Title: Experimental and Theoretical Investigations of New Power Cycles and Advanced Falling Film Heat Exchangers

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ABSTRACT

Part I. THEORETICAL STUDY: Second Law Analysis and Optimization of a Combined Cycle With Integrated Compressor Inlet Air Cooling

A gas/ammonia combined cycle is proposed in which exhaust gases from a Brayton gas topping cycle are used to produce superheated ammonia in a Heat Recovery Ammonia Generator (HRAG). The Brayton topping cycle includes two compressors with an intercooler in-between and a recuperator to preheat the air using turbine exhaust gases. The exhaust gases from the recuperator produce the superheated ammonia. In addition to the ammonia turbine and condenser, the bottoming ammonia Rankine cycle includes an ammonia recuperator to recover the energy from the exhaust of the ammonia turbine. Both air and water-cooled ammonia condensers are analyzed. The ammonia/air condenser is advantageous for locations where wet cooling towers are not feasible.

Gas turbines are essentially constant volume machines; therefore, to increase the power of the gas turbine in the combined cycle, when the environmental air temperature is high, inlet air to the compressor is cooled in the evaporator of an ammonia refrigeration cycle added to the combined air/ammonia power cycle. In this integrated combined power cycle a small fraction of high-pressure ammonia liquid, from the exit of the ammonia pump, is used in the ammonia refrigeration cycle to provide the air cooling. The ammonia from the evaporator is compressed and combined with the exhaust of the ammonia turbine before being condensed in the ammonia condenser.

The second law analysis and optimization of the above combined cycle is presented. The effect of important system parameters on the irreversibility of components in the cycle and the exergy of exhaust streams are evaluated. Total exergy destruction is minimized to find the optimum system. Reasonable constraints for system components are assumed. The power and efficiency of the cycle are evaluated and their dependence on system parameters are presented. The composition of inlet air to the gas topping cycle is assumed to consist of 78.10% N_2, 20.76% O_2, 1.11% H_20, and 0.03% CO_2. The fuel is assumed to be natural gas with equivalent chemical formula $CH_{3.88}$. It is shown that the proposed gas/ammonia combined cycle with integrated air cooling can produce high power and efficiency.

Part II. EXPERIMENTAL STUDY:
The Effective Use of Heat Transfer Additives for Steam Condensation

Reported here is the results of the experimental investigations on the effect of small amounts of heat transfer additives, 4 different additives, (C_{add} < 1000 ppm) on steam condensation in a bundle of horizontal tubes that are internally cooled. The condenser was designed with twelve tubes in an array of three horizontals and four verticals with a 2-inch horizontal and 1.5-inch vertical in-line pitch. By using effective additives, the condensation heat transfer rate can be augmented as much as 30% as compared with heat transfer that operated without additives under the same operating condition. The steam condensation which occurred in our experiments while using effective additives was mostly dropwise-like. When heat transfer additives function effectively, the condensate-droplets become more dispersed and have a smaller shape than those produced without additives. These droplets, unlike traditional turbulence, start at the top portion of the condenser tubes and cover most of the tubes. Such a flow behavior can be explained by the Marangoni effect (in terms of thermodynamic equilibrium) in connection with obtained surface tension data.

We extend our experiment to investigate the dynamic effect of surface tension in the steam condensation process and propose a general criterion for selecting effective additives. We have constructed the dynamic surface tension measurement setup and measured dynamic responses of the surface tension with additives. The measured data indicates that the decreased surface tension is due to the adsorption and subsequent diffusion of additives on to the condensed water surface. As a result, the surface tension of the condensate is reduced and provokes the Marangoni convection. It is our belief that such a phenomena is responsible for an increase in condensation heat transfer.