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FORCED CONVECTION HEAT REJECTION SYSTEM FOR MARS SURFACE APPLICATIONS

Abstract

Waste heat rejection is a significant concern for high-power systems operating on the Martian surface, many of which will be required for future crewed missions, such as fission power systems, cryofuel refrigeration, in-situ resource utilization units, and rovers. For a reactor large enough to sustain a prolonged crewed mission, 100's of kW of heat must be transferred to the environment to maintain steady operation. Current waste heat rejection system designs typically employ radiative cooling, which requires a large surface area and high temperatures to transfer sufficient heat, leading to high mass and reduced power cycle thermal efficiency. Convection offers much higher heat transfer coefficients than radiation, a weaker dependence on temperature, and does not require the heat transfer surface to be exposed to the sky, allowing for a much more compact structure. This study investigates the design of a lightweight, compact, and, as mass and volume are important cost drivers for Mars surface hardware, inexpensive waste heat rejection system for Mars surface applications utilizing forced-convection heat transfer to reject heat to the Martian atmosphere. While a few studies found in the literature have proposed using a convective heat exchanger on Mars, none have performed a detailed study of heat exchanger performance in Mars-like conditions, or experimentally validated heat transfer, pressure drop, and fan efficiency correlations in such conditions. Therefore, an analytical model of a finned-tube cross-flow heat exchanger has been developed using existing heat transfer, pressure drop, and fan efficiency correlations for low Reynolds number flows and a non-linear optimizer to determine the mass-optimal geometry for a given set of heat rejection parameters. The optimal 100 kW heat exchanger operating at 625 K is found to mass 27.0 kg, including the mass of the fan and motor, 95% less than a comparable radiator, require 638 W of fan power to operate, and have a frontal area of 3.94 m$^2 . Optimalgeometriesarealsofoundforheatrejectionratesof 1 kW to 600 kW acrossarangeofcoolantandatmospheretempe$
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