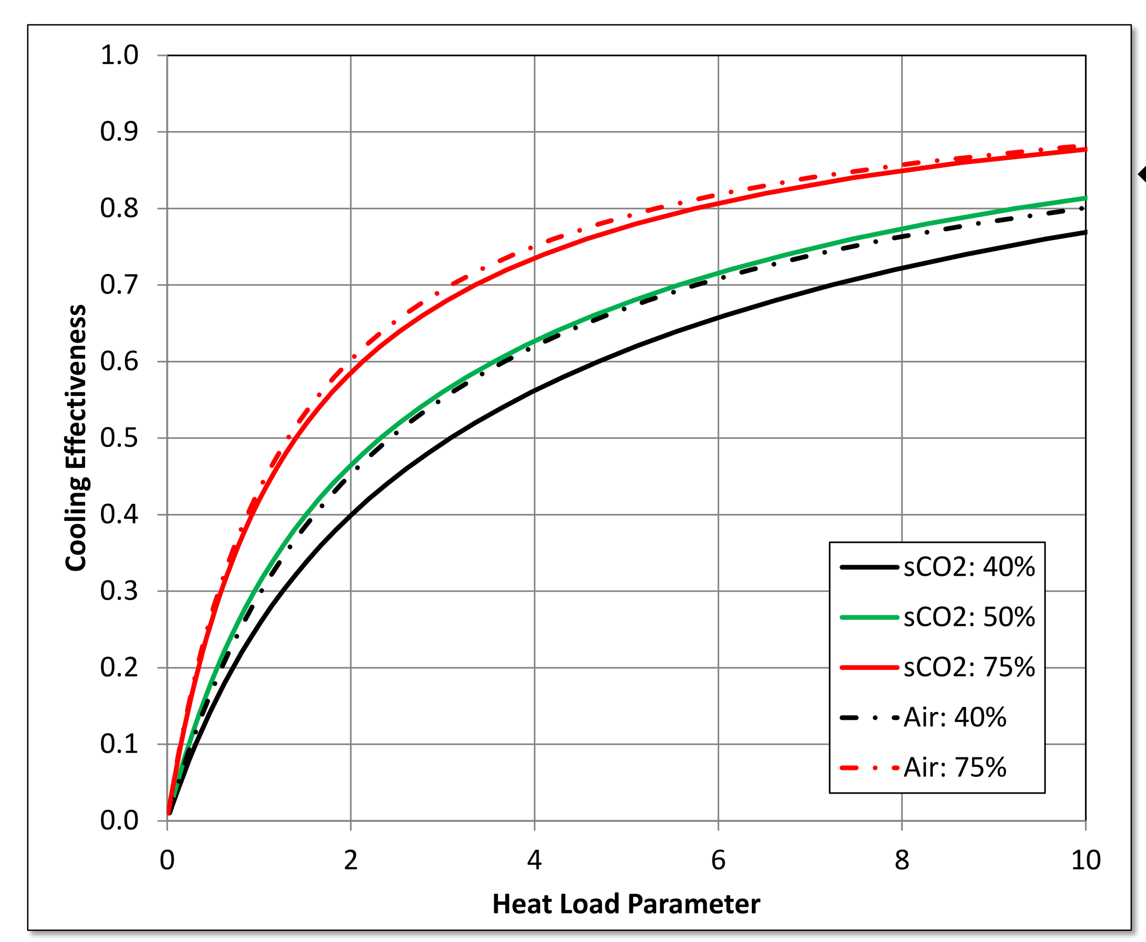
Thermal Capacity of sCO_2 will affect the HLP and thermal efficiency



The high thermal capacity of sCO_2 reduces the coolant outlet temperature



The reduction in outlet temperature shifts the cooling effectiveness curve to the left



Increased thermal efficiency could be obtained with sCO_2 by increasing the number of cooling passes

The pressure of the coolant flow is significant in adjusting the cooling performance