Development of Low-Irreversibility Engines

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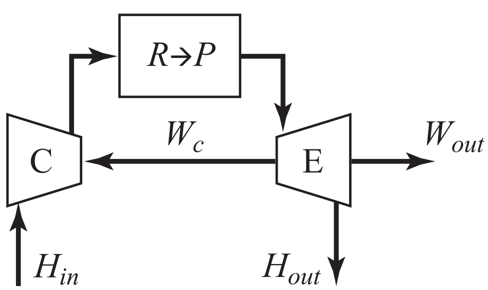
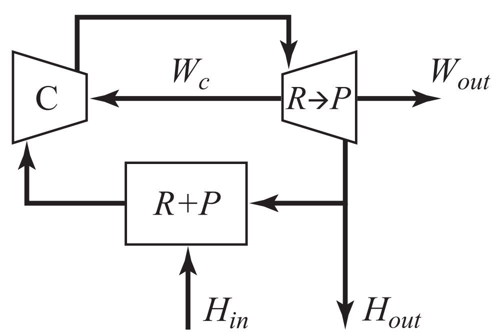
Description: Internal combustion engines suffer from a significant loss of efficiency due to the irreversibility inherent in unrestrained combustion. Consider, for example, the gas turbine engine. As illustrated in the block diagram to the left, atmospheric air is compressed to a high pressure, fuel is injected, and a flame transforms the reactants to products in a process with no work and essentially no heat extraction (adiabatic combustion). The result of this traditional form of combustion is a high temperature gas that is then expanded through a turbine to develop work. The Brayton model, shown on the Mollier diagram of the next page (states 1-2-3-4), is an idealization of this process.

The difficulty with this approach is the entropy generation that occurs between states 2 and 3. This entropy generation leads to a loss of potential work of an amount *i*. This is the irreversibility of the conventional gas turbine (Brayton) cycle.

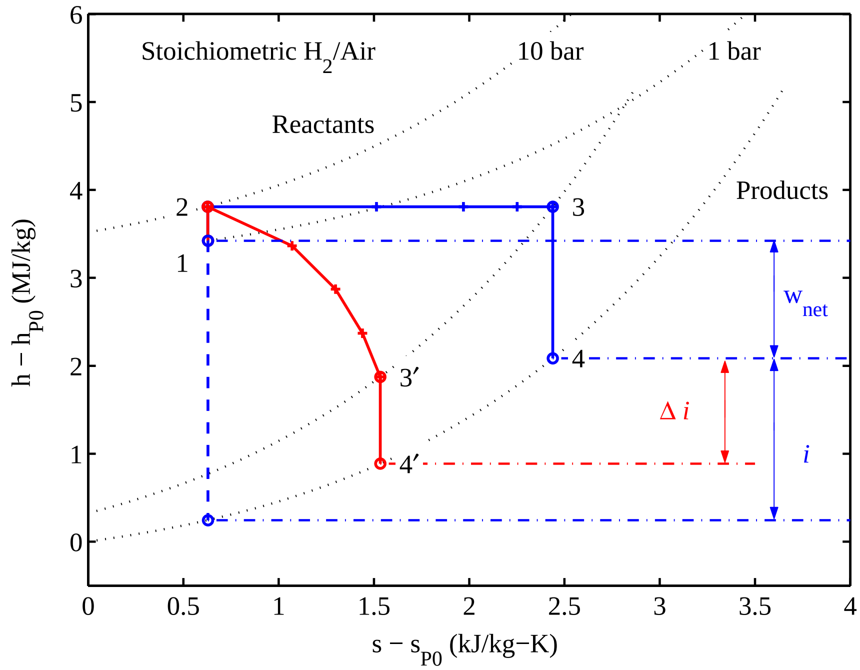




Until recently it was not realized that it is possible to reduce this irreversibility. This can be accomplished by modifying the component configuration as shown in the schematic to the right. The essential aspect of the configuration is that the combustion process is no longer conducted in isolation, but is instead combined with the work extraction process. In this way, a portion of the chemical bond energy that would have been transformed into sensible energy (i.e., would lead to a high temperature) is transformed directly into expansion work in the turbine. The result of this transfer of energy is a lower peak temperature and concomitant lower entropy generation. A secondary but important side benefit is a potentially significant reduction in NOx emissions.

A depiction of this reduced entropy (low-irreversibility) approach is shown by states 1-2-3'-4' on the Mollier diagram. This diagram shows the reduced irreversibility (and therefore increased work) that is possible from implementing a set of processes with a 50% reduction in entropy generation. In this cycle, some sensible energy increase (and temperature rise) is still necessary to insure that the combustion reaction goes to completion.

Studies to date have shown that a carefully designed work extraction process, implemented by intelligent control strategies, may permit significant improvements in the efficiency of the simple cycle gas turbine engines.



Status: Current efforts are focused on combined thermodynamic and chemical kinetic analyses of model low-irreversibility combustion processes, as well as the design of a facility to conduct proof-of-concept testing.

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